APPENDIX-4

微小地震探査

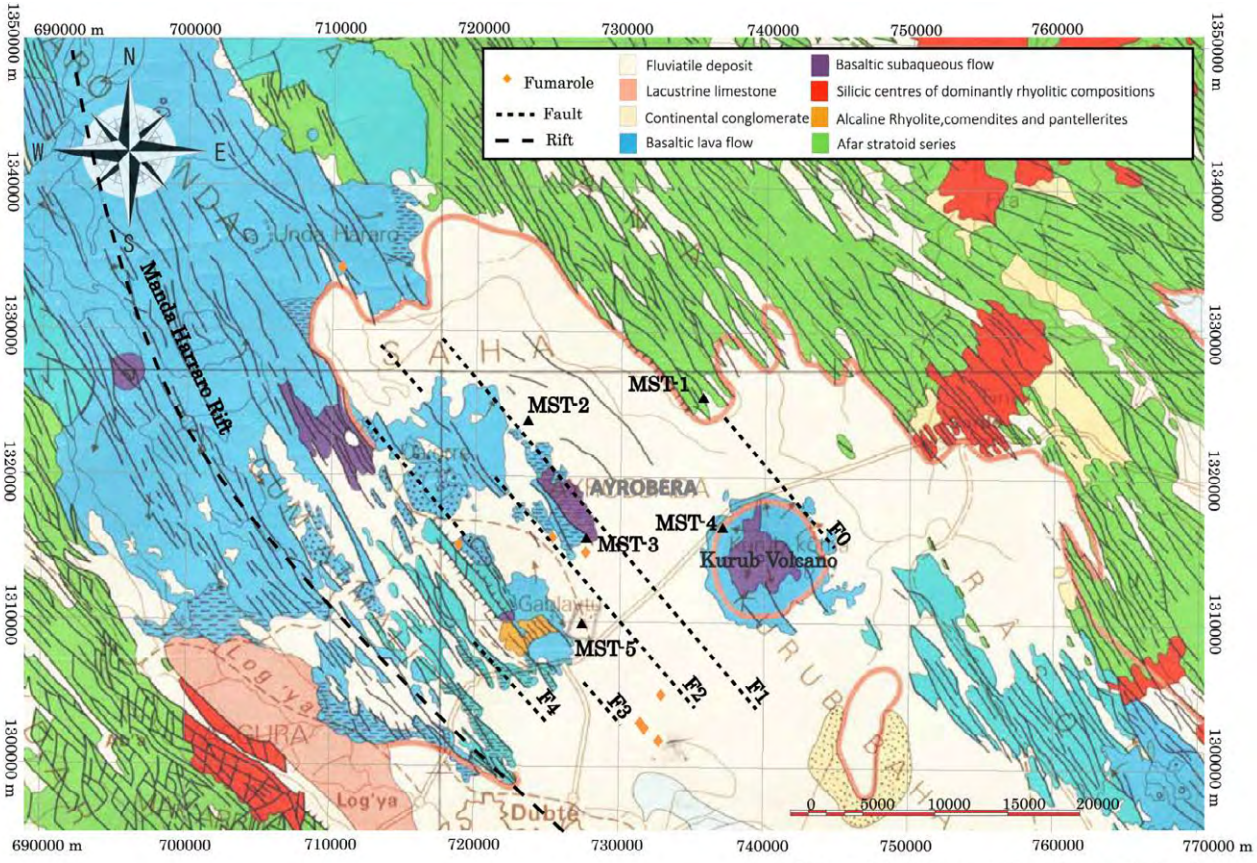
Appendix-4　微小地震探査

A4.1　テンダホ-2 地区

A4.1.1　探査の目的

微小地震探査の目的は、地熱徴候地域及びその周辺で発生する地震活動を把握し、断層構造や断裂系の位置を確認することである。地震計設置位置を図 A4.1.1 に示す。

観測された地震結果は、地熱貯留層モデルの構築及び調査ボーリング計画に使用する。



Microseisimic Survey Map (Tendaho2 Area)
出典: CNRS and CNR, 1975 に調査団加筆

図 A4.1.1　微小地震観測位置図（テンダホ-2 地区）

A4.1.2　地質概要

地熱発電開発マスタープラン策定調査プロジェクトファイナルレポート(2015)によれば、テンダホ-2 地区は、Manda-Harraro 地溝帯に位置する(V.Acocella, 2008, p.2)。基盤は Pliocene-Pleistocene の Afar Stratoid からなり、玄武岩溶岩・火砕岩と堆積岩が分布する。調査地の南西では、Pleistocene の Recent basalt の割れ目噴火による溶岩流が見られる。Ayrobera 周辺では、これらを沖積層が覆い、平原を形成する。また、地溝帯の方向に沿った NW-SE 方向に F0～F4 の断層が存在している。地熱徴候として、観測点 MST-3 付近及び MST-5 付近を通る断層に噴気帯が認められる。MST-3

付近の噴気の温度は約 100℃に近い高温噴気である。

A4.1.3 探査概要

本観測の調査内容は以下のとおりである。

(1) 観測地点の選定

始めに、観測地点の候補地を Google Earth で岩盤が露出している地域を調べ、その後現地踏査を行って観測地点を絞り込み、さらに、車輌の走行や樹木などによる地盤の振動ノイズの影響が少ない場所を選定した。

各観測候補地点では、バックグランドノイズのレベル測定を行った。下図（図 A4.1.2）はテンダホ-2 地区の MST-1 で実施したグラウンドノイズレベルの測定結果である。ノイズレベル測定に用いた地震計は 3 成分で、図の上段は南北成分、中段は東西成分、下段は上下成分である。初動立ち上り方向の極性は、＋側が N、E、Up、－側が S、W、Down である。

MST-1 のノイズレベルは 10μkine と非常に小さく、観測地点として最適地であった。なお、右側の振幅の大きい波形は、地盤に衝撃を与えた時の波形である。

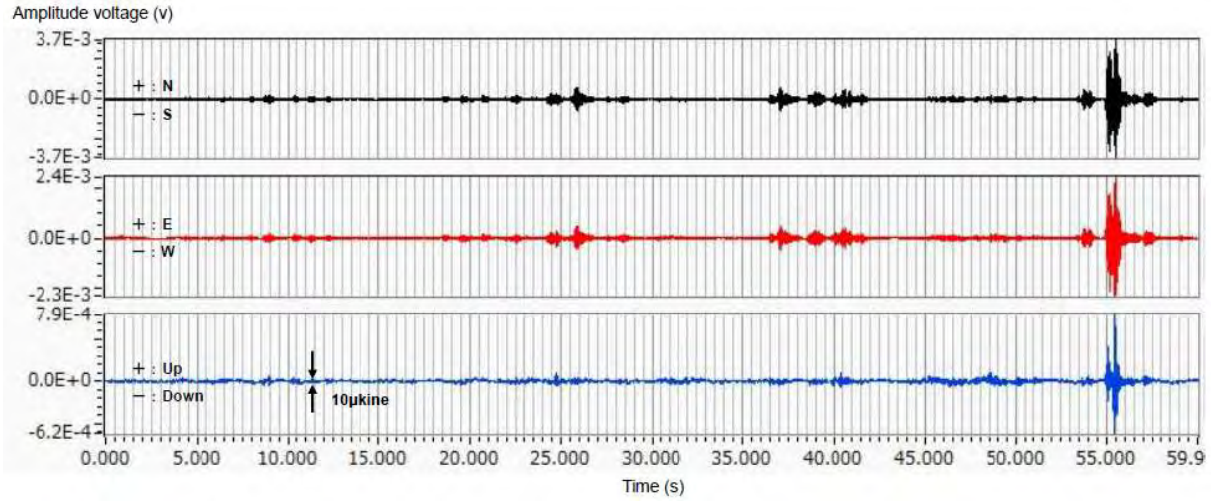


図 A4.1.2 グラウンドノイズレベルの測定結果(テンダホ-2 地区 MST-1)

ノイズレベル測定の結果、観測点 MST-1～MST-3 は 30μkine 以下とノイズが小さい。しかし、観測点 MST-4 及び MST-5 は堅固な岩盤にもかかわらず、MST-4 は 90μkine、MST-5 については 190μkine とノイズが大きかった。各観測点の位置・標高は、エチオピア測量業者が GPS 測量機を利用してキネマティック測量で求めた。表 A4.1.1 に各観測点の位置、標高及びノイズレベルを示す。

表 A4.1.1　地震計設置概要（テンダホ-2 地区）

Station No.	Longitude	Latitude	UTM (easting)	UTM (northing)	Elevation (m)	Ground noise (μkine)
MST-1	41° 9′ 53.8″ E	11° 58′ 53.3″ N	1325430	735742	367	10
MST-2	41° 3′ 17.6″ E	11° 58′ 01.4″ N	1323743	723765	384	20
MST-3	41° 5′ 30.1″ E	11° 53′ 33.5″ N	1315539	727835	376	25
MST-4	41° 10′ 39.1″ E	11° 53′ 58.7″ N	1316387	737184	375	90
MST-5	41° 5′ 18.6″ E	11° 50′ 26.5″ N	1309790	727531	366	190

(2)　データ取得システム

観測装置はドイツ国 Lennartz electronic GmbH 社製 LE-3Dlite MkⅡ地震計、米国 Geospace 社製 GSX-3 データロガー及び 12V バッテリーからなるシステムである。

速度型地震計で捉えられた 3 成分の波形データは、データロガー(USB カード)に自動記録される。データロガーには GPS が内蔵され、観測時刻は 6 分毎に較正される。

微小地震観測は 3 ヶ月の長期間であるため、データロガーへの電源供給は 12V50Ah のシールドバッテリーを 2 個並列結線して利用した。これにより、3 ヶ月間バッテリーを交換する必要もなく常時連続観測が可能となった。データ取得システムのブロック図を図 A4.1.3 に示す。

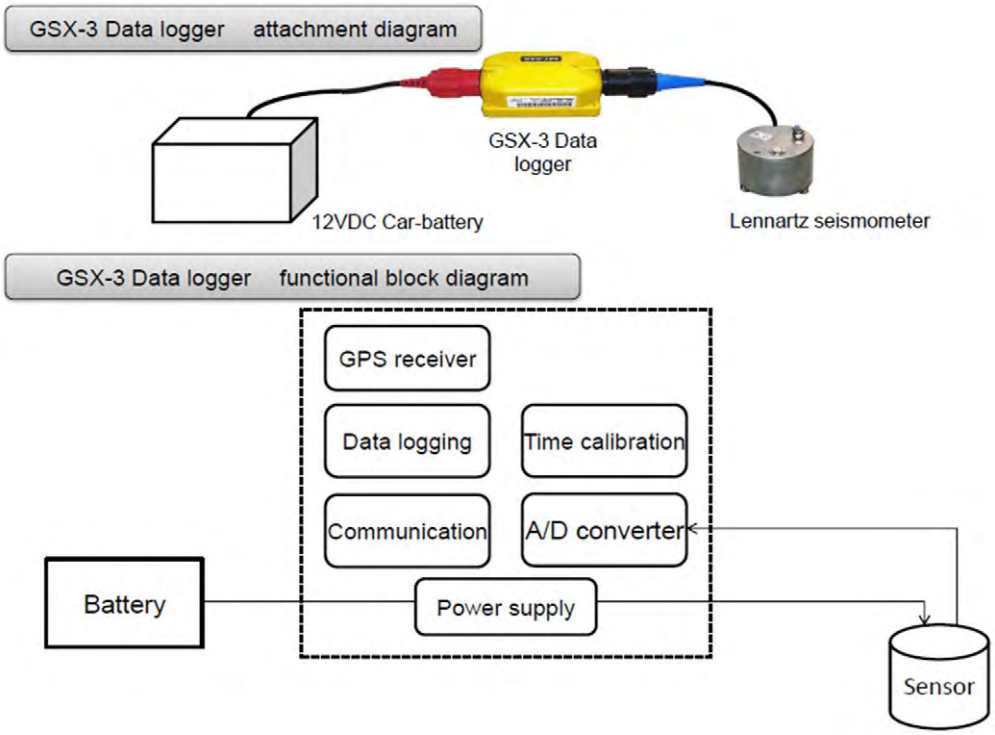


図 4.1.3　データ取得システムのブロック図

(3) 地震計及び周辺機器の設置

テンダホ-2 地区の観測点数は 5 地点で、全観測地点に 3 成分（南北成分、東西成分、上下成分）の速度型地震計を設置した。地震計設置は以下の手順で実施した。

1) 岩盤に付着している土や礫を取り除く。
2) 岩盤に石膏を敷いて地震計設置台を作り、石膏の台座に地震計を埋め込む。
3) 地震計には磁北に設置するための矢印が刻印されているので、方位磁石を用いて矢印を北側に合わせて設置する。
4) 地震計とデータロガー、データロガーと電源バッテリーをそれぞれ接続する。
5) 盗難対策として、バッテリーをチェーンと南京錠で固定し、さらにバッテリーとチェーンをモルタルで固定する。
6) 観測機器をビニールシートで覆い、その中に湿気取りシートを入れ、最後に観測機器を石で覆い隠した。

表 A4.1.2 は地震観測に利用した測定機器である。

表 4.1.2 地震観測の測定機器

Item	Type	Specifications	Photo
Seismometer	LE-3Dlite Mk Ⅱ (Lennartz electronic GmbH., Germany)	Eigenfrequency：1Hz Upper Corner Frequency：100Hz RMS Noise @ 1 Hz：<3nm/s	
Data Logger	GSX-3 (Geospace Technology, USA)	A/D Converter：24bit GPS Time Calibration： Every 6 minutes GPS Accuracy：<20μsec Recording capacity：30Gbyte	
Seismic Recorder	MS-3000 (JGI, Inc., Japan)	Dynamic Range：121dB Sampling：1-4000Hz	

(4) 観測機器の保守と盗難防止対策

無人観測点であるため、データロガーへの電源供給と GPS の信号受信が的確に行われているかの確認を調査団員が定期的に巡回した。さらに機器の盗難防止のために、見張り人を昼夜それぞれ 1 名ずつ立てて盗難防止対策とした。

(5) 観測期間

本地区における観測期間は、5 箇所の地震計設置が全て終了した日を観測開始日とし、地震計回収を最初に始めた観測点を観測終了日とした。従って、観測期間は、2015 年 12 月 23 日 11 時 0 分から 2016 年 3 月 22 日 11 時 30 分までの延べ 90 日間である。それぞれの観測期間中での機器等のトラブルも無く、観測中断はなかった。観測点の観測期間を表 A4.1.3 に示す。

表 A4.1.3　各観測点の地震計設置及び回収日時（テンダホ-2 地区）

Site Code	Observation start time	Observation stop time	Observation days
MST-1	2015.12.22 12:00	2016.3.23 9:00	92days and 21hours
MST-2	2015.12.23 11:00	2016.3.24 8:30	92days and 21hours
MST-3	2015.12.21 11:20	2016.3.22 11:30	93days
MST-4	2015.12.22 15:10	2016.3.23 9:40	92days and 21hours
MST-5	2015.12.21 14:10	2016.3.22 12:20	92days and 22hours

A4.1.4　観測データの処理

(1) 観測データの処理

地震観測データの処理は、ボセッティ地区の 1 観測点を含めた 6 観測点のデータロガーをデータ変換ユニット(Data Transfer Unit)にそれぞれ接続し、波形データを統合した。統合された観測波形データから、地震波と思われる部分を目視により識別し、地震波形の部分を切り出した。図 A4.1.4 にデータ回収システムの概念を示す。

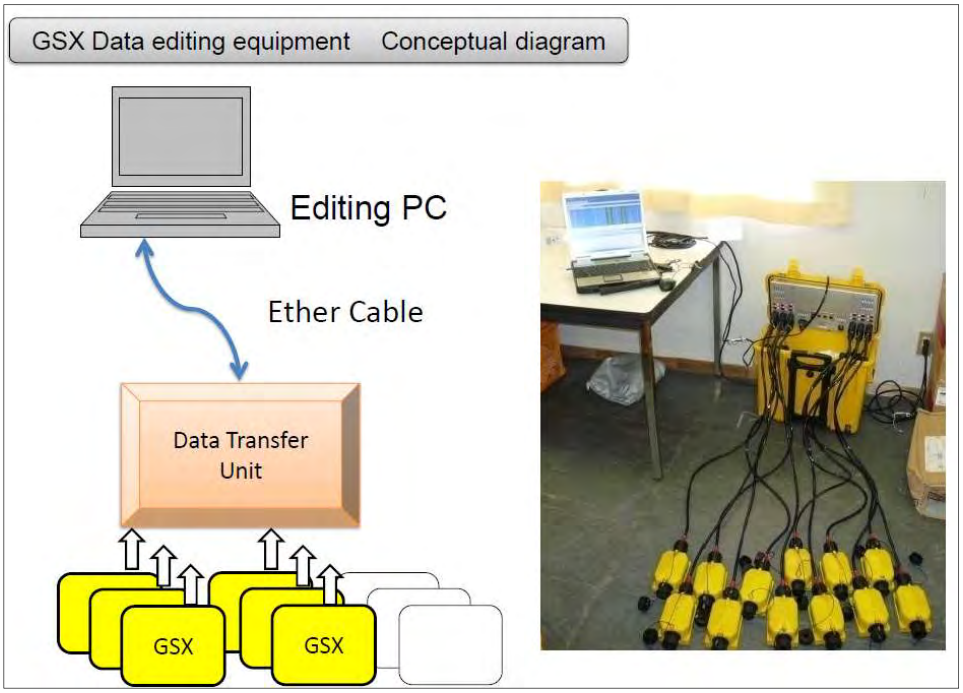


図 A4.1.4　データ回収システムの概念図

(2)　記録の読取り・整理及び震源計算

地震と判定されたデータについて、P 波到達時刻、S 波到達時刻、振動終点時刻を読み取った。震源計算は、3 地点以上の観測点で P 波及び S 波の到達時刻が読み取れる地震について震源位置及びマグニチュードの計算を行った。本観測でのマグニチュードは地震動の継続時間を用いた方法によって求めた。計算式は、M=-2.53+2.85logTd+0.014r、あるいは M=-2.36+2.85logTd である(地熱開発総合ハンドブック,1982,微小地震, p282-290)。なお、Td は振動継続時間(秒)、r は 200km 以内である。

(3)　地震波速度構造

イタリア企業ELC-Electroconsult S.p.Aは、2015年にエチオピア地質調査所及びアイスランド国際開発庁からの依頼で、テンダホ-2地区南西25km付近のTendaho-Alalobeda地熱地域で微小地震観測を行った(Tendaho Geothermal Project Micro-seismic Survey Final Report,1995)。表A4.1.4はその時に使用した4層の水平層からなるモデルである。本観測では、このプロジェクトで使用した速度構造モデルを採用して震源位置を求めた。

表 A4.1.4　テンダホ-2 における速度構造モデル

Layer No.	Thickness(km)	Depth(km)	Vp(km/s)	Vp/Vs
1	5.0	5.0	4.0	1.78
2	4.0	9.0	6.1	
3	17.0	26.0	6.9	
4	-	-	7.8	

出典: 調査団

A4.1.5　調査結果

観測されたデータ記録から、日別地震発生頻度、S-P 時間別地震発生頻度、震源分布等を作成した。以下に調査結果を述べる。

(1) 日別地震発生頻度分布

観測された地震数は 846 個（平均 9.4 個/日）で、最も高い地震の発生頻度は 1 月 21 日の 60 個、1 月 22 日の 119 個であった。図 A4.1.5 に日別地震発生頻度分布図示す。

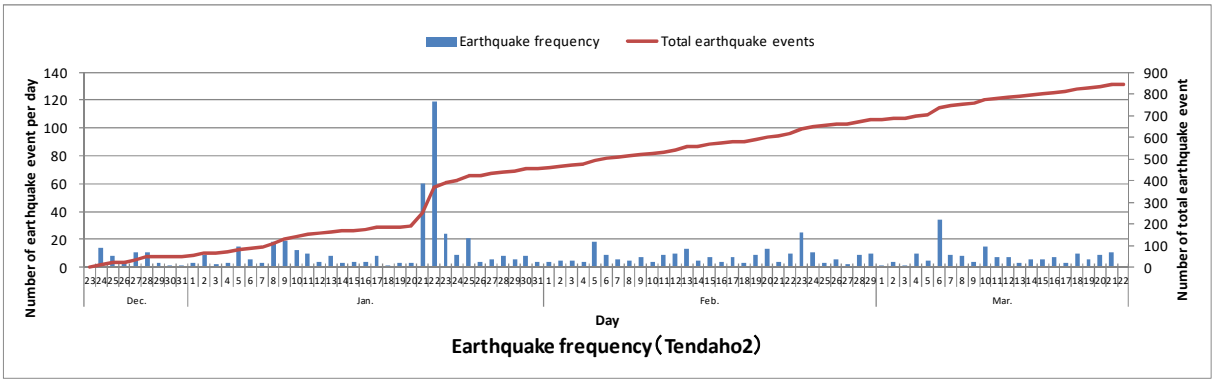


図 A4.1.5　日別地震発生頻度分布図 (テンダホ-2 地区)

(2) S-P 時間別地震発生頻度分布

S-P 時間別地震発生頻度は、全観測を通じて 5 観測点の中でノイズが小さく精度よく P 波、S 波到達時刻の読取りができた観測点 MST-1 を基準とした(図 A4.1.6)。

観測された全地震のうち、S-P 時間が 6 秒未満の地震が圧倒的に多く(393 個)、全地震の半分以上を占めている。特に、4～6 秒の発生頻度が高くなっており、この地震は 1 月 21 日～23 日に集中した群発的な活動によるものである。

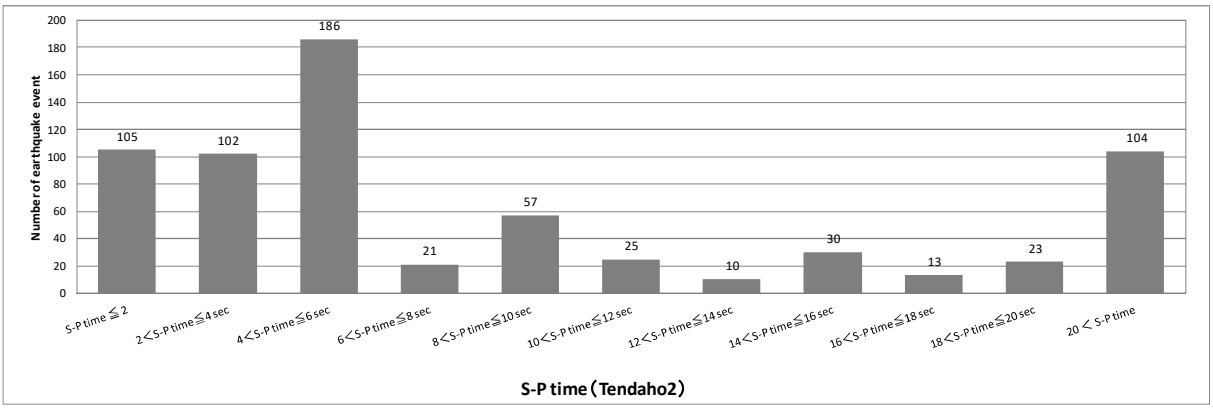


図 A4.1.6　S-P 時間別地震発生頻度分布図(テンダホ-2 地区)

(3) 震源分布図

観測された 846 個の地震のうち、震源が推定されたものは 202 個であった。震源分布の結果は、観測網近傍の局地地震の震源分布と、観測点 MST-3 から 200km 以内の遠地地震を含めた震源分布の 2 通りを作成した(図 3.7～図 3.8)。なお、地震読取りデータ及び震源座標・マグニチュード推定結果を巻末に添付する。

図 A4.1.7 には、本地区に卓越した NW-SE 方向の断層の位置と、F2～F4 の断層間に確認されている噴気孔の位置を示した。図 A4.1.8 には、エチオピア地溝帯(Meseret Teklemariam, 2008)の位置及び JICA 調査団の地質調査結果による断裂系を示した。

【局地地震】

以下に、震源結果を述べる。

・MST-1 付近を通る F0 断層東側に、断層方向の NW－SE の配列で地震が発生している。
・F0 断層付近の地震の深さは 2～6km で、マグニチュードは 1 以下である。
・F0～F2 の断層間には、地震は観測されていない。
・F2～F4 の断層の途切れる噴気帯周辺で地震が集中して発生している。この地震の深さは 1km 以浅と深さ 3km～6km の地震に分けられる。マグニチュードは 1 以下が多い。
・F4 断層付近に発生した地震の一部にマグニチュード 1～2 の地震が見られる。

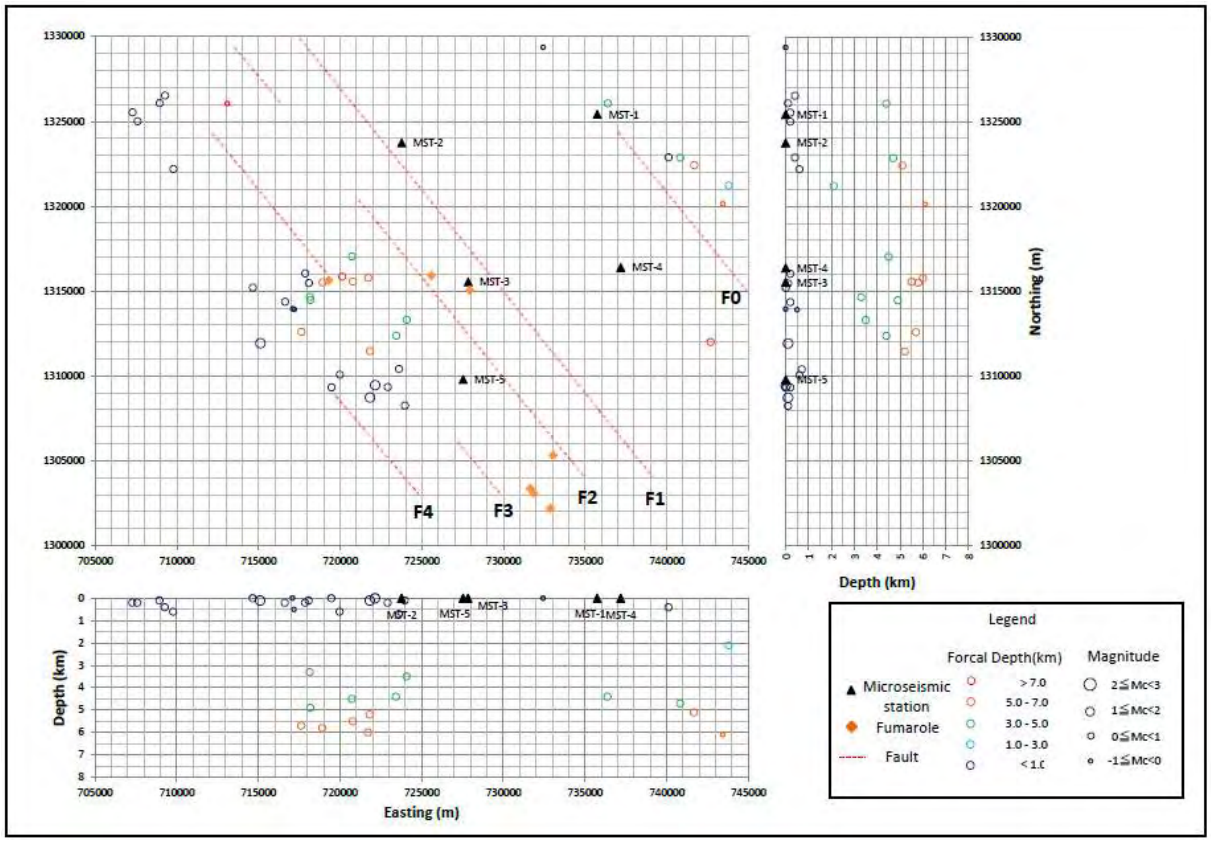


図 A4.1.7　震源推定分布図（テンダホ-2 地区の観測網近傍）

【局地地震及び遠地地震を含めた地震】

・テンダホ-2 地区から 100km 以内の地震は深さ 20km～30km で発生しており、その分布は垂直方向で配列している。マグニチュードは 2 以下である。
・テンダホ-2 地区から 100km 以上の地震は比較的浅いところで発生している。マグニチュードは 2 以上が優勢である。

・地震の分布は、テンダホ-2 地区の南方 100km では NNE－SSW 方向に配列しているが、多くの地震は分散している。
・Dallo、Boina、Tendaho 及び Danab 等の断裂周辺で震源が観測されている。
・テンダホ-2 地区南西 30km 付近(720000E, 129000N)のテンダホダム付近で、1 月 21 日～23 日に群発性による地震が発生しており、その深さは 20km 程度で、マグニチュードは 2～3 の範囲にある。3.1.6 考察でも述べるが、テンダホダム付近では 1969 年 3 月から 4 月にかけて群発地震が発生している。

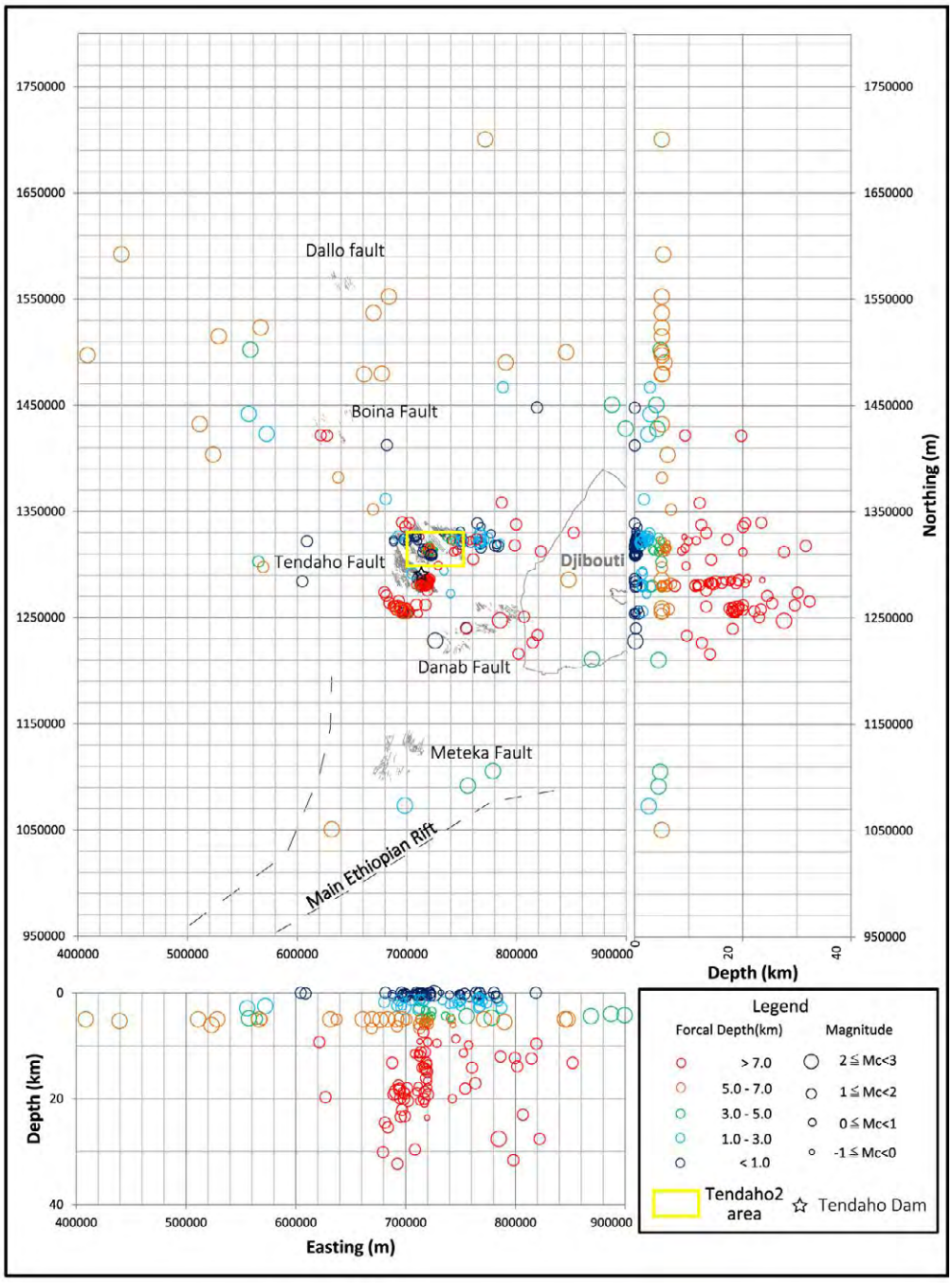


図 A4.1.8　震源推定分布図（テンダホ-2 地区の観測網遠方）

(4) 震源分布図（震源と地質との関係）

推定された震源と地質との関係は以下のとおりである(図A4.1.9)。

・MST-5の西側の震源は、PleistoceneのRecent basaltの割れ目噴火による溶岩流付近にあり、地震は断層周辺で多発している。
・観測点MST-3及びMST-5付近に噴気帯が確認されており、これらの噴気帯で震源が分布している。
・Manda-Harraro 地溝帯周辺において地震が発生している。
・F0断層東側に推定された震源は、湖成堆積物中に分布している。
・Afar Storatoidからなる玄武岩溶岩・火砕岩及び堆積岩が分布する地域には断裂系が多く発達しており、これらの断裂系に震源が分布している。

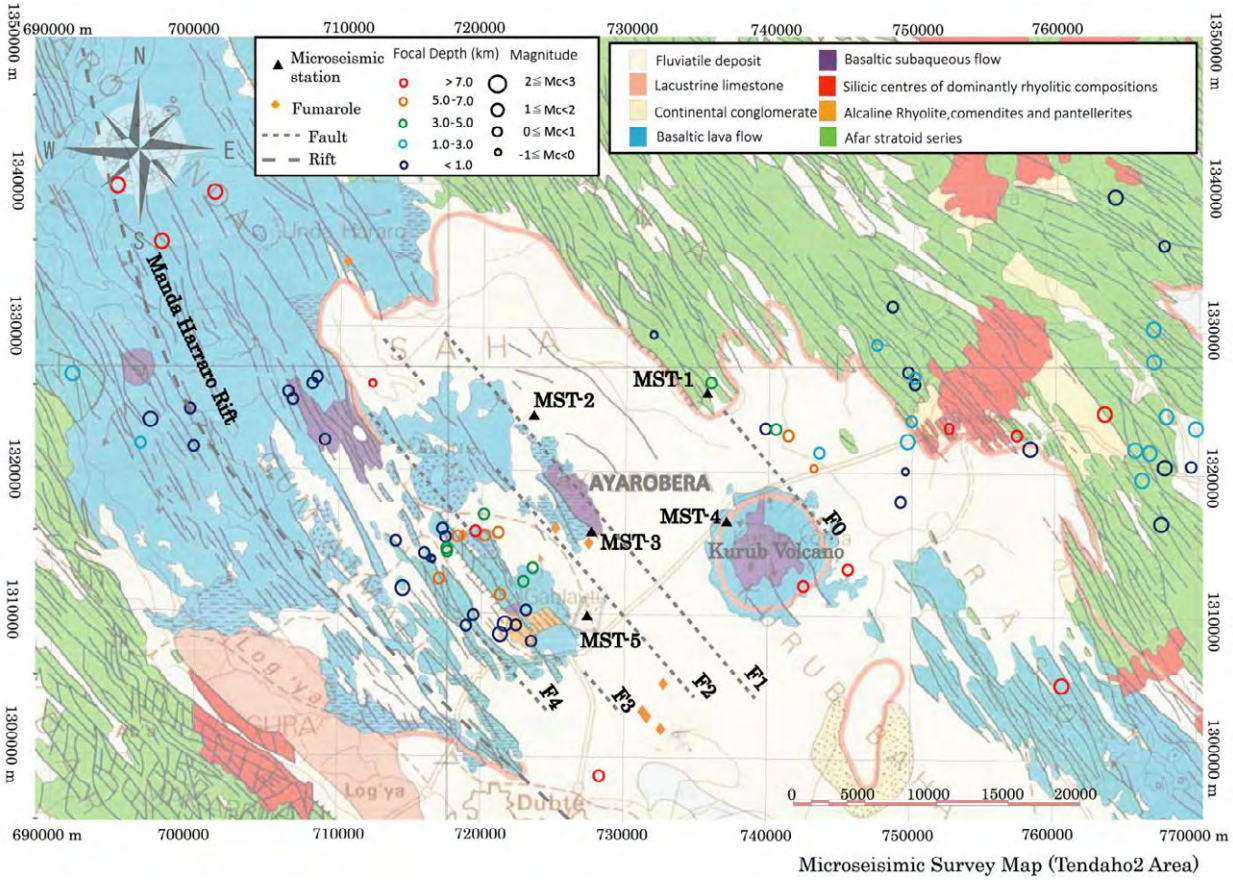


図 A4.1.9　震源推定分布図(テンダホ-2 地区の地質と震源)

(5) マグニチュード別累積頻度分布

自然地震はマグニチュードに応じて、

・極微小地震：M＜1
・微 小 地 震：1≦M＜3
・小　　地　　震：3≦M＜5
・中　　地　　震：5≦M＜7
・大　　地　　震：7≦M

のように分類されている。

本観測によるマグニチュードは、0.8～1付近にピークをもつ正規分布を示し、マグニチュードの範囲は-1.2～2.9にある（図A4.1.10）。本地域での自然地震は、いずれも微小地震または極微小地震に相当している。

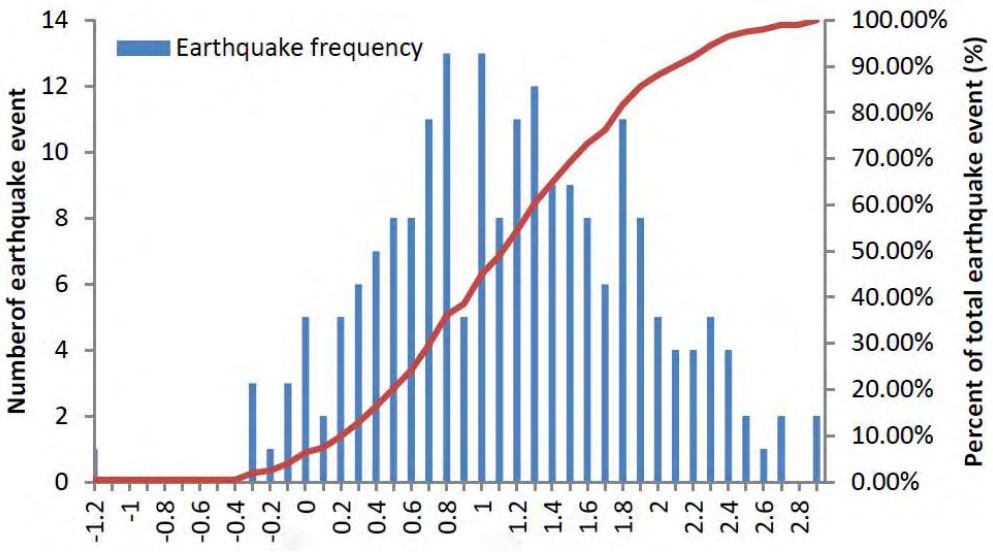


図 A4.1.10　マグニチュード別頻度分布図(テンダホ-2 地区)

(6)　b 値

b値の地震学的な意味について、梅田康弘(2012年)は次のように述べている。b値=1.0が普通(広い領域、長い時間を取るとb値は1.0になる)であり、b値が大きい場合の直線の勾配は急になり、小さい地震の起こる割合が大きい(例えば地下構造が複雑で不均質な場所で、群発地震の起こりやすい地域でよく見られる)。逆にb値が小さい値を取る場合は小さい地震の起こる割合が小さい、或いは小さい地震に対して大きな地震の起こる割合が大きい(例えば地殻はしっかり固く時々大きな地震が起きる)と述べられている。

本観測で計算した b 値を図 A4.1.11 に示す。青丸が直線状に並ぶのは Mc1.5～Mc2.7 の範囲である。Mc1.5 より小さい地震数は直線より下側に外れており、これは小さな地震を観測できなかったためと考えられ、Mc1.5 より小さい地震は計算から除外した。Mc2.7 より大きな地震は直線より下側に外れており、これは観測期間が 90 日と短期間であったと考えられる。

本観測結果での b 値は 1.06 と推定され、通常の構造性地震の b 値(0.7-1.0)(宇津徳治,1977,p133)に近い。

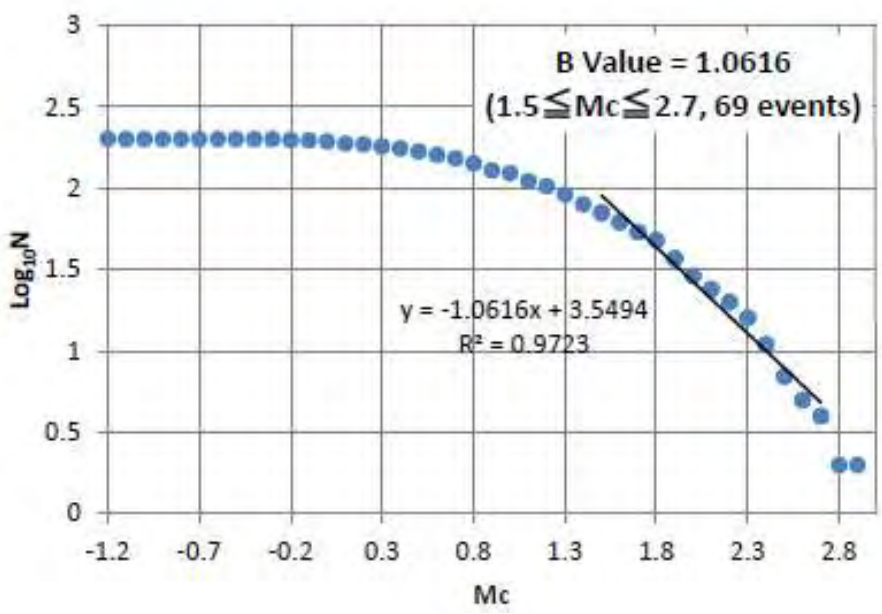


図 A4.1.11　b 値(テンダホ-2 地区)

(7)　和達ダイヤグラム

和達ダイヤグラムを用いて、本地域で発生した微小地震の Vp/Vs の評価を行った。観測された地震の中から精度よく得られた観測点 4 点以上の P 波、S 波の到達時刻を用い、横軸に P 時刻、縦軸に S-P 時間を観測点毎にプロットした(図 A4.1.12)。読取りの観測点毎の走時データから最小二乗法によって Vp/Vs に関する和達ダイヤグラムの勾配を計算した。なお、地震記象とその読取り値に基づいて得られた和達ダイヤグラムを巻末資料に添付する。

表 A4.1.5 は 5 つの地震を用いて計算した Vp/Vs 値と平均値である。その結果、Vp/Vs の平均値 1.814 は、震源計算に使用された Vp/Vs=1.78 とほぼ一致した値が得られ、使用した Vp/Vs=1.78 は妥当なものと結論付けられる。

表 A4.1.5　Vp/Vs の値(テンダホ-2 地区)

Event No.	Event origin time	Vp/Vs	Average of Vp/Vs
58	2016.1.11 02:06	1.722	1.814
65	2016.1.15 03:50	1.913	
99	2016.1.22 04:00	1.906	
142	2016.2.12 03:53	1.779	
172	2016.2.29 02:57	1.751	

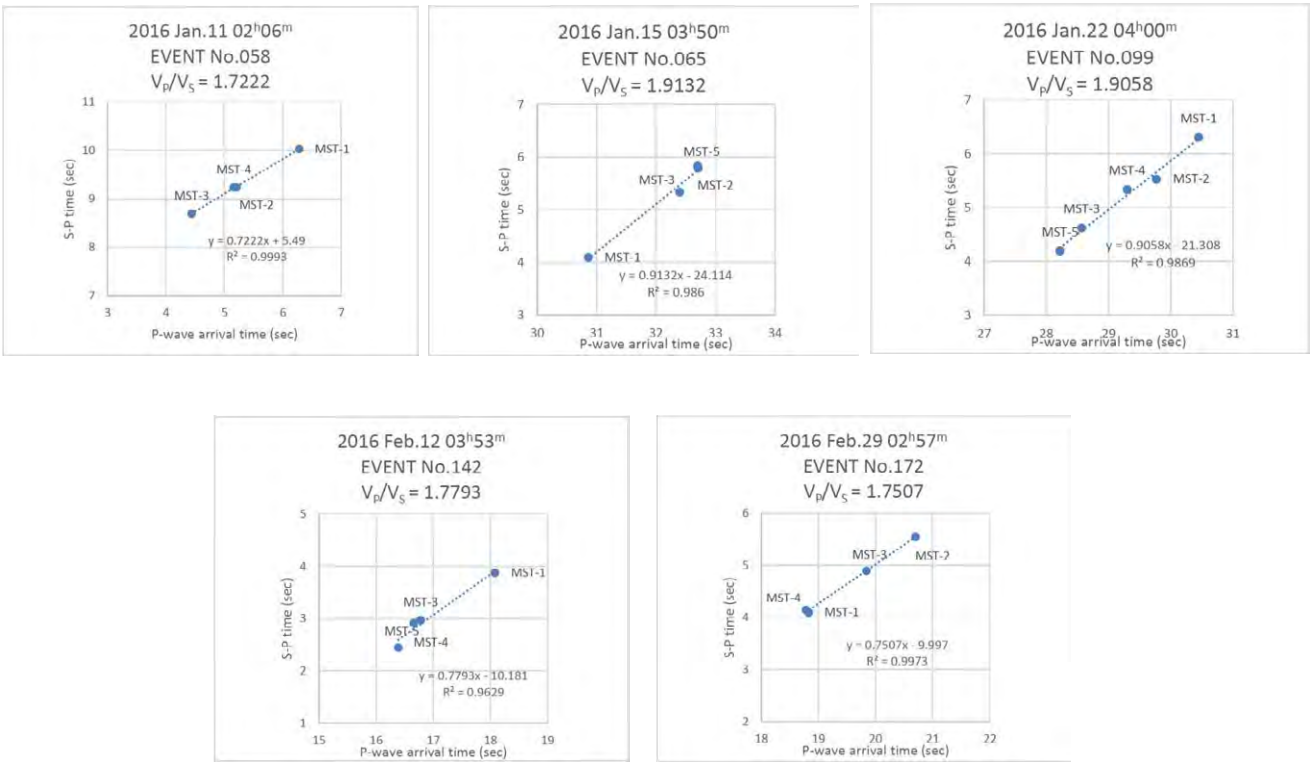


図 A4.1.12　和達ダイヤグラム(テンダホ-2 地区)

A4.1.6　考察

(1)　2009 年から 2015 年に発生した震源分布域との関係

震源分布は、赤丸が本観測で得られた震源の位置、青丸は 2009 年から 2015 年の地震活動の位置である(図 A4.1.13)。2009 年から 2015 年の地震分布は、1995 年にイタリア外務省が実施した微小地震観測、CEDIM(Center for Disaster Management and Risk Reduction Technology)の Earthquake　-report.com 及び USGS(United States Geological Survey)の Earthquake-Report.com の震源分布を参考とした。ただし、2009 年から 2015 年に発生した地震は M4 クラス以上に限定されたエチオピア及びジブチ国内で観測された地震観測結果であり、M4 以下の小地震～極微小地震の分布は不明である。

この図から2009年から2015年の地震活動域は、エチオピア地溝帯内での分布、ジブチ国Hanle地区(ジブチ国地熱開発のための情報収集・確認調査の一環として実施された微小地震観測地区)周辺での分布、テンダホ-2地区、及びBoinaやTendaho断層付近に分布している。

本観測で推定された震源位置は、2009年から2015年の地震分布とほぼ同じ位置に震源範囲が重なり、同地区を含む広範囲で地震が活発に発生していることが判明した。

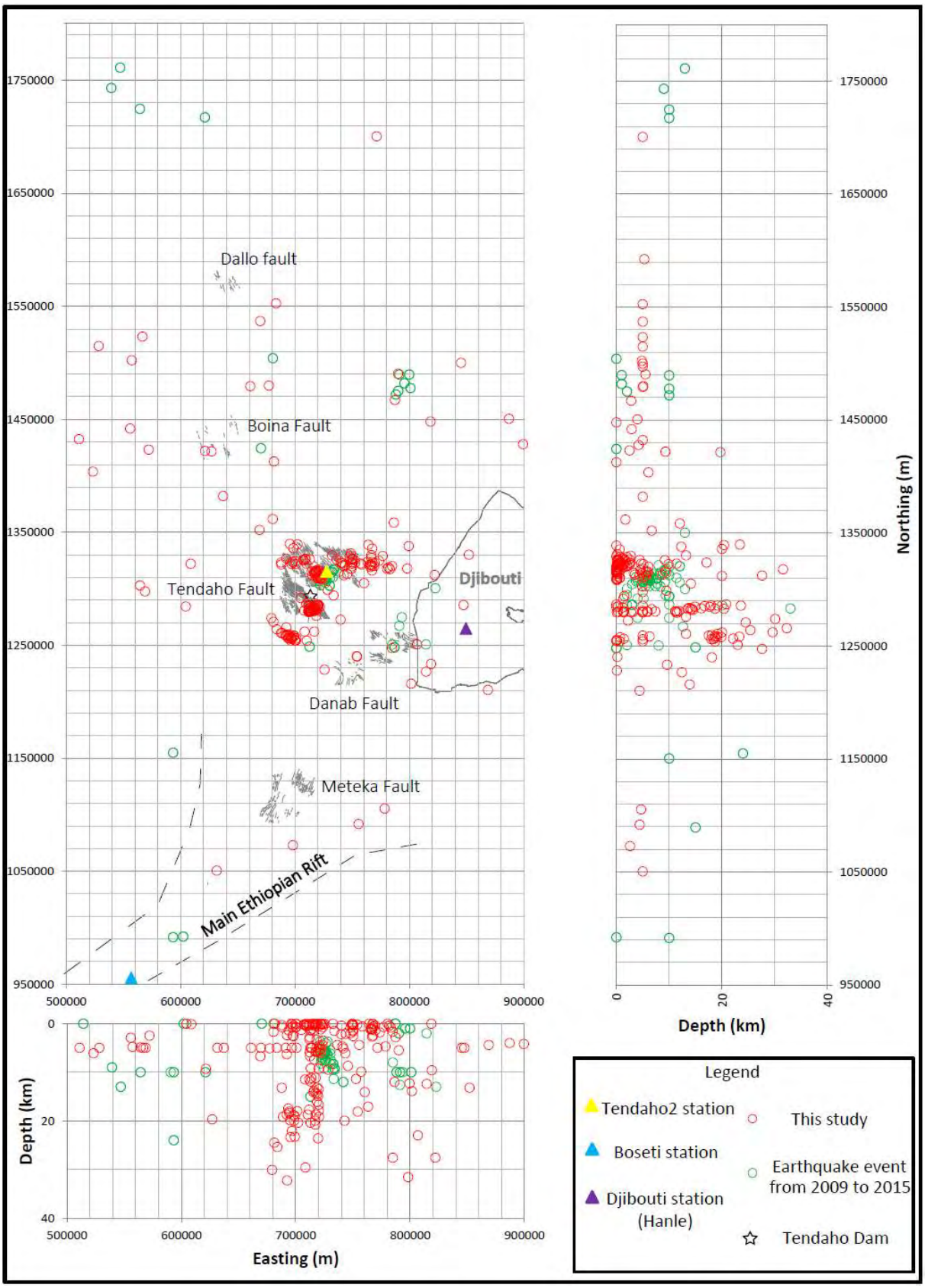


図 A4.1.13　2009 年～2015 年(M4 以上)の震源推定分布と本観測の震源推定分布

(2) アファール地域における地震活動度と本観測結果との比較（表 A4.1.6）

アファール地域における地震活動度(Ayele et. al, 2015)によると、Tendaho dam 近辺(黄色の☆印)で 1969 年に群発地震が発生している(図 A4.1.14)。また、アファール地域中央部の震源とする数百もの地震が発生した。なお、観測点 MST-5 から南方約 15km に位置する町である。

表A4.1.6 アファール地域における地震活動と本観測結果との比較

地震発生地域	既存観測結果 (Ayele et al, 2015)	本調査結果
テンダホダム周辺	・群発地震が 1969 年 3 月~4 月にかけて観測された。	・群発地震が2016年1月21~23日にかけて観測された。 ・震源の深さは約20km, マグニチュードは2～3であった。
アファール地域中央部	・多くの地震 (マグニチュード4.5～6.5)が1989年8月20~22日にかけて観測された。	・地震が同地域において観測された。

出典: 調査団

本観測を含めた地域は、断層の活動による地震やアファール地溝帯間での地震が集中して発生しており、地震・火山活動はこれらの断層と密接に関連していると考えられる。また、地熱地域では、主に岩の割れ目・亀裂が滑ることで地震が起きると言われていることから、本観測で推定された震源は断層付近で発生しており、断層付近での地震活動を裏付けるものと推定される。

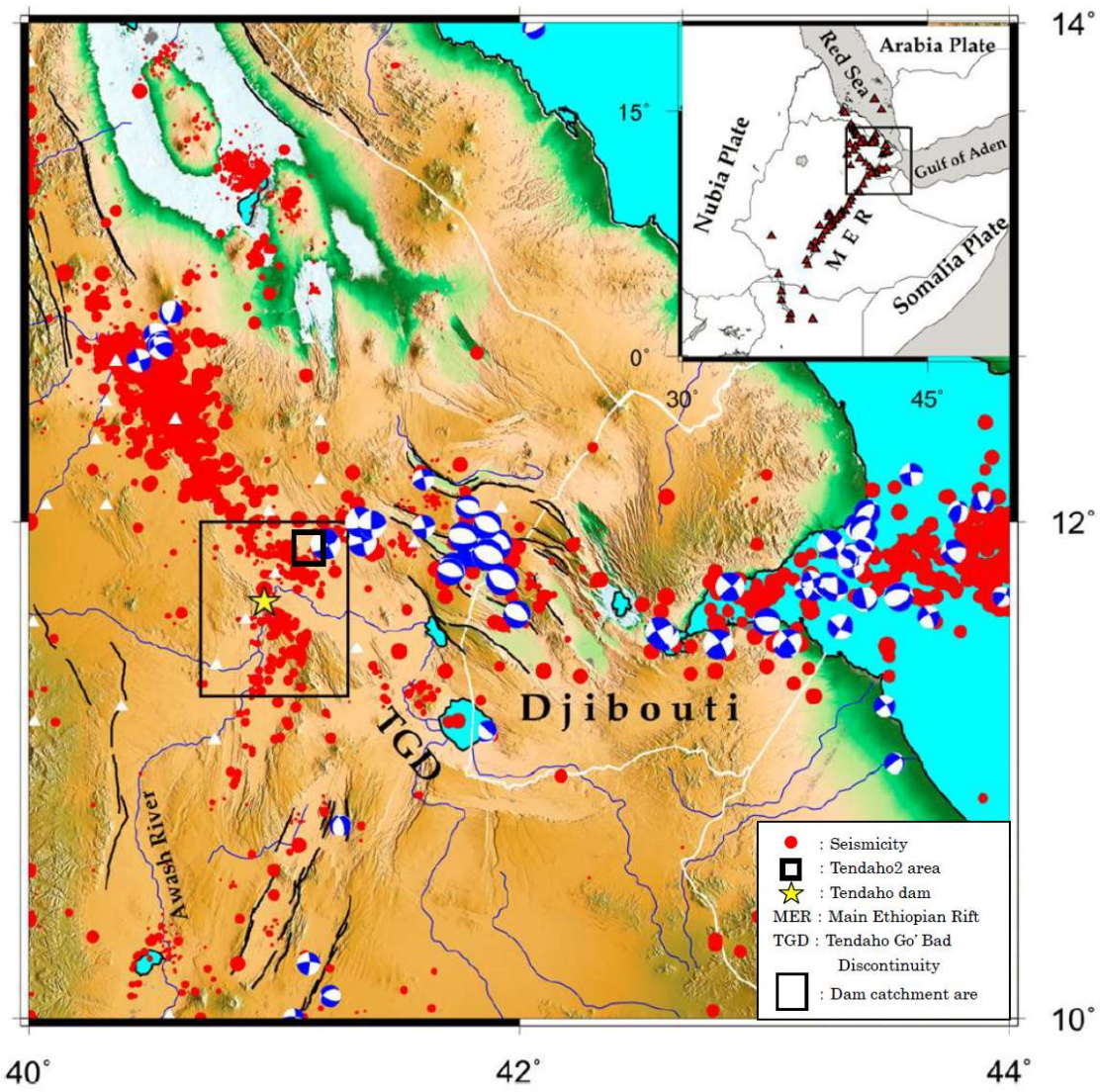


図 4.1.14　アファール地域における地震活動

(3)　地熱と微小地震との関係

テンダホ-2 地区には、断層 F0～F4 が NW-SE 方向に通り、断層 F2～F4 の間に噴気孔が数多く確認することができる。地震の分布は断層や噴気孔周辺に集中している。これらの地震の深さは、1km 以浅と深さ 3km～6km のグループに分けることができ、地震発生の深さは地熱流体との関係によるものと考えられる。また、噴気帯と地震の多発地域の位置関係から地震多発地域は地熱流体の上昇域に当っていると推定される。特に集中して地震が発生している地域は、割れ目の発達を示している可能性が高い。

(4)　過去に計算された b 値との比較

Ayele et al (2015)はテンダホダム周辺地域の地震活動の評価のために、2009 年から 2011 年の間に同地域で発生した 5320 個の地震に対して Keir et al (2006)と同じ方法でマグニチュード(ML)を決定し、この結果得られた b 値は 0.79±0.01 であった。

本観測でのb値は1.06であり、Ayele et al.(2015)が算出したb値よりも若干高いが、通常の構造性地

震の値となった。

A4.1.7 まとめ

テンダホ-2 地区に発生している微小地震活動の特徴を以下のように整理した（表 A4.1.7）。

表 A4.1.7 震源分布の特徴(テンダホ-2 地区)

項目	特徴
地震	・震源は断層周辺で発生しており、過去の地震観測で発生した位置と一致する。これらの地震はこの断層に沿って応力解放に伴って発生したものと考えられる。 ・F2～F4 断層間の地震は、深さ 1km 以浅に発生している地震と深さ 2km～6km の地震に分かれる。マグニチュードは 0～1 の極微小地震である。 ・F2～F4 断層間の地震は、噴気活動が盛んな地域と概ね一致している。噴気地域直下で地震活動が活発していると推定される。 ・震源計算された全地震のマグニチュードの範囲は-1.2～2.8の範囲にあり、微小地震または極微小地震に相当する。 ・本観測で推定された b 値は 1.06 であることから、b 値は普通の構造性地震とほぼ同じ 1 に近い。 ・和達ダイヤグラムの勾配から Vp/Vs＝1.814 が求められ、震源計算に使用された Vp/Vs=1.78 とほぼ同じ値が得られた。
地質	・MST-5付近の震源は、PleistoceneのRecent basaltの割れ目噴火による溶岩流が見られる付近にあり、震源は断層付近に分布している。 ・Afar Storatoidからなる玄武岩溶岩・火砕岩及び堆積岩の断裂系が発達した地域で、震源が分布している。 ・アファール地溝帯間での地震が集中して発生しており、地震・火山活動はこれらの断層と密接に関連していると考えられる。
地熱	・地震は、断層や噴気孔周辺に集中して分布している。 ・地震の深さは1km以浅と深さ3km～6kmであり、地熱流体との相関関係があると考えられる。 ・噴気帯と地震の多発地域の位置関係から、地震多発地域は地熱流体の上昇域に当っていると推定される。

A4.2 ボセッティ地区

A4.2.1 観測の目的

微小地震観測の地震計設置位置を図 A4.2.1 に示す。

ボセッティ地区では、地震発生の有無の確認を行う目的のため、1 地点の観測点を設置して微小地震観測を行った。

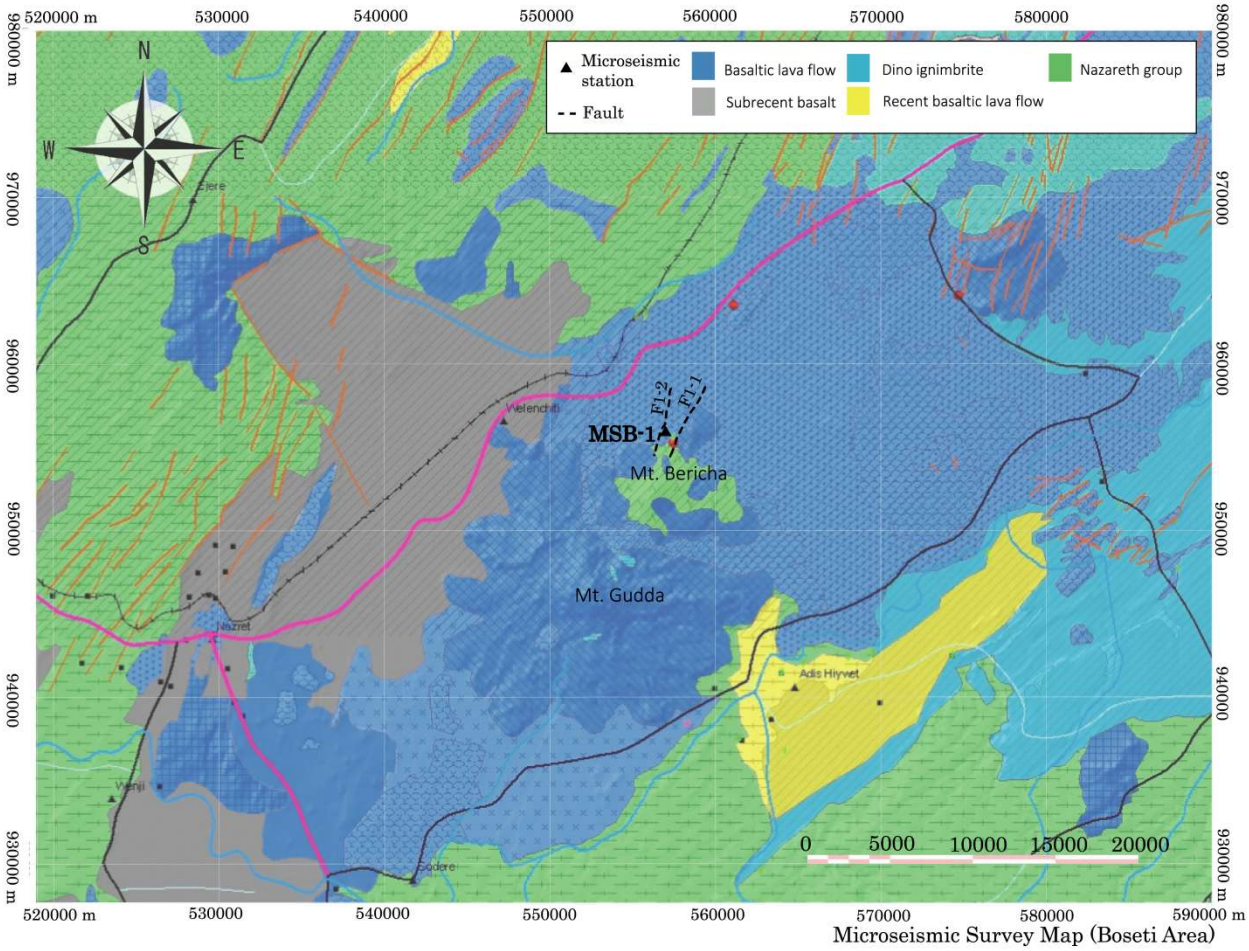


図 A4.2.1 微小地震観測位置図（ボセッティ地区）

A4.2.2 地質概要

地熱発電開発マスタープラン策定調査プロジェクトファイナルレポート(2015)によれば、ボセッティ地域はNE-SW方向へ発達するエチオピア地溝帯の中央部に位置し、地溝帯内部にはNE-SW方向の断裂系が発達している。基盤は玄武岩からなり、この基盤に火山噴出物が覆い、さらにこの上位にNazareth層群に属する玄武岩・流紋岩溶岩・火砕岩等が被覆している。地熱徴候は、Bericha山山頂付近を通る断層破砕帯(F1-2,F1-1)沿いに噴気・温泉等が認められる。

A4.2.3 観測概要

本観測の調査内容は以下のとおりである。

(1) 観測地点の選定

観測地点は Bericha 山北側の裾野とし、地震計設置地点はグラウンドノイズを測定して、ノイズの小さい溶岩台地上に選定した。観測地点の周囲には噴気孔が多く見られ、地震計設置地点は噴気孔から数 10m の場所にある。

(2) データ取得システム

観測装置はテンダホ-2 地区で使用したものと同型で、ドイツ国 Lennartz electronic GmbH 社製 LE-3Dlite Mk Ⅱ地震計、米国 Geospace 社製 GSX-3 データロガー及び 12V バッテリーである。

(3) 地震計及び周辺機器の設置

ボセッティ地区は、1 地点に 3 成分（南北成分、東西成分、上下成分）の速度型地震計を設置した。表 A4.2.1 は地震計を設置した座標・標高及びノイズレベルである。

表 A4.2.1　地震計設置概要（ボセッティ地区）

Station No.	Longitude	Latitude	UTM (easting)	UTM (northing)	Elevation (m)	Ground noise (μkine)
MSB-1	39° 31′ 01.5″ E	8° 38′ 50.5″ N	955906	556889	1356	40

(4) 観測機器の保守と盗難防止対策

テンダホ-2 地区と同様に、観測機器の確認を調査団員が定期的に巡回した。また、機器の盗難防止のために、見張り人を昼夜それぞれ 1 名ずつ立てた。

(5) 観測期間

ボセッティ地区における観測期間は 93 日間である。観測期間中に機器等のトラブルは無かった。観測期間を表 A4.2.2 に示す。

表 A4.2.2　観測地点の地震計設置及び回収日時（ボセッティ地区）

Site Code	Observation start time	Observation stop time	Observation days
MSB-1	2015.12.24 17:50	2016.3.26 9:50	93days and 16hours

A4.2.4　観測データの処理

(1) 観測データの処理

地震観測データの処理は、テンダホ-2 地区の 5 観測点を含めた 6 観測点と同時に行った。統合された観測波形データから、地震波の部分を目視により識別し、地震波形の部分を切り出した。

(2) 記録の読取り・整理

SEG-D フォーマット形式のデータから、地震と判定されたデータの P 波到達時刻、S 波到達時刻を読み取った。

A4.2.5　調査結果

93 日間の微小地震観測を行った結果、230 個の地震が確認された。なお、1 観測点による観測であ

るため、震源計算は行っていない。

調査結果は、図 A4.2.2～図 A4.2.3 に示す日別地震発生頻度分布及び S-P 時間別地震発生頻度分布である。

(1) 日別地震発生頻度分布

観測期間中、230 個（平均 2.4 個/日）の地震が観測され、このうち 1 月 8 日に 13 個、3 月 6 日に 43 個の地震が集中して観測された。

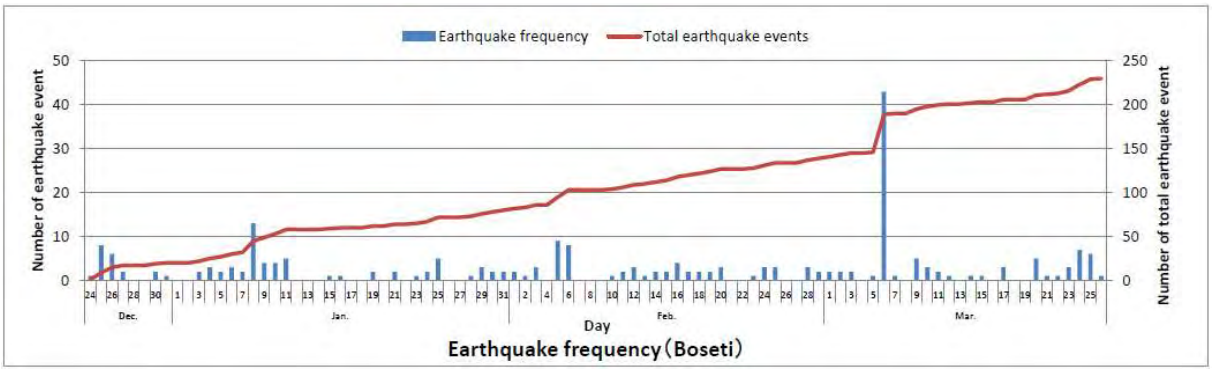


図 A4.2.2　日別地震発生頻度分布図(ボセッティ地区)

(2) S-P 時間別地震発生頻度分布

S-P 時間 4 秒未満の地震が圧倒的に多く、全地震の半分以上を占めている。特に 2 秒以下の局地地震は 73 個（平均 0.7 個/日）と際立っている。これは 3 月 6 日の群発地震の多発によるものである。

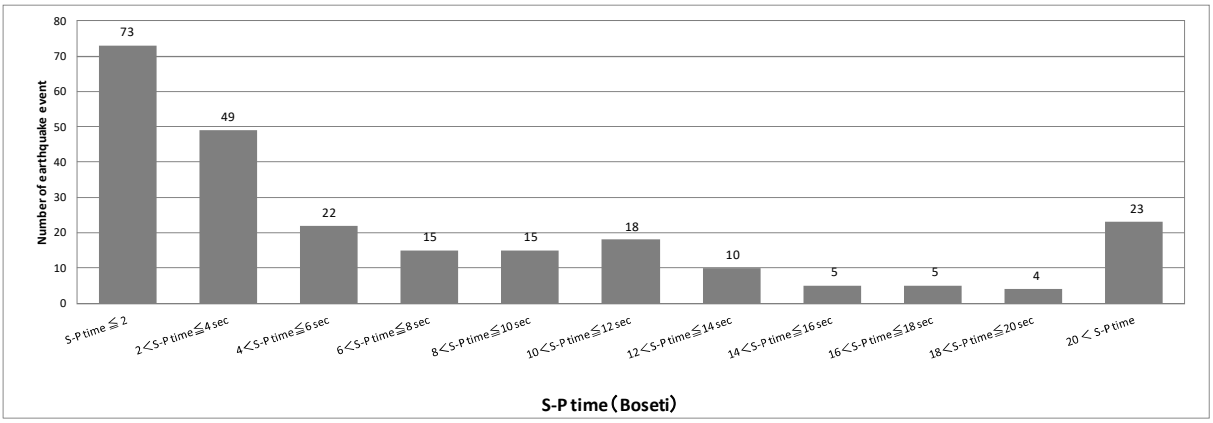


図 A4.2.3　S-P 時間別地震発生頻度分布図(ボセッテイ地区)

A4.2.6　考察

(1) 過去の震源分布域との関係

エチオピア地溝帯をはじめとする断層付近は、これまでの地震観測によって地震多発地帯であることが判明しており、震源分布は地溝帯と同じ NE-SW 方向で、マグニチュードの規模は 3 以下の

微小地震が優勢である(Ayele et al, 2015)。また、Bericha 山山頂周辺の割れ目に多量の噴気が認められ、山体の中心に近づくほど温度が高いと考えられている(地熱発電開発マスタープラン策定調査プロジェクトファイナルレポート,2015)。

本地区での地震観測では、局地地震の S-P 時間 2 秒以下の地震が数多く観測され、これらの局地地震はボセッティ地区周辺の断層や、地殻の不均質度が高い地下構造の急変するところで発生していると考えられる。

A4.2.7 まとめ

ボセッティ地区の地震活動の特徴は以下の通りである（表 A4.2.3）。

表 A4.2.3 震源分布の特徴(ボセッティ地区)

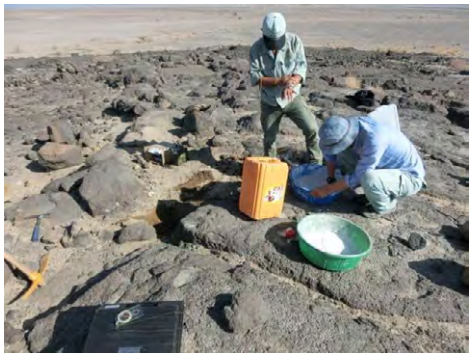
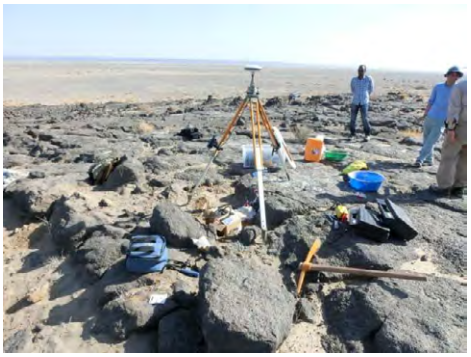
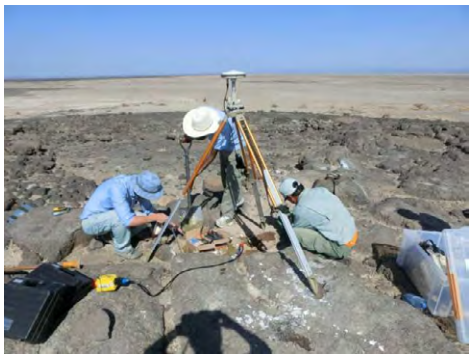
項目	特徴
地震	・本地区には、小規模な地震が発生している。 ・93 日間の観測期間中に 230 個（平均 2.4 個/日）の地震が観測された。 ・S-P 時間 4 秒以下の局地地震が、1 月 8 日及び 3 月 6 日に集中して観測された。 ・S-P 時間 4 秒未満の地震が全地震の半分以上を占めている。特に 2 秒以下の局地地震は 68 個（平均 0.7 個/日）である。
地質	・本地区周辺の断層や地下構造の急変するところでの地震が考えられる。 ・地熱徴候を示唆している噴気等で、地震が発生している可能性が考えられる。

A4.3　作業写真（テンダホ地区）

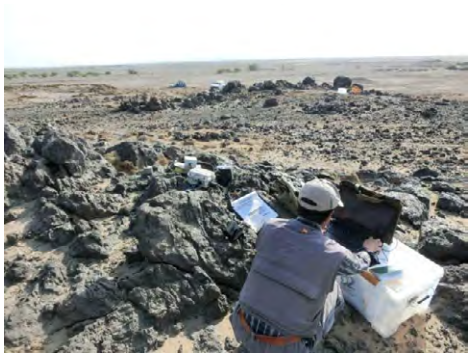
地震計設置　テンダホ-2：MST-1

<table>
<tr><td> 
</td><td>  </td></tr>
<tr><td>観測点設置箇所の全景</td><td>ノイズ測定中</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>ノイズ測定中</td><td>地震計設置箇所の地盤整形</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>石膏の台座に地震計を埋め込んだ状況</td><td>石膏の台座に地震計を埋め込んだ状況</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>観測機器にビニールシートを被せている作業</td><td>石で観測施設全体を覆い隠した観測点</td></tr>
</table>

地震計設置　テンダホ-2：MST-2

	
観測点 MST-2 の全景	ノイズ測定中
	
地震計設置箇所の地盤整形	石膏の台座に地震計を埋め込んだ状況
	
周辺機器の設置作業	周辺機器設置の全景
	
周辺機器をモルタルにて固定	石で観測施設全体を覆っている作業

地震計設置　テンダホ-2：MST-3

	
観測点設置箇所の全景	ノイズ測定中
	
石膏の準備	石膏の台座に地震計を埋め込んだ状況
	
モルタルの準備	周辺機器をモルタルにて固定
	
バッテリーをチェーンと南京錠で固定	石で観測施設全体を覆っている作業

地震計設置　テンダホ-2：MST-4

	
観測点設置箇所の全景	観測点設置箇所の全景
	
ノイズ測定中(1 箇所目の測定)	ノイズ測定中(1 箇所目の測定)
	
ノイズ測定中(2 箇所目の測定)	地震計設置箇所の地盤整形
	
石で観測施設全体を覆い隠した観測点	石で観測施設全体を覆い隠した観測点

地震計設置　テンダホ-2：MST-5

	
観測点設置箇所の全景	ノイズ測定中
	
石膏の台座に地震計を埋め込む作業	周辺機器の設置作業
	
周辺機器をモルタルにて固定	周辺機器をモルタルにて固定
	
観測機器にビニールシートを被せている作業	石で観測施設全体を覆い隠した観測点

地震計回収　テンダホ-2：MST-1～MST-5

	
TENDAHO2：MST-1 の機器の撤収作業	TENDAHO2：MST-1 の機器の撤収作業
	
TENDAHO2：MST-2 の機器の撤収作業	TENDAHO2：MST-3 の機器の撤収作業
	
TENDAHO2：MST-4 の機器の撤収作業	TENDAHO2：MST-5 の機器の撤収作業

A4.4　作業写真（ボセッティ地区）

地震計設置/回収　ボセッティ：MSB-1

<table>
<tr><td> 
</td><td>  </td></tr>
<tr><td>観測点設置箇所の全景</td><td>ノイズ測定中</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>石膏の準備</td><td>石膏の台座に地震計を埋め込む作業</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>周辺機器の設置作業</td><td>石で観測施設全体を覆い隠した観測点</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>機器の撤収作業</td><td>機器撤去後の風景</td></tr>
</table>

A4.5 微小地震計観測データ（テンダホ-2 地区）

Tendaho2 event identifier

No.	Station	Date	Arrival time				F-P	Hypocenter					Magnitude
			Hour	Minute	Second(P)	Second(S)	(sec)	Longitude	Latitude	Northing(m) [Zone 37]	Easting(m) [Zone 37]	Depth (km)	
1	MST-1	2015/12/24	03	26	45.04	49.75(NS) 49.78(EW)	35	11.9527	40.8100	1321964	697099	2.5	0.9
	MST-2		03	26	43.08	46.31(NS) 46.32(EW)	32						
	MST-3		03	26	44.08	47.95(NS) 47.96(EW)	29						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
2	MST-1	2015/12/24	07	47	24.47	32.48(NS) 32.56(EW)	39	12.2760	41.6332	1358473	786441	12.0	1.1
	MST-2		07	47	26.14	35.30(NS) 35.32(EW)	36						
	MST-3		07	47	26.53	35.53(NS) 35.53(EW)	32						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
3	MST-1	2015/12/24	12	59	2.39	5.73(NS) 5.70(EW)	33	11.9843	40.9037	1325536	707278	0.2	0.7
	MST-2		12	59	0.54	2.59(NS) 2.60(EW)	23						
	MST-3		12	59	1.68	4.55(NS) 4.56(EW)	22						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
4	MST-1	2015/12/24	15	45	1.31	28.70(NS) 28.45(EW)	97	14.0373	40.6997	1552515	683542	5.0	2.4
	MST-2		15	45	1.23	28.42(NS) 28.36(EW)	98						
	MST-3		15	45	2.77	31.05(NS) 31.13(EW)	102						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
5	MST-1	2015/12/24	16	40	23.92	27.23(NS) 27.23(EW)	28	11.9795	40.9065	1325003	707590	0.2	0.7
	MST-2		16	40	22.05	24.08(NS) 24.08(EW)	26						
	MST-3		16	40	23.23	25.99(NS) 25.96(EW)	24						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
6	MST-1	2015/12/24	16	50	23.22	26.72(NS) 26.72(EW)	31	11.7425	41.0977	1298932	728611	9.5	0.8
	MST-2		16	50	22.78	26.28(NS) 26.27(EW)	29						
	MST-3		16	50	21.58	23.91(NS) 23.94(EW)	24						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
7	MST-1	2015/12/25	00	08	32.82	38.69(NS) 38.69(EW)	-	11.9095	41.5752	1317847	780510	0.0	1.4
	MST-2		00	08	34.57	41.75(NS) 41.79(EW)	50						
	MST-3		00	08	33.87	40.42(NS) 40.34(EW)	43						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
8	MST-1	2015/12/25	01	42	18.60	21.10(NS) 21.10(EW)	-	11.8667	40.9978	1312591	717623	5.7	0.5
	MST-2		01	42	17.07	18.86(NS) 18.87(EW)	20						
	MST-3		01	42	16.72	18.17(NS) 18.18(EW)	26						
	MST-4		-	-	-	-	-						
	MST-5		01	42	16.71	18.28(NS) 18.28(EW)	22						
9	MST-1	2015/12/26	13	14	59.72	62.62(NS) 62.59(EW)	-	11.8608	40.9747	1311927	715109	0.1	1.0
	MST-2		13	14	58.26	59.93(NS) 59.89(EW)	40						
	MST-3		13	14	57.88	59.40(NS) 59.42(EW)	27						
	MST-4		-	-	-	-	-						

	MST-5		-	-	-	-	-						
10	MST-1	2015/12/27	15	03	37.05	51.93(NS) 51.93(EW)	77	11.6123	42.1862	1285633	847497	5.0	2.1
	MST-2		15	03	38.45	54.69(NS) 54.67(EW)	82						
	MST-3		15	03	37.32	53.02(NS) 52.96(EW)	92						
	MST-4		-	-	-	-	-						
	MST-5		15	03	37.49	52.79(NS) 52.87(EW)	86						
11	MST-1	2015/12/27	15	18	16.28	48.48(NS) 48.55(EW)	101	13.7032	39.2623	1514913	528365	5.0	2.5
	MST-2		15	18	15.84	46.96(NS) 47.02(EW)	102						
	MST-3		15	18	16.85	49.02(NS) 48.99(EW)	98						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
12	MST-1	2015/12/28	03	33	51.19	55.04(NS) 55.05(EW)	26	11.9644	40.7253	1323209	687863	0.7	0.6
	MST-2		03	33	49.36	51.78(NS) 51.81(EW)	21						
	MST-3		03	33	50.42	53.44(NS) 53.46(EW)	26						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
13	MST-1	2015/12/28	08	00	34.46	40.99(NS) 40.67(EW)	-	11.6798	40.8802	1291831	704945	1.3	1.5
	MST-2		08	00	33.27	37.44(NS) 37.44(EW)	49						
	MST-3		08	00	32.38	35.99(NS) 35.95(EW)	59						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
14	MST-1	2015/12/28	09	19	18.97	40.09(NS) 39.95(EW)	78	13.3765	40.4863	1479255	660949	5.0	2.1
	MST-2		09	19	18.92	39.47(NS) 39.29(EW)	74						
	MST-3		09	19	19.42	41.96(NS) 41.96(EW)	83						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
15	MST-1	2015/12/28	11	08	47.82	68.62(NS) 68.48(EW)	101	13.3813	40.6360	1479892	677156	5.1	2.3
	MST-2		11	08	47.54	68.10(NS) 67.97(EW)	93						
	MST-3		11	08	48.94	70.12(NS) 70.12(EW)	100						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
16	MST-1	2015/12/29	23	48	28.17	30.58(NS) 30.57(EW)	31	11.8853	41.0027	1314659	718141	3.3	0.4
	MST-2		23	48	26.72	28.03(NS) 28.01(EW)	21						
	MST-3		23	48	26.49	-	13						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
17	MST-1	2015/12/30	01	05	56.72	68.99(NS) 69.06(EW)	-	11.1048	41.0675	1228355	725827	0.1	2.2
	MST-2		01	05	56.69	68.42(NS) 68.61(EW)	-						
	MST-3		01	05	55.30	66.32(NS) 66.40(EW)	82						
	MST-4		-	-	-	-	-						
	MST-5		01	05	54.50	65.17(NS) 65.27(EW)	98						
18	MST-1	2016/1/1	02	22	22.74	35.37(NS) 35.47(EW)	64	12.7727	40.6732	1412582	681627	0.0	1.9
	MST-2		02	22	22.03	34.04(NS) 33.95(EW)	65						
	MST-3		02	22	23.93	36.19(NS) 36.37(EW)	78						
	MST-4		02	22	24.16	37.80(NS) 38.16(EW)	-						
	MST-5		02	22	23.16	39.05(NS) 38.87(EW)	86						
19	MST-1	2016/1/2	04	25	32.15	34.69(NS) 34.66(EW)	20	11.8905	40.9707	1315206	714650	0.0	0.4
	MST-2		04	25	29.86	31.76(NS) 31.79(EW)	19						
	MST-3		04	25	30.45	31.79(NS) 31.79(EW)	21						

	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
20	MST-1	2016/1/2	11	44	23.60	25.47(NS) 25.52(EW)	17	11.8727	41.0570	1313301	724072	3.5	0.2
	MST-2		11	44	22.59	24.03(NS) 24.01(EW)	16						
	MST-3		11	44	21.61	22.37(NS)22.39(EW)	16						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
21	MST-1	2016/1/2	13	12	33.17	35.19(NS) 35.11(EW)	34	11.9925	41.2952	1326764	749918	0.2	0.9
	MST-2		13	12	34.98	38.35(NS) 38.34(EW)	28						
	MST-3		13	12	34.67	37.78(NS) 37.75(EW)	32						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
22	MST-1	2016/1/3	13	29	24.81	27.78(NS) 27.72(EW)	16	11.9573	41.3207	1322896	752728	11.4	0.3
	MST-2		13	29	26.55	30.41(NS) 30.27(EW)	19						
	MST-3		13	29	26.04	29.47(NS) 29.45(EW)	21						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
23	MST-1	2016/1/3	20	33	19.27	40.19(NS) 40.20(EW)	72	11.7387	39.6318	1297733	568847	5.0	1.9
	MST-2		20	33	17.62	37.65(NS) 37.65(EW)	64						
	MST-3		20	33	18.44	38.33(NS) 38.42(EW)	60						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
24	MST-1	2016/1/4	10	42	31.60	53.03(NS) 53.17(EW)	96	13.4672	41.6795	1490379	790110	5.5	2.4
	MST-2		10	42	32.11	54.38(NS) 54.47(EW)	98						
	MST-3		10	42	33.56	55.67(NS) 55.70(EW)	110						
	MST-4		-	-	-	-	-						
	MST-5		10	42	33.22	56.32(NS) 56.25(EW)	114						
25	MST-1	2016/1/5	19	29	0.48	25.36(NS) 25.37(EW)	86	13.5480	42.1890	1499990	845205	5.0	2.2
	MST-2		19	29	1.64	27.02(NS) 27.00(EW)	84						
	MST-3		19	29	2.20	28.23(NS) 28.21(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
26	MST-1	2016/1/6	22	33	59.90	64.36(NS) 64.37(EW)	23	11.9507	40.8435	1321767	700750	0.1	0.5
	MST-2		22	33	58.04	60.91(NS) 60.87(EW)	22						
	MST-3		22	33	59.00	62.39(NS) 62.42(EW)	18						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
27	MST-1	2016/1/7	06	27	19.39	38.52(NS) 38.64(EW)	57	13.2570	41.6520	1467082	787380	2.8	1.6
	MST-2		06	27	20.14	40.14(NS) 40.14(EW)	51						
	MST-3		06	27	20.93	41.50(NS) 41.50(EW)	51						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
28	MST-1	2016/1/8	16	34	35.26	45.22(NS) 45.24(EW)	50	11.4005	40.7307	1260827	688831	19.2	1.5
	MST-2		16	34	34.05	43.41(NS) 43.29(EW)	50						
	MST-3		16	34	33.40	41.98(NS) 42.02(EW)	46						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
29	MST-1	2016/1/8	18	39	17.76	27.74(NS) 27.66(EW)	-	11.4300	40.6863	1264062	683974	25.4	1.7
	MST-2		18	39	16.12	26.02(NS) 25.69(EW)	57						
	MST-3		18	39	16.25	24.51(NS) 24.39(EW)	63						
	MST-4		-	-	-	-	-						

	MST-5		-	-	-	-	-						
30	MST-1	2016/1/8	19	05	40.22	50.13(NS) 50.15(EW)	-	11.3425	40.8325	1254479	699986	0.0	0.0
	MST-2		19	05	39.16	48.51(NS) 48.38(EW)	-						
	MST-3		19	05	38.37	46.67(NS) 46.63(EW)	-						
	MST-4		19	05	39.12	48.09(NS) 48.08(EW)	-						
	MST-5		19	05	37.66	45.64(NS) 45.71(EW)	-						
31	MST-1	2016/1/8	21	32	50.17	59.90(NS) 60.02(EW)	42	11.4448	40.7643	1265753	692475	32.3	1.3
	MST-2		21	32	49.29	58.26(NS) 58.26(EW)	-						
	MST-3		21	32	49.19	56.78(NS) 56.78(EW)	46						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
32	MST-1	2016/1/8	21	36	41.80	51.58(NS) 51.52(EW)	68	11.3790	40.7618	1258469	692247	6.3	1.9
	MST-2		21	36	40.52	49.87(NS) 49.65(EW)	-						
	MST-3		21	36	39.78	48.15(NS) 48.11(EW)	74						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
33	MST-1	2016/1/8	21	40	41.10	51.09(NS) 51.06(EW)	-	11.4113	40.9108	1262149	708487	29.6	1.6
	MST-2		21	40	41.63	49.25(NS) 49.22(EW)	57						
	MST-3		21	40	40.34	47.87(NS) 47.84(EW)	54						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
34	MST-1	2016/1/8	22	12	48.07	57.97(NS) 58.03(EW)	42	11.4910	40.6618	1270794	681261	24.5	1.3
	MST-2		22	12	46.71	56.03(NS) 56.05(EW)	46						
	MST-3		22	12	47.26	54.85(NS) 54.75(EW)	43						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
35	MST-1	2016/1/8	22	37	29.82	39.60(NS) 39.67(EW)	67	11.3398	40.8403	1254189	700843	5.0	1.8
	MST-2		22	37	28.65	37.98(NS) 37.95(EW)	66						
	MST-3		22	37	27.97	36.57(NS) 36.42(EW)	63						
	MST-4		-	-	-	-	-						
	MST-5		22	37	27.10	35.26(NS) 35.31(EW)	70						
36	MST-1	2016/1/8	22	51	20.82	30.75(NS) 30.66(EW)	56	11.3797	40.8260	1258586	699250	19.1	1.6
	MST-2		22	51	20.36	28.91(NS) 28.88(EW)	54						
	MST-3		22	51	18.95	27.46(NS) 27.53(EW)	51						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
37	MST-1	2016/1/8	23	09	34.55	44.48(NS) 44.55(EW)	-	11.3717	40.8036	1257686	696813	0.7	0.8
	MST-2		23	09	33.51	42.90(NS) 42.68(EW)	-						
	MST-3		23	09	33.02	-	-						
	MST-4		23	09	33.65	-	-						
	MST-5		23	09	32.05	40.08(NS) 40.12(EW)	27						
38	MST-1	2016/1/8	23	35	56.05	65.93(NS) 66.10(EW)	36	11.3662	40.8170	1257086	698277	18.8	1.1
	MST-2		23	35	54.84	64.27(NS) 64.16(EW)	39						
	MST-3		23	35	54.18	62.73(NS) 62.62(EW)	36						
	MST-4		23	35	55.12	63.94(NS) 64.00(EW)	32						
	MST-5		-	-	-	-	-						
39	MST-1	2016/1/9	00	37	2.59	12.56(NS) 12.55(EW)	-	11.3525	40.8056	1255567	697038	0.1	0.0
	MST-2		00	37	1.54	10.83(NS) 10.81(EW)	-						

	MST-3		00	37	0.74	9.12(NS) 9.11(EW)	-						
	MST-4		00	37	1.51	10.66(NS)10.71(EW)	-						
	MST-5		00	37	0.15	8.32(NS) 8.28(EW)	-						
40	MST-1	2016/1/9	04	04	2.41	32.75(NS)32.53(EW)	96	13.7783	39.6168	1523296	566676	5.0	2.4
	MST-2		04	04	2.01	31.36(NS) 31.42(EW)	99						
	MST-3		-	-	-	-	-						
	MST-4		04	04	3.95	34.73(NS) 34.80(EW)	96						
	MST-5		-	-	-	-	-						
41	MST-1	2016/1/9	04	50	39.78	49.61(NS) 49.66(EW)	-	11.3372	40.9280	1253956	710416	18.7	0.9
	MST-2		-	-	-	-	-						
	MST-3		04	50	38.49	46.39(NS) 46.42(EW)	-						
	MST-4		04	50	38.65	47.68(NS) 47.66(EW)	29						
	MST-5		-	-	-	-	-						
42	MST-1	2016/1/9	04	53	24.02	33.82(NS) 33.84(EW)	47	11.3763	40.8265	1258218	699307	23.3	1.5
	MST-2		04	53	22.96	32.07(NS) 32.09(EW)	54						
	MST-3		04	53	22.32	30.58(NS) 30.59(EW)	50						
	MST-4		04	53	22.82	31.95(NS) 31.97(EW)	-						
	MST-5		-	-	-	-	-						
43	MST-1	2016/1/9	04	54	29.86	39.70(NS) 39.69(EW)	-	11.3740	40.7882	1257933	695125	19.9	1.8
	MST-2		04	54	28.84	38.10(NS) 38.07(EW)	75						
	MST-3		04	54	28.03	36.57(NS) 36.57(EW)	58						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
44	MST-1	2016/1/9	11	18	0.09	10.07(NS) 10.07(EW)	71	11.3812	40.7612	1258708	692173	18.7	2.1
	MST-2		11	17	59.02	68.33(NS) 68.31(EW)	87						
	MST-3		11	17	58.12	66.87(NS) 66.87(EW)	92						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
45	MST-1	2016/1/9	13	47	59.34	62.46(NS) 62.46(EW)	15	11.9540	40.9265	1322197	709788	0.6	0.0
	MST-2		13	47	57.53	59.21(NS) 59.13(EW)	14						
	MST-3		13	47	58.47	60.81(NS) 60.83(EW)	13						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
46	MST-1	2016/1/9	13	53	46.90	56.90(NS) 56.84(EW)	51	11.3893	40.7812	1259625	694350	18.1	1.6
	MST-2		13	53	46.18	55.16(NS) 55.03(EW)	-						
	MST-3		13	53	44.99	53.61(NS) 53.55(EW)	55						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
47	MST-1	2016/1/9	13	52	40.07	50.32(NS) 50.16(EW)	60	11.3582	40.7813	1256177	694390	18.4	1.7
	MST-2		13	52	39.11	48.66(NS) 48.39(EW)	60						
	MST-3		13	52	38.36	47.05(NS) 46.89(EW)	63						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
48	MST-1	2016/1/9	15	29	15.68	25.50(NS) 25.51(EW)	76	11.3857	40.7545	1259202	691442	5.0	2.0
	MST-2		15	29	14.51	23.68(NS) 23.70(EW)	81						
	MST-3		15	29	13.81	22.12(NS) 22.11(EW)	73						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
49	MST-1	2016/1/9	16	17	55.20	65.26(NS) 65.24(EW)	67	11.3602	40.7773	1256396	693952	1.4	1.9
	MST-2		16	17	54.21	63.41(NS) 63.42(EW)	77						

	MST-3		16	17	53.32	61.69(NS) 61.71(EW)	72						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
50	MST-1	2016/1/10	01	28	38.23	48.24(NS)48.27(EW)	-	11.3558	40.8022	1255933	696665	5.0	2.0
	MST-2		01	28	37.27	46.47(NS) 46.43(EW)	88						
	MST-3		01	28	36.52	44.78(NS) 44.76(EW)	80						
	MST-4		01	28	37.20	46.39(NS) 46.42(EW)	72						
	MST-5		-	-	-	-	-						
51	MST-1	2016/1/10	02	06	4.53	14.64(NS) 14.63(EW)	74	11.3417	40.7982	1254363	696238	0.0	1.9
	MST-2		02	06	3.56	12.76(NS) 12.77(EW)	82						
	MST-3		02	06	2.65	11.36(NS) 11.36(EW)	72						
	MST-4		02	06	3.37	12.68(NS) 12.67(EW)	65						
	MST-5		02	06	2.06	10.21(NS) 10.19(EW)	-						
52	MST-1	2016/1/10	04	02	32.00	41.96(NS) 41.93(EW)	41	11.3577	40.8452	1256165	701358	18.0	1.2
	MST-2		04	02	31.15	40.27(NS) 40.26(EW)	42						
	MST-3		04	02	30.37	38.69(NS) 38.67(EW)	40						
	MST-4		04	02	30.93	39.99(NS) 39.99(EW)	38						
	MST-5		-	-	-	-	-						
53	MST-1	2016/1/10	10	57	42.10	50.93(NS) 50.96(EW)	52	12.2268	40.5545	1352122	669097	6.7	1.4
	MST-2		10	57	40.69	48.41(NS) 48.41(EW)	41						
	MST-3		10	57	41.97	50.63(NS) 50.65(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
54	MST-1	2016/1/10	11	59	29.53	31.52(NS) 31.49(EW)	13	12.0335	41.2857	1331293	748845	0.2	0.0
	MST-2		11	59	31.39	34.64(NS) 34.67(EW)	14						
	MST-3		11	59	31.36	34.69(NS) 34.68(EW)	15						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
55	MST-1	2016/1/10	14	27	0.96	10.94(NS) 10.93(EW)	53	11.3855	40.7735	1259196	693516	17.5	1.5
	MST-2		14	26	59.88	69.12(NS) 69.09(EW)	57						
	MST-3		14	26	59.06	67.55(NS) 67.54(EW)	48						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
56	MST-1	2016/1/11	01	52	54.74	64.61(NS) 64.66(EW)	41	11.4007	40.7212	1260839	687794	13.2	1.3
	MST-2		01	52	53.44	62.81(NS) 62.71(EW)	47						
	MST-3		01	52	52.61	61.37(NS) 61.23(EW)	43						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
57	MST-1	2016/1/11	02	05	30.59	40.44(NS) 40.49(EW)	37	11.5200	40.6444	1273991	679346	30.1	1.2
	MST-2		02	05	29.29	38.75(NS) 38.48(EW)	41						
	MST-3		02	05	29.52	37.41(NS) 37.14(EW)	34						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
58	MST-1	2016/1/11	02	07	6.28	16.32(NS) 16.29(EW)	42	11.3617	40.8025	1256579	696698	22.1	1.3
	MST-2		02	07	5.21	14.43(NS) 14.46(EW)	44						
	MST-3		02	07	4.44	13.15(NS) 13.12(EW)	42						
	MST-4		02	07	5.16	14.37(NS) 14.42(EW)	36						
	MST-5		-	-	-	-	-						
59	MST-1	2016/1/12	02	58	10.07	12.44(NS)12.38(EW)	29	11.8698	41.2558	1313155	745743	8.7	0.8

	MST-2		02	58	11.21	14.44(NS) 14.46(EW)	28						
	MST-3		02	58	10.24	12.70(NS) 12.68(EW)	31						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
60	MST-1	2016/1/12	23	04	42.32	44.39(NS) 44.39(EW)	13	11.9307	41.2928	1319920	749720	0.0	-0.1
	MST-2		23	04	43.84	47.29(NS) 47.31(EW)	12						
	MST-3		23	04	43.42	45.96(NS) 45.96(EW)	14						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
61	MST-1	2016/1/13	00	31	19.36	24.62(NS) 24.57(EW)	46	11.9963	40.7673	1326765	692420	2.4	1.2
	MST-2		00	31	17.43	21.28(NS) 21.24(EW)	40						
	MST-3		00	31	18.51	23.21(NS) 23.12(EW)	38						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
62	MST-1	2016/1/13	04	42	5.40	14.31(NS) 14.18(EW)	54	11.9092	41.7380	1317980	798260	31.6	1.5
	MST-2		04	42	6.93	16.98(NS) 16.89(EW)	45						
	MST-3		04	42	6.84	15.45(NS) 15.54(EW)	48						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
63	MST-1	2016/1/13	22	39	34.74	37.33(NS) 37.32(EW)	11	11.8787	40.9938	1313914	717183	0.5	-0.3
	MST-2		22	39	33.24	34.68(NS) 34.68(EW)	10						
	MST-3		22	39	33.07	34.37(NS) 34.36(EW)	11						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
64	MST-1	2016/1/14	03	23	11.33	21.36(NS) 21.36(EW)	40	11.3397	40.8338	1254166	700133	0.7	1.3
	MST-2		03	23	10.38	19.55(NS) 19.61(EW)	-						
	MST-3		03	23	9.47	17.92(NS) 17.94(EW)	39						
	MST-4		-	-	-	-	-						
	MST-5		03	23	8.66	16.87(NS) 16.83(EW)	46						
65	MST-1	2016/1/15	03	50	30.86	34.98(NS) 34.92(EW)	55	12.1008	41.4270	1338877	764174	0.0	1.6
	MST-2		03	50	32.70	38.51(NS) 38.55(EW)	53						
	MST-3		03	50	32.40	37.73(NS) 37.74(EW)	60						
	MST-4		03	50	31.88	35.58(NS) 35.62(EW)	53						
	MST-5		03	50	32.71	38.48(NS) 38.52(EW)	58						
66	MST-1	2016/1/15	19	48	33.52	49.38(NS) 49.34(EW)	54	11.0833	41.8793	1226714	814584	12.4	1.6
	MST-2		19	48	34.29	50.63(NS) 50.67(EW)	61						
	MST-3		19	48	32.98	48.57(NS) 48.59(EW)	48						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
67	MST-1	2016/1/16	01	01	18.20	33.94(NS) 33.55(EW)	77	10.9880	41.7598	1216037	801615	13.9	1.9
	MST-2		01	01	18.66	35.06(NS) 35.12(EW)	78						
	MST-3		01	01	17.35	32.83(NS) 32.64(EW)	61						
	MST-4		01	01	16.63	31.59(NS) 31.66(EW)	66						
	MST-5		-	-	-	-	-						
68	MST-1	2016/1/16	01	43	9.68	25.51(NS)25.77(EW)	78	11.1442	41.9202	1233492	818982	9.6	1.9
	MST-2		01	43	10.56	27.08(NS) 26.97(EW)	66						
	MST-3		01	43	9.47	24.63(NS) 24.78(EW)	69						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						

69	MST-1	2016/1/17	02	30	35.93	38.15(NS) 38.06(EW)	29	11.9618	41.2970	1323372	750146	2.6	0.5
	MST-2		02	30	37.61	41.14(NS) 41.14(EW)	17						
	MST-3		02	30	37.50	40.11(NS) 40.14(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
70	MST-1	2016/1/17	13	06	42.28	48.01(NS) 47.97(EW)	39	11.6185	40.9430	1285092	711843	0.3	1.2
	MST-2		13	06	41.26	46.36(NS) 46.36(EW)	-						
	MST-3		13	06	40.21	44.49(NS) 44.35(EW)	40						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
71	MST-1	2016/1/17	16	57	47.22	52.91(NS) 52.91(EW)	40	11.6333	40.9253	1286720	709905	0.0	1.2
	MST-2		16	57	46.23	51.09(NS) 51.26(EW)	40						
	MST-3		16	57	45.17	49.47(NS) 49.50(EW)	45						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
72	MST-1	2016/1/21	02	53	43.12	72.24(NS) 72.45(EW)	115	13.5887	39.5293	1502297	557264	4.8	2.6
	MST-2		02	53	42.29	70.64(NS) 70.67(EW)	126						
	MST-3		02	53	43.56	73.00(NS) 73.07(EW)	111						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
73	MST-1	2016/1/21	11	45	56.14	62.49(NS) 62.50(EW)	61	11.5692	40.9457	1279636	712171	0.1	1.8
	MST-2		11	45	55.21	60.96(NS) 60.97(EW)	74						
	MST-3		11	45	54.16	58.98(NS) 58.92(EW)	69						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
74	MST-1	2016/1/21	22	33	15.59	21.59(NS) 21.59(EW)	46	11.5750	40.9947	1280318	717512	5.8	1.5
	MST-2		22	33	14.78	20.38(NS) 20.41(EW)	51						
	MST-3		22	33	13.65	18.25(NS) 18.28(EW)	56						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
75	MST-1	2016/1/21	22	38	52.59	58.91(NS) 58.92(EW)	23	11.5722	40.9600	1279978	713732	1.3	0.6
	MST-2		22	38	51.71	57.36(NS) 57.36(EW)	-						
	MST-3		22	38	50.63	55.33(NS) 55.33(EW)	24						
	MST-4		22	38	51.44	56.87(NS) 56.88(EW)	-						
	MST-5		-	-	-	-	-						
76	MST-1	2016/1/21	22	39	11.01	17.15(NS) 17.19(EW)	48	11.5758	40.9475	1280375	712366	5.9	1.4
	MST-2		22	39	9.95	15.74(NS) 15.75(EW)	53						
	MST-3		22	39	8.93	13.80(NS) 13.78(EW)	44						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
77	MST-1	2016/1/21	22	42	4.89	11.05(NS) 11.06(EW)	33	11.5768	40.9648	1280498	714256	0.3	1.0
	MST-2		22	42	3.93	9.60(NS) 9.61(EW)	36						
	MST-3		22	42	2.90	7.50(NS) 7.50(EW)	32						
	MST-4		22	42	3.78	-	36						
	MST-5		-	-	-	-	-						
78	MST-1	2016/1/21	22	50	11.62	17.96(NS)17.96(EW)	49	11.5812	40.9540	1280970	713071	11.9	1.4
	MST-2		22	50	10.76	16.50(NS) 16.50(EW)	52						
	MST-3		22	50	9.73	14.62(NS) 14.59(EW)	43						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						

79	MST-1	2016/1/21	22	58	13.49	19.26(NS) 19.24(EW)	51	11.6027	41.0050	1283387	718618	16.1	1.4
	MST-2		22	58	12.59	18.21(NS) 18.22(EW)	45						
	MST-3		22	58	11.56	16.18(NS) 16.18(EW)	45						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
80	MST-1	2016/1/21	23	12	24.49	30.84(NS) 30.84(EW)	74	11.5727	40.9643	1280037	714205	5.0	1.8
	MST-2		23	12	23.82	29.39(NS) 29.38(EW)	74						
	MST-3		23	12	22.65	27.37(NS) 27.38(EW)	62						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
81	MST-1	2016/1/21	23	36	57.29	63.58(NS) 63.57(EW)	50	11.5765	40.9595	1280457	713675	11.2	1.5
	MST-2		23	36	56.43	62.19(NS) 62.17(EW)	-						
	MST-3		23	36	55.31	60.28(NS) 60.28(EW)	52						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
82	MST-1	2016/1/21	23	38	13.32	19.36(NS) 19.36(EW)	48	11.5993	40.9940	1283010	717420	18.7	1.5
	MST-2		23	38	12.49	18.24(NS) 18.23(EW)	54						
	MST-3		23	38	11.49	16.35(NS) 16.34(EW)	51						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
83	MST-1	2016/1/21	23	38	40.22	46.27(NS) 46.27(EW)	22	11.6360	40.9908	1287064	717047	20.8	0.6
	MST-2		23	38	39.55	-	25						
	MST-3		23	38	38.93	43.19(NS) 43.19(EW)	25						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
84	MST-1	2016/1/21	23	39	18.84	25.24(NS) 25.23(EW)	24	11.5983	40.9540	1282869	713058	20.4	0.7
	MST-2		23	39	18.08	23.85(NS) 23.89(EW)	32						
	MST-3		23	39	16.96	22.28(NS) 22.28(EW)	24						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
85	MST-1	2016/1/21	23	51	27.48	33.71(NS) 33.74(EW)	57	11.5760	40.9832	1280420	716257	7.4	1.7
	MST-2		23	51	26.91	32.38(NS) 32.38(EW)	63						
	MST-3		23	51	25.64	30.33(NS) 30.38(EW)	58						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
86	MST-1	2016/1/22	00	48	51.09	56.96(NS) 56.95(EW)	46	11.5967	40.9760	1282701	715459	14.1	1.3
	MST-2		00	48	50.19	55.82(NS) 55.82(EW)	-						
	MST-3		00	48	49.12	53.76(NS) 53.84(EW)	39						
	MST-4		00	48	49.93	55.33(NS) 55.24(EW)	45						
	MST-5		-	-	-	-	-						
87	MST-1	2016/1/22	00	50	2.19	8.49(NS) 8.45(EW)	40	11.5740	40.9508	1280174	712731	1.4	1.3
	MST-2		00	50	1.32	6.88(NS) 6.98(EW)	46						
	MST-3		00	50	0.14	4.98(NS) 4.89(EW)	39						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
88	MST-1	2016/1/22	01	02	23.28	29.02(NS)29.03(EW)	29	11.6057	40.9818	1283701	716088	13.8	0.7
	MST-2		01	02	22.25	27.87(NS) 27.86(EW)	25						
	MST-3		01	02	21.37	25.84(NS) 25.83(EW)	25						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
89	MST-1	2016/1/22	01	05	12.82	18.46(NS) 18.48(EW)	21	11.5980	41.0197	1282882	720221	13.5	0.6

	MST-2		01	05	12.00	17.49(NS) 17.49(EW)	-						
	MST-3		01	05	10.85	15.37(NS) 15.35(EW)	24						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
90	MST-1	2016/1/22	01	09	34.81	40.64(NS) 40.80(EW)	-	11.6140	40.9420	1284593	711737	17.7	0.2
	MST-2		01	09	33.41	39.43(NS) 39.44(EW)	-						
	MST-3		01	09	32.83	-	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
91	MST-1	2016/1/22	01	09	50.28	55.49(NS) 55.50(EW)	-	11.6093	41.0342	1284147	721794	1.2	-0.2
	MST-2		01	09	49.76	54.45(NS) 54.43(EW)	13						
	MST-3		01	09	47.81	52.27(NS) 52.24(EW)	11						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
92	MST-1	2016/1/22	01	15	36.05	42.01(NS) 42.01(EW)	37	11.5790	40.9947	1280761	717509	11.2	1.2
	MST-2		01	15	35.15	40.88(NS) 40.89(EW)	37						
	MST-3		01	15	34.07	38.79(NS) 38.81(EW)	41						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
93	MST-1	2016/1/22	01	44	50.41	56.41(NS) 56.45(EW)	36	11.5960	40.9492	1282607	712533	6.7	1.0
	MST-2		01	44	49.54	54.89(NS) 54.88(EW)	35						
	MST-3		01	44	48.46	53.01(NS) 53.03(EW)	31						
	MST-4		01	44	49.26	54.67(NS) 54.69(EW)	33						
	MST-5		-	-	-	-	-						
94	MST-1	2016/1/22	02	46	17.57	23.91(NS) 23.90(EW)	55	11.5762	40.9427	1280408	711839	3.2	1.6
	MST-2		02	46	16.67	22.23(NS) 22.33(EW)	56						
	MST-3		02	46	15.63	20.46(NS) 20.41(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
95	MST-1	2016/1/22	03	30	1.27	7.07(NS) 7.06(EW)	32	11.5977	40.9948	1282826	717513	14.3	1.0
	MST-2		03	30	0.37	5.92(NS) 5.95(EW)	-						
	MST-3		03	29	59.32	63.93(NS) 63.93(EW)	36						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
96	MST-1	2016/1/22	03	37	32.52	39.05(NS) 39.04(EW)	25	11.5672	40.9428	1279412	711864	11.5	0.7
	MST-2		03	37	31.62	37.56(NS) 37.58(EW)	-						
	MST-3		03	37	30.60	35.72(NS) 35.72(EW)	26						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
97	MST-1	2016/1/22	03	49	50.89	57.15(NS) 57.17(EW)	31	11.5353	41.0042	1275937	718579	13.2	1.0
	MST-2		03	49	50.00	56.75(NS) 56.78(EW)	33						
	MST-3		03	49	48.93	54.06(NS) 54.02(EW)	37						
	MST-4		03	49	49.66	55.57(NS) 55.56(EW)	-						
	MST-5		-	-	-	-	-						
98	MST-1	2016/1/22	04	00	30.45	36.75(NS)36.76(EW)	50	11.5822	40.9808	1281100	715997	1.4	1.4
	MST-2		04	00	29.77	35.29(NS) 35.31(EW)	49						
	MST-3		04	00	28.57	33.17(NS) 33.22(EW)	43						
	MST-4		04	00	29.30	34.65(NS) 34.63(EW)	-						
	MST-5		04	00	28.22	32.42(NS) 32.41(EW)	49						

99	MST-1	2016/1/22	04	07	23.51	29.79(NS) 29.82(EW)	27	11.5030	41.1988	1272515	739847	2.2	0.8
	MST-2		04	07	23.00	30.75(NS) 30.78(EW)	30						
	MST-3		04	07	21.56	26.59(NS) 26.60(EW)	28						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
100	MST-1	2016/1/22	04	08	5.52	11.85(NS) 11.81(EW)	25	11.569446666666666	40.9528	1279673	712947	5.0	0.7
	MST-2		04	08	4.67	10.36(NS) 10.37(EW)	-						
	MST-3		04	08	3.56	8.44(NS) 8.41(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
101	MST-1	2016/1/22	07	09	13.22	18.83(NS) 18.86(EW)	21	11.5815	40.9570	1281009	713398	5.0	0.6
	MST-2		07	09	11.73	17.71(NS) 17.72(EW)	-						
	MST-3		07	09	10.83	15.64(NS) 15.66(EW)	26						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
102	MST-1	2016/1/22	11	00	22.53	28.43(NS) 28.43(EW)	35	11.5888	41.0080	1281859	718956	14.5	1.1
	MST-2		11	00	21.71	27.38(NS) 27.40(EW)	-						
	MST-3		11	00	20.66	25.32(NS) 25.31(EW)	36						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
103	MST-1	2016/1/22	12	30	45.16	50.80(NS) 50.89(EW)	13	11.6233	41.0144	1285681	719632	23.6	-0.1
	MST-2		12	30	44.25	49.99(NS) 50.04(EW)	-						
	MST-3		12	30	43.30	48.22(NS) 48.25(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
104	MST-1	2016/1/22	12	30	55.70	61.97(NS) 62.02(EW)	34	11.5708	40.9472	1279822	712340	2.8	1.1
	MST-2		12	30	54.73	60.51(NS) 60.51(EW)	37						
	MST-3		12	30	53.71	58.47(NS) 58.48(EW)	35						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
105	MST-1	2016/1/22	13	08	12.23	18.61(NS) 18.64(EW)	31	11.5790	40.9095	1280697	708219	11.5	0.8
	MST-2		13	08	10.87	17.10(NS) 17.11(EW)	28						
	MST-3		13	08	10.29	15.36(NS) 15.33(EW)	27						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
106	MST-1	2016/1/22	13	38	49.95	55.42(NS) 55.41(EW)	27	11.6260	41.0190	1285979	720126	17.9	0.8
	MST-2		13	38	49.08	54.45(NS) 54.48(EW)	-						
	MST-3		13	38	48.01	52.52(NS) 52.48(EW)	29						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
107	MST-1	2016/1/22	15	21	19.06	30.73(NS) 30.71(EW)	74	11.2735	41.6095	1247489	784897	27.6	2.0
	MST-2		15	21	19.68	31.85(NS) 31.88(EW)	81						
	MST-3		15	21	18.40	29.63(NS) 29.63(EW)	86						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
108	MST-1	2016/1/22	21	55	35.84	41.29(NS) 41.33(EW)	43	11.6257	41.0218	1285945	720436	19.2	1.3
	MST-2		21	55	34.95	40.40(NS) 40.42(EW)	47						
	MST-3		21	55	33.85	38.50(NS) 38.46(EW)	44						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
109	MST-1	2016/1/23	04	12	18.07	23.55(NS) 23.57(EW)	33	11.6155	41.0145	1284814	719644	14.9	1.0

	MST-2		04	12	17.18	22.57(NS) 22.57(EW)	-						
	MST-3		04	12	16.13	20.50(NS) 20.51(EW)	34						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
110	MST-1	2016/1/23	05	20	47.72	53.20(NS) 53.22(EW)	25	11.6193	41.0193	1285242	720168	16.7	0.6
	MST-2		05	20	46.84	52.25(NS) 52.27(EW)	18						
	MST-3		05	20	45.79	50.24(NS) 50.26(EW)	28						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
111	MST-1	2016/1/23	23	58	9.04	17.52(NS) 17.61(EW)	71	11.4105	40.9878	1262113	716892	20.0	1.8
	MST-2		23	58	8.41	16.50(NS) 16.52(EW)	70						
	MST-3		23	58	7.28	14.55(NS) 14.59(EW)	63						
	MST-4		23	58	7.81	15.32(NS) 15.39(EW)	57						
	MST-5		-	-	-	-	-						
112	MST-1	2016/1/24	05	44	19.02	20.98(NS) 20.98(EW)	22	11.9892	41.2993	1326399	750375	1.6	0.5
	MST-2		05	44	20.87	24.32(NS) 24.28(EW)	23						
	MST-3		05	44	20.52	23.62(NS) 23.63(EW)	23						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
113	MST-1	2016/1/25	11	58	11.00	17.27(NS) 17.24(EW)	26	11.9295	41.6153	1320102	784867	1.7	0.8
	MST-2		11	58	12.61	20.41(NS) 20.41(EW)	29						
	MST-3		11	58	11.94	19.08(NS) 19.09(EW)	29						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
114	MST-1	2016/1/26	02	36	25.19	42.36(NS) 42.40(EW)	54	11.6163	39.9587	1284305	604509	0.0	1.5
	MST-2		02	36	23.47	39.00(NS) 39.03(EW)	49						
	MST-3		-	-	-	-	-						
	MST-4		02	36	25.33	-	47						
	MST-5		-	-	-	-	-						
115	MST-1	2016/1/27	14	57	35.34	58.68(NS) 58.82(EW)	76	12.8727	39.6648	1423147	572133	2.5	2.0
	MST-2		14	57	34.36	56.57(NS) 56.57(EW)	74						
	MST-3		14	57	35.39	58.66(NS) 58.74(EW)	72						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
116	MST-1	2016/1/28	09	17	26.09	28.13(NS) 28.12(EW)	19	11.8952	41.0355	1315773	721710	6.0	0.2
	MST-2		09	17	24.87	26.23(NS) 26.25(EW)	16						
	MST-3		09	17	24.61	-	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
117	MST-1	2016/1/28	10	55	21.64	24.11(NS) 24.14(EW)	48	11.8380	41.0390	1309451	722138	0.0	1.3
	MST-2		10	55	20.61	22.39(NS) 22.39(EW)	43						
	MST-3		-	-	-	-	-						
	MST-4		10	55	21.04	23.02(NS)23.08(EW)	-						
	MST-5		-	-	-	-	-						
118	MST-1	2016/1/28	10	58	31.14	33.60(NS)33.59(EW)	20	11.8270	41.0557	1308247	723964	0.1	0.3
	MST-2		10	58	30.13	-	16						
	MST-3		10	58	28.98	29.86(NS) 29.90(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
119	MST-1	2016/1/28	12	18	39.38	41.91(NS) 41.95(EW)	28	11.8369	41.0461	1309340	722915	0.2	0.6
	MST-2		12	18	38.38	-	23						
	MST-3		12	18	37.23	38.07(NS) 38.07(EW)	-						
	MST-4		-	-	-	-	-						

	MST-5		12	18	37.34	38.19(NS) 38.19(EW)	22						
120	MST-1	2016/1/28	15	01	58.05	60.80(NS) 60.83(EW)	21	11.8370	41.0145	1309321	719469	0.0	0.2
	MST-2		15	01	56.76	58.54(NS) 58.54(EW)	17						
	MST-3		15	01	55.92	57.12(NS) 57.15(EW)	14						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
121	MST-1	2016/1/29	06	40	24.95	27.44(NS) 27.45(EW)	21	11.8437	41.0192	1310062	719972	0.6	0.4
	MST-2		06	40	23.67	25.48(NS) 25.47(EW)	18						
	MST-3		06	40	22.83	24.06(NS) 24.06(EW)	21						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
122	MST-1	2016/1/30	09	08	57.86	83.93(NS) 83.78(EW)	78	13.8982	40.5697	1537022	669602	5.0	2.2
	MST-2		09	08	57.73	83.51(NS) 83.55(EW)	84						
	MST-3		09	08	58.29	85.87(NS) 85.86(EW)	85						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
123	MST-1	2016/1/30	11	29	30.91	33.81(NS) 33.79(EW)	31	11.8595	41.2277	1311987	742682	20.0	0.8
	MST-2		11	29	31.20	35.31(NS) 35.29(EW)	23						
	MST-3		11	29	30.66	33.72(NS) 33.73(EW)	32						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
124	MST-1	2016/1/31	02	54	54.65	57.20(NS) 57.21(EW)	34	11.8315	41.0360	1308729	721816	0.1	1.0
	MST-2		02	54	53.62	55.41(NS) 55.39(EW)	33						
	MST-3		-	-	-	-	-						
	MST-4		02	54	53.95	56.05(NS) 56.15(EW)	35						
	MST-5		02	54	52.44	53.40(NS) 53.45(EW)	31						
125	MST-1	2016/1/31	09	36	19.28	22.34(NS) 22.33(EW)	40	11.9440	41.3717	1321468	758298	0.6	1.2
	MST-2		09	36	20.93	25.38(NS) 25.42(EW)	-						
	MST-3		09	36	20.30	24.21(NS) 24.22(EW)	40						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
126	MST-1	2016/1/31	10	20	28.80	30.49(NS) 30.50(EW)	30	12.0097	41.2757	1328646	747778	2.0	0.8
	MST-2		10	20	30.71	33.84(NS) 33.84(EW)	30						
	MST-3		10	20	30.49	33.53(NS) 33.53(EW)	28						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
127	MST-1	2016/2/1	10	42	22.22	24.46(NS) 24.47(EW)	41	11.8960	41.0210	1315854	720130	9.3	0.9
	MST-2		10	42	21.13	22.60(NS) 22.62(EW)	23						
	MST-3		-	-	-	-	-						
	MST-4		-	-	-	-	-						
	MST-5		10	42	20.60	-	-						
128	MST-1	2016/2/1	20	16	26.59	35.38(NS)35.39(EW)	34	12.3138	40.6602	1361815	680535	1.7	1.0
	MST-2		20	16	25.87	33.00(NS) 33.01(EW)	33						
	MST-3		20	16	27.72	35.35(NS) 35.37(EW)	28						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
129	MST-1	2016/2/1	20	35	46.65	79.94(NS) 79.95(EW)	129	9.5013	40.1982	1050505	631518	5.0	2.7
	MST-2		20	35	45.98	78.74(NS) 78.90(EW)	124						
	MST-3		20	35	45.09	77.27(NS) 77.25(EW)	125						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						

130	MST-1	2016/2/2	06	02	53.55	59.62(NS) 59.57(EW)	57	11.9053	41.5987	1317410	783076	0.8	1.7
	MST-2		06	02	55.20	62.62(NS) 62.61(EW)	56						
	MST-3		06	02	54.40	61.30(NS) 61.29(EW)	62						
	MST-4		-	-	-	-	-						
	MST-5		06	02	54.23	61.44(NS) 61.47(EW)	65						
131	MST-1	2016/2/3	04	10	48.63	51.25(NS) 51.22(EW)	12	11.8790	40.9930	1313951	717092	0.0	-0.1
	MST-2		04	10	47.14	48.61(NS) 48.61(EW)	12						
	MST-3		04	10	46.96	48.26(NS) 48.26(EW)	14						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
132	MST-1	2016/2/4	00	17	24.89	27.56(NS) 27.56(EW)	21	11.8828	40.9887	1314371	716617	0.2	0.3
	MST-2		00	17	23.44	24.71(NS) 24.70(EW)	16						
	MST-3		00	17	23.27	24.53(NS) 24.53(EW)	20						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
133	MST-1	2016/2/4	03	16	4.01	30.23(NS) 30.21(EW)	-	12.6973	39.2143	1403674	523270	6.1	2.3
	MST-2		03	16	2.72	28.54(NS) 28.51(EW)	91						
	MST-3		03	16	3.52	29.87(NS) 29.84(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
134	MST-1	2016/2/5	00	18	44.73	47.07(NS) 47.07(EW)	25	11.8978	41.0002	1316040	717858	0.2	0.4
	MST-2		00	18	43.27	44.42(NS) 44.42(EW)	21						
	MST-3		00	18	43.17	44.50(NS) 44.50(EW)	15						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
135	MST-1	2016/2/5	21	09	23.18	24.93(NS) 24.94(EW)	20	11.8643	41.0510	1312374	723425	4.4	0.3
	MST-2		21	09	21.76	23.73(NS) 23.73(EW)	20						
	MST-3		21	09	21.13	21.96(NS) 21.96(EW)	16						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
136	MST-1	2016/2/8	23	02	20.14	34.87(NS) 34.87(EW)	68	12.0133	42.2325	1330097	852041	13.2	1.9
	MST-2		23	02	21.82	37.78(NS) 37.80(EW)	64						
	MST-3		23	02	21.03	36.69(NS) 36.74(EW)	76						
	MST-4		23	02	20.05	34.31(NS) 34.36(EW)	-						
	MST-5		-	-	-	-	-						
137	MST-1	2016/2/11	00	29	33.06	35.50(NS) 35.50(EW)	22	11.8837	41.0030	1314475	718178	4.9	0.4
	MST-2		00	29	31.67	33.15(NS) 33.16(EW)	-						
	MST-3		00	29	31.44	32.86(NS) 32.83(EW)	17						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
138	MST-1	2016/2/11	05	52	35.70	64.27(NS) 64.34(EW)	98	12.9565	39.1017	1432327	511026	5.0	2.5
	MST-2		05	52	34.38	62.55(NS) 62.44(EW)	112						
	MST-3		05	52	35.45	64.13(NS) 64.09(EW)	112						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
139	MST-1	2016/2/11	14	38	22.16	23.44(NS) 23.48(EW)	11	12.0173	41.1348	1329372	732430	0.0	-0.3
	MST-2		14	38	23.79	26.24(NS) 24.91(EW)	-						
	MST-3		14	38	25.32	26.25(NS) 26.26(EW)	10						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						

140	MST-1	2016/2/11	14	40	41.52	42.88(NS) 42.90(EW)	21	11.9428	41.2385	1321218	743789	2.1	0.5
	MST-2		14	40	43.12	45.64(NS) 45.67(EW)	21						
	MST-3		14	40	42.57	44.70(NS) 44.70(EW)	23						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
141	MST-1	2016/2/11	15	07	55.37	56.77(NS) 56.76(EW)	29	11.9538	41.2192	1322418	741673	5.1	0.8
	MST-2		15	07	56.98	59.41(NS) 59.49(EW)	-						
	MST-3		15	07	56.81	58.58(NS) 58.58(EW)	29						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
142	MST-1	2016/2/12	03	53	18.08	21.95(NS) 21.96(EW)	29	11.6992	41.1445	1294175	733754	1.5	0.9
	MST-2		03	53	18.28	22.20(NS) 22.19(EW)	33						
	MST-3		03	53	16.78	19.75(NS) 19.75(EW)	29						
	MST-4		03	53	16.66	19.54(NS) 19.60(EW)	28						
	MST-5		03	53	16.39	18.85(NS) 18.82(EW)	-						
143	MST-1	2016/2/12	06	02	46.61	51.13(NS) 51.12(EW)	23	11.9740	40.8415	1324347	700514	0.7	0.5
	MST-2		06	02	44.61	47.43(NS) 47.42(EW)	20						
	MST-3		06	02	45.66	49.36(NS) 49.37(EW)	23						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
144	MST-1	2016/2/13	05	12	1.55	2.66(NS) 2.67(EW)	20	11.9582	41.2048	1322885	740107	0.4	0.4
	MST-2		05	12	3.15	5.52(NS) 5.55(EW)	-						
	MST-3		05	12	3.53	4.69(NS) 4.69(EW)	22						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
145	MST-1	2016/2/13	13	55	2.71	24.06(NS) 24.19(EW)	62	11.7855	39.5918	1302902	564477	4.9	1.8
	MST-2		13	55	1.24	21.19(NS) 21.17(EW)	59						
	MST-3		13	55	1.81	22.31(NS) 22.31(EW)	58						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
146	MST-1	2016/2/13	17	57	16.88	29.83(NS) 29.81(EW)	57	11.3028	41.8100	1250939	806771	23.0	1.7
	MST-2		17	57	17.92	31.33(NS) 31.34(EW)	60						
	MST-3		17	57	16.70	29.23(NS) 29.19(EW)	55						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
147	MST-1	2016/2/14	00	36	2.37	24.41(NS)24.38(EW)	93	10.9320	42.3732	1210521	868781	4.4	2.3
	MST-2		00	36	3.42	25.68(NS) 25.66(EW)	97						
	MST-3		00	36	2.21	24.07(NS) 24.26(EW)	96						
	MST-4		00	36	0.98	22.16(NS) 22.18(EW)	97						
	MST-5		00	36	2.14	23.56(NS) 23.41(EW)	105						
148	MST-1	2016/2/15	04	27	53.73	72.42(NS) 72.43(EW)	61	13.0808	41.9375	1447924	818569	0.0	1.7
	MST-2		04	27	54.93	74.78(NS) 74.77(EW)	56						
	MST-3		04	27	55.95	76.01(NS) 75.98(EW)	55						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
149	MST-1	2016/2/15	15	28	50.35	51.40(NS) 51.40(EW)	16	11.9872	41.1708	1326064	736378	4.4	0.3
	MST-2		15	28	52.15	53.64(NS) 53.63(EW)	20						
	MST-3		15	28	52.26	53.81(NS) 53.82(EW)	19						
	MST-4		-	-	-	-	-						

	MST-5		-	-	-	-	-						
150	MST-1	2016/2/16	09	09	25.35	31.40(NS) 31.40(EW)	32	11.9492	40.7268	1321519	688042	0.3	0.8
	MST-2		09	09	23.59	27.92(NS) 27.93(EW)	26						
	MST-3		09	09	24.47	29.40(NS) 29.40(EW)	25						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
151	MST-1	2016/2/16	15	20	22.40	27.45(NS) 27.42(EW)	33	12.1090	40.8582	1339294	702229	20.4	1.1
	MST-2		15	20	21.30	25.44(NS) 25.44(EW)	36						
	MST-3		15	20	22.42	27.59(NS) 27.55(EW)	38						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
152	MST-1	2016/2/17	11	40	15.48	56.60(NS) 56.48(EW)	119	13.5422	38.1560	1497250	408675	5.0	2.7
	MST-2		11	40	14.76	54.44(NS) 54.43(EW)	115						
	MST-3		11	40	15.85	56.33(NS) 56.28(EW)	119						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
153	MST-1	2016/2/18	12	35	41.97	47.12(NS) 47.11(EW)	21	12.0105	41.5417	1328992	776756	0.7	0.5
	MST-2		12	35	43.70	50.55(NS) 50.60(EW)	24						
	MST-3		12	35	43.39	49.60(NS) 49.60(EW)	21						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
154	MST-1	2016/2/19	23	50	13.74	19.50(NS) 19.54(EW)	36	12.1137	40.7967	1339766	695530	23.4	1.3
	MST-2		23	50	12.73	17.40(NS) 17.35(EW)	42						
	MST-3		23	50	13.35	19.52(NS) 19.47(EW)	48						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
155	MST-1	2016/2/20	06	07	14.04	27.90(NS) 27.97(EW)	65	12.4990	40.2622	1382060	637150	5.0	1.8
	MST-2		06	07	12.25	25.93(NS) 25.99(EW)	66						
	MST-3		06	07	14.27	27.97(NS) 27.97(EW)	64						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
156	MST-1	2016/2/20	06	08	39.56	58.06(NS) 58.01(EW)	66	12.8605	40.1185	1421972	621366	9.3	1.8
	MST-2		06	08	38.31	56.41(NS) 56.43(EW)	-						
	MST-3		06	08	39.76	58.57(NS) 58.61(EW)	62						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
157	MST-1	2016/2/20	06	26	42.18	59.74(NS) 59.82(EW)	62	12.8567	40.1708	1421573	627047	19.7	1.8
	MST-2		06	26	41.69	58.36(NS) 58.05(EW)	61						
	MST-3		06	26	42.53	60.40(NS) 60.22(EW)	66						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
158	MST-1	2016/2/20	06	29	39.77	45.24(NS) 45.22(EW)	46	12.0785	40.8243	1335895	698568	20.0	1.4
	MST-2		06	29	38.66	42.91(NS) 42.76(EW)	45						
	MST-3		06	29	39.83	44.81(NS) 44.81(EW)	51						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
159	MST-1	2016/2/21	19	57	37.23	42.09(NS) 42.07(EW)	48	11.9675	40.8163	1323610	697778	0.5	1.2
	MST-2		19	57	35.30	38.52(NS) 38.51(EW)	36						
	MST-3		19	57	36.33	40.20(NS) 40.30(EW)	37						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						

160	MST-1	2016/2/22	00	47	32.19	36.83(NS) 36.82(EW)	40	11.7960	41.3900	1305106	760436	14.1	1.1
	MST-2		00	47	33.33	38.96(NS) 38.96(EW)	33						
	MST-3		00	47	32.62	36.87(NS) 36.85(EW)	34						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
161	MST-1	2016/2/23	01	14	14.83	18.99(NS) 18.98(EW)	44	11.9977	41.4503	1327482	766818	1.2	1.4
	MST-2		01	14	16.67	22.22(NS) 22.22(EW)	52						
	MST-3		01	14	16.36	21.25(NS) 21.26(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
162	MST-1	2016/2/23	09	28	58.14	69.26(NS) 69.27(EW)	51	11.2118	41.3245	1240403	753819	0.2	1.6
	MST-2		09	28	58.54	69.65(NS) 69.65(EW)	56						
	MST-3		09	28	57.09	66.74(NS) 66.74(EW)	53						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
163	MST-1	2016/2/25	05	28	4.36	5.95(NS) 5.95(EW)	10	11.9330	41.2352	1320127	743434	6.1	-0.3
	MST-2		05	28	5.79	8.49(NS) 8.47(EW)	11						
	MST-3		05	28	5.28	7.32(NS) 7.32(EW)	10						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
164	MST-1	2016/2/26	09	32	55.96	60.14(NS) 60.17(EW)	53	11.9238	41.4420	1319302	765982	1.2	1.3
	MST-2		09	32	57.87	63.18(NS) 63.17(EW)	39						
	MST-3		09	32	57.15	61.76(NS) 61.77(EW)	45						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
165	MST-1	2016/2/26	19	21	33.57	35.83(NS) 35.80(EW)	18	11.8930	41.0098	1315513	718915	5.8	0.2
	MST-2		19	21	32.11	33.56(NS) 33.56(EW)	17						
	MST-3		19	21	31.99	33.34(NS) 33.35(EW)	17						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
166	MST-1	2016/2/27	13	41	41.42	43.46(NS) 43.45(EW)	33	11.9493	41.2943	1321987	749867	1.4	1.0
	MST-2		13	41	43.10	46.38(NS) 46.38(EW)	31						
	MST-3		13	41	42.57	45.43(NS) 45.44(EW)	36						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
167	MST-1	2016/2/28	01	03	1.80	5.94(NS) 5.96(EW)	43	11.9427	41.4378	1321383	765510	1.2	1.1
	MST-2		01	03	3.64	9.15(NS) 9.15(EW)	36						
	MST-3		01	03	3.28	7.68(NS) 7.65(EW)	35						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
168	MST-1	2016/2/28	01	10	43.62	47.86(NS) 47.90(EW)	43	11.9557	41.4763	1322859	769692	1.4	1.2
	MST-2		01	10	45.37	51.01(NS) 51.02(EW)	-						
	MST-3		01	10	44.43	50.08(NS) 50.10(EW)	35						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
169	MST-1	2016/2/28	16	33	58.35	62.54(NS) 62.53(EW)	37	11.9317	41.4563	1320183	767536	0.1	1.0
	MST-2		16	34	0.09	5.77(NS) 5.79(EW)	31						
	MST-3		16	33	59.63	64.33(NS) 64.29(EW)	32						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
170	MST-1	2016/2/28	23	48	40.38	44.40(NS) 44.44(EW)	42	11.9408	41.4470	1321189	766510	1.0	1.3

	MST-2		23	48	42.04	47.75(NS) 47.75(EW)	-						
	MST-3		23	48	41.65	46.31(NS) 46.29(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
171	MST-1	2016/2/29	02	26	38.07	42.25(NS) 42.25(EW)	44	11.8963	41.4538	1316270	767298	0.0	1.2
	MST-2		02	26	39.89	45.51(NS) 45.44(EW)	-						
	MST-3		02	26	38.84	43.82(NS) 43.81(EW)	38						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
172	MST-1	2016/2/29	02	57	18.83	23.13(NS) 23.13(EW)	40	11.9655	41.4188	1323891	763417	17.1	1.2
	MST-2		02	57	20.70	26.23(NS) 26.26(EW)	-						
	MST-3		02	57	19.84	24.74(NS) 24.73(EW)	-						
	MST-4		02	57	18.78	22.92(NS) 22.93(EW)	41						
	MST-5		-	-	-	-	-						
173	MST-1	2016/2/29	03	11	1.17	5.32(NS) 5.27(EW)	24	11.9320	41.4732	1320236	769370	0.4	0.7
	MST-2		03	11	3.17	8.48(NS) 8.46(EW)	23						
	MST-3		-	-	-	-	-						
	MST-4		03	10	59.94	-	31						
	MST-5		-	-	-	-	-						
174	MST-1	2016/2/29	03	15	26.33	30.61(NS) 30.50(EW)	36	12.0182	41.4503	1329750	766797	2.7	1.1
	MST-2		03	15	28.12	33.63(NS) 33.65(EW)	34						
	MST-3		-	-	-	-	-						
	MST-4		03	15	26.18	30.35(NS) 30.32(EW)	39						
	MST-5		03	15	28.07	33.16(NS) 33.16(EW)	33						
175	MST-1	2016/2/29	03	31	20.28	24.70(NS) 24.60(EW)	35	11.9637	41.4577	1323726	767650	2.5	1.0
	MST-2		03	31	22.12	27.70(NS) 27.69(EW)	33						
	MST-3		03	31	21.54	26.72(NS) 26.71(EW)	33						
	MST-4		-	-	-	-	-						
	MST-5		03	31	21.82	26.61(NS) 26.88(EW)	36						
176	MST-1	2016/2/29	10	24	50.43	52.40(NS) 52.40(EW)	26	11.9848	41.2993	1325920	750379	0.4	0.7
	MST-2		10	24	52.27	55.62(NS) 55.62(EW)	26						
	MST-3		10	24	51.91	54.98(NS) 55.02(EW)	24						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
177	MST-1	2016/2/29	22	48	47.53	59.04(NS) 59.02(EW)	71	11.8560	41.9562	1312338	822107	27.6	1.8
	MST-2		22	48	49.08	61.86(NS) 61.83(EW)	64						
	MST-3		22	48	49.10	60.26(NS) 60.23(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
178	MST-1	2016/3/2	21	00	32.16	34.61(NS) 34.60(EW)	32	11.8465	41.0525	1310402	723602	0.7	0.6
	MST-2		21	00	31.14	32.83(NS) 32.84(EW)	27						
	MST-3		21	00	30.00	30.70(NS) 30.71(EW)	18						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
179	MST-1	2016/3/4	12	06	1.98	18.03(NS) 18.21(EW)	70	11.9582	39.9997	1322124	608844	0.1	1.8
	MST-2		12	06	0.40	14.73(NS) 14.75(EW)	61						
	MST-3		12	06	1.40	15.94(NS) 15.78(EW)	65						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
180	MST-1	2016/3/4	18	36	31.85	34.23(NS) 34.24(EW)	21	11.8927	41.0022	1315470	718080	0.1	0.3

	MST-2		18	36	30.40	31.58(NS) 31.60(EW)	23						
	MST-3		18	36	30.28	-	13						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
181	MST-1	2016/3/4	02	0	36.05	37.97(NS) 37.96(EW)	21	11.9067	41.0265	1317038	720720	4.5	0.4
	MST-2		02	0	34.61	35.68(NS) 35.69(EW)	22						
	MST-3		02	0	34.49	35.67(NS) 35.65(EW)	16						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
182	MST-1	2016/3/4	21	07	48.30	50.33(NS) 50.31(EW)	29	11.8933	41.0268	1315563	720768	5.5	0.7
	MST-2		21	07	46.88	48.33(NS) 48.33(EW)	27						
	MST-3		21	07	46.74	47.85(NS) 47.85(EW)	23						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
183	MST-1	2016/3/5	02	30	11.43	14.51(NS) 14.51(EW)	22	11.9525	41.3633	1322400	757382	9.9	0.5
	MST-2		02	30	13.03	17.33(NS) 17.32(EW)	19						
	MST-3		02	30	12.31	16.41(NS) 16.47(EW)	22						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
184	MST-1	2016/3/6	00	57	56.14	58.48(NS) 58.47(EW)	30	11.8562	41.0362	1311458	721815	5.2	0.7
	MST-2		00	57	55.01	56.63(NS) 56.62(EW)	28						
	MST-3		-	-	-	-	-						
	MST-4		00	57	55.62	57.64(NS) 57.65(EW)	-						
	MST-5		00	57	54.17	55.34(NS) 55.38(EW)	24						
185	MST-1	2016/3/8	02	04	5.56	7.28(NS) 7.26(EW)	14	11.9187	41.5873	1318874	781827	0.4	0.1
	MST-2		02	04	7.47	10.60(NS) 10.62(EW)	16						
	MST-3		-	-	-	-	-						
	MST-4		02	04	6.02	8.38(NS) 8.39(EW)	16						
	MST-5		-	-	-	-	-						
186	MST-1	2016/3/11	11	10	56.23	58.42(NS) 58.37(EW)	28	11.9117	41.2895	1317814	749374	0.2	0.8
	MST-2		11	10	57.90	61.32(NS) 61.33(EW)	26						
	MST-3		11	10	57.29	59.67(NS) 59.70(EW)	28						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
187	MST-1	2016/3/12	06	37	20.52	47.23(NS)47.32(EW)	68	9.9902	41.5397	1105396	778430	4.7	2.0
	MST-2		06	37	20.85	47.47(NS) 47.54(EW)	73						
	MST-3		06	37	19.41	44.95(NS) 45.01(EW)	67						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
188	MST-1	2016/3/12	14	06	24.11	67.86(NS) 68.01(EW)	136	14.4027	38.4393	1592333	439559	5.3	2.9
	MST-2		14	06	23.66	67.10(NS) 67.15(EW)	129						
	MST-3		14	06	24.80	68.06(NS) 68.25(EW)	133						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
189	MST-1	2016/3/12	19	18	9.87	11.09(NS) 11.08(EW)	14	11.9578	41.2113	1322854	740816	4.7	0.0
	MST-2		19	18	11.43	13.79(NS) 13.79(EW)	14						
	MST-3		19	18	11.27	12.97(NS) 12.97(EW)	15						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
190	MST-1	2016/3/13	02	29	40.87	68.77(NS) 68.77(EW)	-	9.8687	41.3302	1091782	755544	4.4	2.1
	MST-2		02	29	41.44	68.57(NS) 68.65(EW)	-						

	MST-3		02	29	39.67	66.17(NS) 66.13(EW)	73						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
191	MST-1	2016/3/15	02	49	40.51	70.57(NS) 70.60(EW)	-	9.7017	40.8063	1072954	698175	2.6	2.4
	MST-2		02	49	40.49	69.62(NS) 69.80(EW)	89						
	MST-3		02	49	39.56	67.89(NS) 67.94(EW)	95						
	MST-4		-	-	-	-	-						
	MST-5		02	49	38.75	67.61(NS) 67.53(EW)	-						
192	MST-1	2016/3/16	14	08	59.33	70.68(NS) 70.72(EW)	48	11.2073	41.3288	1239909	754296	18.1	1.4
	MST-2		14	08	59.80	70.92(NS) 70.91(EW)	44						
	MST-3		14	08	58.45	68.54(NS) 68.53(EW)	47						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
193	MST-1	2016/3/17	03	37	21.95	30.57(NS) 30.60(EW)	35	12.0885	41.7513	1337846	799515	12.3	1.0
	MST-2		03	37	23.60	33.61(NS) 33.62(EW)	32						
	MST-3		03	37	23.74	32.82(NS) 32.81(EW)	34						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
194	MST-1	2016/3/17	17	55	46.08	69.94(NS) 69.97(EW)	83	13.0965	42.5688	1450542	887085	4.0	2.3
	MST-2		17	55	47.48	72.12(NS) 72.12(EW)	96						
	MST-3		17	55	47.36	72.83(NS) 72.78(EW)	96						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
195	MST-1	2016/3/18	05	04	11.39	35.03(NS) 35.03(EW)	75	12.8908	42.6798	1427928	899469	4.2	2.2
	MST-2		05	04	12.86	37.36(NS) 37.37(EW)	86						
	MST-3		05	04	12.84	37.59(NS) 37.52(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
196	MST-1	2016/3/18	07	47	7.31	32.78(NS) 32.82(EW)	-	13.0427	39.5145	1441910	555784	2.9	2.3
	MST-2		07	47	5.97	31.09(NS) 31.10(EW)	90						
	MST-3		07	47	7.52	33.29(NS) 32.89(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
197	MST-1	2016/3/18	18	34	38.46	43.13(NS)43.05(EW)	29	12.0702	41.4577	1335512	767545	0.6	0.8
	MST-2		18	34	40.27	46.29(NS) 46.31(EW)	28						
	MST-3		18	34	40.70	45.69(NS) 45.61(EW)	-						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
198	MST-1	2016/3/18	21	29	52.89	57.64(NS) 57.61(EW)	31	11.9718	41.5122	1324683	773581	1.8	1.0
	MST-2		21	29	54.79	60.72(NS) 60.70(EW)	34						
	MST-3		21	29	53.61	60.01(NS) 60.01(EW)	35						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
199	MST-1	2016/3/20	07	04	3.48	6.60(NS) 6.62(EW)	26	11.9892	40.9190	1326082	708944	0.1	0.7
	MST-2		07	04	1.66	3.50(NS) 3.51(EW)	26						
	MST-3		07	04	2.80	5.58(NS) 5.57(EW)	28						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
200	MST-1	2016/3/20	09	41	11.32	13.86(NS) 13.85(EW)	114	11.9887	40.9570	1326056	713084	9.2	-1.2
	MST-2		09	41	9.50	11.55(NS) 11.54(EW)	131						

	MST-3		09	41	10.61 5	73.24(NS) 73.24(EW)	117						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
201	MST-1	2016/3/20	16	47	38.13	41.35(NS) 41.34(EW)	15	11.9932	40.9220	1326527	709268	0.4	0.1
	MST-2		16	47	36.25	38.04(NS) 38.03(EW)	15						
	MST-3		16	47	37.62	40.26(NS) 40.24(EW)	14						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						
202	MST-1	2016/3/21	16	46	10.72	51.84(NS) 51.88(EW)	146	15.3668	41.5288	1700488	771475	5.0	3.0
	MST-2		16	46	10.35	52.80(NS) 52.83(EW)	130						
	MST-3		16	46	12.16	54.23(NS) 54.62(EW)	148						
	MST-4		-	-	-	-	-						
	MST-5		-	-	-	-	-						

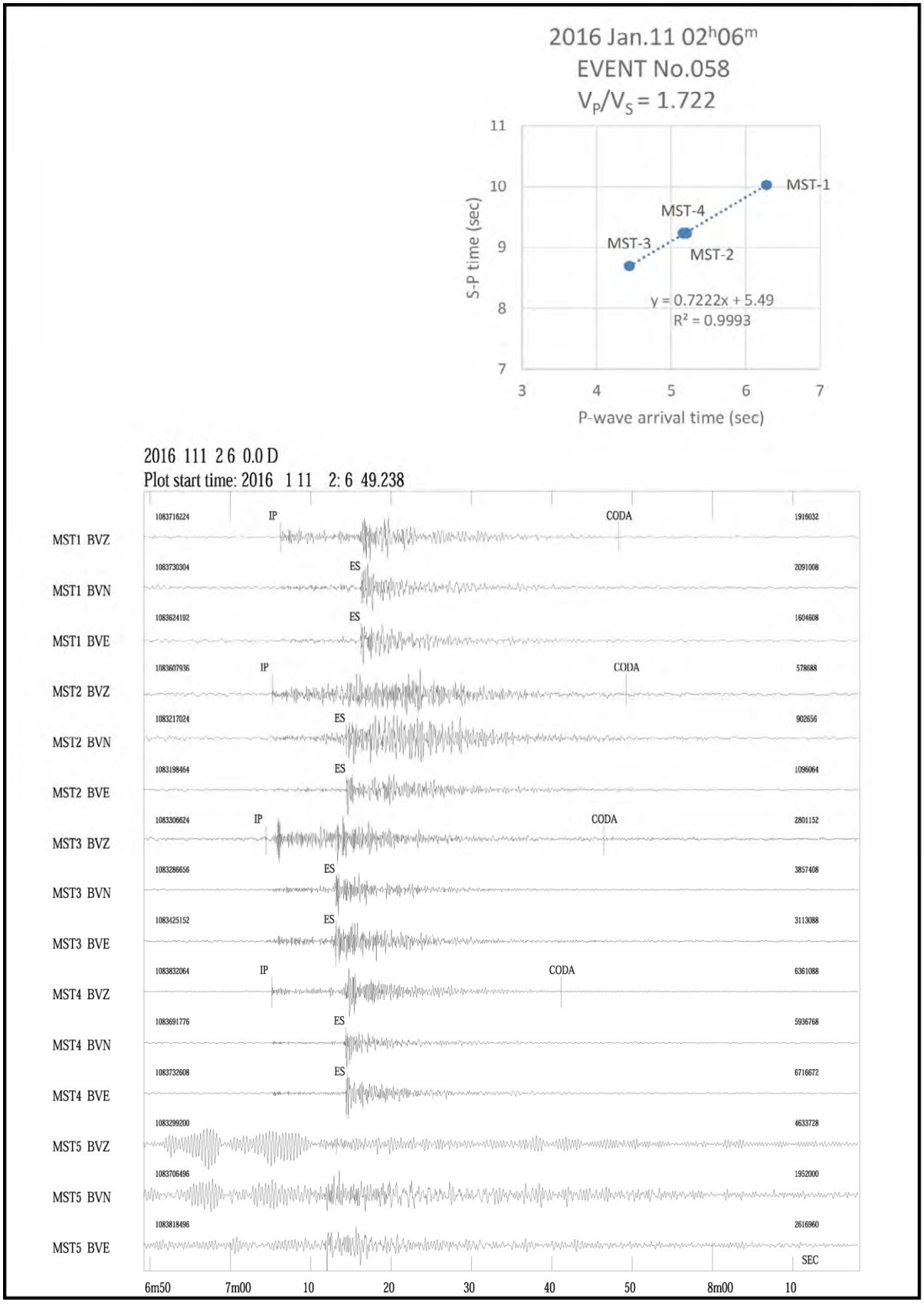
A4.6 微小地震計観測データ（ボセッティ地区）

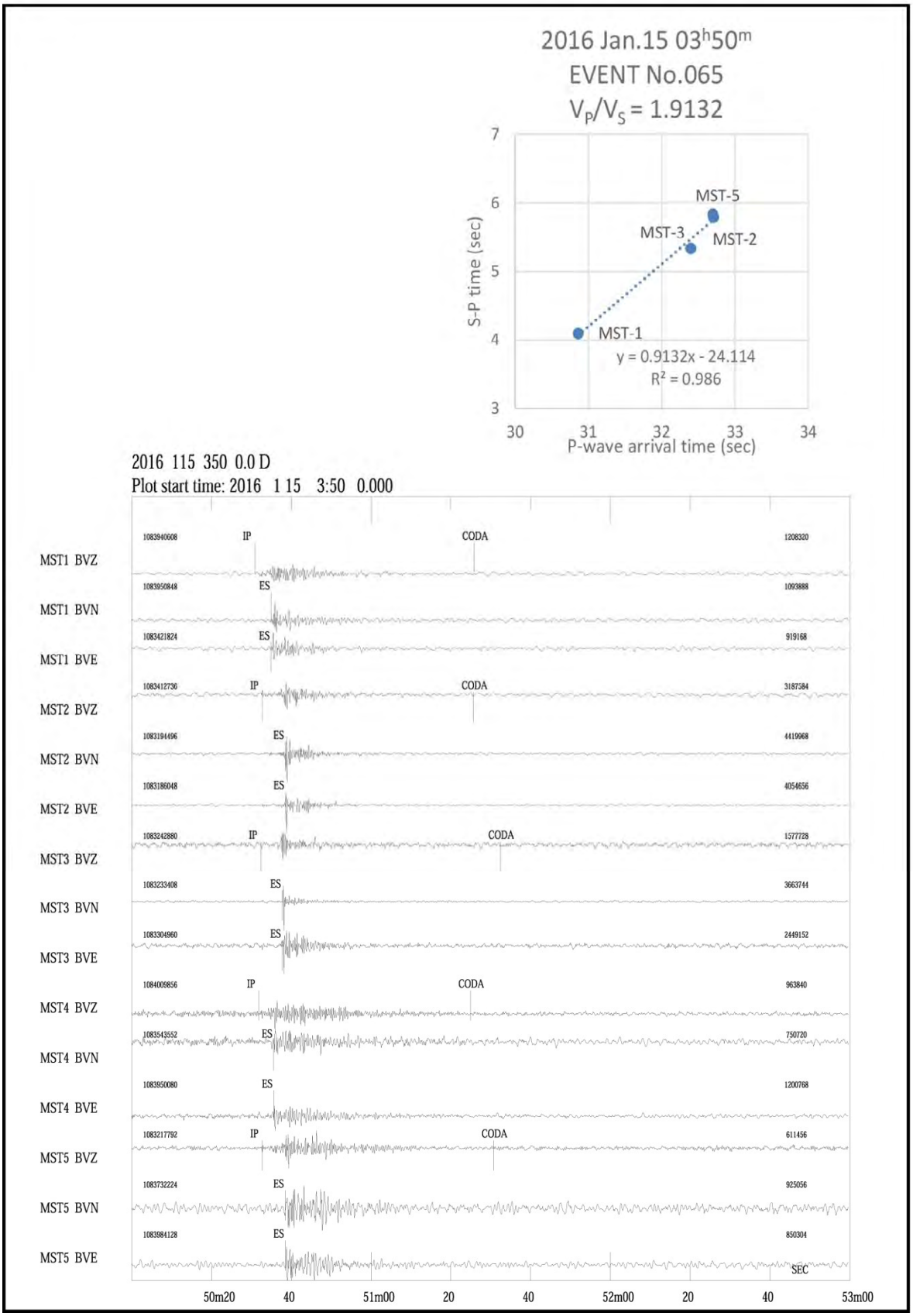
Boseti event identifier

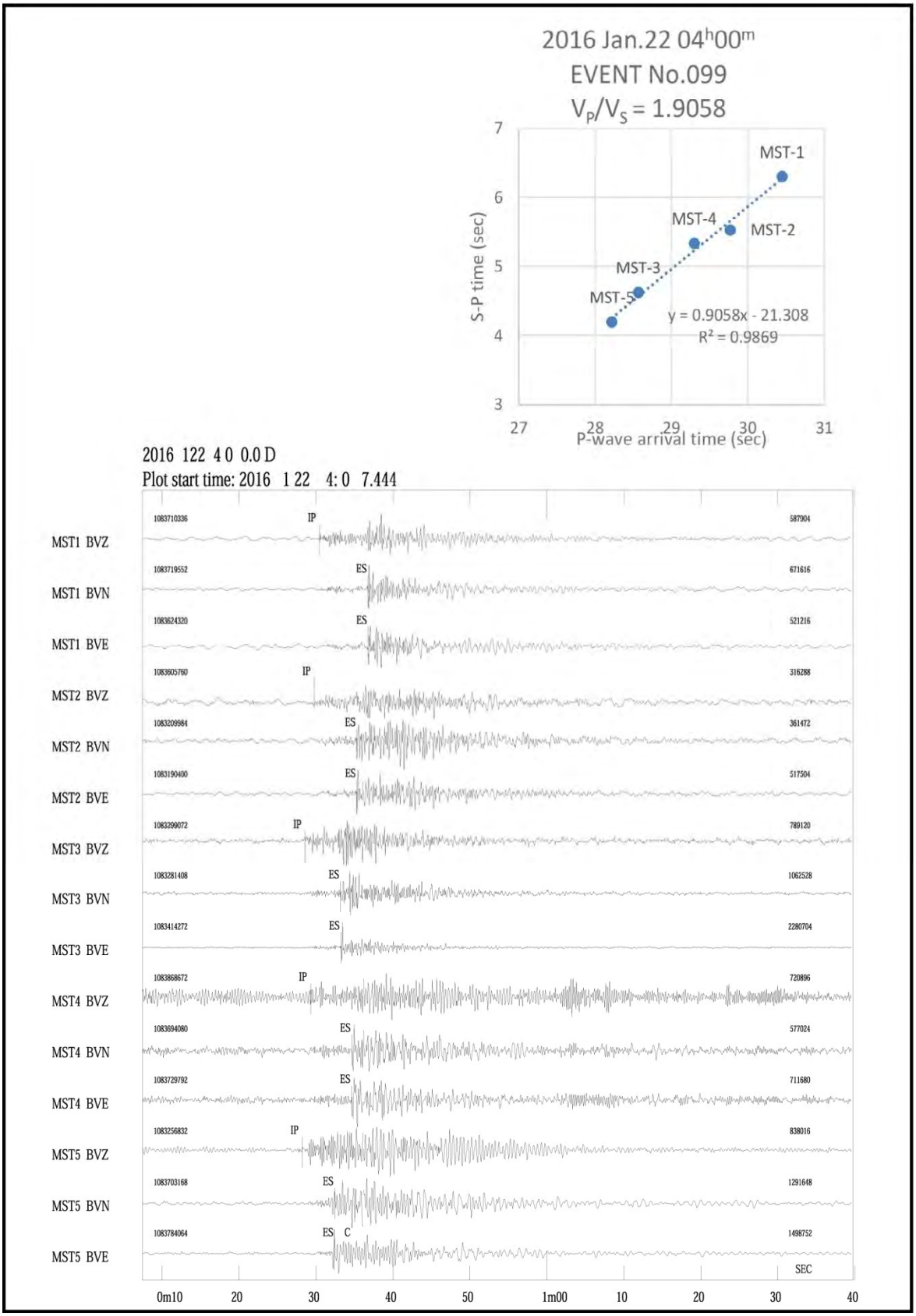
No.	Station	Date	Arrival time			
			Hour	Minute	Second(P)	S-Ptime
1	MSB-1	2015/12/24	03	26	44	5
2	MSB-1	2015/12/25	00	53	03	12
3	MSB-1	2015/12/25	02	12	49	9
4	MSB-1	2015/12/25	02	36	15	19
5	MSB-1	2015/12/25	02	00	52	11
6	MSB-1	2015/12/25	04	49	59	10
7	MSB-1	2015/12/25	04	57	30	32
8	MSB-1	2015/12/25	05	56	54	10
9	MSB-1	2015/12/25	22	22	07	–
10	MSB-1	2015/12/26	01	31	18	1
11	MSB-1	2015/12/26	08	08	46	2
12	MSB-1	2015/12/26	08	09	27	2
13	MSB-1	2015/12/26	08	11	34	2
14	MSB-1	2015/12/26	08	31	24	2
15	MSB-1	2015/12/26	13	56	13	3
16	MSB-1	2015/12/27	04	19	37	–
17	MSB-1	2015/12/27	15	03	23	6
18	MSB-1	2015/12/30	03	05	05	3
19	MSB-1	2015/12/30	15	57	11	4
20	MSB-1	2015/12/31	03	05	05	3
21	MSB-1	2016/1/3	06	40	40	7
22	MSB-1	2016/1/3	08	23	43	1
23	MSB-1	2016/1/4	02	14	38	18
24	MSB-1	2016/1/4	05	40	55	12
25	MSB-1	2016/1/4	17	22	37	10
26	MSB-1	2016/1/5	12	48	50	19
27	MSB-1	2016/1/5	15	11	07	18
28	MSB-1	2016/1/6	09	55	19	9
29	MSB-1	2016/1/6	13	33	39	6
30	MSB-1	2016/1/6	17	39	00	6
31	MSB-1	2016/1/7	12	15	08	–
32	MSB-1	2016/1/7	17	00	50	2
33	MSB-1	2016/1/8	00	21	11	2
34	MSB-1	2016/1/8	00	21	22	2
35	MSB-1	2016/1/8	00	27	05	3
36	MSB-1	2016/1/8	00	39	28	1
37	MSB-1	2016/1/8	01	06	27	4
38	MSB-1	2016/1/8	04	24	10	1
39	MSB-1	2016/1/8	04	24	28	1
40	MSB-1	2016/1/8	04	41	00	4
41	MSB-1	2016/1/8	05	20	10	4
42	MSB-1	2016/1/8	06	34	11	3
43	MSB-1	2016/1/8	07	22	19	8
44	MSB-1	2016/1/8	07	39	02	1
45	MSB-1	2016/1/8	13	31	53	7
46	MSB-1	2016/1/9	01	37	43	2
47	MSB-1	2016/1/9	09	37	15	12
48	MSB-1	2016/1/9	16	29	57	11
49	MSB-1	2016/1/9	21	01	41	10
50	MSB-1	2016/1/10	01	53	26	3
51	MSB-1	2016/1/10	02	24	05	2
52	MSB-1	2016/1/10	02	26	11	2
53	MSB-1	2016/1/10	22	21	15	1
54	MSB-1	2016/1/11	00	25	30	4
55	MSB-1	2016/1/11	00	49	19	8
56	MSB-1	2016/1/11	01	01	53	8
57	MSB-1	2016/1/11	06	33	14	7
58	MSB-1	2016/1/11	06	33	58	18
59	MSB-1	2016/1/15	13	36	08	25
60	MSB-1	2016/1/16	02	43	48	10
61	MSB-1	2016/1/19	17	09	37	12
62	MSB-1	2016/1/19	17	30	00	12
63	MSB-1	2016/1/21	16	03	48	1
64	MSB-1	2016/1/21	16	40	26	8
65	MSB-1	2016/1/23	11	40	39	13
66	MSB-1	2016/1/24	02	16	50	4
67	MSB-1	2016/1/24	09	40	44	19
68	MSB-1	2016/1/25	01	40	17	–
69	MSB-1	2016/1/25	04	10	46	9
70	MSB-1	2016/1/25	08	12	15	3
71	MSB-1	2016/1/25	09	25	13	10
72	MSB-1	2016/1/25	12	06	24	10
73	MSB-1	2016/1/28	23	32	17	8
74	MSB-1	2016/1/29	03	16	6	26
75	MSB-1	2016/1/29	10	42	55	12
76	MSB-1	2016/1/29	13	19	58	3
77	MSB-1	2016/1/30	12	37	30	5
78	MSB-1	2016/1/30	23	11	20	6
79	MSB-1	2016/1/31	14	00	13	20
80	MSB-1	2016/1/31	21	01	15	5
81	MSB-1	2016/2/1	00	16	17	5
82	MSB-1	2016/2/1	02	29	21	3
83	MSB-1	2016/2/2	14	29	20	4
84	MSB-1	2016/2/3	11	27	55	4
85	MSB-1	2016/2/3	11	28	15	4
86	MSB-1	2016/2/3	11	28	29	4
87	MSB-1	2016/2/5	09	02	54	12
88	MSB-1	2016/2/5	09	04	37	4
89	MSB-1	2016/2/5	11	11	53	4
90	MSB-1	2016/2/5	11	12	11	4
91	MSB-1	2016/2/5	11	12	31	4
92	MSB-1	2016/2/5	11	19	32	12
93	MSB-1	2016/2/5	12	09	02	4
94	MSB-1	2016/2/5	12	30	30	6
95	MSB-1	2016/2/5	13	07	35	4
96	MSB-1	2016/2/6	01	41	36	4
97	MSB-1	2016/2/6	02	48	02	4
98	MSB-1	2016/2/6	03	32	24	6
99	MSB-1	2016/2/6	03	36	08	6
100	MSB-1	2016/2/6	09	21	22	4
101	MSB-1	2016/2/6	17	23	22	6
102	MSB-1	2016/2/6	17	31	15	4
103	MSB-1	2016/2/6	17	54	20	3
104	MSB-1	2016/2/10	01	43	14	12
105	MSB-1	2016/2/11	09	07	23	44
106	MSB-1	2016/2/11	12	16	53	4
107	MSB-1	2016/2/12	15	57	55	7
108	MSB-1	2016/2/12	15	58	29	7
109	MSB-1	2016/2/12	15	59	08	7
110	MSB-1	2016/2/13	01	04	11	14
111	MSB-1	2016/2/14	00	36	36	32
112	MSB-1	2016/2/14	12	17	58	18
113	MSB-1	2016/2/15	06	47	53	14
114	MSB-1	2016/2/15	18	50	52	14
115	MSB-1	2016/2/16	02	57	12	3

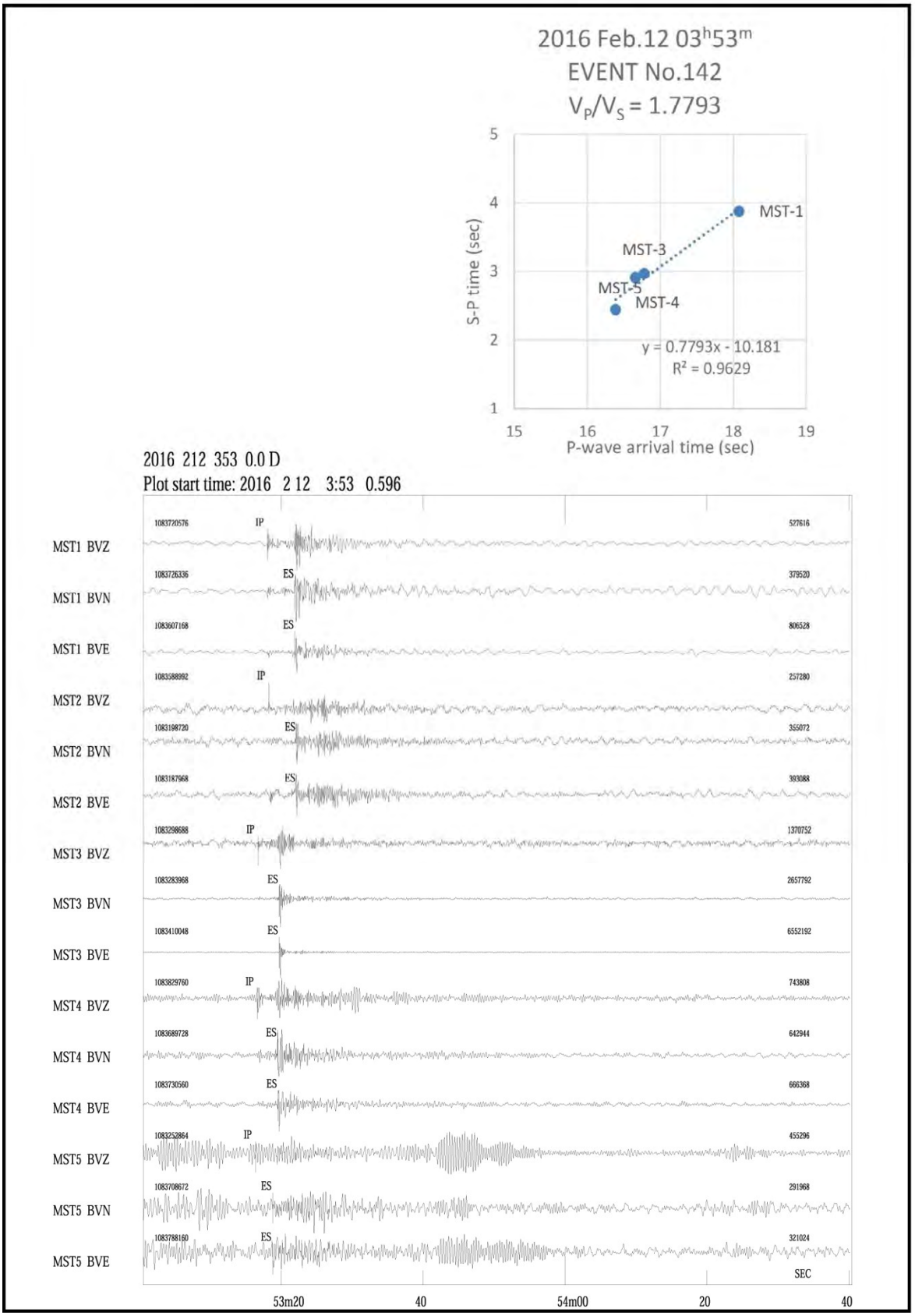
No.	Station	Date	Arrival time			
			Hour	Minute	Second(P)	S-Ptime
116	MSB-1	2016/2/16	05	07	58	9
117	MSB-1	2016/2/16	11	38	11	15
118	MSB-1	2016/2/16	12	04	23	13
119	MSB-1	2016/2/17	02	26	17	5
120	MSB-1	2016/2/17	06	08	58	12
121	MSB-1	2016/2/18	02	42	02	13
122	MSB-1	2016/2/18	10	54	28	12
123	MSB-1	2016/2/19	13	39	03	2
124	MSB-1	2016/2/19	22	25	56	3
125	MSB-1	2016/2/20	05	22	44	30
126	MSB-1	2016/2/20	15	29	12	35
127	MSB-1	2016/2/20	15	34	42	15
128	MSB-1	2016/2/23	05	41	50	40
129	MSB-1	2016/2/24	05	56	36	13
130	MSB-1	2016/2/24	23	45	25	3
131	MSB-1	2016/2/24	23	56	13	2
132	MSB-1	2016/2/25	01	58	03	15
133	MSB-1	2016/2/25	05	21	54	5
134	MSB-1	2016/2/25	15	08	18	3
135	MSB-1	2016/2/28	02	47	00	15
136	MSB-1	2016/2/28	07	32	42	24
137	MSB-1	2016/2/28	13	32	41	–
138	MSB-1	2016/2/29	03	35	54	5
139	MSB-1	2016/2/29	23	24	03	6
140	MSB-1	2016/3/1	14	38	03	12
141	MSB-1	2016/3/1	23	51	42	–
142	MSB-1	2016/3/2	15	11	32	7
143	MSB-1	2016/3/2	16	17	17	5
144	MSB-1	2016/3/3	09	24	41	3
145	MSB-1	2016/3/3	16	15	44	5
146	MSB-1	2016/3/5	03	04	32	20
147	MSB-1	2016/3/6	00	24	25	2
148	MSB-1	2016/3/6	00	47	21	–
149	MSB-1	2016/3/6	02	21	31	2
150	MSB-1	2016/3/6	04	10	59	2
151	MSB-1	2016/3/6	04	11	28	2
152	MSB-1	2016/3/6	04	53	44	2
153	MSB-1	2016/3/6	06	33	20	2
154	MSB-1	2016/3/6	06	33	30	2
155	MSB-1	2016/3/6	08	15	09	2
156	MSB-1	2016/3/6	08	33	39	2
157	MSB-1	2016/3/6	09	39	53	2
158	MSB-1	2016/3/6	10	01	33	2
159	MSB-1	2016/3/6	10	01	41	2
160	MSB-1	2016/3/6	10	02	23	2
161	MSB-1	2016/3/6	10	33	36	2
162	MSB-1	2016/3/6	10	34	18	2
163	MSB-1	2016/3/6	10	34	36	2
164	MSB-1	2016/3/6	10	40	11	2
165	MSB-1	2016/3/6	10	40	37	2
166	MSB-1	2016/3/6	10	42	22	2
167	MSB-1	2016/3/6	10	42	50	2
168	MSB-1	2016/3/6	10	42	58	2
169	MSB-1	2016/3/6	10	43	31	2
170	MSB-1	2016/3/6	10	43	46	2
171	MSB-1	2016/3/6	11	59	26	2
172	MSB-1	2016/3/6	13	42	52	2
173	MSB-1	2016/3/6	14	12	59	2
174	MSB-1	2016/3/6	14	13	53	2
175	MSB-1	2016/3/6	14	25	24	2
176	MSB-1	2016/3/6	14	25	37	2
177	MSB-1	2016/3/6	14	25	56	2
178	MSB-1	2016/3/6	21	15	15	2
179	MSB-1	2016/3/6	21	21	04	2
180	MSB-1	2016/3/6	22	10	56	2
181	MSB-1	2016/3/6	22	21	16	2
182	MSB-1	2016/3/6	22	22	06	2
183	MSB-1	2016/3/6	22	22	46	2
184	MSB-1	2016/3/6	22	27	14	2
185	MSB-1	2016/3/6	22	28	24	2
186	MSB-1	2016/3/6	22	29	59	2
187	MSB-1	2016/3/6	22	46	38	2
188	MSB-1	2016/3/6	23	37	57	2
189	MSB-1	2016/3/6	23	47	25	1
190	MSB-1	2016/3/7	09	16	24	–
191	MSB-1	2016/3/9	00	42	10	2
192	MSB-1	2016/3/9	01	21	25	23
193	MSB-1	2016/3/9	01	27	56	14
194	MSB-1	2016/3/9	09	14	28	7
195	MSB-1	2016/3/9	11	17	10	7
196	MSB-1	2016/3/10	00	53	59	4
197	MSB-1	2016/3/10	08	44	49	3
198	MSB-1	2016/3/10	22	45	25	10
199	MSB-1	2016/3/11	02	32	30	3
200	MSB-1	2016/3/11	02	46	43	4
201	MSB-1	2016/3/12	01	42	18	2
202	MSB-1	2016/3/14	12	25	41	5
203	MSB-1	2016/3/15	02	49	32	22
204	MSB-1	2016/3/17	05	44	27	4
205	MSB-1	2016/3/17	17	17	02	3
206	MSB-1	2016/3/17	17	17	46	8
207	MSB-1	2016/3/20	00	18	05	4
208	MSB-1	2016/3/20	07	15	42	12
209	MSB-1	2016/3/20	14	25	54	4
210	MSB-1	2016/3/20	14	33	33	4
211	MSB-1	2016/3/20	17	54	48	15
212	MSB-1	2016/3/21	14	49	45	3
213	MSB-1	2016/3/22	07	15	38	18
214	MSB-1	2016/3/23	03	40	58	–
215	MSB-1	2016/3/23	10	4	48	2
216	MSB-1	2016/3/23	10	41	31	10
217	MSB-1	2016/3/24	01	31	35	21
218	MSB-1	2016/3/24	01	36	30	12
219	MSB-1	2016/3/24	01	42	04	14
220	MSB-1	2016/3/24	02	40	18	4
221	MSB-1	2016/3/24	09	04	31	5
222	MSB-1	2016/3/24	11	52	12	5
223	MSB-1	2016/3/24	11	53	04	22
224	MSB-1	2016/3/25	00	43	48	22
225	MSB-1	2016/3/25	00	44	34	32
226	MSB-1	2016/3/25	11	40	34	2
227	MSB-1	2016/3/25	13	38	29	2
228	MSB-1	2016/3/25	14	24	43	2
229	MSB-1	2016/3/25	23	29	26	2
230	MSB-1	2016/3/26	07	22	02	30

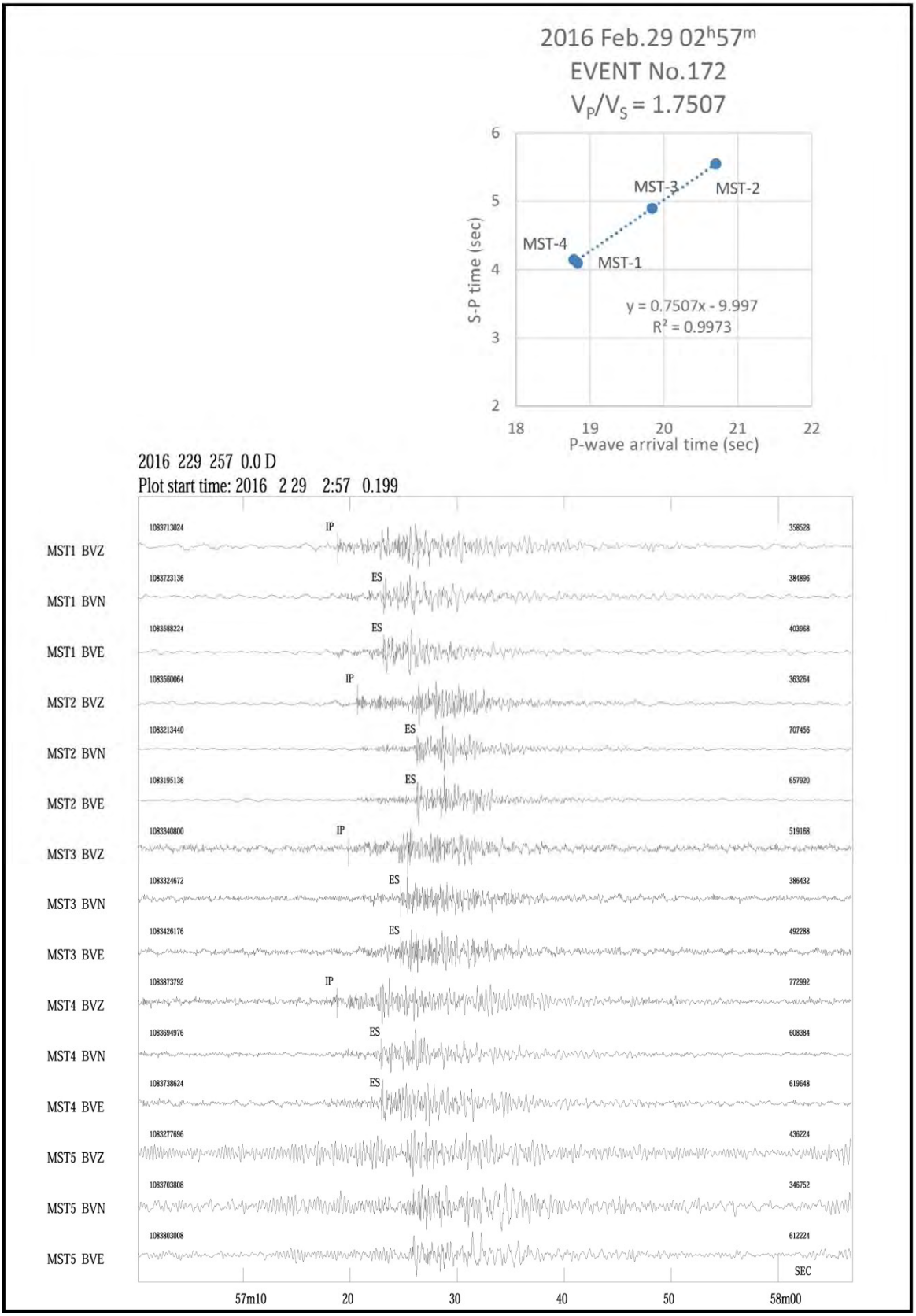
A4.7　地震記象データ（テンダホ-2 地区）


2016 Jan.11 02h06m
EVENT No.058
VP/VS = 1.722
S-P time (sec)
P-wave arrival time (sec)
MST-1
MST-2
MST-3
MST-4
y = 0.7222x + 5.49
R² = 0.9993
2016 111 2 6 0.0 D
Plot start time: 2016 1 11 2: 6 49.238
MST1 BVZ
MST1 BVN
MST1 BVE
MST2 BVZ
MST2 BVN
MST2 BVE
MST3 BVZ
MST3 BVN
MST3 BVE
MST4 BVZ
MST4 BVN
MST4 BVE
MST5 BVZ
MST5 BVN
MST5 BVE
IP
ES
CODA
SEC
6m50
7m00
8m00


2016 Jan.15 03h50m
EVENT No.065
VP/VS = 1.9132
S-P time (sec)
P-wave arrival time (sec)
MST-5
MST-3
MST-2
MST-1
y = 0.9132x - 24.114
R² = 0.986
2016 115 350 0.0 D
Plot start time: 2016 1 15 3:50 0.000
MST1 BVZ
MST1 BVN
MST1 BVE
MST2 BVZ
MST2 BVN
MST2 BVE
MST3 BVZ
MST3 BVN
MST3 BVE
MST4 BVZ
MST4 BVN
MST4 BVE
MST5 BVZ
MST5 BVN
MST5 BVE
IP
ES
CODA
SEC
50m20
40
51m00
20
40
52m00
20
40
53m00


2016 Jan.22 04h00m
EVENT No.099
Vp/Vs = 1.9058
MST-1
MST-2
MST-3
MST-4
MST-5
y = 0.9058x - 21.308
R² = 0.9869
S-P time (sec)
P-wave arrival time (sec)
2016 122 4 0 0.0 D
Plot start time: 2016 1 22 4: 0 7.444
MST1 BVZ
MST1 BVN
MST1 BVE
MST2 BVZ
MST2 BVN
MST2 BVE
MST3 BVZ
MST3 BVN
MST3 BVE
MST4 BVZ
MST4 BVN
MST4 BVE
MST5 BVZ
MST5 BVN
MST5 BVE
IP
ES
C
SEC
0m10
20
30
40
50
1m00
10
20
30
40


2016 Feb.12 03h53m
EVENT No.142
Vp/Vs = 1.7793
S-P time (sec)
P-wave arrival time (sec)
MST-1
MST-3
MST-5
MST-4
y = 0.7793x - 10.181
R² = 0.9629
2016 212 353 0.0 D
Plot start time: 2016 2 12 3:53 0.596
MST1 BVZ
MST1 BVN
MST1 BVE
MST2 BVZ
MST2 BVN
MST2 BVE
MST3 BVZ
MST3 BVN
MST3 BVE
MST4 BVZ
MST4 BVN
MST4 BVE
MST5 BVZ
MST5 BVN
MST5 BVE
IP
ES
SEC
53m20
40
54m00
20
40


2016 Feb.29 02h57m
EVENT No.172
VP/VS = 1.7507
S-P time (sec)
P-wave arrival time (sec)
MST-1
MST-2
MST-3
MST-4
y = 0.7507x - 9.997
R² = 0.9973
2016 229 257 0.0 D
Plot start time: 2016 2 29 2:57 0.199
MST1 BVZ
MST1 BVN
MST1 BVE
MST2 BVZ
MST2 BVN
MST2 BVE
MST3 BVZ
MST3 BVN
MST3 BVE
MST4 BVZ
MST4 BVN
MST4 BVE
MST5 BVZ
MST5 BVN
MST5 BVE
IP
ES
SEC
57m10
58m00

APPENDIX-5

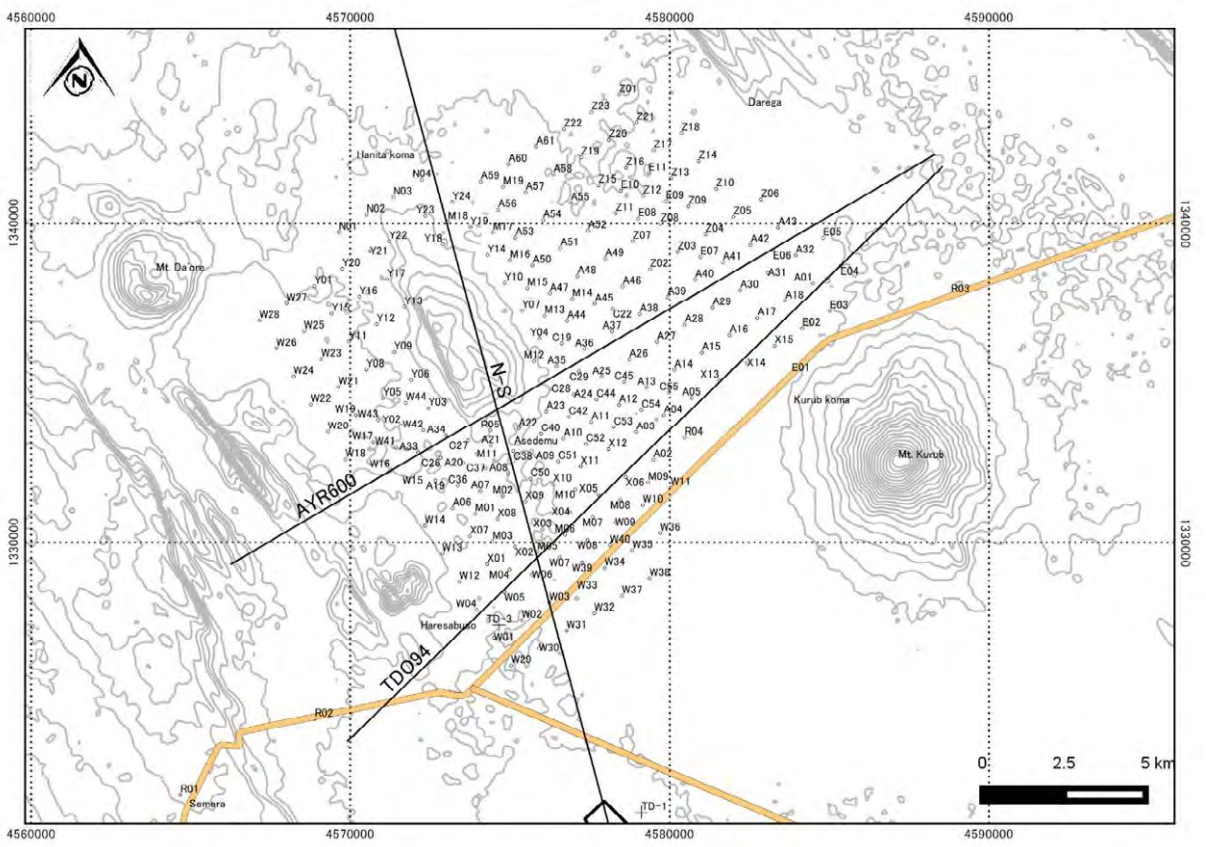
地温調査

Appendix-5　地温調査

A5.1　調査手法

(1) 調査範囲

測点位置を図 A5.1.1 に示す。調査地内の 220 点で温度測定を行ったほか、調査地内外に 5 点のリファレンス測点を設け、観測期間毎日測定し、観測期間中の地温季節変化を確認した。



出典: 調査団

図 A5.1.1　地温調査測点位置図

(2) 調査手順

調査は以下の手順にて実施した。図 A5.1.2 に作業写真を示す。

- エンジンオーガー（φ40mm）で、深さ約 30~50cm まで穿孔する。
- ステンレス製のプローブ（全長 2.2.m、外径 13.8mm）を電動ハンマーで打設し、深さ 2.0m まで打ち込む。打設地点は、GPS を使用して座標を記録する。
- 礫などとの衝突などにより、深さ 2.0m まで打設できない場合は、打設位置を数 m ずらして再度プローブ打設を行う。
- プローブ挿入後翌日（約 17 時間後）に 2.0m 深地温をサーミスタ温度計により計測する。プローブ打設後の温度の平衡状態にかかる時間については、以下に示すように確認した。
- 地温測定後、打設したプローブは油圧ジャッキなどを使用して引き抜く。

オーガーによる掘削 (深度 0.3~0.5m)

プローブ削孔 (深度 2.0m)

地温測定

油圧ジャッキによる引き抜き

出典: 調査団

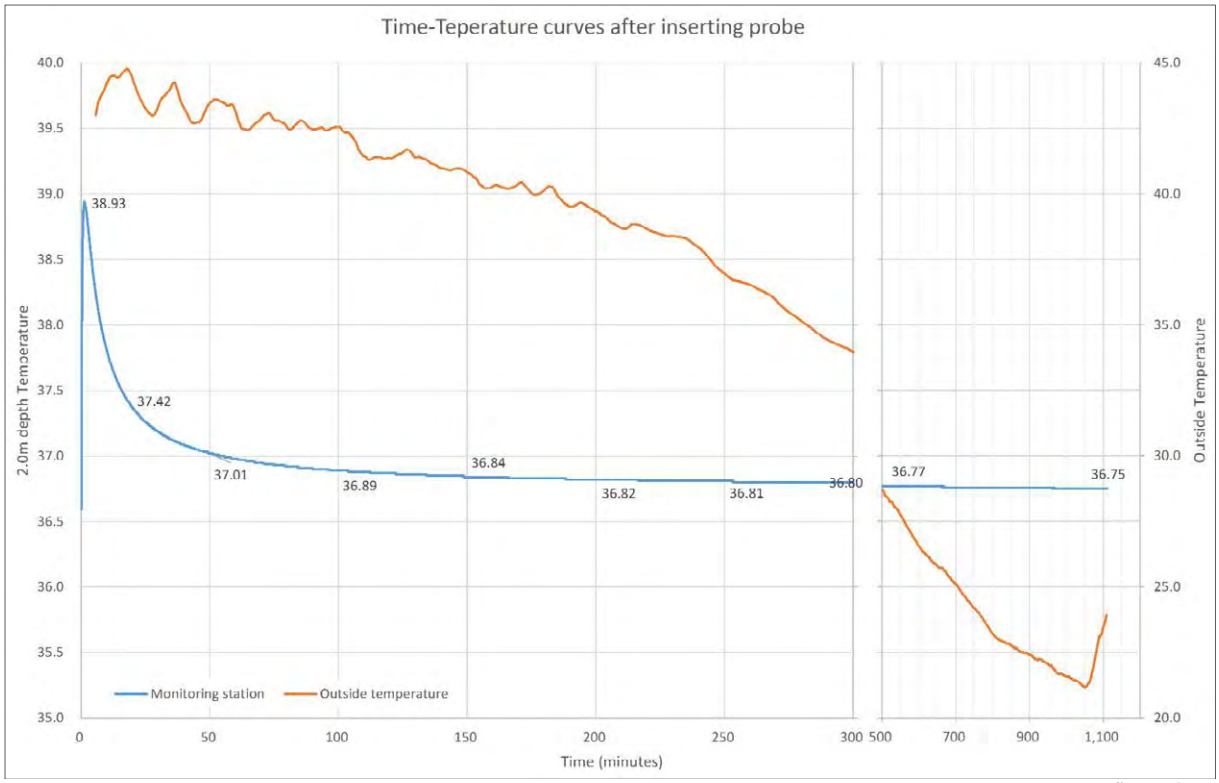
図 A5.1.2　地温調査作業写真

(3) 温度平衡

掘削・プローブ挿入直後から継続的に地温の測定を実施し、温度平衡状態に至る時間を確認した。

図 A5.1.3 にプローブ挿入直後の 2m 深地温の変化を示す。プローブ挿入の直後は挿入による摩擦熱で高温となっているが、約 3 時間後にはほぼ平衡状態に達していることが確認できる。後述する季節変化の計測では、調査期間においては最大 0.13℃/日、平均-0.028℃/日の温度変化が確認されており、平衡状態後にも非常に緩やかな温度低下が認められる。

本調査では、作業効率を考慮し、プローブ挿入後の翌日に計測を実施した。すなわち計測は、プローブ挿入後約 17 時間以上経過しており、完全に温度が平衡状態となった後に測定している。



出典: 調査団

図 A5.1.3　プローブ挿入後の 2m 深地温変化

(4) 日変化

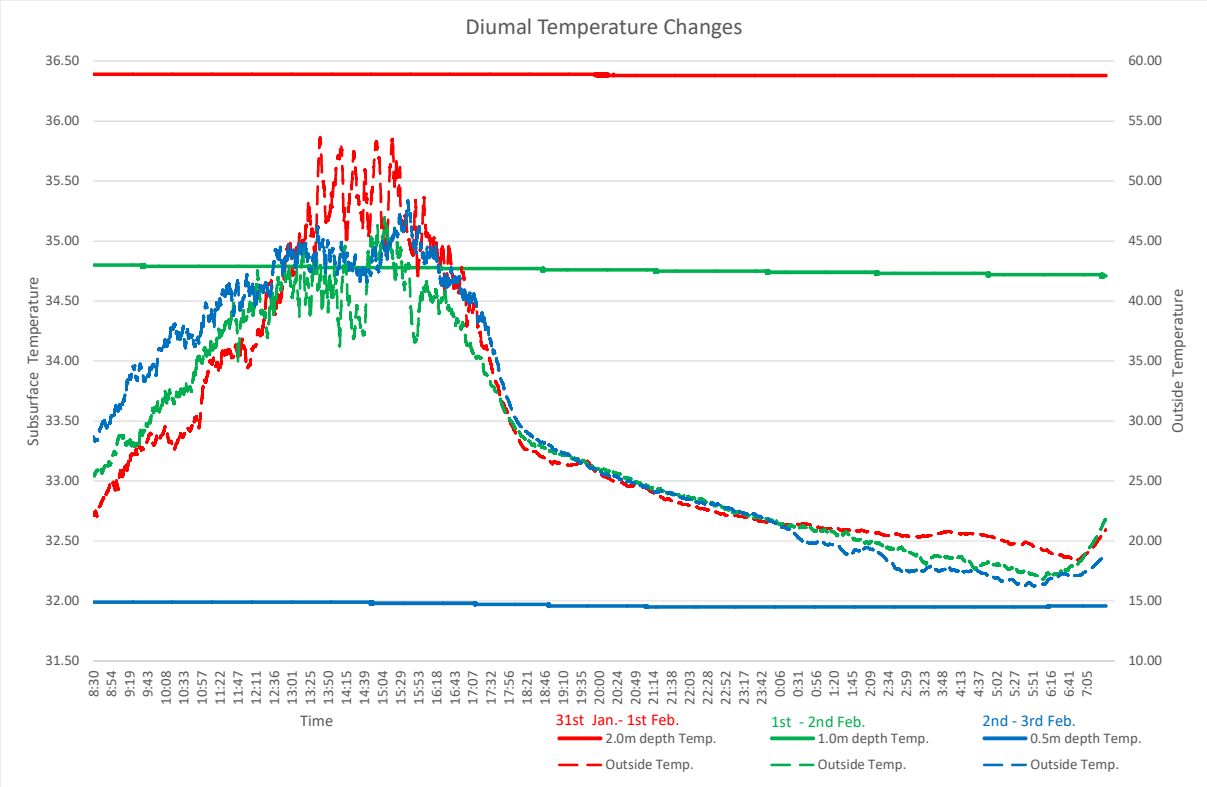
日射や外気温による地温の影響を確認するため、0.5m から 2.0m 深地温の日変化を計測した。計測地点は、調査地点とほぼ同緯度、同標高に設けたリファレンス点において、24 時間計測を実施した。

測定結果を表 A5.1.1 および図 A5.1.4 に示す。観測日における 2.0m 深地温の日変化はほとんどなく 0.01°C の温度の変化のみであった。1.0m 深では、0.09°C の外気温の変化と相関の無い温度低下が認められた。0.5m 深では、測定日における温度差は軽微ながらも、夜半に向けて温度が下がり、夜明けとともに温度が上昇する傾向が見出せる。よって、本地域においても過去の研究（例えば Coolbaugh et al. 2007）と同様に、2.0m 深地温は太陽放射および外気温の変化による影響がないと言える。

表 A5.1.1　日変化における観測結果概要（単位: °C）

深度	最高温度	最低温度	温度差
0.5m	31.99	31.95	0.04
1.0m	34.80	34.71	0.09
2.0m	36.39	36.38	0.01

出典: 調査団



出典: 調査団

図 A5.1.4　2m 深地温の日変化

(5) 季節変化補正

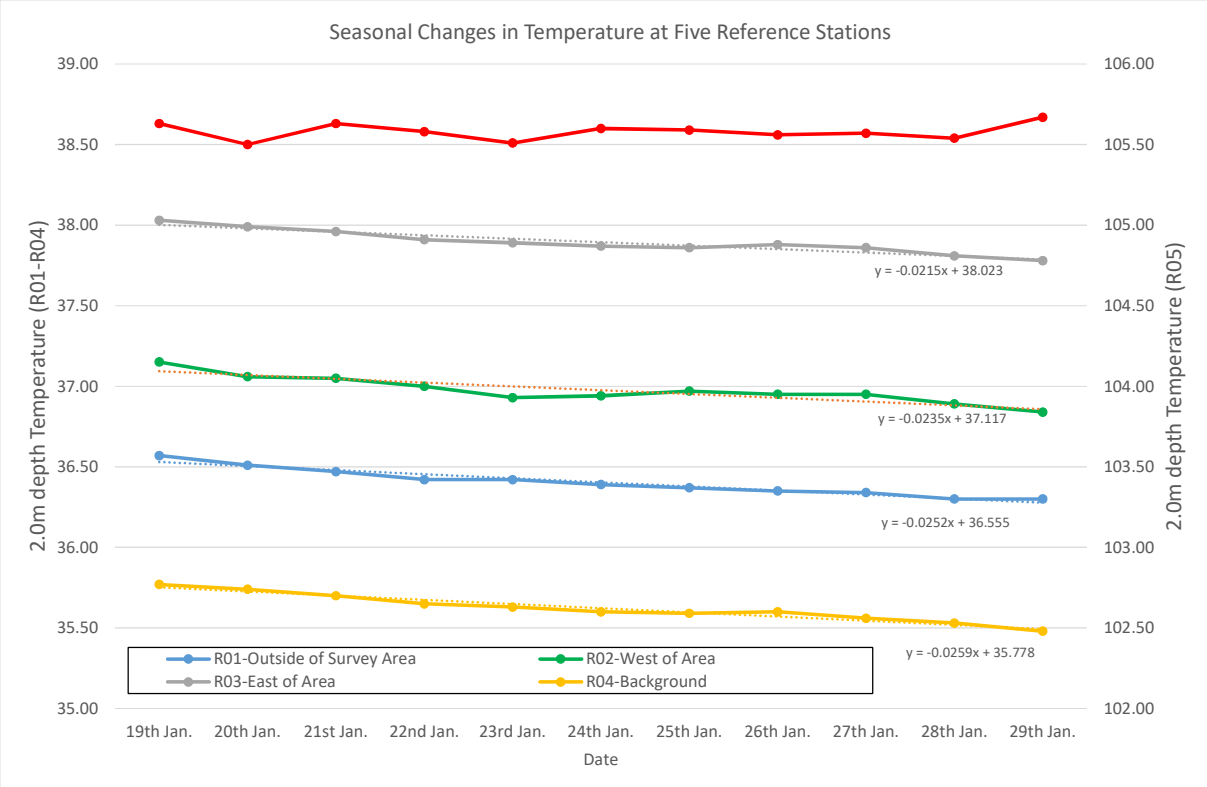
地温調査は、2016 年 1 月 18 日から 1 月 29 日の 12 日間調査を実施した。季節変化による測定結果の補正のため、測定期間中毎日、調査範囲内外に設置したリファレンス点の 2m 深地温の 12 日間の温度変化を計測した。

測定結果グラフを図 A5.1.5 に示す。噴気帯内に設けた R05 点以外のすべてのリファレンス点において、測定開始日から測定終了日にかけて地温の低下が認められた。短期間で調査が完了したため、温度低下幅は、表 A5.1.2 に示すように最大で 0.31℃、平均日変化は-0.024℃ と非常に小さかった。本データを用いて季節変化による補正値を設定し、すべての観測点を観測初日（2016 年 1 月 19 日）に補正した。補正値は非常に小さいため、補正前後のデータに大きな違いは生じなかった。

表 A5.1.2　リフェレンス点における観測結果概要（単位: ℃）

Sta. No.	平均	最高温度	最低温度	温度差
R01	36.40	36.57	36.30	0.27
R02	36.98	37.15	36.84	0.31
R03	37.89	38.03	37.78	0.25
R04	35.62	35.77	35.48	0.29
R05	105.58	105.67	105.50	0.17

出典: 調査団



出典: 調査団

図 A5.1.5　調査期間中のリファレンス点 2m 深地温の変化

A5.2 調査結果

下表に 2m 深地温測定結果を示す。

表 A5.1.3 2m 深地温測定結果 (1)

S.No.	Cordinates		Day	Time	Outside	Subsurface Temperature				Ground Type	Vegetation	Other
	X	Y	dd.mm.yy	HH:MM	Temp.	2.0m	1.5m	1.0m	0.5m	Soil/Gravel/Rock	Yes/No	
A01	737757	1320125	19.01.16	2:02	39.9	37.04	36.68	36.14	35.47	Soil	No	
A02	732916	1314692	22.01.16	2:32	32.2	37.23	36.69	35.83	34.83	Soil	No	
A03	732381	1315537	22.01.16	10:48	34.4	39.29	38.32	36.9	35.36	Soil	No	
A04	733225	1316072	22.01.16	11:16	35.55	38.74	38.28	37.56	36.34	Soil	No	
A05	734070	1316607	22.01.16	11:55	34.45	36.71	36.22	35.89	35.14	Soil	No	
A06	726777	1313170	21.01.16	11:59	35.67	41.39	40.61	39.01	37.05	Soil	No	
A07	727622	1313705	21.01.16	1:08	34.64	49.57	45.85	43.08	40.14	Soil	No	
A08	728467	1314240	21.01.16	1:29	34.23	54.97	51.94	47.05	41.39	Soil	No	
A09	729311	1314776	21.01.16	1:58	36.69	52.63	49.73	45.71	41.17	Soil	No	
A10	730158	1315311	19.01.16	9:45	30.8	46.05	44.25	41.62	38.26	Soil	No	
A11	731003	1315847	19.01.16	10:16	30.5	40.2	39.24	38.06	36.53	Soil	No	
A12	731848	1316381	19.01.16	10:41	33.4	38.18	37.13	36.02	34.91	Soil	No	
A13	732693	1316916	19.01.16	11:09	35.5	36.91	36.21	35.41	34.35	Soil	No	
A14	733535	1317450	19.01.16	11:32	34.8	36.21	35.69	34.85	33.94	Soil	No	
A15	734379	1317985	19.01.16	11:56	35.1	36.19	35.83	35.31	34.72	Soil	No	
A16	735219	1318523	19.01.16	12:25	37.7	37.59	37.12	36.58	35.65	Soil	No	
A17	736069	1319056	19.01.16	12:48	38.5	37.78	37.41	36.81	36.06	Soil	No	
A18	736913	1319590	19.01.16	1:36	39.1	38.65	38.27	37.55	36.66	Soil	No	
A19	726242	1314015	21.01.16	11:27	32.56	45.66	43.42	40.71	36.96	Soil	No	
A20	727087	1314550	21.01.16	12:39	35.41	63.96	58.22	51.82	45.15	Soil	No	
A21	727931	1315085	19.01.16	11:03	33.36	53.15	49.82	46.6	43.38	Soil	No	
A22	728776	1315620	19.01.16	11:40	35.3	50.92	48.07	44.7	40.57	Soil	No	
A23	729621	1316156	19.01.16	11:59	35.64	46.36	44.04	41.32	38.5	Soil	No	
A24	730465	1316691	19.01.16	12:16	38.72	38.76	38.06	37.06	35.6	Soil	No	
A25	731310	1317226	19.01.16	12:24	38.61	37.4	36.82	36.1	35.1	Soil	No	
A26	732155	1317762	19.01.16	12:44	37.93	36.49	36.11	35.57	34.76	Soil	No	
A27	732999	1318297	19.01.16	12:59	38.89	36.39	35.8	35.05	34.33	Soil	No	

出典: 調査団

表 A5.1.3　2m 深地温測定結果 (2)

S.No.	Cordinates		Day	Time	Outside	Subsurface Temperature				Ground Type	Vegetation	Other
	X	Y	dd.mm.yy	HH:MM	Temp.	2.0m	1.5m	1.0m	0.5m	Soil/Gravel/Rock	Yes/No	
A28	733844	1318832	23.01.16	10:04	31.25	35.53	35.16	34.69	34.16	Soil	No	
A29	734689	1319367	19.01.16	1:28	37.08	36.99	36.57	35.95	35.01	Soil	No	
A30	735533	1319903	19.01.16	2:09	36	38.16	37.77	37.17	35.99	Soil	No	
A31	736378	1320438	19.01.16	2:27	36.71	37.58	37.12	36.45	38.12	Soil	No	
A32	737225	1320972	19.01.16	2:17	37.85	38.98	38.61	38.02	37.16	Soil	No	
A33	725707	1314859	21.01.16	10:45	32.25	49.92	46.13	41.83	39.02	Soil	No	
A34	726551	1315395	21.01.16	10:14	29.36	43.9	42.6	40.61	38.39	Soil	No	
A35	729930	1317536	20.01.16	10:23	39.69	41.3	40.34	39.09	37.17	Soil	No	
A36	730778	1318067	20.01.16	10:40	30.86	37.88	37.04	35.93	34.27	Soil	No	
A37	731619	1318606	20.01.16	11:02	32.09	37.98	37.32	36.5	35.24	Soil	No	
A38	732464	1319141	20.01.16	11:21	33.09	36.27	35.67	34.89	34.07	Soil	No	
A39	733309	1319677	20.01.16	11:00	31.1	35.4	34.96	34.36	34.62	Soil	No	
A40	734153	1320212	20.01.16	10:23	31.1	35.53	35.07	34.35	33.23	Soil	No	
A41	734998	1320747	20.01.16	10:00	39.7	38.47	38	37.21	36.43	Soil	No	
A42	735843	1321283	20.01.16	9:31	39.4	36.98	36.57	36.01	35.33	Soil	No	
A43	736687	1321818	20.01.16	9:05	27.4	35.93	35.36	34.72	33.8	Soil	No	
A44	730239	1318916	20.01.16	12:18	33.5	38.1	37.36	36.23	34.95	Soil	No	
A45	731084	1319451	20.01.16	11:55	32.8	37.21	36.58	35.68	35.63	Soil	No	
A46	731932	1319985	20.01.16	11:32	33.6	36.65	36.08	35.31	34.44	Soil	No	
A47	729704	1319760	20.01.16	12:39	36.1	36.98	36.36	35.64	34.67	Soil	No	
A48	730549	1320296	20.01.16	1:19	36.8	37.47	36.92	36.13	35.02	Soil	No	
A49	731394	1320831	20.01.16	1:50	38.3	37.15	36.49	35.77	34.98	Soil	No	
A50	729169	1320605	21.01.16	9:43	29.5	36.87	36.34	35.65	34.8	Soil	No	
A51	730014	1321140	21.01.16	9:21	27.2	37.01	36.39	35.42	34.32	Soil	No	
A52	730858	1321676	21.01.16	8:52	26.8	37.61	37.06	36.3	35.35	Soil	Yes	
A53	728634	1321450	26.01.16	1:42	37.89	36.87	35.94	34.57	33.8	Soil	No	
A54	729476	1321987	21.01.16	10:12	31.2	37.9	37.4	36.51	35.5	Gravel	No	
A55	730323	1322520	21.01.16	10:48	33.1	37.19	36.7	35.94	35.27	Soil	No	
A56	728098	1322294	21.01.16	2:37	36.5	39.02	38.56	37.7	36.48	Gravel	No	
A57	728943	1322830	21.01.16	12:09	32.5	37.29	36.72	35.94	35	Soil	No	
A58	729788	1323365	21.01.16	11:23	34.2	35.48	35.03	34.42	33.55	Soil	No	
A59	727563	1323139	21.01.16	12:37	32.2	37.92	37.6	36.96	36.1	Soil	No	
A60	728408	1323674	21.01.16	1:12	36.4	36.21	35.77	35.22	34.67	Soil	No	
A61	729252	1324210	21.01.16	1:45	35.4	36.37	35.75	35.05	34.22	Soil	Yes	
X01	727848	1311481	22.01.16	10:35	29	42.99	41.65	40.22	38.34	Soil	No	
X02	728692	1312016	22.01.16	11:02	30.1	48.19	45.06	41.87	38.34	Soil	No	
X03	729537	1312551	22.01.16	1:28	36.9	47.76	45.26	42.33	39.3	Soil	No	
X04	730382	1313086	22.01.16	12:57	34.7	48.37	46.29	43.92	40.67	Soil	No	
X05	731227	1313622	22.01.16	12:26	35.7	42.36	41.07	39.4	37.13	Soil	No	
X06	732071	1314157	22.01.16	12:02	34.5	39.52	38.78	37.82	36.38	Soil	No	
X07	727313	1312325	22.01.16	10:08	29.1	41.16	39.8	38	36.2	Soil	No	
X08	728157	1312861	22.01.16	9:25	26	48.65	45.28	41.99	39.12	Soil	No	
X09	729002	1313396	22.01.16	8:52	25.9	48.99	46.24	43.34	40.1	Soil	No	
X10	729847	1313931	22.01.16	8:16	25.1	48.5	45.35	41.76	38.2	Soil	No	
X11	730691	1314466	22.01.16	10:15	29.46	42.72	40.96	39.02	36.54	Soil	No	
X12	731536	1315002	22.01.16	10:31	30.56	40.22	39.06	37.73	36.41	Soil	No	
X13	734915	1317143	22.01.16	12:11	34.2	37.29	36.91	36.3	35.61	Soil	No	
X14	735759	1317678	22.01.16	12:31	36.85	36.89	36.68	36.17	65.49	Soil	No	
X15	736604	1318213	22.01.16	12:46	35.39	38.64	38.17	37.2	36.22	Soil	No	
Y01	722495	1319927	24.01.16	11:05	34.5	39.56	38.61	37.31	35.91	Soil	No	
Y02	725171	1315704	24.01.16	8:20	24.3	51.97	48.62	44.54	40.06	Soil	No	
Y03	726016	1316239	24.01.16	1:15	39.83	44.67	42.62	40.08	37.14	Soil	No	
Y04	729395	1318380	24.01.16	10:03	30.36	39.91	39.32	39.24	38.4	Soil	No	
Y05	724622	1316524	24.01.16	8:54	25.8	41.08	39.42	37.47	33.73	Soil	No	
Y06	725481	1317084	24.01.16	12:54	37.55	41.15	40.1	38.58	36.65	Soil	No	
Y07	728860	1319225	26.01.16	11:11	31.14	38.42	37.81	36.8	35.5	Soil	Yes-sparse	
Y08	724101	1317393	24.01.16	9:25	27.9	44.01	42.43	40.45	37.9	Soil	No	
Y09	724946	1317929	24.01.16	1:08	34.7	44.86	42.66	40.23	37.37	Soil	No	
Y10	728324	1320070	26.01.16	11:38	34.11	40.39	39.5	38.12	36.4	Soil	No	
Y11	723566	1318238	24.01.16	9:55	31.9	41.63	40.01	38.03	35.97	Soil	No	
Y12	724410	1318773	24.01.16	12:39	36.5	42.46	41.16	39.77	36.97	Soil	No	
Y13	725255	1319309	25.01.16	10:09	31.6	41.46	40.59	39.36	37.21	Soil	No	
Y14	727789	1320914	26.01.16	11:52	34.24	38.74	38.07	37.1	35.79	Soil	No	
Y15	723030	1319083	24.01.16	10:25	32.1	40.23	39.18	38.07	36.5	Soil	No	
Y16	723875	1319618	24.01.16	12:13	32.9	42.7	41.07	39.1	36.64	Soil	No	
Y17	724720	1320153	25.01.16	9:35	30.6	39.87	38.49	37.3	35.87	Soil	No	Near fault scarp
Y18	726409	1321224	26.01.16	1:25	38.54	40.67	39.56	38.05	36.4	Soil	Yes-Grass	Near fault scarp
Y19	727254	1321759	26.01.16	12:06	34.78	37.29	36.57	35.38	33.54	Soil	No	
Y20	723340	1320463	24.01.16	11:35	36.8	39.15	38.31	37.34	35.86	Soil	Yes	
Y21	724184	1320998	25.01.16	8:31	26.5	40.61	39.53	38.4	36.63	Soil	No	
Y22	724771	1321306	25.01.16	8:55	28.2	37.82	37.33	36.6	35.36	Soil	No	Near fault scarp
Y23	725877	1322086	26.01.16	12:48	36.6	39.14	38.35	37.42	35.79	Soil	No	
Y24	726701	1322512	26.01.16	12:32	34.42	38.24	37.56	36.47	35.24	Soil	No	

出典: 調査団

表 A5.1.3　2m 深地温測定結果 (3)

S.No.	Cordinates		Day	Time	Outside	Subsurface Temperature				Ground Type	Vegetation	Other
	X	Y	dd.mm.yy	HH:MM	Temp.	2.0m	1.5m	1.0m	0.5m	Soil/Gravel/Rock	Yes/No	
Z01	731786	1325815	23.01.16	8:23	22.9	36.56	36.21	35.67	34.97	Soil	Yes	
Z02	732774	1320521	23.01.16	10:28	31.52	36.03	35.63	35	34.09	Soil	No	
Z03	733618	1321057	23.01.16	10:57	34.6	35.81	35.38	34.82	34.05	Soil	No	
Z04	734463	1321592	23.01.16	11:20	33.17	36.39	36.11	35.56	34.81	Soil	No	
Z05	735308	1322127	23.01.16	11:34	33.72	37.34	36.95	36.32	35.39	Soil	No	
Z06	736152	1322663	23.01.16	11:48	34.42	35.65	35.2	34.7	33.73	Soil	No	
Z07	732238	1321366	23.01.16	1:10	35.06	37.14	36.61	35.75	34.54	Soil	No	
Z08	733083	1321901	23.01.16	12:52	34.77	35.88	35.22	34.3	33.4	Soil	No	
Z09	733928	1322437	23.01.16	12:28	35.73	35.76	35.4	34.89	34.02	Soil	No	
Z10	734772	1322972	23.01.16	12:10	35.1	37.04	36.44	35.58	34.7	Soil	No	
Z11	731703	1322211	23.01.16	1:40	38.7	37.42	36.98	36.29	35.31	Soil	No	
Z12	732548	1322746	23.01.16	2:16	38.1	38.06	37.51	36.78	35.58	Soil	No	
Z13	733392	1323281	23.01.16	1:38	38.37	37.66	37.17	36.54	35.66	Gravel	No	
Z14	734237	1323817	23.01.16	2:04	37.55	36.23	35.7	35.17	34.3	Soil	Yes-shrubs	
Z15	731168	1323055	23.01.16	12:54	36.7	35.77	35.31	34.68	32.65	Soil	No	
Z16	732012	1323591	23.01.16	12:51	34.8	35.26	34.73	34.03	32.94	Soil	No	
Z17	732857	1324126	23.01.16	12:14	33.7	36.34	35.75	35.01	34.12	Soil	No	
Z18	733702	1324661	23.01.16	11:47	34.1	36.4	36.03	35.49	34.67	Soil	No	
Z19	730632	1323900	23.01.16	9:55	29.09	35.65	35.22	34.51	33.39	Soil	Yes	
Z20	731477	1324435	23.01.16	10:34	32.8	34.83	34.29	33.55	32.49	Soil	Yes	
Z21	732322	1324971	23.01.16	11:25	33.3	36.23	35.75	35.01	34.01	Soil	Yes	
Z22	730097	1324745	23.01.16	9:22	27.4	35.89	35.45	34.63	33.64	Soil	No	
Z23	730942	1325280	23.01.16	8:52	26.8	34.51	34.2	33.66	32.2	Soil	Yes	
C19	730085	1318226	28.01.16	11:17	29.73	39.45	38.47	37.16	35.52	Soil	No	
C22	731636	1319300	21.01.16	8:14	24.3	37.65	35.94	35.35	34.5	Soil	No	
C26	726397	1314705	26.01.16	9:32	30.69	47.98	45.03	41.63	37.94	Soil	No	
C27	727241	1315240	26.01.16	9:53	32.03	45.85	43.88	41.07	37	Gravel	No	Near foothill
C28	729775	1316846	28.01.16	10:58	31.4	41.98	40.86	39.19	37.35	Soil	No	
C29	730620	1317381	28.01.16	10:40	28.8	37.39	36.66	35.72	34.8	Soil	No	
C36	726932	1313860	27.01.16	7:51	25.36	44.31	42.8	41.08	38.64	Soil	No	
C37	727777	1314395	26.01.16	12:38	34.4	59.59	55.56	50.65	44.03	Soil	No	
C38	728621	1314930	26.01.16	12:09	33.03	50.62	47.98	44.9	40.87	Soil	No	
C40	729466	1315466	26.01.16	10:43	34.63	55.47	51.7	47.71	41.83	Soil	No	
C42	730311	1316001	26.01.16	11:38	30.2	42.06	40.52	38.24	35.35	Soil	No	
C44	731155	1316536	26.01.16	11:16	29.5	37.55	36.81	35.93	34.61	Soil	No	
C45	732000	1317072	26.01.16	10:55	30.42	37.47	36.48	35.21	33.66	Soil	No	
C50	729157	1314086	26.01.16	8:40	27.4	49.36	46.79	43.7	39.94	Soil	No	
C51	730001	1314621	26.01.16	9:01	28.7	54.75	51.82	48.07	42.29	Soil	No	
C52	730846	1315156	26.01.16	9:25	29.79	41.6	40.41	38.48	36.56	Soil	No	
C53	731691	1315692	26.01.16	9:50	29.6	39.52	38.76	37.8	36.26	Soil	No	
C54	732535	1316227	26.01.16	10:12	30.5	40.2	39.58	38.61	36.51	Soil	No	
C55	733380	1316762	26.01.16	10:32	32.9	36.6	36.13	35.37	34.03	Soil	No	
M01	727467	1313015	26.01.16	7:41	28.2	42.46	40.97	39.1	35.84	Soil	No	
M02	728312	1313550	26.01.16	8:17	27.01	52.43	49.27	45.34	40.33	Soil	No	
W01	728074	1309256	25.01.16	1:09	36.08	38.99	37.74	36.35	34.64	Soil	No	
W02	728918	1309791	25.01.16	1:27	38.18	42.54	41.13	39.16	36.49	Soil	No	
W03	729763	1310326	25.01.16	1:44	35.9	42.16	40.97	39.24	37.14	Soil	No	
W04	727538	1310101	25.01.16	12:52	35.95	39.4	38.51	37.4	35.7	Soil	No	
W05	728383	1310636	25.01.16	12:30	35.65	44.53	42.7	40.27	37.43	Soil	No	
W06	729228	1311171	25.01.16	12:10	34.4	44.22	42.88	40.73	37.8	Soil	No	
W07	730072	1311706	25.01.16	10:52	33.65	42.28	40.6	38.61	36.4	Soil	No	
W08	730917	1312242	25.01.16	10:29	32.49	50.41	48	44.56	39.6	Soil	No	
W09	731762	1312777	25.01.16	10:10	31.46	39.58	38.84	37.71	35.88	Soil	No	
W10	732606	1313312	25.01.16	9:45	31.8	38.16	37.46	36.57	35.07	Soil	No	
W11	733451	1313848	25.01.16	9:28	30.82	35.36	34.96	34.36	33.19	Soil	No	
W12	727003	1310945	25.01.16	1:01	35.03	37.98	36.87	35.46	33.19	Soil	No	
W13	726468	1311790	25.01.16	12:40	34.5	41	39.93	38.57	36.36	Soil	No	
W14	725933	1312635	25.01.16	12:19	32.3	39.8	38.94	37.59	35.25	Soil	No	
W15	725552	1314169	25.01.16	11:45	33.9	41.69	39.88	37.95	35.81	Soil	No	
W16	724862	1314324	25.01.16	11:08	32.9	43.91	42.04	39.75	37.11	Soil	No	
W17	724327	1315169	27.01.16	8:51	25.3	39.33	37.97	36.5	34.72	Soil	No	
W18	723482	1314633	27.01.16	8:28	25.1	39.3	38.26	36.93	35.14	Soil	No	
W19	723791	1316013	27.01.16	10:08	30.73	38.68	37.39	35.8	33.79	Soil	No	
W20	722947	1315478	27.01.16	1:35	32.35	35.49	34.64	33.22	31.83	Dessicated clay	Yes-shrubs	
W21	723256	1316858	27.01.16	10:25	35.55	39.92	38.83	37.49	35.84	Soil	No	
W22	722412	1316323	27.01.16	12:50	36.63	33.44	32.63	31.58	30.8	Dessicated clay	Yes-shrubs	
W23	722721	1317703	27.01.16	10:42	32.42	40.5	39.18	37.68	36.05	Soil	No	
W24	721876	1317167	27.01.16	12:20	33.44	32.96	32.41	31.7	31.03	Dessicated clay	Yes-shrubs	
W25	722186	1318547	27.01.16	11:01	33.65	38.5	37.81	36.79	35.47	Soil	No	
W26	721341	1318012	27.01.16	11:55	37.33	33.34	32.64	31.8	31.27	Dessicated clay	Yes-shrubs	
W27	721650	1319392	27.01.16	11:17	33.44	37.37	36.6	35.55	34.27	Soil	No	Near fault scarp
W28	720806	1318857	27.01.16	11:34	33.13	32.65	32.21	31.57	31.08	Dessicated clay	Yes-shrubs	
W29	728609	1308411	27.01.16	12:54	32.2	39.68	38.45	36.8	35.23	Soil	No	

出典: 調査団

表 A5.1.3　2m 深地温測定結果 (4)

S.No.	Cordinates		Day	Time	Outside	Subsurface Temperature				Ground Type	Vegetation	Other
	X	Y	dd.mm.yy	HH:MM	Temp.	2.0m	1.5m	1.0m	0.5m	Soil/Gravel/Rock	Yes/No	
W30	729454	1308947	27.01.16	12:37	36.5	43.56	41.86	39.77	37.2	Soil	No	
W31	730298	1309482	27.01.16	12:01	30.6	40.33	39.42	38.31	37.02	Soil	No	
W32	731143	1310017	27.01.16	11:24	32.9	40.18	38.9	37.64	35.86	Soil	No	
W33	730608	1310862	27.01.16	10:59	31.3	43.77	42.2	39.94	37.28	Soil	No	
W34	731452	1311397	27.01.16	10:27	30.9	41.73	40.16	38.43	36.78	Soil	No	
W35	732297	1311932	27.01.16	10:01	26.8	39.47	38.53	37.38	35.84	Soil	No	
W36	733142	1312468	27.01.16	9:39	26.5	35.98	35.32	34.49	33.22	Soil	No	
W37	731988	1310552	29.01.16	8:01	25.4	40.7	39.62	38.34	36.34	Soil	No	
W38	732832	1311088	29.01.16	8:20	24.5	38.53	37.18	35.71	33.62	Soil	No	
W39	730762	1311552	29.01.16	8:44	23.49	48.37	45.47	42.1	38.46	Soil	No	
W40	731607	1312087	29.01.16	9:03	24.5	41.08	39.53	38.03	35.3	Soil	No	
W41	725017	1315014	29.01.16	11:29	26.5	45.25	42.61	39.46	36.03	Soil	No	
W42	725861	1315549	29.01.16	11:58	26.3	51.65	49.2	45.3	39.81	Soil	No	
W43	724481	1315859	29.01.16	12:30	26.8	49.32	46.53	43.56	40.4	Soil	No	
W44	725326	1316394	29.01.16	1:05	30.7	49.91	46.84	42.39	37.43	Soil	No	
E01	737139	1317369	28.01.16	8:00	22.2	38	37.54	36.79	35.6	Soil	No	
E02	737449	1318749	28.01.16	8:28	24	36.86	36.53	35.78	34.78	Soil	No	
E03	738293	1319284	28.01.16	8:49	25.3	36.47	36.04	35.46	34.34	Soil	No	
E04	738603	1320664	28.01.16	9:24	26.7	37.97	37.61	37.09	36.22	Soil	No	
E05	738067	1321508	28.01.16	9:46	25.3	35.1	34.57	33.87	31.99	Soil	No	
E06	736533	1321128	28.01.16	10:18	24.5	37.28	36.89	36.23	35.41	Soil	No	
E07	734308	1320902	28.01.16	10:40	25.8	35.49	35.07	34.45	33.85	Soil	No	
E08	732393	1322056	28.01.16	11:09	29.9	37.34	36.76	35.91	34.85	Soil	No	
E09	733238	1322591	28.01.16	11:34	26.4	38.02	37.58	36.71	35.46	Soil	No	
E10	731858	1322901	28.01.16	12:00	27.7	37.51	37.05	36.31	35.16	Soil	No	
E11	732702	1323436	28.01.16	12:20	28.06	34.86	34.43	33.82	32.56	Soil	No	
M03	728003	1312171	28.01.16	11:47	28.77	37.83	36.61	35.17	34.73	Soil	No	
M04	728538	1311326	28.01.16	12:29	28.89	41.12	39.74	37.93	35.71	Soil	No	
M05	729382	1311861	28.01.16	12:47	29.65	45.22	43.69	41	38.48	Soil	No	
M06	730227	1312396	28.01.16	1:05	30.02	47.92	45.43	42.4	39.55	Soil	No	
M07	731072	1312932	28.01.16	1:24	30.29	45.34	43.3	40.82	38.42	Soil	No	
M08	731916	1313467	29.01.16	9:26	25.7	38.82	38.18	37.15	35.63	Soil	No	
M09	732761	1314002	29.01.16	9:46	26.5	36.54	35.84	35.05	34.05	Soil	No	
M10	730537	1313776	29.01.16	10:09	24.1	44.11	42.36	40.3	37.45	Soil	No	
M11	727509	1314818	29.01.16	10:53	23.04	66.82	61.46	54.22	45.32	Soil	No	
M12	729240	1317690	29.01.16	10:18	25.56	40.76	39.44	37.77	35.46	Soil	No	
M13	729549	1319070	29.01.16	10:41	26.77	37.27	36.52	35.5	34.2	Soil	No	
M14	730394	1319606	29.01.16	10:59	28.52	37.36	36.83	36.04	34.76	Soil	No	
M15	729014	1319915	29.01.16	11:14	29.78	37.77	37.22	36.48	35.46	Soil	No	
M16	728479	1320760	29.01.16	11:29	30.75	36.56	35.93	35.1	33.85	Soil	No	
M17	727944	1321604	29.01.16	11:44	31.03	39.16	38.64	37.66	36.2	Soil	No	
M18	726564	1321914	29.01.16	11:59	27.7	38.06	36.86	35.8	34.4	Soil	No	
M19	728253	1322984	29.01.16	12:37	30.18	37.06	36.62	35.84	34.7	Soil	No	
N01	723227	1321575	29.01.16	2:20	29.88	37.25	36.53	35.38	33.64	Soil	No	
N02	724071	1322110	29.01.16	2:05	32.18	36.79	36.32	35.62	34.56	Soil	No	
N03	724888	1322645	29.01.16	1:37	27.44	40.03	40.03	39.36	37.54	Soil/Rock	No	Basalt outcrops nearby.
N04	725761	1323181	29.01.16	1:22	30.56	38.28	37.76	36.94	35.72	Soil	No	

出典: 調査団

APPENDIX-6

環境影響評価報告書（案）

Federal Democratic Republic of Ethiopia
Geological Survey in Ethiopia (GSE)

DRAFT REPORT

ON

ENVIRONMENTAL AND SOCIAL ASSESSMENT (ESIA)

IN

TENDAHO-2 (AYROBERA) GEOTHERMAL SITE

AUGUST 2016

NIPPON KOEI CO., LTD.

SUMIKO RESOURCES EXPLORATION & DEVELOPMENT CO., LTD.

JMC GEOTHERMAL ENGINEERING CO., LTD.

Table of Contents

ACRONYMS

CHS: Community Health and Safety

CSA: Central Statistics Agency

EA: Environmental Assessment

EEP: Ethiopian Electric Power

EEU: Ethiopian Electric Utility

EIA: Environmental Impact Assessment

EMP: Environmental Management Plan

EMP: Environmental Monitoring Plan

EPE: Environmental Policy of Ethiopia

ESIA: Environmental and Social Impact Assessment

ESMP: Environmental and Social Management Plan

FDRE: Federal Democratic Republic of Ethiopia

FGD: Focused Group Discussion

FI: Financial Intermediary

GSE: Geological Survey of Ethiopia

IFC: International Finance Corporation

ILO: International Labor Organization

NGO: Non Governmental Organization

NMSA: National Meteorological Survey Authority

OHS: Operational Health and Safety

TOR: Terms of Reference

UN: United Nations

WB: World Bank

WHO: World Health Organization

WMP: Waste Management Plan

EXECUTIVE SUMMARY

This report deals with Environmental and Social Impact Assessment for a geothermal Test Well Drilling project at Ayrobera Site. The site is located in Afar Regional State, Dubti woreda, Ayrolaf-gebelaytu kebele. The study was launched in the first week of February 2016, of which about 20 days were actual field work. The study employed a range of methodologies: review of documents, field survey, Focus Group Discussions, interview, and public consultations; all of the data collections were supported by audio and video recordings. Environmental guidelines using locally accepted standards were also employed where they are appropriate. All significant impacts were evaluated using appropriate parameters and impact rating. The study involved about 50 kebele dwellers as well as nearly 50 key stakeholders representing different organizations, institutions, offices and local administrations.

The project is to be carried out in part of Ayrolaf-gebelaytu kebele, a location deserted and uninhabited. It is characterized by sandy, dry, flat, and harsh climatic condition. Due to this, almost no single plant species, or grazed cattle are observed. Except at the eastern corner of the site (10 km away) where it is temporarily settled by little pastoral households, no human being dared to live within the proposed site.

Findings from environmental assessment reveal a number of adverse impacts derived from the proposed test well drilling project. These are gaseous emissions that are carried in the source stream. The other is water pollution from well drilling, stimulation, and production. Dissolved minerals could also poison surface or ground waters. Solids emissions due to accident associated with a fluid treatment or minerals recovery system; noise pollution, dust and vibration from drilling and testing operations.

To address negatively impacting environmental issues, the following measures should be considered.

In light of the nature and features of Ayrobera site (arid, climatically harsh and deserted) the implementation of the project would bring no adverse environmental and social impact throughout the phases. The study reveals that likely adverse impacts might be generic, particularly involving occupational accidents and hazards. This includes health ailments such as malaria, bodily injuries, and fire hazard, among others. These accident, would definitely affect project staff and temporary workers who would appear in all phases of the project. The impacts could occur provided that the project owner and the concerned contractor failed to implement mitigation measures.

The economic impact assessment covered analysis on project related to job opportunity, disposable income, cost of living, and enhancing local economy. The finding reveals nearly all of the economic impacts of the project as favorable. Among others, the project would provide with 106 temporary job opportunities for the local community, in all phases of the project. The creation of additional income on the part of migrant and local people (in the form of wage) will bring about a change in the life of particularly households of respective workers. This in turn will enhance the flow of cash and disposable income in the kebele and nearby towns. The increase in the demand for goods and services would also contribute to the expansions of the existing businesses and establishments of small ventures, at least in the nearest towns. The project will contribute to the revenue generating sources of the Government in the form of withholding and profit taxes.

In general, the findings from document review at international, national, regional and local levels fit with the objective of the test well drilling project. In addition, all of the stakeholders consulted expressed their positive view over the exploration of the site. Similarly, the concerned regional and local administration already given their confirmation in that, the site has not been settled, not used for grazing, or never been reserved for other development works. On top of that, the project fully accords with the Federal Environmental Guideline of EPA, 2003, in that the proposed site is not classified as environmentally sensitive. What is more, the processional conclusion of the study team is strongly positive; thus the proposed site could be explored.

CHAPTER ONE: BACKGROUND AND JUSTIFICATION

1.1 Overview

This ESIA report is the continuation of the previous study, "Environmental and Social Impact Study for formulating Master Plan on Development of Geothermal Energy in Ethiopia". One of the objectives of the study was to select and prioritize fifteen potential geothermal sites in three Regional States: Afar; Oromiya and Somali. Multidisciplinary approaches were used to prioritize the potential sites, ESIA study being among others.

Accordingly, the result was achieved mainly from reconnaissance field survey and from ground surface scientific investigation only. However, geothermal power plant development by its very nature is complex with high coefficient of uncertainty and high cost of well drilling. Thus, it is quite reasonable that the selected site need to be supplemented//verified// by further and detail scientific investigations so as to locate the most appropriate and potential drilling points within the selected Ayrobera site. Hence, the following activities (or studies) are planned to be carried out:

- Geophysical field survey
- Analysis of conceptual model
- Cost estimation for test well drilling
- Environmental and social consideration

The purpose and/ or objective of the above activities is to generate viable justification to conduct test well drilling at the selected site. As can be expected from the nature of the project, outcome the above studies will again be inter-disciplinary for decision making. Thus, ESIA as one component was planned and conducted in the selected Ayrobera site, in Afar Regional State.
From the perspective of geothermal power plant development, this particular phase of the study can be perceived as pre-construction or prefeasibility phase. Thus, it will be too early to set targets on production capacity of the power plant and corresponding time schedule.

This ESIA study is carried strictly based on EPA guidelines and in reference to national standards. After determining the capacity of the power plant, however, securing approval of Regulatory Bodies will be mandatory; in such cases, from Ministry of Environment and Forest.

Here it will be important to notify that TOR of the previous prioritization study site list does not request //or mention// Ayrobera but Allalo Beda as Tendaho-3. Though the Woreda /Dubti/ is the same for both sites they are nearly 40 Km apart along the road and 12Km air distance. The ESIA study team, however, has conducted baseline survey of Ayrobera within a specified period for the present study. Findings of this study revealed that it will not significantly affect the results of the previous prioritization study.
The previous master plan study was a comprehensive document consisting of a wide range of information. Thus, it will be worthwhile to notify that this report is squeezed as much as possible to focus only on specific findings of the selected site by omitting common and

repetitive features. Hence, any official or evaluator interested in reviewing this report may need to refer both documents (?) for sound decision making.

1.2. Objective

The main objective of this study is to produce specific ESIA report for test well drilling on the selected Ayrobera; Tendaho-2; Dubti Woreda; Afar Region. With this understanding, the proposed ESIA study is expected to carry out the following tasks;

- Describe the present state of human and natural environment and its surrounding;
- Identify potential negative and positive impacts of the envisaged test well drilling;
- Develop//propose// mitigation measures and the corresponding management plan;
- Serve as a spring board for ESIA of the upcoming power plant development in the project area;

1.3 Definitions

The following definitions, in the context of this ESIA report, are selectively made for common understanding. Some of these definitions are directly taken from JICA guideline for environmental and social considerations, 2010.

1. "**Scientific investigation or technical studies**": These studies are limited to geotechnical studies such as geophysics, geochemistry, geology etc.

2. "**Techno-economic studies**": Studies primarily based on the findings of technical studies but incorporate engineering and economic aspects at project level.

3. "**ESIA studies**": These are based on findings of techno-economic results, analyzes environmental and social aspects at project level and approval of regulatory bodies.

4. "**Environmental and social considerations**": It refers to the means considering environmental impacts including air, water, soil, ecosystem, flora, and fauna, as well as social impacts including involuntary resettlement, respect for the human rights of indigenous people, and so on.

5. "**Projects"**: Undertakings that project proponents conduct and get JICA's support.

6. "**Environmental and social considerations studies**": It incorporates baseline surveys, predicting and evaluating the adverse and likely impacts of projects on the environment and on local community, and the subsequent mitigation measures that are set to avoid and minimize negative effects.

7. "**Environmental impact assessment**": includes evaluating the environmental and social impacts of projects, analyzing alternative plans, and preparing adequate mitigation measures and monitoring plans in accordance with the laws/guidelines of host countries.

8. A "**strategic environmental assessment**": It is an assessment implemented at policy, planning, and program levels, but not a project-level EIA.

9. An "**examination of environmental and social considerations**": This is a confirmation of the measures taken by project proponents etc. to meet the requirements of the guidelines in view of the project's characteristic features and the inherent nature of the affected countries and/or area.

10. "**Screening**": Deciding whether proposed projects are likely to have impacts that need to be assessed by conducting environmental and social considerations studies according to project description and site description. JICA conducts screening by classifying proposed projects into four categories: A, B, C, and FI (Financial Intermediary).

11. "**Scoping**": Refers to choosing alternatives for analysis, a range of significant and potentially significant impacts, and study methods.

12. "**Local stakeholders**": They are affected individuals or groups (including illegal dwellers) and local NGOs. "Stakeholders" are also individuals or groups, who have views about cooperation projects, including local stakeholders.

13. An "**Environmental Impact Assessment (EIA) level study**": It is a study that includes the analysis of alternative plans, the prediction and assessment of environmental impacts, and the preparation of mitigation measures and monitoring plans based on detailed field surveys.

14. An "**Initial Environmental Examination (IEE) level study**": A study that includes an analysis of alternative plans, a prediction and assessment of environmental impacts, and a preparation of mitigation measures and monitoring plans based on easily available information including existing data and simple field surveys.

15. "**Detailed design study**": It is a study that decides the detailed plan of a project such as project objective, confirmation of feasibility, scale of input and activities, and it is conducted after the approval of the project by concerned body.

1.4 Study Approach and Methodology

The Environmental and Social Impact Assessment for the project site was conducted based on nationally and internationally accepted practices, procedures and regulations. The study focuses on the activities of the test well drilling, and thus evaluates the possible environmental and social impacts, and ultimately provides recommendations. Launching the test well drilling, need to follow the Ethiopian Government legal requirements. For issues that don't have national regulation or standard, best international practices and guidelines would be considered.

Methodology: The methodology used for the study was mainly primary and secondary data. The secondary data included reviewing of documents related to the test well drilling project. The primary data involved, interview, structured questionnaires and professional observations.

Sources of Data:

The major sources of data were:-

- Documents involving prior studies on the targeted area;
- Project related documents from the concerned stakeholders such as JICA and GSE;
- Relevant regulations, codes and technical standards of Federal Democratic Republic of Ethiopia.
- CSA's census and other related documents;
- Government organizations in Afar Regional State;
- Dubti woreda and kebele administrations and sector offices;
- Baseline information from field survey;
- Current related literature review and emerging technologies in thermal well drilling sector;

***Questionnaire*:** Standardized questionnaire was employed for households. The questionnaire was meant for the sample settlers located in two different locations within the woreda. The data collected were, mainly, on livelihood/ and economic situations, level of income and household expenses, environmental issues, major constraints of the kebele/community, and views of target group on the proposed Project.

Interview: Semi structured questionnaire was conducted with selected stakeholders at all level: federal level authorities/experts, regional officials and experts, woreda and kebele representatives, etc. The interview revolved around:

- Launching test well drilling for geothermal power plant;
- Extent of stakeholders' support on the activity;
- Potentially negative and/or positive impacts of the test well drilling;
- Identifying mitigation measures, if there is a need.

***Focus Group Discussion**:* FGD was conducted around the selected site. The participants included community representatives, elders, religious leaders, representatives of women, and youth, among others. The FGD was meant to gather the views of the community, whether or not they would be willing to support the activity of the drilling project. Furthermore, they were let to discuss their fears and worries about displacement and other unforeseen reverse impacts which could result from the test well drilling, etc.

***Observations**:* Firsthand data collections through preplanned observations were carried out within and around Ayrobera site. The purpose of the observation, among others, was to look into the situation of the environment, settlement pattern, land use, existing infrastructure, the available social services, visual amenity, among others. The data collected through professional observation was presumed to strengthen other data and what is more fill the information gap that might occur on the interview and questionnaire.

***Audio and visuals**:* The other firsthand data collection was audios, pictures and movies. The technique was used for capturing the real scene of the study area, record scenario and events

valuable for the study. On top of that, meetings and discussions conducted between the study team and the concerned stakeholders have been audio taped, pictures taken and videos recorded.

Concerned stakeholders from different offices and households from Ayrolaf-Gebelayitu kebele (in two villages, namely, Boina and Asboda) were consulted. The whole setting of field data collection is systematically presented in Table 1.1.

Table 1.1: ***Designs of Data Collection Method***

Activity		*Purpose*
Orientation to leading members of each woreda administration		Awareness creation for common understanding about the project objective Secure permission and letter of cooperation to the corresponding Kebeles and target sites Assignment of facilitator and local guide from woreda administration
Interview through structured questioners to Dubti woreda sector offices(Head//Expert)		Determine alignment of their guideline(office) with the proposed project Enables to know if there is existing or planned activity in the project surrounding
	Agriculture /pastoralist office	
	Economic & finance office	Visualize synergy or destructive effects with proposed objective of the project
	Education office	
	Health office	Get personal view of the respondents from their professional experience.
	Culture & tourism office	
	Land use and environment office	
	Water & energy office	To access official documents (localized)relevant to the proposed project
FG discussion consisting of 5 up to 7 community members; elders; religeious leaders; community leaders; youths; women;		Get their collective (averaged)view through discussion
Interview through structured questioners to directly//indirectly// affected communities		Get personal view of each household and his expectation from the proposed Project
Personal observation of the study team		Strengthen information collected
Interview of Key experts or specialists		Capture policy or planning level issues (Federal & Regional)
Pictures ; video camera and sound tracks taken during each orientation and interview		To enhance credibility of the data collection Data conformation or justification for any deviation that may occur in implementation phase

From the perspective of geothermal power plant development, this particular phase of the study can be perceived as pre-construction or prefeasibility phase. Thus, it will be too early to set targets on production capacity of the power plant and corresponding time schedule. The scope of this ESIA study is, thus, limited to "test well drilling phase". That is why; this particular ESIA study is designed for internal consumption of JICA but after review made by concerned bodies from Ministry of Mine Petroleum and Natural Gas. As long as data gap exists, we believe that it is a wise decision and the right move. On top of that, this ESIA study is carried strictly based on EPA guidelines and in reference to national standards so as to serve as a spring board for ESIA of the power plant development. After determining the capacity of the power plant, however, securing approval of Regulatory Bodies will be mandatory; in such cases, it will be from Ministry of Environment and Forest.

On the other hand, scope of the study has been governed by review of readily available data, documents reviewed (either from GSE or JICA resources), and findings of previous studies conducted in some particular sites. Data from field survey was properly exploited and limiting values of national guidelines adequately assessed. In addition to this, literature data and experiences of other projects were thoroughly reviewed.

1.6 Significance of the study

It is well understood that geothermal projects are costly, time consuming and long lasting. Even in the absence of feasibility study, preliminary investigation on socio-environmental conditions of the prospected site seems a wise decision as it is also a cost minimizing option. This is what shall be practiced for other mega projects. Carrying out parallel or side-by-side ESIA study with other sectors is, thus, quite justifiable for various project phases. It is a widely accepted fact that ESIA is a pro-active means of avoiding such socio-environmental consequences that otherwise would be much more expensive (risky) to correct them after their occurrence.

Experience learnt from mega projects of Ethiopia demonstrated that critical issues and grievances arise not from imported, well established technology or techno-economic study findings but mainly from socio-environmental aspects.

Hence, the significance of this study is to: (i) provide, decision makers, with background to socio-environmental facts about the proposed site; and (ii) help to identify issues to be considered and incorporated during implementation of the proposed project.

1.7Assumptions

It can be observed that both techno-economic and ESIA studies have common border to share with and at the same time play different role/scope/ to deal with certain issues. Some basic data such as generation rates, capacity, amount etc. that serve as inputs for ESIA are taken from techno-economic studies. It is natural therefore detailed works of these input data are dealt in techno-economic while analysis of their outcome is carried out by ESIA study team. It is with this approach that the overall project feature can be easily understood.

However, in conditions of such data-gaps, assumptions generated from professional judgment are employed. It is strongly believed that these assumptions are not far from what might be expected after completion of techno-economic study findings and may not significantly affect the final outcome. Any project reviewer interested in detailed works shall be offered this ESIA study findings with a copy of techno-economic study documents as a reference. As a result the following assumptions are made.

- As this ESIA document is a continuation of the Master Plan Study, the current report is squeezed focusing only on Ayrobera project site by omitting common and repetitive features, particularly, on policy frame work and analysis alternatives.

- The study team reviewed existing and available geothermal technologies used elsewhere and selected most widely practiced technology with moderate capacity for its impact assessment.

- The ambient air, noise and dust levels are assumed to be at their best quality/level/ as compared to threshold values of national standards due to the pristine nature of the environmental setting of the project site. The area is also characterized by sparsely populated community with traditional way of life that has insignificant influence on the natural setting. In most of the sites, geothermal springs and fumaroles still exist for several years and no significant effect had been observed.

- Any change after detailed techno-economic feasibility study may require an additional environmental management measures which will again require an amendment of this ESIA study.

1.8 Organization of the Report

This ESIA report is organized in to the following seven Chapters: Chapter One is *Background* of the study. Chapter Two is devoted to *Project Description on Test Well Drilling*. Chapter Three overviews findings of, *Legal, Policy and Institutional Framework* governing environmental issues as related to the envisaged project. The existing *Baseline Conditions* of the project areas are described in Chapter Four; which is followed by impact assessment at chapter Five. Then mitigation measures and management plan is dealt in Chapter Six; finally Chapter Seven deals with Conclusions *and Recommendations*

CHAPTER TWO: PROJECT DESCRIPTION

2.1 Overview

This section describes the scope and technologies to be employed in geothermal power plant. Scope of this project is limited to the determination of geothermal viability through test well drilling at Ayrobera site. Scientific investigations carried so far are limited to ground surface studies. This project is formulated to verify findings of ground surface studies through test

well drilling. Due to this effect, production capacity of the prospected power plant and related utilities may not be accurately determined. Thus, discussions on power generation, transmission and distribution are not major topics to be covered in this study. Hence, the scope of this study can be viewed as prefeasibility. Basic data required for project description are not yet finalized. In few cases, professional judgment and assumptions are made to describe the project.

It is a widely practiced procedure that a full-fledged development project has various phases in common to accomplish its task. In a similar approach, test well drilling projects have various interdependent phases, such as:

- Pre drilling phase (survey & conceptual modeling);
- Construction phase (civil & non-civil works);
- Drilling phase (development & commissioning phase);
- Testing phase (operation phase);
- Decommissioning phase;

Starting from the very inception, test well drilling involves the following major steps;
Site survey;

- Land securing;
- Fencing and bordering;
- Land escaping and leveling;
- Resource mobilization;
- Camp site construction and utility development;
- Water development works for drilling purpose & domestic consumption
- Well pad preparation;
- Usage of consumable row materials and chemicals;
- Well drilling;
- Testing;
- Commissioning;

The above activities are reviewed from socio-environmental perspectives in the following sections. Basic data required for reviewing are listed in table 2.1but still with some data gap.

Table 2.1: Basic data required from findings of techno-economic studies

Description		Remark
Project Name	ESIA study for test well drilling	
Location	Ayrobera; Dubti Woreda; Afar Region	
GPS location	Not yet decided	
Estimated plant size	In hectare, not yet determined	
Proposed drilling technology	Reported to be on procurement bid	
Purpose of the project	Confirm the potential of geothermal systems and resources	
Number of operating days	300 days/year	

Consumable raw materials & input chemicals	Described in the body of the document	
Plant life time	One year	
Main water source	Irrigation pond at Dubti drilling sub-surface water in the site	
Water requirement	300 m^3 / day	
Flow rate of water source	At least five years data at the worst scenario	
Waste water generation /day	Industrial and domestic waste water	
Power source & requirement	Government captive power	
Project cost	Data not available	
Employees:	Expatriate:	Taken from similar projects such as Aluto
	Direct and indirect employment: a total of 69 workers. Of this, skilled 23, unskilled: 46 (for detail see chapter 4).	

2.2 Existing Technologies for Extracting Geothermal Energy

Key technologies for exploration and drilling, reservoir management and stimulation, and energy recovery and conversion are described below.

2.2.1 Technologies for exploration and drilling

Since geothermal resources are found in deep underground, exploration methods (including geological, geochemical and geophysical surveys) have been developed to locate and assess them. The objectives of geothermal exploration are to identify and rank prospective geothermal reservoirs prior to drilling, and to provide methods of characterizing reservoirs (including the properties of the fluids) that enable estimates of geothermal reservoir performance and lifetime. Exploration of a prospective geothermal reservoir involves estimating its location, lateral extent and depth with geophysical methods and then drilling exploration wells to test its properties, minimizing the risk.

Today, geothermal wells are drilled over a range of depths down up to 5 km using methods similar to those used for oil and gas. Advances in drilling technology have enabled high-temperature operation and provide directional drilling capability. Typically, wells are deviated from vertical to about 30 to 50° inclination from a 'kick-off point' at depths between 200 and 2,000 m. Several wells can be drilled from the same pad, heading in different directions to access larger resource volumes, targeting permeable structures and minimizing the surface impact.

Reservoir engineering efforts are focused on two main goals: (a) to determine the volume of geothermal resource and the optimal plant size based on a number of conditions such as sustainable use of the available resource; and (b) to ensure safe and efficient operation during the lifetime of the project. The modern method of estimating reserves and sizing power plants is to apply reservoir simulation technology. First a conceptual model is built, using available

data, and is then translated into a numerical representation, and calibrated to the unexploited, initial thermodynamic state of the reservoir (Grant et al., 1982). Future behavior is forecast under selected load conditions using a heat and mass transfer algorithm, and the optimum plant size is selected.

Injection management is an important aspect of geothermal development, where the use of isotopic and chemical tracers is common. Cooling of production zones by injected water that has had insufficient contact with hot reservoir rock can result in production declines. In some circumstances, placement of wells could also aim to enhance deep hot recharge through production pressure drawdown, while suppressing shallow inflows of peripheral cool water through injection pressure increases.

Given sufficient and accurate calibration with field data, geothermal reservoir evolution can be adequately modeled and proactively managed. Field operators monitor the chemical and thermodynamic properties of geothermal fluids, and map their flow and movement in the reservoir. This information, combined with other geophysical data, is feedback to recalibrate models for better predictions of future production (Grant et al., 1982).

2.2.2 Geothermal Power Plants

There are different geothermal technologies with distinct levels of maturity. Geothermal energy is currently extracted using wells or other means that produce hot fluids from: a) hydrothermal reservoirs with naturally high permeability; and b) EGS-type reservoirs with artificial fluid pathways. The technology for electricity generation from hydrothermal reservoirs is mature and reliable, and has been operating for more than 100 years.

The basic types of geothermal power plants in use today are steam condensing turbines and binary cycle units. Steam condensing turbines can be used in flash or dry-steam plants operating at sites with intermediate- and high-temperature resources (≥150°C). The power plant generally consists of pipelines, water-steam separators, vaporizers, de-misters, heat exchangers, turbine generators, cooling systems, and a step-up transformer for transmission into the electrical grid. The power unit size usually ranges from 20 to 110 MW (Di Pipe, 2008), and may utilize a multiple flash system, flashing the fluid in a series of vessels at successively lower pressures, to maximize the extraction of energy from the geothermal fluid. The only difference between a flash plant and a dry-steam plant is that the latter does not require brine separation, resulting in a simpler and cheaper design.

As it is discussed in the preceding sections, the scope of this ESIA study is limited to the level of test well drilling. Thus, discussion on the details of geothermal power plants is not timely except perhaps issues that link with the test well drilling. The following table summarizes types of widely used geothermal power plants.

Table 2.2: Commonly used geothermal energy technologies

No.	Technology	Resource temperature	Reservoir fluid	Working fluid
1	Dry Steam Power Plants	≥150°C	Steam	Geo-fluid
2	Single Flash Steam Power Plants	≥150°C	Steam and water	Geo-fluid
3	Double Flash Power Plants	≥150°C	Steam and water	Geo-fluid
4	Binary Cycle Power Plants	107° to 182°C	steam or water or both	Organic solvent or ammonia
5	Combined Cycle Plants	107° to 182°C		Organic solvent or ammonia and Geo-fluid

Despite a more complex design, binary power systems are generally less expensive than steam systems for temperature close to 176^0C.. The cost of binary systems rises as temperature drops. Binary systems may be preferred in highly sensitive environmental areas, since they operate as closed-loop, virtually emissions-free system produced.

2.2.3 Resource Characteristics

Temperature, pressure, and volumes of fluid geothermal reservoirs are the primary determinants of the size and type of power conversion equipment//technology option//. Assuming sufficient volumes of fluid are produced, temperature determines the most efficient conversion design. While binary plants can utilize any temperature resource, low temperature resources are constrained to the binary model. Medium temperature resources can be economical by using either flash or binary systems.

High temperature resources are most economical when steam or flash systems are employed, as these are simpler and therefore less costly. Flash systems are less expensive than binary systems, but may not be efficient at lower temperatures. Steam plant equipment costs rise as temperature decreases (as a result of efficiency losses).

2.2.4 Cooling systems

Developers have two basic cooling options: water or air cooling. Hybrid air-water systems have been demonstrated to a limited extent and are considered important for future advancement (see “New Technology” for more information). Both air and water-cooled systems use cooling fan motors. Some maintenance is required; typically an annual check-up of fan motors and belts as well as system lubrication.

Most power plants, including most geothermal plants, use water-cooled systems typically in cooling towers. As these are more efficient, they generally require less land than air-cooled systems. Water-cooled systems are less expensive to build and operate if water is readily available and inexpensive to obtain. These systems lose most of the water to the atmosphere by evaporation in the form of water vapor, while the remainder is injected back into the system. Emissions from a wet cooling tower (i.e. water vapor plus dissolved solids or minerals) depend upon the quality of the geothermal liquid injected back through the system.

Because the efficiency of power generation is affected by the difference between the temperature of the fluid exiting the turbine and the temperature of the cooling medium, air-cooled systems are influenced by seasonal changes in air temperature. These systems can be extremely efficient in the cold months, but are less efficient in hotter seasons when the contrast between the air and water temperature is reduced.

The ideal temperature difference between the air and the resource is 200^oF (93^oC) for an air-cooled system. Air cooling is beneficial in areas where extremely low emissions are desired, where water resources are limited, or where the view of the landscape is particularly sensitive to the effects of vapor plumes (as vapor plumes are only emitted into the air by water cooling towers). While air-cooled systems are only used at binary facilities today, these could theoretically be used with any geothermal conversion technology

Detailed evaluation of surface water and/or groundwater availability should be carried out before recommending a particular technology. Most of the geothermal prospect areas are located at reasonable distance from Awash River and Lakes. But some sites will face difficulties concerning the availability of water of the right quality.

2.3 Processes and Activities in Test-well Drilling

Activities of this phase includes bordering and fencing; site lay out development; construction of road**;** water supply system, electric power supply; site clearing earth work; temporary camp construction; resource mobilization including rig transportation and derrick/mast foundations; drainage, drill site cellar and waste sump development;

Road construction: Heavy duty road compacted with gravels might be required as rig components are as heavy as 50 tons and possess unusually big width // up to 8 m height // of the machinery.

Site preparation: Drilling site need to be labeled, compacted and covered with heavy thick layer of good surfacing material (i.e., quarried stone). Dimensions of the drilling area need to provide maximum maneuverability for drilling operations. Figure below provides for the minimum area dimensions required for drilling rig and its different components.

Drilling site need to have adequate drainage and ditches not to allow accumulation of water and also to prevent having a muddy and unsafe working area. Drainage ditches should be dug on the base of the slope to prevent flooding of the drill site. The areas not occupied by any rig component should slope slightly towards the outer working perimeter of the drill site and the slope to end at the ditches. Slope should be no less than two degrees (2°).

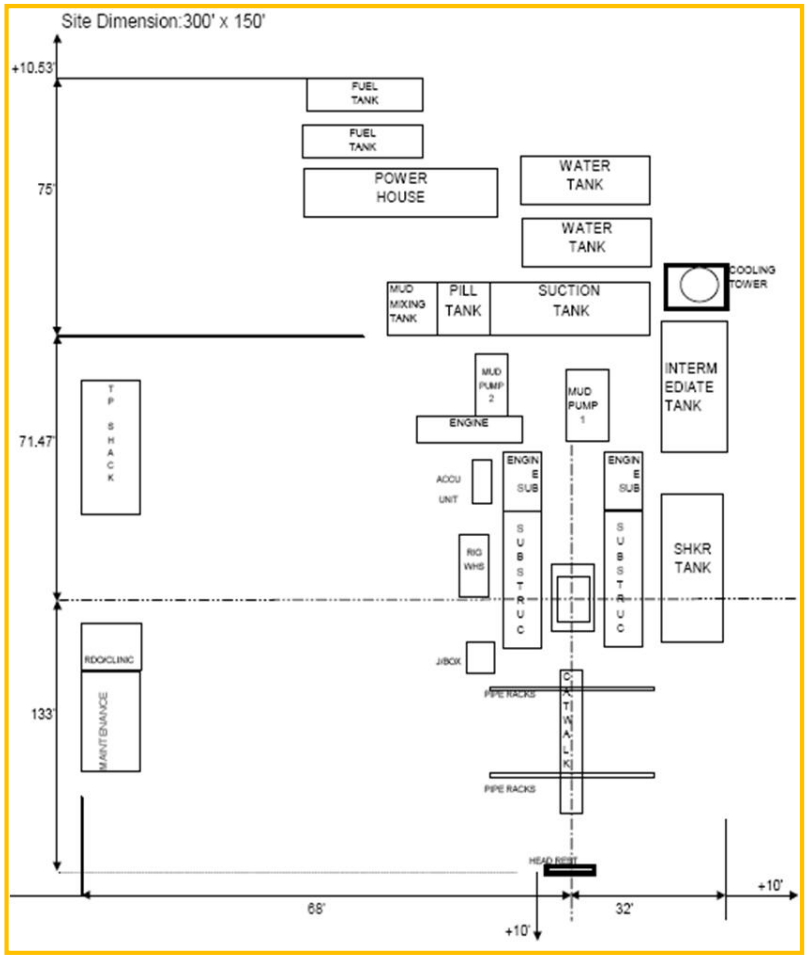


Fig 2.1: Representative drilling site and its components

Shallow ditches (rig perimeter canal) around the rig substructure, mud and fuel tanks, mixing hoppers, cementing unit, and other rig components near the substructure should be channeled into the cellar terminating on the floor area of the cellar under the rig's V-door where a shallow ditch can be channeled into the cellar for drainage to the sump. Areas outside the perimeter of the drill site must have proper slopes (angle of repose) to totally discard possibility of landslides or washouts. Shallow ditches (sump berms) are to be constructed on this slope if directly above the waste pond (sump) and channeled away from the sump to prevent flowing of rainwater, excess clean water and the like to the sump. This will maximize usage of sump capacity to hold only rig fluid wastes and rainwater directly flowing to the sumps.

***Waste pond (sump)*:** For all wells drillings and work-over, comparable waste pond must be provided, up to 3000m^2 or sometimes its volume may increase or decrease depending on the limitations of the pad layout. Sump walls should be built up from fill materials and should be systematically and adequately compacted and reinforced with cement lining to prevent fluid from escaping through the walls and/or prevent sump walls from breaking. Ideally, a sump should be divided into two compartments with the intake section at a slightly higher elevation than the outlet or discharge end of the sump. The weir between the sump compartment and at the discharge end should be built to act as an efficient filter for the different pollutants (i.e. oil, mud chemicals, cement and cement additives, etc.) discarded during drilling or work-over.

Two discharge outlets with the other at a higher elevation might be installed on the second sump (and or succeeding sumps for two or more sump system) for effective recycling of discarded fluid during drilling. This will also serve as suction ends during re-injection of fluid wastes. Intake end of this outlet should have a strainer installed to prevent suction of undesirable solids that may damage suction/recycling pumps. The drill site will be consolidated by injecting cement in 30m deep holes drilled at various locations on drill site using small rigs

***Water and electric supply*:** Electric power for drilling purpose can be tapped either from neighboring Dry Port Terminal or Semera Town. Step up transformers might be required. On the other hand, well drilling is a water intensive operation. Ayrobera project site, on the other hand, does not have access to water.
Water lines from source to drilling site must be installed in an accessible terrain so as to easily remedy possible causes of low water rig supply. Water supplied to the drill site should be analyzed first to determine the presence of hazardous elements which might be detrimental to any of the drilling operations. The water line should be provided with proper flow controls at the suction and discharge end. Suction end of the water line should be provided with screens or filters to ensure that no materials will flow through the water line to cause its clogging.

For Ayrobera project two options can be planned:

1. To pump water from Dubti irrigation ponds through pipeline all across Dubti to Ayrobera
2. To drill water well for this purpose and insert a submersible pump for water supply.

Rig move/up of drilling rig and associated equipment: Rig dismantled into various parts and its accessories will be moved using heavy duty tracks at various steps. Moving sequence should be followed. Drilling materials, consumables and equipment required for spud should be at the drill site right before completion of rig up operations.

2.3.1 Drilling processes

The rig has drill strings with strong drill bit at the bottom end to exert a rotating force to crash stones and penetrate to the depth. Drilling fluid is pumped through the drill pipes to the well and come out through the nozzles of the bit to the surface carrying with it drilled cuttings of

rocks. These drilling fluids and disposed cuttings might be of environmental concerns, thus need to be assessed.

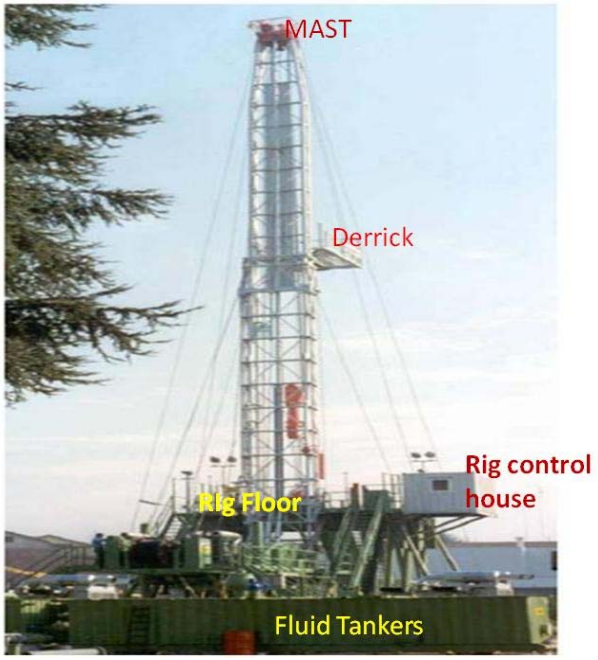


Photo 2.1: A view of a rig

A number of well drillings, up to ten, can be drilled in a single project site for a medium geothermal power plant development. Each well is dug up to 2500 m depth into the ground. Thus, socio-environmental concerns, particularly from resource mobilization, emission and waste disposal are expected to be high. The above picture demonstrates a representative drilling machine (what is usually called Rig).

2.3.2 Drilling fluids

Drilling fluids could be pure water. Aerated water with soap or bentonite mud with some additives can be used. Nature of rock formation and extent of circulation loss determines fluid selection. Various types
//combination// of additives can be used depending on the type //diameter//of well to be drilled. Table 2:3 summarizes mud chemicals and other additives to that purpose.

Table 2.3: Mud chemicals and additives

Classification	Application	Typical Product
Ph Control Additives	product designed to control the degrees of acidity or alkalinity of a fluid	1. Caustic Soda (NaOH) 2. Lime 3. Sodium Bicarbonate 4. Potassium Hydroxide (KOH)
Calcium Removers	chemicals designed to prevent and overcome the contaminating effects of anhydrite, gypsum and cement	1. Sodium Carbonate (Soda Ash) 2. Sodium Bicarbonate
Thinners/Dispersants	Chemicals that are used to modify the clay particle properties of drilling mud to control viscosity, gel strength and filtrate loss. Additives referred to lignosulfonate and lignite chemicals	1. Lignosulfonate Q-Broxin II Sperseme CF Unical CF CFL 2. Lignites Carbonox Ligco Tannathin Ground Lignite
Filtrate Reducers	chemicals designed to control and reduce filtrate or fluid loss of drilling fluid into the formation	1. Sodium Carbox Methyl (CMC) 2. Polyanionic Cellulose (PAC, Polypac, IDF FLA) 3. Sodium polyacrylate (SP101, MYDRON P-29) 4. Synthetic Resin Polymer (Resinex) 5. Organic Polymer (Hi-temp II, Mil-temp II)
Weighting Materials	product used to increase mud density, to control formation, check caving, facilitate pulling dry pipe and as an aid in combating some types of circulation loss	1. Barites MI Bar, Baroid, Milbar 2. Iron Oxides 3. Calcium Carbonate 4. Galena

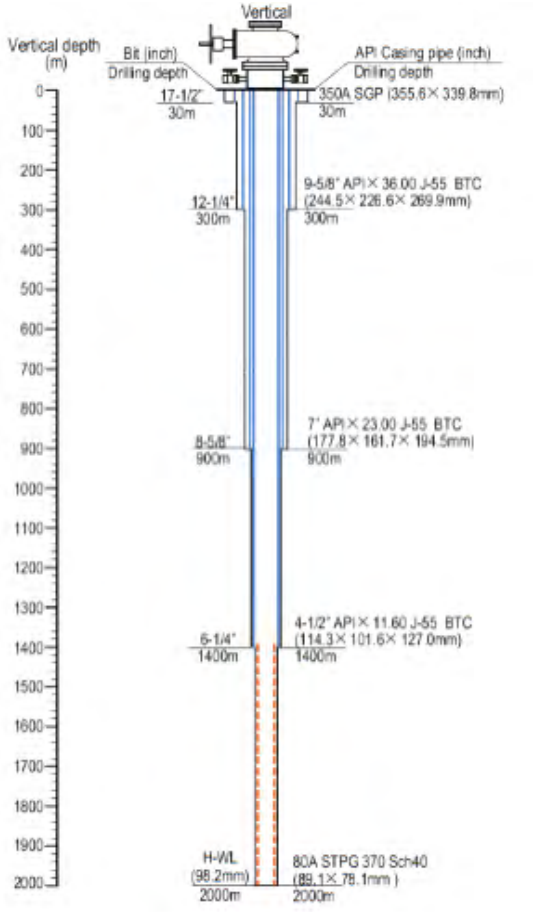


Figure 2.1: Typical Geothermal well casing configuration (slim hole)

Test wells are constructed with concentric casings, called surface; anchor; and production casings that are cemented with G-grade cement, bentonite and other additives until the production casing.

Table 2.4: Chemicals and additives

CEMENT ADDITIVES (APPROXIMATE EQUIVALENTS)

FUNCTION	USE	PRODUCTS
Extender Bentonite	To absorb free water allowing a lower slurry density, increase gel strength and yield	Premium Gel, Hydrogel, Aquagel
Silica Flour	HT strength retrogression	ERC 200 mesh, Seagull 200 mesh, Repcas 200 mesh, Insulyte 325 mesh
Accelerator	To speed up setting time in surface jobs	$CaCl_2$ (78-80%), CA-1, D98, A3-L
Friction Reducer	To indicate turbulence flow at low pump rates. To reduce slurry viscosity	BJ CD-31, Dowell D59, Messina CAFR-3P, Halliburton CRR22
Fluid Loss Reducer	To control slurry fluid loss in permeable zones, reducing "Bridging"	BJ FL-22, FL-50, Halliburton Hallad-22A Messina CAFL-1
Low Temperature Retarder	To retard thickening time of cement to allow placement in moderate temperature.	BJ R-5, Dowell D28, Halliburton HR7, Messina CA-RB
High Temperature Retarder	To retard thickening of cement and to allow placement in higher temperature	BJ R-11, Dowell D13, Halliburton HR-12, Messina CA-R10
Silica Sand	As an LCM material in loss circulation plugs.	70 Mesh Sand
Silicate Sealing Pre-Flush	Gelling agent to replace flushed mud wall cake with quick sealing cement wall cake to reduce bridging & LCM problems	Flochek P (Flochek 21) D 75 (Zoneloks)

Waste cuttings and mud: Huge amount of waste is expected from this activity, particularly if the number of test wells is more. Percolation of this fluid will contaminate ground water resources.

Emission: During well testing emission of gases along with the steam is inevitable, at least in testing phase. Major component of the gas is Hydrogen Sulphide, H_2S, which is toxic. Data on other constituents of the gas is not available. Mitigation measures need to be sought to minimize the impact of toxic gas emission. On the other hand, the following table summarizes percentage composition of samples taken from geothermal sites.

Table 2.5: Trace constituents in selected geothermal fields (mg/1)

Geothermal field	As	B	H_2S	NH_3	Li	Source
Tendaho (TD-4) (separated water)	0.4	4.6	< 0.1	1.49	1.06	Aquater, 1996
Wairaki (NZl) (deep water)	4.7	30	1.7	0.2	14	Brown, 1995
Salton Sea (USA) (deep water)	12	390	16	386	215	Brown, 1995
Cerro Prieto (Mexico) (deep water)	4.7	19	0.6	127		Brown, 1995
Nesjavellir (Iceland) (separated water)	0.05	2.1				Wetangula, 2004
Threshold value	0.3	0.5	*0.05	*1.5		EPA, 2000 and *Brown, 1995

2.3.4 Potential Impacts Associated with Drilling Process

It is well understood that geothermal fluids contain high concentrations of heavy metals and other toxic elements, including radon, arsenic, mercury, ammonia and boron, which may damage the freshwater systems into which they are released as waste water depending on site specific conditions.

Hydrogen sulphide (H_2S) is a main component of geothermal steam and is responsible for the rotten egg smell of geothermal areas. It is corrosive and classed as very toxic. H_2S is a heavy gas and can linger in valleys, polluting local populations. It forms sulphur dioxide (SO_2) in the atmosphere causing acid rain.

Landscape impact is another significant factor. As each geothermal borehole produces only a few megawatts of power, a number of boreholes may be drilled across large area, connected to the main power station with pipes and roads. Numerous test holes are drilled for every borehole that goes into production. In a similar approach, the following specific environmental impacts may likely to happen:

- Gaseous emissions
- Water pollution
- Solids emissions
- Noise pollution
- Land use
- Land subsidence
- Induced seismicity
- Induced landslides
- Water use
- Disturbance of natural hydrothermal manifestations
- Disturbance of wildlife habitat and vegetation
- Altering natural vistas
- Catastrophic events.

Thus, it can be concluded that certain impacts must be considered and managed if geothermal energy is to be developed as a larger part of a more environmentally sound, sustainable energy portfolio for the future. Most of the potentially important environmental impacts of geothermal power plant development are associated with ground water use and contamination, and related concerns about land subsidence and induced seismicity as a result of water injection and production into and out of a fractured reservoir formation. Issues of air pollution, noise, safety, and land use also merit some consideration.

CHAPTER THREE: POLICY FRAMEWORK

3.1 Over view

It is quite obvious that policy elements for this "test well drilling project" are nearly the same with what has been dealt for the Master Plan on Development of Geothermal Energy in Ethiopia. In addition to this, results of this study are supposed to be used until capacity of the reserve is determined for power plant development. On the other hand, regulation of financial institution for this transition period project is assumed to be at minimal. Therefore, this chapter focuses only on summary of policy elements that are useful to generate conclusion and recommendation. Hence, any official interested in reviewing this document may need to have a copy of the master plan study for further verification.

Huge development projects usually impose certain environmental and social impacts. There are a number of standards in the world that impose limits on the harmful substances that may be contained in the industrial emissions and effluents. These standards, however, vary based on the type and scale of the industries. Countries also have their own regulatory framework that provides guidelines regarding these emissions and effluent. The government of Ethiopia through specific legislations regulates the environmental management system for all projects across the country. Following this, the statutory bodies responsible for insuring environmental compliance by the project promoters include:

- The then Environmental Protection Authority of Ethiopia, EPA, now Ministry of Environment and Forest;
- Regional Environmental Authority Bureau;
- Ministry of Mine Petroleum and Natural Gas, and,
- Ethiopian Electric Utility

Similar to other developmental projects, the proposed test well drilling is subject to several policies and programs aimed at development and environmental protection. Therefore, as part of ESIA reviewing policies, legislations and institutional frameworks most relevant to the proposed project is necessary. In addition to this, standard requirements of ESIA process need to be adhered to. For the purpose ESIA scoping process-those national and international environmental standards, regulations and guidelines that can provide a framework for the ESIA Study process are identified, reviewed and presented.
These standards are, then, used as a benchmark to measure and evaluate significance of environmental and social impacts. Environment is a cross-cutting issue for several development sectors that use natural resources as raw materials and for other development activities which may pollute the environment. To deal with environmental issues, Ethiopia has developed a number of legal frameworks and guidelines that emanates from international conventions.

3.2 International Conventions and Protocols

In addition to national environmental legislations, the Federal Democratic Republic of Ethiopia is also member of a number of regional and international conventions and protocols on environment. The government has established an Environmental Protection Authority, and then Ministry designated to implement the conventions and protocols.

According to Article 9(4) of the Constitution of the Federal Democratic Republic of Ethiopia, once an international agreement is ratified through the established procedure, it automatically becomes an integral part of the law of the land. Consequentially, the adopted Conventions and the Protocols have already become the integral part of the national laws. In line to this, the following documents are relevant to the ESIA study of this project.

• **Convention on Biological Diversity:** Goals of the conservation of biodiversity: the sustainable use of the components of biodiversity; and the fair and equitable sharing of the benefits arising from the use of genetic resources.

• **The United Nations Convention to Combat Desertification (CCD):** The objective of the Convention is to combat desertification and mitigate the effects of droughts in countries experiencing serious drought and/or desertification, particularly in Africa.

• **Framework Convention on Climate Change (FCCC):** This convention takes into account the fact that climate change has trans-boundary impacts. The basic objective being to provide with agreed limits on the release of greenhouse gases into the atmosphere so as to prevent the occurrence of climate change. It also aims to prepare countries to minimize the impact of climate change.

- **The Universal Declaration of Human Rights**: The declaration makes clear a common standard of achievement for all peoples and all nations: to promote respect for human rights and freedoms, and to secure their universal and effective recognition and observance. Environmental and social considerations refer not only to the natural environment, but also to social issues such as involuntary resettlement and respect for the human rights of indigenous peoples.

- **Japan International Cooperation Agency, JICA**
  Owing to the recent increase of public Interest in environmental issues and adopting most international conventions, the government of Japan, through JICA has developed Guidelines for Environmental and Social Considerations (2010) and applied them to Loan aid and technical cooperation. Among these conventions, Principle 17 of the Rio Declaration; Agenda 21; and Organization for Economic Cooperation and Development (OECD) Council Recommendations are prominent. JICA's Business Protocol and Mid-term Plan clearly state that JICA implements cooperation activities in accordance with these guidelines. With respect to human rights and in view of the principles of democratic governance, measures for environmental and social considerations are implemented by ensuring a wide range of meaningful stakeholder participation and transparency of decision-making, as well as by working for information disclosure and by ensuring efficiency.

3.3 Legal and Policy Context

The concept of Sustainable Development and Environmental Rights are enshrined in Articles 43, 44 and 92 of the Constitution of FDRE.

In Article 43: the Right to development, where people's right to:

- Improved living standards and to sustainable development;
- Participate in national development and, in particular, to be consulted with respect to policies and projects affecting their community;
- The enhancement of their capacities for development and to meet their basic needs, are recognized;

In Article 44: Environmental Rights, all persons are entitled to:

- Live in a clean and healthy environment;
- Compensation, including relocation with adequate state assistance

In Article 92: Environmental Objectives, it is declared that;

- Government shall ensure that all Ethiopians live in a clean and healthy environment;
- Programs and projects design shall not damage or destroy the environment;
- Peoples have the right to full consultation and expression of views;
- Government and citizens have the duty to protect the environment.

3.4 Environmental Policy of Ethiopia

Ethiopia adopted its Constitution in 1995, which provides the basic and comprehensive principles and guidelines for environmental protection, and management. The Environmental Policy is predicated on a growing concern for the degradation of the natural resource base. The overall policy goal is to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through sound management and use of natural, human made and cultural resources and the environment as a whole.

The following are extracts from the National Environmental Policy which provide essential guidance for activities of environmental agencies in general.

- Incorporate the full economic, social and environmental costs and benefits of natural resources development;
- Appropriate and affordable technologies which use renewable resources efficiently shall be adopted, adapted, developed and disseminated;
- When a compromise between short term economic growth and long term environmental protection is necessary, then development activities shall minimize degrading and polluting impacts on ecological and life support systems;
- Regular and accurate assessment and monitoring of environmental conditions shall be undertaken;
- Ensure that ESIAs consider not only physical and biological impacts but also address social, socio-economic, political and cultural conditions;

- Recognize that public consultation is an integral part of ESIA and ensure that ESIA procedures make provision for both an independent review and public comment before consideration by decision makers;
- Establish the necessary institutional framework and determine the linkage of its parts for undertaking, coordinating and approving ESIAs and the subsequent system of environmental audits required to ensure compliance with conditions;
- Develop detailed sectoral technical guidelines in ESIA and environmental audits;
- Ensure that preliminary and full ESIAs are undertaken by the relevant sectoral ministries or departments, if in the public sector, and by the developer if in the private sector.

3.4.1 Institutional Framework

The FDRE consists of 9 Federal and Regional States. Proclamations 33/ 1992, 41/ 1993 and 4/ 1995 define the duties and responsibilities of the Regional States which include planning, directing and developing social and economic development programs as well as protection of natural resources. The most important step in setting up the legal framework for the environment in Ethiopia has been the establishment of the Environmental Protection Authority (EPA), Proclamation no. 299/ 2002. According to this Proclamation, The EPA as a Federal Environmental agency is responsible for:

- The establishment of a required system for Environmental Auditing of public and private sector projects, as well as social and economic development policies, strategies, laws, and programs of federal level functions;
- Reviewing and passing decisions and follow-up the implementation of Environmental Impact Study Reports of projects, as well as social and economic development programs or plans where they are:
    - subject to federal licensing, execution or supervision;
    - proposed activities subject to execution by a federal agency;
    - Likely to entail inter or trans regional, and international impacts.
- Notifying its decision to the concerned licensing agency at or before the time specified in the appropriate law or directives;
- Auditing and regulating the implementation of the conditions attached to the decision;
- Provide advice and technical support to the regional environmental agencies, sectoral institutions and the proponents;
- Making its decisions and the EA report available to the public, resolving all complaints and grievances in good faith and at the appropriate time;
- Developing incentive or disincentive structures required for compliance of EA requirements pave the way and involve in EA awareness creation, etc.

The Regional Environmental Agencies are responsible to:

- Adopt and interpret federal level EA policies and systems or requirements in line with their respective local realities;

- Establish a system for EA of public and private projects, as well as social and economic development policies, strategies, laws, or programs of regional level functions;
- Inform EPA about malpractices that affect the sustainability of the environment regarding EA and cooperate with EPA in compliant investigations;
- Administer, oversee, and pass major decisions regarding impact assessment of:
    - projects subject to licensing by regional agency;
    - projects subject to execution by a regional agency;
    - projects likely to have regional impacts.

The Proclamation assigns responsibilities to different organizations for environmental development and management activities on one hand, and environmental protection, regulation and monitoring on the other. It gives the EPA the legal powers required for enforcing as well as spearhead the enforcement of and ensure compliance with environmental laws and standards.

In this regard, EPA has established an Environmental Impact Assessment system including the preparation of Procedural and Sectoral Guidelines as a prerequisite for the approval of new development activities and projects.

"Environmental Protection Organs Establishment Proclamation (Proclamation no. 295 of 2002)" stipulates the need to establish a system that enables to foster coordinated but differentiated responsibilities among environmental protection agencies at Federal and Regional levels. The proclamation requires the establishment of Sectoral and Regional Environmental Units and Agencies, respectively. This shows that institutionalizing and mainstreaming environmental concerns involve legal foundation.

"Environmental Impact Assessment Proclamation (Proclamation no. 299 of 2002)" provides EA with mandatory legal prerequisite for the implementation of major development projects, programs and plans. This proclamation is a proactive tool and a backbone to harmonizing and integrating environmental, economic and social considerations into a decision making process in a manner that promotes sustainable development.

"Environmental Pollution Control Proclamation (Proclamation no. 300 of 2002)" is promulgated with a view to eliminate or, when not possible to mitigate pollution as an undesirable consequence of social and economic development activities. This proclamation is one of the basic legal documents, which need to be observed as corresponding to effective EA administration.

In addition to the above proclamations, other relevant regulations in relation to the proposed project, as listed in Table 3.1 are also reviewed.

3.4.2 Applicable Proclamations/ Guidelines

Proclamations and EPA Guidelines applicable to the proposed project are listed in Table 3.1.

Table 3.1: Proclamations and Guidelines

Sn	*Title*	*No.*	*Date of Issue*
1	Environmental Impact Assessment Proclamation	299	31-Dec-02
2	Environmental Pollution Control Proclamation	300	03-Dec-02
3	Environmental Protection Organs Establishment Proclamation	295	31 Oct 2002
4	Expropriation of Landholdings for Public Purposes and Payment of Compensation Proclamation	455	15-Jul-05
5	Rural Land Administration Proclamation	89	07-Jul-97
6	Ethiopian Water Resource Management Proclamation	197	Mar, 2000
7	Solid Waste Management Proclamation	513	12-Feb-07
8	Environmental Impact Assessment Procedural Guideline Series 1		Nov. 2003
9	Draft EMP for the Identified Sectoral Developments in the Ethiopian Sustainable Development & Poverty Reduction Program (ESDPRP)		01-05-04
10	Investment Proclamation	280	02 Jul 2002
11	Council of Ministers Regulations on Investment Incentives and Investment Areas Reserved for Domestic Investors	84	07-Feb-03
12	The FDRE Proclamation , "Payment of Compensation for Property Situated on Landholdings Expropriated for Public Purposes	455	Y,2005
13	The Council of Ministers Regulation , "Payment of Compensation for Property Situated on Landholdings Expropriated for Public Purposes"	135	Y,2007
14	Oromya Regional Administration Council Directives, "Payment of Compensation for Property Situated on Landholdings Expropriated for Public Purposes".	5	Y,2003
15	Investment (Amendment) Proclamation	373	28 Oct 2003

Here, it is worthwhile to summarize the provisions, particularly those key sectors relevant to the project, namely water, and energy, among others.

Water Resources Management policy of Ethiopia: The overall goal of Water Resources Policy is to enhance and promote all national efforts towards the efficient, equitable and optimum utilization of the available Water Resources of Ethiopia for significant socioeconomic development on sustainable basis that incorporate environmental conservation and protection requirements.

Ethiopian National Energy Policy and Energy Law: Ensuring that the development of energy supply and utilization is environmentally benign. The energy policy gives priority to the planning and expansion of the energy supply required for economic development, particularly the implementation of the Agriculture Development Led Industry, ADLI, while at the same time, taking measures to transform energy consumption in the country from traditional to modern sources.

Proclamation on Solid Waste Management: The proclamation on Solid Waste Management No. 513/2007 is intended to create a sustainable path to limit the adverse effects of waste and maximize all potential benefits. The primary objective of the proclamation is to enhance at all

levels capacities to prevent the possible adverse impacts while creating economically and socially beneficial assets out of solid waste. It also sets clear guidelines on the interregional transportation of waste as well as the disposal of toxic materials and recyclable goods. Urban administrations are required to create enabling conditions to promote investment on the provision of solid waste management services. Following the proclamation, all waste disposal facilities need to follow relevant environmental and local regulations as well as secure all required permits before implementation. EPA is empowered to issue directives for the proper implementation of the proclamation and regulations.

Environmental Pollution Control Proclamation: The law recognizes the fact that some social and economic development endeavors may inflict environmental harm that could make the endeavors counterproductive. It also underlines the fact that the protection of the environment, in general, and the safe guarding human health and well-being, as well as maintaining the biota and the aesthetic value of nature, in particular, are the duty and responsibility of all. To this end, the law aims to eliminate or, when not possible, to mitigate pollution as an undesirable consequence of social and economic development activities.

The national EPA Guideline provides categories, relevant requirements for an EIA, and lists project types under each category. In accordance with this Guideline, projects are categorized into three schedules:

Schedule-I: Projects, which may have adverse and significant environmental impacts and therefore require a full Environmental Impact Assessment.

Schedule-2: Projects whose type, scale or other relevant characteristics have potential to cause some significant environmental impacts but are not likely to warrant a full EIA study.

Schedule-3: Projects which would have no impact and do not require an EIA.

Accordingly, the 2002 guideline categorizes geothermal power plant establishments under Schedule I activity.

A closer look from perspectives of above mentioned conventions, policies and strategies it can be inferred that there is a qualitative need to conduct a complete ESIA assessment in order to safeguard the environment and concerned inhabitants from any possible negative impacts that may emanate from development of this power plant. Other aspects which impose requirement of conducting a full ESIA, as discussed in subsequent sections, will also demonstrate the need for quantitative determination.

Realizing the causes and impacts of industrial projects, the Environmental Assessment and Management Guidelines of Ethiopia recommends the following criterion for environmental management.

- New industry should be situated at a sufficient distance from environmentally sensitive areas wherever practically possible;
- Environmental monitoring during construction and operation;
- Implement an environmental management system which ensures environmental responsibility at all levels;
- Knowledge of local, national and international environmental requirements;

- Utilize environmentally friendly technologies;
- Implement cleaner production strategy - alternative products, production processes, raw materials, energy sources, prevent or reduce waste, waste recycling, re-use;
- Introduce water and energy saving measures;
- Discharge points should be located downstream of supply sources of drinking water;
- Delineation of location of waste dumps;
- Locate chimneys and waste pipes appropriately;
- Monitor volume and composition of discharges regularly;
- Ensure that sensitive environments and residential areas will not be affected by noise, especially at night;
- Develop reliable information system and mechanism for labelling, handling, and stocking of dangerous substances;
- Maintain safety equipment;
- Emergency procedures and rehabilitation upon closure of industry;
- Training programme to assist labour force in adapting to an industrial life style.

The following issues of health and safety are also addressed in the Council of Ministers Regulations on Industrial Operation No. 182/1994, and Labor Proclamation No.42/1993:

- Protective clothing and equipment;
- Training;
- Medical facilities;
- Procedures for safe transport, storage, handling, and use of explosives and chemicals;
- Notification of licensing authority upon serious accidents, and necessity for mitigation measures
- All installations to be rendered safe upon termination of license;
- Forbids industrial establishment in sensitive location as outlined in the regulations;
- Waste of hazardous products should be treated properly;
- Measure for reduction of discharges to the air;
- Location of discharge outlets for waste water and of chimneys to ensure dispersal of discharge substances;
- Plan of operation which considers short and long-term pollution;
- Management of hazardous waste to be in accordance with the strictest national and international regulations and guidelines;
- Controlled use of dangerous substances;
- Water consumption to be in accordance with existing water use in the area;
- Utilize environmentally friendly technology;

3.5 EIA Procedures in Ethiopia

Table 3.2: Outlines of the EIA procedures in Ethiopia.

N	*EIA Stage*	*Action*	*Agency involved*

o			
1	*Screening*	Preparation of project profile; decision on whether or not the project requires an EIA	EPA
2	*Scoping of the EIA*	Developing TORs initiating initial public consultation.	EPA, funding agency, consultant
3	*Environmental Impact Study*	Impact assessment; design of mitigation measures; design monitoring and audit plan	EPA, funding agency, consultant, proponent
4	*Reviewing the adequacy of the EIA*	Review contents and provide comments for necessary revisions.	EPA, funding agency
5	*Decision Making*	Summary evaluation made available to public; decisions & conditions for approval made public	EPA
6	*Systematic EIA Follow ups*	Ensuring implementation of agreed mitigation measures; periodic review & alteration of management plan if required	Private contractors, EPA, funding agency

EIA Process: The general description of the EIA process and the permit requirements are detailed in the Environmental Impact Assessment Procedural Guideline Series 1 of the FDRE released in Nov 2003. As per the Guidelines, it involves sufficient information that enable the determination of whether and under what conditions the project shall proceed. Thus, as a minimum, the following descriptions shall be presented:

- the nature of the project, including the technology and processes to be used and their physical impacts;
- the content and amount of pollutants that will be released during implementation as well as during operation;
- source and amount of energy required for operation;
- characteristics and duration of all the estimated direct or indirect, positive or negative impacts on living things and the physical environment;
- measures proposed to eliminate, minimize, or mitigate negative impacts;
- a contingency plan in case of accidents;
- procedures of internal monitoring and auditing during implementation and operation.

Reviewing: The purpose of review is to examine and determine whether the EIA report is an adequate assessment of the environmental effects and of sufficient relevance and quality for decision- making. Reviewing is conducted at various stages in the EIA processes and includes reviewing of Screening report, Scoping report, TORs, EIA Report, and Performance (monitoring or audit) reports at different stages in the project cycle.

Reviewing may include considerations of the adequacy of:

- Compliance with the "approved TOR";
- Required information;
- The examination of alternatives, assessment of impacts, appropriateness of mitigation measures and monitoring schemes as well as implementation arrangements;
- The use of scientific and analytical techniques;
- The extent of public involvement and reflection of their concerns;
- Presentation of the information to decision makers at Regional, Sectoral, and Local levels.

Decision Making: EIA is an on-going process of review, negotiations and incremental decision-making at various levels of the project cycle, about whether or not the proposal is to proceed, and under what conditions. Decision-making is consultative, participatory and influences others to behave responsibly and sustainably. It also acknowledges and implements mandates and responsibility. Full-scale assessment is required where the project is known to have significant adverse environmental impacts. Important considerations of decision-making are:

- A summary of evaluation is made available to the public;
- Reasons for decision and conditions of approval are made public;
- There is the right of appeal against decision;
- Approval can be reversed or permit can be revoked on the advent of changing circumstances;
- Approval of a proposal cannot immune the proponent from being accountable of the occurrence of adverse significant impacts in the course of the implementation of the project.

The licensing agency shall, prior to issue of an operating license for a project, ensure that the EIA of the project has been approved. Approval of an EIA report is only to mark a simple agreement to the proposal. The culmination of the approval procedure will be the issuance of an Environmental Clearance Certificate upon the satisfactory trial operation phase.

3.6 Regulatory Requirements of Financial Institutions

Here, it will be necessary to notify that the government of Japan, through JICA has developed Guidelines for Environmental and Social Considerations (2004) and applied them to Loan aid and technical cooperation. As a representative sample, techno-feasibility study of the power development at the Aluto-Langano geothermal field has been conducted as part of FY2009 Studies for Economic Partnership Projects in Developing Countries promoted by the "Ministry of Economy, Trade and Industry of Japan (METI)" and that was entrusted to West Japan Engineering Consultants Inc. (West JEC) through Ernst & Young Shin Nihon LLC and the Japan External Trade Organization (JETRO).

Other key institutions for financial support: World Bank, the African Development Bank (AfDB), the International Finance Corporation (IFC), the European Investment Bank (EIB) and the local Development Bank of Ethiopia (DBE). However, detailed guidelines of these financial

institutions are omitted for this particular study since test well drilling is an intermediate project for power plant development.

3.7 National Standards and Limit Values

The EPA of FDRE has been actively engaged in the preparation of national environmental quality standards for air, water, noise, etc. To date, some of these standards are still in draft form. In such cases, International Standards are commonly relied upon. The provisional standards for industrial pollution control and prevention which has been prepared by EPA in collaboration with UNIDO and issued in 2003 provides:

- Standards for Specified Industrial Sectors;
- Standards for Industrial Effluents (General);
- Standards for Gaseous Emissions (General);
- Standards for Noise Limits.

Ambient air and water qualities; noise levels: The proposed draft standards as formulated by the FDRE for ambient air quality, noise levels, emission levels and discharge to wastewater are given in the Table 3.3, Table 3.4 and Table 3.5 respectively.

Table 3.3: Draft Standards for Industrial Emission and Effluent limits; EPA, FDRE

No.	*Process*	*Pollutant*	*Parameter Required*	*Draft Standard*	*Competent Authority*
1	Processing Industry	Discharge of wastewater	pH	6 up to 9	EPA, FDRE
			BOD5 at 20°C	25 mg/ l	
			COD	150 mg/ l	
			Total Phosphorus as P	5 mg/ l	
			Suspended Solids	50 mg/ l	
			Mineral oils at the oil trap or interceptor	20 mg/ l	
2	Stack Emissions	Emission of pollutant gases	Total particulates	150 mg/ Nm3	EPA, FDRE
			SO2	1000 mg/ Nm3	
	Industrial processing		NO2	2000 mg/ Nm3	

Table 3.4: Draft Standards for Ambient air condition; EPA,FDRE

Ambient Air Quality		
Parameter	*Standard (µg/ m3)*	*Averaging Time*
SO_2	500	10 min
	125	24 hr
	50	1 yr
NO_2	200	24 hr
	40	1 yr
CO	100,000	15 min
	60,000	30 min
	30,000	1 hr
PM10	50	1 yr
	150	24 hr

Limit values for industrial emission and effluents: The above mentioned draft standard also issued draft limit values for industrial emission and effluents as indicated in Table 3.6.

In September 2003 EPA and the United Nations Industrial Development Organization have announced national noise standards to be achieved at noise sensitive locations. Such areas include domestic dwellings, hospitals, schools, places of worship, or areas of high amenity. The sensitivity to noise is usually greater at night-time than during the day, by about 10dB (A). Ideally, if the total noise level from all sources is taken into account, the noise level at sensitive locations should be kept within the following values.

Table 3.5: Ambient noise Quality / noise standards/ where people live or work

Category of the area	*Limits in dB(A) Leq*		*Remark*
	Day time	*Night time*	
Industrial	75	70	1: Day time reckoned from 6 am to 9 pm 2: Night time reckoned from 9 pm to 6 am
Commercial	65	55	
Residential	55	45	

Note: In some particularly quiet areas, such as pastoral, rural settings, where the background noise levels are very low, lower noise limits may be more appropriate.

In cases where sector specific standards are not available then general standards for industrial effluent and for gaseous emission are adapted from other countries in our case, South Africa and Netherlands. In this part of the document the following three standards are stated:

- standards which shall be applied to all effluents discharged to inland waters, other than those from specific sectors;
- standards which shall be applied to all effluents which shall be applied to lands (for all industrial sectors);
- standards for gaseous emission.

3.8 International Limit values, as of IFC Standards

The EHS Guidelines released on 30 April 2007 are technical reference documents with general and industry specific examples of Good International Industry Practice (GIIP). The World Bank 'EHS Guidelines for manufacturing industries have set standards for air emissions levels and effluent levels from manufacturing as given below.

Emissions: Table 3.6 gives the emission guidelines for specified manufacturing sector. These guidelines are achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques. These are: levels should be achieved, without dilution, at least 95% of the time that the plant is operating, to be calculated as a proportion of annual operating hours.

Table3.6: EHS Emission guidelines

No.	*Pollutants*	*Units*	*Guideline values*
1	Particulate Matter	mg/ Nm3	30 (a)
2	Dust	mg/ Nm3	50
3	SO_2	mg/ Nm3	400
4	NOx	mg/ Nm3	600
5	HCI	mg/ Nm3	10 (b)
6	Total organic carbon	mg/ Nm3	10
7	Dioxins-furans	mgTEQ/Nm3	0.1 (b)
8	Total Metals ©	mg/ Nm3	0,5
	Notes		
*	* Emissions from the stack unless otherwise noted. Daily average values corrected to 273K, 101.3 kPa,10 percent O2 and dry gas, unless otherwise noted		
a	a10 mg/ Nm3 if more than 40 percent of the resulting heat release comes from hazardous waste.		
b	b If more than 40 percent of the resulting heat release comes from hazardous waste average values over the sample period of a minimum of 30 minutes and a maximum of 8 hours.		
c	c Total Metals = Arsenic (As), Lead (Pb), Cobalt (Co), Chromium (Cr), Copper (Cu), Manganese (Mn), Nickel (Ni), Vanadium (V) and Antimony (Sb)		

Ambient Air Quality: As per EHS General Guidelines, projects with significant sources of air emissions should ensure that emissions do not result in pollutant concentrations that reach or exceed relevant ambient air quality guidelines and standards by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines.

Effluents: Effluent guidelines as specified in the EHS Guidelines is applicable for discharges of treated waters for general use may equally applied to the proposed geothermal power plant and is given in Table 3.7.

Table 3.7: EHS Guidelines for effluent

No.	*Pollutant*	*Units*	*Guideline value*
1	pH	pH	6 – 9
2	BOD	mg/l	30
3	COD mg/l	mg/l	125
4	Total Nitrogen mg/l 10	mg/l	10
5	Total Phosphorus mg/l 2	mg/l	2
6	Oil and grease mg/l 10	mg/l	10
7	Total suspended solids mg/l 50	mg/l	50
8	Total coliform bacteria	MPNb/100 ml	400(a)
	a Not applicable to centralized, municipal, waste water treatment systems which are included in guidelines for Water and Sanitation EHS b MPN = Most Probable Number		

Noise Levels: For noise levels beyond the property boundary of the Plant, the general EHS Guidelines on Noise Management specify the noise level guidelines applicable to this project. Noise levels should not exceed the levels as given in Table 3.8, or result in a maximum increase in background levels of 3 dB at the nearest receptor location off site.

Table 3.8 : EHS Guidelines on Noise Management

No	Receptor	One hour Leq (dBA)*	
		Day time	Nighttime
		07.00-22.00	22.00-07.00
1	Residential, institutional, educational (a)	55	45
2	Industrial, commercial	70	70
* Guidelines values are for noise levels measured out of doors. Source : Guidelines for Community Noise, WHO, 1999 @ For Acceptable indoor noise level for residential, institutional, and educational settings, WHO, 1999.			

The General EHS Guidelines on Occupational Health & Safety specify the noise level guidelines **applicable to different working environments. Noise levels should not exceed the above levels:**

- No employee shall be exposed to noise levels greater than 85 dB (A) for a duration of more than 8 hours per day without hearing protection. In addition, no unprotected ear should be exposed to a peak sound pressure level (instantaneous) of more than 140 dB(C). The use of hearing protection shall be strictly enforced when the sound level

over 8 hours reaches 85 dB (A), the peak sound levels reach 140 dB(C) or the average maximum sound level reaches 110 dB (A).

- For every 3 dB (A) increase in sound levels, the 'allowed' exposure period or duration should be reduced by 50%.

Effluent and emission from geothermal activities: During operation phase, emission of particularly H_2S, fluoride or carbonates and discharge that contains solubilized metals is expected. As per the 'EHS Guidelines for industrial processes, the concentration of Total Suspended Solids (TSS) should be limited to 50 mg/ l at the point of discharge. EHS General Guidelines for Ambient Air Quality standards as specified above shall also apply to the industrial area.

3.9 Strategic Environment Assessment, SEA

From basic definition of the concept it can be inferred that SEA focuses mainly on policy level issues before implementing certain programs or projects between two or more parties; I.e. bilateral or multilateral relations. To this effect, the ESIA study team has identified the following policy guidelines relevant.

- Alignment of the project from policy perspectives;
- Energy policy of the country verses geothermal;
- Project perspective from guidelines of financial institutions;
- Alignment of JICA guidelines with national policies.

3.9.1 Alignment of the Project from Policy Perspectives

The entire legislative framework applicable to the proposed project is governed by the laws of Federal Democratic Republic of Ethiopia (FDRE). National policies and regulation were reviewed; guidelines of relevant Federal and Regional Offices were studied; sufficient numbers of officials were also interviewed. It is concluded that the proposed project can be materialized in alignment with national regulations and international conventions. However, from policy perspective the following two important findings are identified:

- *As per 'Environmental Impact Assessment Procedural Guidelines Series 1'* of November 2003, t*he proposed geothermal power plant or test well drilling has significant environmental impacts, and, therefore, requires a full ESIA/EA. The plant will be, then, responsible/accountable/ for implementing environmental management plans at its facilities in coordination with the Federal EPA or the Regional EPA*

- Guideline of National Environmental Policy, Article 7; *Recognize that public consultation is an integral part of EIA and ensure that EIA procedures make provision for both an independent review and public disclosure before consideration by decision makers,*

The proposed project inevitably requires environmental and planning approvals from the Federal or Regional Government Authorities. Thus, this study has been prepared to form part of the development application, assessment and approvals process of the proposed project.

Geothermal power plant Project Office will be responsible for the construction, commissioning and operation of the project.

3.9.2 Project Perspective from Regulatory bodies of Financial institutions

This ESIA study for the proposed geothermal power plant has been carried out within the framework of local, national and international environmental regulations and guidelines of relevant financial institutions: African Development Bank (AfDB), World Bank, the International Finance Corporation (IFC), the European Investment Bank (EIB) and the local Development Bank of Ethiopia (DBE) are among potential financial institutions.

ESIA study of this project is, thus, screened in line with World Bank Standard Guidelines and then six Safe Guard Policies of the Bank are identified as relevant and subsequently adequately reviewed. These Operational Policies are: OP 4.01; OP 4.02; OP 4.04; OP 4.10; OP 4.11; and OP 4.12. Next to this, guidelines of remaining banks are reviewed. In the course of doing the task, it is learnt that once required activities, say, for World Bank is carried out successfully then similar approaches can be used for the other financial institutions. Hence, for the purpose of this ESIA study, those national and international environmental standards, regulations and guidelines that can be used as benchmark to measure and evaluate significance of environmental and social impacts are identified, reviewed and presented.

Bankable document: Findings from local financial institutions revealed that approval of both the feasibility and the ESIA study of this project by authorized government body enable the proposed geothermal power plant project secure basic requirements of local bank loans. However, some additional work on the above operational Policies is further required for bank loans from international financial institutions.

3.9.3 Energy Policy of the Country verses Geothermal Energy

As Ethiopia is situated in the Rift System rich with geothermal resource, power plant development using these resources seems sensible. Only few countries in the world have such resources. These days, the need for clean energy is fundamental not only at country level but also become worldwide demand through various international conventions (protocols) to sustain climate changes. With this regard and having sufficient resource with appropriate technology, establishment of geothermal plants seems the right option for the current power demands of Ethiopia. It is for this reason EEPCo puts priority of geothermal energy development second to hydropower.

3.9.4 Alignment of JICA's Guideline with National Policies

Main elements of JICA's guidelines for Official Development Assistance, ODA, are briefly discussed in the preceding section. On the other hand, Ethiopian guidelines for environmental assessment are thoroughly discussed in different parts of this document.

3.9.5 Summary of findings

From the above discussions, it can be concluded that the two guidelines do not have major contradiction, except perhaps certain procedural adjustments during project implementation. Thus, Strategic Environment Assessment, SEA, proves to be applicable for this test well

drilling project as one component of geothermal power plant establishment. Level of alignments of these guidelines is summarized in Table 3.9 format below

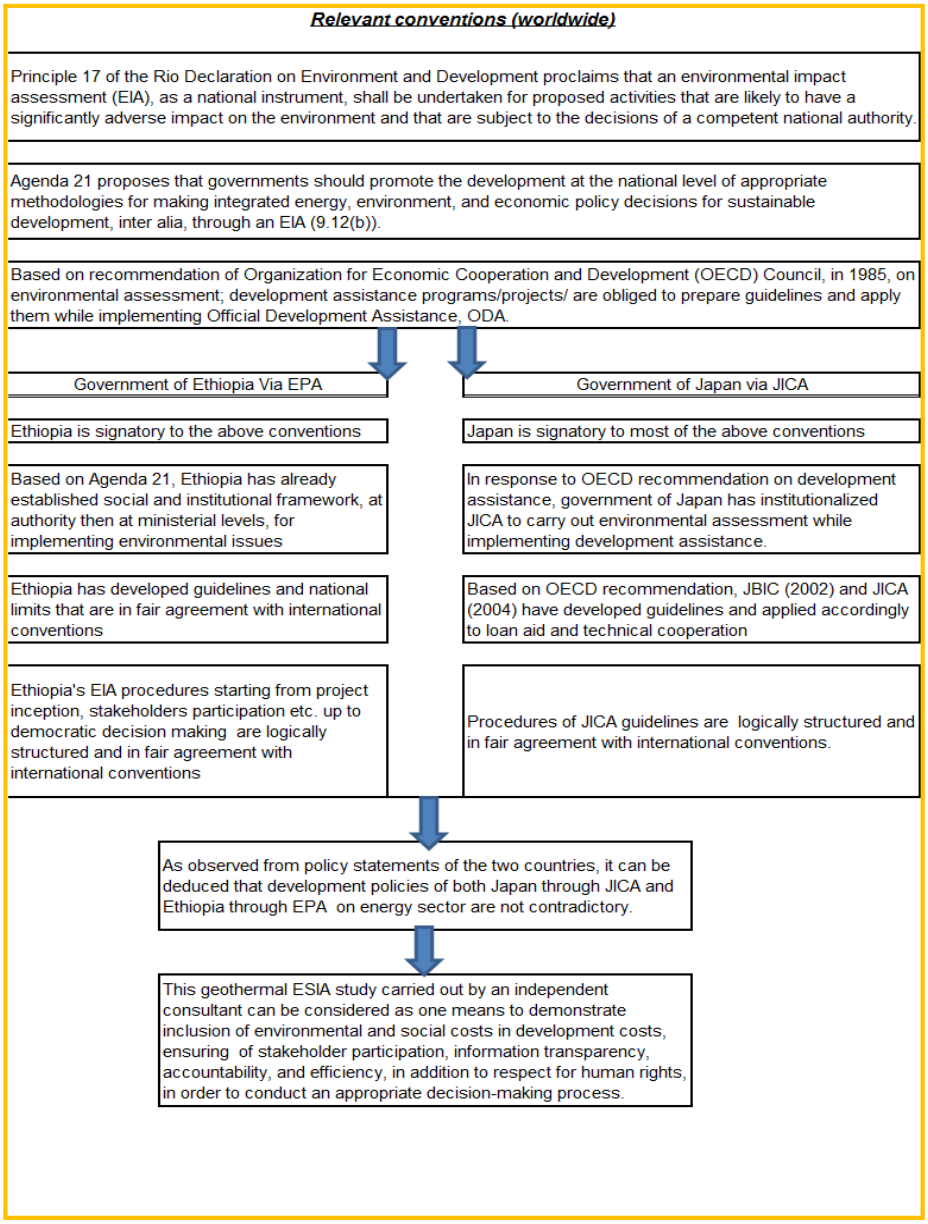


Table 3.9: Alignment between JICA's and EPA's Guidelines

CHAPTER FOUR: BASELINE SURVEY

This chapter discusses the base line data collected during the field work. Some information is also gathered from documents and AFD study for test drilling in Ayrobera. Here it will be important to notify that TOR of the previous prioritization study site list does not request/or mention Ayrobera but Allalo Beda as Tendaho-3. Though the Woreda /Dubti/ is the same for both sites they are nearly 40 Km apart on the road and 12Kms on air distance. In this chapter, the past ESIA information on Ayrobera is updated as follows.

4.1 Major Features of the Site

4.1.1 Location

Ayrobera geothermal site is located in the Afar Region at the central part Afar depression. Administratively it is found in Dubti Woreda (Zone 01). As shown in the Map below, the site is specifically located within Ayirolef–Gebelaytukebele borders and closely located to Semera Town (23kms NE). The neighboring village is Krrub or BattiHurrde. In the local language of the community Hurrde means "town" while Krrub is the name of a hill around the village. Elders of the community say that the village is very old and served as camp site during Italian invasion. The project site is situated about 35 km away from Logia town which is at about 596 km from Addis Ababa. According to the National Geothermal Energy Resource survey map there are two potential geothermal sites in and around Tendaho. The geographical location of Ayrobera site found to be 41^0 9' 20'' Easting and 11^0 54' 34" Northing.

4.1.2 Other Features of the Site

Ayrobera site is a flat dry land covered with mainly sand and ash, not fertile for agriculture. It is characterized by shortage of rain/water, both for drinking and farming. Summary of meteorological data of the project surrounding is given in the table below while its detail is attached at Annex. The community depends on water from precipitation of fumaroles. According to the woreda administrators, the community has been embraced by relief/safety net program.

4.1.3 Physical Settings

(a) ***Isohyets and elevation zone:*** The area is arid and dry and with very low and erratic rain fall pattern. Its annual rain fall is very low which ranges between 20ml – 30ml precipitation. Tendaho including Ayrobera area is one of the valley floor of Afar Depression, which resulted due to the continued and slowly rift apart of the Earth's crust, which is the immediate consequence of continuous sequence of earthquakes and the valley floor sinking which forms grabens. Thus, the Ayrobera geothermal potential site is located at low altitudes, which is in between 250 -500mts above sea level. On the other hand the eastern & western mountain ranges which are found close to these thermal sites, have relatively high altitudes which range from 800-1500 m above sea level.

Table 4.1: Climatic data of the site and its surrounding

Summary of meteorological data available for the targeted Ayrobera site measured from its nearest surrounding Dubti

Component	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Rain fall	22.18	13.63	7.47	21.72	13.88	21.39	15.57	30.99	14.60	15.06	19.90	10.58	19.47		
Average max temp	37.54	37.68	38.14	37.89	36.69	36.80	38.15	37.97	38.48	39.73	37.26	37.65		37.76	
Average min temp	22.31	22.28	23.61	23.15	23.01	22.13	23.89	23.28	21.66	23.93	22.80	21.91		22.62	
Relative humidity	48.2	52.9	46.2	50.5	49	45.8	50.4	51.6	50.9		54.8	52.3		55.6	
Wind	1.30	1.30	1.50	1.40	1.40	1.60									
Sun hour											8.20	8.60		8.60	

Source: Ethiopian Meteorological Agency

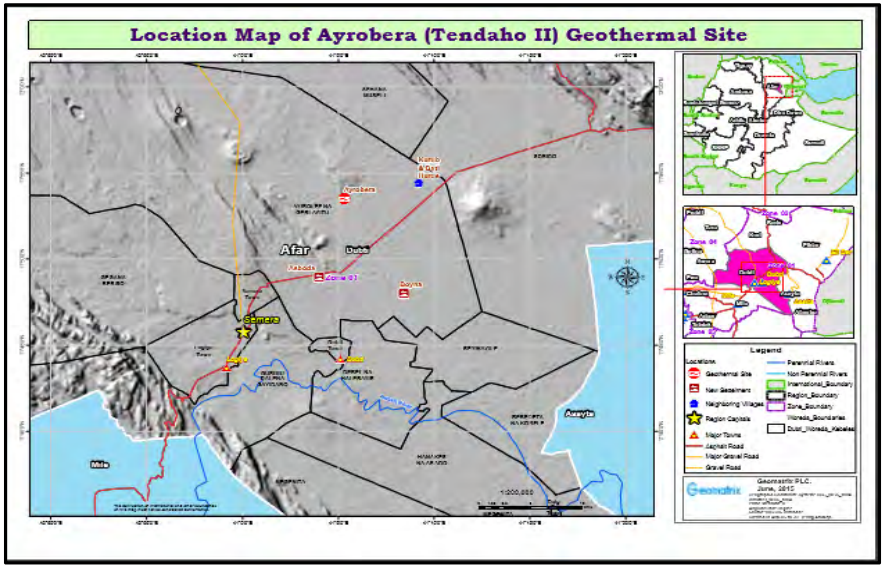


Fig. 4.1: Location Map of Ayrobera (Tendaho II) Geothermal Site

(b) ***Land cover:*** In general, Tendaho valley floor is predominantly covered by exposed sand soil surface specifically the central part; while the northern part of the Tendaho valley floor and its eastern and western mountain ranges /plateau is covered by Exposed Rock Surfaces with Scattered Grass Vegetation. Moreover, State farm and perennial marsh is also located in the south and near (6-10km) to Tendaho Geothermal sites. On the other hand, salt deposits/flats and pockets of Exposed rock surfaces are found in the North Eastern direction of Tendaho Geothermal sites. For the detail please refer Map # 3.3.

(c) ***Soil types:*** The major soil types in the area are Lithosols, Eutric Regosols, Orthic Solonchaks and Calcaric Fluvisols. Among these, Orthic Solonchaks and Lithosols are the predominant soils which occupy Tendaho valley floor. Calcaric Fluvisols soil type also dominates and extends to perennial Marsh areas. On the other hand, Eutric Regosols also partially covers its Western part plateau.

(d) ***Geology:*** In general, Tendaho area is predominantly covered by the recent quaternary period deposition (such as extrusive and intrusive basalt flows, rhyolites, trachyte and alluvial and/or lacustrine sediments. Moreover, Cenozoic period deposition such as alluvial lacustrine & Marine sediments, Bishoftu Formation (such as Alkaline basalt & trachyte) and Afar Series-Alakaline basalt occupies the small portion of the central part of Tendaho valley floor.

Tendaho geothermal Energy sites are specifically located in Miocene_Pliocene age Afar Series-Alakaline basalt (with subordinate alkaline & per-alkaline silicics rhyolitic dome & flows & Ignimbrites). Some portion of the geothermal bound site is also covered by the recent period (Holocene) deposits of undifferentiated alluvial lacustrine & beach sediments. In this regard, it is assumed that Afar Series-Alkaline basalt is the main sources for the geothermal energy in the area.

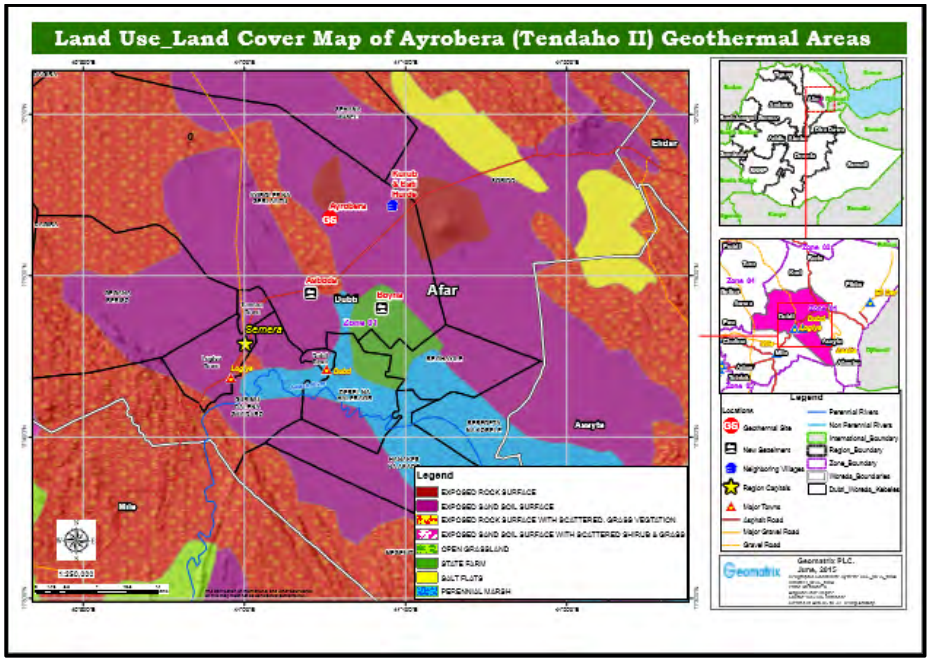


Fig.4.2 Land Cover Map of Tendaho Geothermal Energy Development Area

4.2 The Sample

From the total 1,138 people settled in the two villages 50 sample of representatives were selected to involve them in the study. Of this, 25 from Boina and 25 from Asboda were selected. Female participants were 9 while the rest 41 were male (Table 4.2).

The age of the sample group ranges from 18-65. Except six of them, all participants were married. In terms of educational status, more than half of them (56%) claimed to be illiterate. Except one person, with high school level the, remaining 21 sample population were elementary graduates (Table 4.2).

Occupation wise, 50% of the participants claimed to engage in cattle rearing while the rest equal percent were employed in Tendaho Sugar Plantation. Their yearly income ranges between ETB 10, 000 to 40, 000 (Table 4.3). As reported, on average, the workers at the plantation earn a monthly salary of ETB 800.

Table 4.2: Respondents Background

Village	Sex		Age		Marital status		Educ. status	
	M	F	18-30	>30	Single	Married	Illiterate	Elementary
Boyina	22	3	22	3	6	19	16	8*
Asboda	19	6	3	22	0	25	12	13
Total	***41***	***9***	***25***	***25***	***6***	***44***	***28***	***21***

Table 4.3:-Number of Respondents, Occupation and Annual income

Village	Occupation		Annual income (birr)	
	Cattle rearing	Employed	10-20,000	21-40,000
Boyina	12	13	25	0
Asboda	13	12	6	19
Total	***25***	***25***	***31***	***19***

In the sample house hold, there were 115 children; the smaller proportion is girls (30%). Of the total children, 60% of them go to school while the rest 40% were off school. In fact about 10% of the children were found under school age. Different reasons were forwarded for not sending 30% of the children to school; two of them were lack of awareness and children having responsibility in household chores.

Table 4.4:-Sample household, number of children and school children

Village	Nº of children		Nº of school children	
	Boys	Girls	Boys	Girls
Boyina	9	19	3	3
Asboda	66	16	50	13
Total	***75***	***35***	***53***	***16***

Although land is taken as communal property in the entire Afar Region, some people claim that they occupy limited plot of land particularly meant for agriculture practice. As reported, hundreds of out growers are working with sugarcane plantation. In line with that, the average land holding size is about 1/2 hectare. The total size owned by Boyina participants for example was only 6 hectare, while that of Asboda was 14 hectare Table 4.5).

Table 4.5:-Households who owned land

No of households	Size within the site	Size outside the site	Type of production
Boyina	-	75 hectare	Sugarcane
Asboda	-	25 hectare	Sugar/maize
Total	**-**	***100 hectare***	**-**

Except one person who reported that he produced maize, the rest are out-growers engaged in sugarcane production. The sample household owned about 1,455 livestock mainly cattle, goat, and camel. Goat and sheep represent the larger number; see Table 4.6. The price of the animals (at the time of data collection), in terms of the total value of livestock owned by the sample population has been ETB 2,720,000.

Table 4.6:Number, Type and Price of Livestock Owned by Respondents

Village	Type of livestock	No of livestock	Current price (birr) per livestock	Total Price/birr
Boyina	Cattle	319	2,000	638,000
	Goat/sheep	470	1,000	470,000
	Camel	84	10,000	840,000
Asboda	Cattle	284	2,000	568,000
	Goat/sheep	668	1,000	668,000
	Camel	30	10,000	300,000
	Total	***1,855***		***2,720,000***

4.3 Socio-Econimic Baseline Data

4.3.1 Demographic Characteristics

In the two settlement areas, there are 1,138 people: Boyna 554 and Asboda 584. The gender distribution of the two kebeles is significantly wide. For example in Boyna of the 554 dwellers only 93 of them are female. On the other hand the bigger majority of Asboda community is female, of 584 people they are 350 (Table 4.7).

Table 4.7: Number of People and Gender Proportion in, the two Villages

Kebele	Male	Proportion	Female	Proportion
Boyna	461	83%	93	17%
Asboda	234	40%	350	60%
Total	**695**		**443**	

In terms of accessing socio-economic services, Ayrolaf-Gebelaytu kebele is by far benefited. One reason for such favor is the fact that the kebele has been selected for a resettlement area. Initially, the settlers had been provided with water, energy, education and health services. However, since the last one year, even water has become scarce. The issue has been discussed in the other section of this chapter.

4.3.2 Land Use and Settlement Pattern

With 16 kebeles, and 4 small towns, the area of Dubti Woreda is about 5,400 km^2. Following the traditional land holding system, the entire land of the woreda belonged to no one but the community at large. The land holding size in the Dubti woreda is from 3 to 4.5 hectares per person. The big proportion of the fertile land, particularly that proximate Awash River, is assigned for sugar production- Tendaho sugarcane plantation. In fact, there are out-grower farmers who supply the same sugar cane for the factory. The rest body of the land is dry, sandy and barely habitable. The good example is Ayrolaf-Gebelaytu kebele which is dominantly dry and sandy; however, some part of the area is closer to the sugar plantation. Except for the government led settlement area, the land is practically empty, uninhabited. The site Ayrobera, as already mentioned, is also extremely dry and dusty, and it is a no man's land.

4.3.3 Religion, Language, Custom and Values

Ayrolaf-Gebelaytu residents belonged to mainly Afar speaking people. According to the kebele officials, nearly all of the residents are Afar. And yet, tribes, namely Asobakari, Bedewaita, Mandit, and Hintiba are dominant. Due to the proximity of Ayrolaf-Gebelaytu kebele to Semera town and the prevalent harsh climate of the area, nearly all of the kebele residents are resettled in to two separate places. The first settlement area is called Boina while the other is Asboda.

In both settlement areas, basic necessities such as water and health services were accessed through the effort made by Afar Regional government. However, due to engine failure, the supply of water and energy has been discontinued for more than a year. As the result, women, for example, are forced to travel for more than four hours per day to fetch water.

Photo 4.1: FGD in Boina village

4.3.4 Water Facility

Independent questionnaires were developed for energy and water sector offices at woreda levels with the aim of assessing sources and supply status around the site (see the attached format). Data on water sector is included with the assumption that clean and adequate water supply is among the priorities in the surrounding community. On the other hand, settings of Woreda Administration structure assign energy and water issues in one sector office.

With regard to water source and supply, Ayrolaf-Gebelaytu is supplied with communal tap water from Tendaho Sugar Project. It seems that Resettlement Action Plan was undertaken by the sugar project. However, currently this tap water supply is not functional due to technical failure in the electrical pump. These days, water is supplied to the residents using heavy trucks at a cost of ETB 6,000.00 per truck. Each day five trucks of water is supplied at a cost of ETB 30,000.00 per day. One can compare maintenance cost of existing water supply system with the cost of water transporting over a month, two months, and three months.

On the other hand, few households (nearly 25) located at closer to Ayrobera geothermal site do not have any access to water. They lived at the buffer zone of Ayrolaf-Gebelaytu kebele bordering with Serdo and Saha kebeles. There seems unclear administrative boundary among the kebeles.

Thus there is a strong need of residents to implement community projects to access potable water source (characterized by community participation in collaboration with other development organizations), parallel to the main geothermal project.

4.3.5: Education Facility, Ayrolaf-Gebelayitu Kebele

As it is depicted in Table 4.8, the kebele runs three schools. The first two schools, Dubti 2nd Ersha and Dubti 4th Ersha are located in the center of the two settlement sites. Although the peoples are known for being pastoralists with frequent mobility, the people were already settled. Such a life style would make it possible for the community to have access to Education.

Table 4.8: Number of Schools, Teachers and Students, Ayrolaf-Geblaytu Kebele

School name	Grade Level	Number of Students			Number of Teachers		
		Male	Female	Total	Male	female	Total
Dubti 2nd Ersha	Grade 1- 7	102	64	166	9	4	13
Dubti 4th Ersha	Grade 1-6	92	31	123	5	4	9
Gumeatameli	Grade 1- 2	287	33	320	2	-	2

Photo 4.2: A School in Asboda

Dubti 2nd Ersha conducts class up to grade 7 whereas Dubti 4th Ersha limited to grade 6 only. Students qualified for grade 8 have to travel 5 to 10 kilometer, which is very difficult taking in to account the economic condition and awareness level of the community. As per the information obtained from the representatives of the community, most of female students give up before completing grade 6 or 7. According to the observation of the study team, class rooms are wide enough and relatively properly equipped for teaching and learning process.

The third school, Gumeatameli, hosts larger number of students. It is located 41 kilometer away from the Woreda. The school provides class only for grade 1 and grade 2 students. According to the Woreda education office, except road there is no basic facilities such as water, electricity and latrine (Table 4.9) Data from the Woreda education office shows that student teacher ratio is extremely low i.e.143.5 (287:2).

Table 4.9: Level of Schools STR and Facilities, Ayrolaf-Gebelayitu Kebele

School Name	STR	Dropout rate	Water	Electricity	Latrine	Clinic	Road
Dubti 2nd Ersha	.08	zero	Yes	No	Yes	No*	Yes
Dubti 4th Ersha	.07	zero	Yes	No	Yes	No*	Yes
Gumeatameli	.00625	Zero	No	No	No	No	Yes

The clinics are not located within the school compound, but found at the center of their settlement village where students could access them easily. Dubti 2nd and 4th schools have better facilities. The student teacher ratio and dropout rate are encouraging. For example students access to clinics, latrine and water, and enjoy ventilation. Currently both schools do not have electric service. However, the electric line is already in place. As depicted in Table 4.9, the third school is devoid of facilities under discussion; thus, the situation calls for immediate attention.

4.3.6 Health Facilities

When compared to other Kebeles of Dubti woreda, Ayrolaf-Gebelaytu Kebele is said to be much better in accessing socio-economic services. For example each of the settlement areas has its own health centers run by 3 professionals in Boina and 4 in Asboda.

Table 4.10: Health Facility Centers, Ayrolaf-gebelaytu kebele

Village	Nº of nurses	Others
Boina	2	1
Asboda	2	2

Critical challenges were identified by respondents. In line with that, water has remained number one problem for all groups of participants. The issue has been given priority not only among the community but also offices and institutions (Table4.11). Lack of energy and shortage of animal feed were the second and the third serious challenges respectively facing the community of Boyina and Asboda.

Table 4.11: Major challenges of the Study area in Priority Order

Priority	Asboda	Boyna	Water/energy office	Health office
First	Water	Water	Water	Electricity
Second	Electricity	Animal Feed	Road	Water
Third	Animal feed	Energy-fuel wood	Education	Medicine

Table 4.12:Kebele Level Critical Health Ailment in Priority Order

Priority	Ailments
First	Water born disease
Second	Malaria

4.3.7 Woreda and Kebele Level Development Organizations

Tendaho Sugar Factory, one of the giant sugar factories is found in Dubti Woreda particularly in the project kebele. 84% of sample households are employees in the factory or on the plantation. The other big public enterprise in the project kebele is Semera Dry port which has also created and provided job opportunities to the community. The establishment of the Tendaho Sugar plantation/factory and the Dry Port in the Ayrolaf-Geblaytu Kebele has brought about a significant change in the economy and the life style of the community. In line with this, the existence of the two organizations brought about a positive impact on reducing the level of poverty. The experience of the community to work with big firms on wage basis is an asset and a fertile ground to join the test well drilling project.

Kebele Level basic infrastructures: The project site is located by the side of the main asphalt road, Addis Ababa to Djibouti, which allows the project site to be easily accessible. There is a network of electric power, meant to supply energy to the residents of the Ayrolaf-Geblaytu kebele, though power has not yet been released. Like the rest of the rural part of the country, the main source of energy in the kebele is biomass, in the form of firewood or charcoal.

According to the sample respondents, a household spends close to ETB 150 per month for electricity and fuel consumption. The kebele enjoys access to mobile and internet network. Other services like banking, fuel stations, hospitals and pharmacies are available in either Semera, or the woreda, Dubti.

Road Construction: The proposed site for test well drilling in Ayrobera is located about 7 km away from the main asphalt road, Addis Ababa-Djbuti. Thus, the implementation of the test well drilling requires the construction of about 7 kilometer road along the sandy land. Besides, there is a need to construct additional 5 kilometer (depending on the distance between test wells) road to move resources and machineries within the project area, from one potential test well to the other. The construction of roads will be relatively less costly.

4.3.8 Woreda Level Farming and Livestock

Dubti Woreda is one of the woredas of Afar Regional State. The woreda consists of 14 kebles, 4 of which are pastoralist, 8 are semi pastoralist and the remaining 2 are kebeles/ town.

Table 4.13: - Major types of crops produced in the semi pastoral areas

Major crops	Average/h	Land Coverage
Maize	29 quintal	753 hectare
Onion	180 boxes	41 hectare
Tomato	240 boxes	67 hectare
Green paper	9 boxes	5 hectare
Other crops		8 hectare

According to the woreda agricultural office, a total of 1,923 hectares of land is appropriate for farming. Recently most of the fertile land owned by the community in the woreda is used for sugar cane out-grow program. The livestock that are found in the woreda is indicated in Table 4.14.

Table 4.14:Number of livestock owned by sample group

Cattle	Donkey, horse mules	Sheep	Goats	Camel
40599	1591	46819	5727	5966

Although the community is dependent on livestock and livestock products, shortage of food is becoming more and more serious. One of the reasons is that the incorporation of fertile land into sugarcane development. Shortage of rain has also influenced the crop production, and feed for animals and /or grazing land. The view of the agricultural experts in the woreda agrees with the community representatives, in that the major problem of livestock breeding in all kebeles is lack of fertile land and water; mainly due to the inclusion of fertile land for sugar cane farming. Loss of livestock due to disease is becoming common, thus the government has been trying to compensate it by providing animal medicine free of charge.

4.3.9 Kebele Level Economy and Livelihood

The two major settlement villages of the kebele- Boina and Asboda, are located in different places. Although both villages are established within areas with fertile ground for business, there is no observable business like activities. In both villages there are only cooperatives shops owned and run by the community for basic goods and food items.

The entire community is mainly pastoralists, but nearly all households depend on wage from the sugar factory, sugarcane plantation and Semera dry port. As the data collected from a sample indicates, the annual income of nearly all households is from wage. About 84% of the sample is employees of the two government organizations. Only 16% of the 50 households are engaged in other activities. Except one person who completed high school, the rest didn't have the required skill and qualification to earn a better salary.

As mentioned earlier, members of both villages didn't engage in other agricultural work except sugar cane production. Almost all households in Boina village for example have 1 hectare of land used for farming sugar cane under outgrown program, and ½ hectare for grazing. Similarly each household in Asboda village own ½ hectare for out-grow program; however, no one owned privately land for grazing. As per the kebele officials, the sugar cane out-grow program was launched for the first time; thus, the actual annual production and income earned was not determined. In line with this, the sugar factory presumed sugarcane out grower with 1 hectare could earn annual income of ETB 35,000; and ETB 15,000 up to 20,000 on ½ hectare of land. It is on this assumption that the annual revenue of the sample from crop production was determined (see Table 4.15). Although the sugar cane outgrow program is new in Ayrolaf-Gebelaytu kebele, it has been implemented and feasible for people living around sugar cane factories elsewhere in Ethiopia. If well handled, the arrangement will have a significant positive impact on earning of the target community.

Table 4.15:Economic and Basic Social Services in Boyna and Asboda villages

N°	N° of family	Annual Income			Value of live stock	Farm land(h)	Grazing land (h)	Access to				Major Occupation
		Wage	Crop	Total				school	Health center	Water	Elec	
1	2	15000	35000	50000	51000	1	½	√	√	√	No	Employee
2	1	10000	35000	45000	40000	1	½	√	√	√	No	Employee
3	5	10000	35000	45000	135000	1	½	√	√	√	No	Employee
4	1	10000	35000	45000	135000	1	½	√	√	river	No	Employee
5	1	10000	25000	35000	75000	1	½	√	√	√	No	House wife
6	4	10000	25000	35000	74000	1	½	√	√	river	No	Employee
7	4	15000	35000	50000	90000	1	½	√	√	√	No	Employee
8	2	12000	35000	47000	140000	1	½	√	√	√	No	Employee
9	1	15000	35000	50000	51000	1	½	√	√	√	No	Employee
10	3	20000	35000	55000	105000	1	½	√	√	√	no	Employee
11	5	12000	35000	47000	40000	1	½	√	√	√	No	Employee
12	4	10000	35000	45000	120000	1	½	√	√	√	No	Employee
13	3	15000	35000	50000	80000	1	½	√	√	√	No	Employee
14	2	6000	35000	41000	64000	1	½	√	√	√	No	House wife
15	4	10000	35000	45000	44000	1	½	√	√	√	No	Employee
16	7	15000	35000	50000	36000	1	½	√	√	√	No	Employee
17	1	15000	25000	40000	76000	1	½	√	√	√	No	Employee
18	5	12000	25000	37000	126000	1	½	√	√	√	No	Employee
19	3	5000	35000	40000	52000	1	½	√	√	√	No	Semi-Past
20	1	12000	35000	47000	55000	1	½	√	√	√	No	Employee
21	7	10000	35000	45000	65000	1	½	√	√	√	No	Employee
22	4	15000	35000	50000	133000	1	½	√	√	√	No	Employee
23	6	10000	35000	45000	58000	1	½	√	√	√	No	Employee
24	4	12000	35000	47000	90000	1	½	√	√	√	No	Employee
25	5	10000	20000	30000	78000	1	½	√	√	√	No	Pastoralist

Asboda Village												
1	6	12000	10000	50000	30000	½	No	√	√	River	No	Employee
2	5	12000	20000	20000	30000	½	No	√	√	River	No	Employee
3	4	20000	20000	40000	29000	½	No	√	√	river	No	House wife
4	3	40000	0	40000	80000	½	No	√	√	river	No	Employee
5	14	40000	15000	55000	120000	½	No	√	√	river	No	Employee
6	8	40000	15000	55000	60000	½	No	√	√	river	No	Employee
7	5	30000	20000	50000	30000	½	No	√	√	River	No	Employee
8	8	60000	20000	80000	44000	½	No	√	√	River	No	Employee
9	6	15000	35000	50000	51000	½	No	√	√	River	No	Employee
10	7	20000	20000	40000	105000	½	No	√	√	river	no	Employee
	Sub T			1542000								

No	No. family members	Annual Income			Total value of live stock	Farming land in hectare	Grazing land in hectare	Access to				Major occupation
		Wage &Others	Crop	Total				school	Health center	Water	Electric	
11	8	12000	20000	32000	35000	½	No	√	√	River	No	Employee
12	5	15000	20000	35000	78000	½	No	√	√	River	No	Employee
13	4	12000	25000	37000	52000	½	No	√	√	River	No	Employee
14	3	6000	25000	31000	35000	½	No	√	√	River	No	House wife
15	1	20000	20000	40000	43000	½	No	√	√	River	No	Employee
16	2	18000	18500	36500	46000	½	No	√	√	River	No	Employee
17	4	20000	18500	38500	36000	½	No	√	√	River	No	Employee
18	5	10000	20000	30000	95000	½	No	√	√	River	No	pastoralist
19	3	20000	20000	40000	45000	½	No	√	√	River	No	Employee
20	1	30000	18500	38500	36000	½	No	√	√	River	No	Employee

21	6	15000	20000	35000	38000	½	No	√	√	River	No	Employee
22	8	30000	20000	50000	91000	½	No	√	√	River	No	Employee
23	3	20000	20000	40000	82000	½	No	√	√	River	No	Employee
24	1	30000	18500	48500	120000	½	No	√	√	River	No	Pastoralist
25	2	10000	18500	28500	60000	½	No	√	√	River	No	Employee
	Sub T			**560500**								
	G. Total			**2102500**								

The average annual real earnings of the household (excluding the expected revenue from the sugar cane outgrow program) is ETB 17,060 and only ETB 1,421 per month. The lowest annual earning is as low as ETB 5,000 or ETB 416 per month. The highest annual income among the sample was ETB 60,000 (ETB 5000 per month). This shows how difficult life could have been without earning from employment.

Assuming that the presumed annual revenue (from sugar cane outgrow program) will be actualized, the estimated average income of the sample will reach ETB 42,050. While the lowest is ETB 20,000, the highest is ETB 80,000. In other words, the average monthly income of the household is expected to grow to ETB 3504.167; the highest ETB 6,666 and the lowest ETB 1,666.

Being semi- pastoralist, every household masters the skill of livestock breeding. However the return from livestock breeding has been low when seen from the number of livestock that each family owned. Two reasons can be attributed for the lower return: severe shortage of grazing land and the culture/values of the Afar community (as it does not encourage sale of livestock products such as dairy products. The estimated value of live stocks as obtained from the sample group is as low as ETB 29000 and as high as ETB 140,000.

4.3.10 Ecological Features

4.3.10.1 Flora

The National Biodiversity and Action Plan (IBC,2005) recognizes the following new classification of ecosystems in Ethiopia: Afroalpine and Sub-Afroalpine, Dry Evergreen Montane Forest and Grassland Complex, Moist Evergreen Montane Forest, *Acacia-Commiphora* Woodland, *Combretum-Terminalia* Woodland, Lowland Semi-evergreen Forest, Desert and Semi- Desert Scrubland, and Inland Waters.

These diverse ecosystems have endowed Ethiopia with a diverse biological wealth of plants, animals, and microbial species. In the view of this, the study area falls within the *Acacia- Commiphora* woodland which occupies the main rift valley, desert and semi-desert Scrubland towards the Afar Depression.

According to Simon and Zerihun (2006), the rift valley area where most of the proposed geothermal sites are located has three tree-shrub type of vegetation which can be recognized based on species composition and differences in environmental factors. These are: (1) the highly extensive *Acacia tortilis*, *A. Senegal* and *A. seyal* dominated type on flat and undulating terrain; (2) *Acacia tortilis, Euphorbia candelabrum* and *Croton dychogamus*dominated type on rocky substratum, and (3) *Oleaeuropaea*ssp. *cuspidata*, *Acacia ebtaica* dominated type at higher altitude along the escarpment of the Rift Valley. Tendaho-Dubti areas fall in the third category.

Conservation attentions need to be employed to grasses and sedge as they are used as food for animals. In Afar, animals play a central role in all walks of life. Cattle, goats and camels, in particular, have values that go beyond the production of meat. Their importance is based on the full set of services they provide (milk, meat, hides, draught power), and above all they have cultural symbolism. Those plants identified by the community as having medicinal value need to get conservation attention. As a representative effect, Environment and Rural land office head of Dubti Woreda remind the study team that eradication of draught resistant trees due to expansion of sugar project causes dislocation of local residents beyond what has been planned by the government. Afar community uses these draught resistant trees as an indicator of water availability in that surrounding. He emphasizes the necessity of public participation and benefit involvement in project formulation.

4.3.10.2 Fauna

The two ecosystems mentioned above, namely, *Acacia- Commiphora* woodland and Desert and Semi-Desert Scrubland are also home to a high diversity of wildlife. Around Ayrobera Geothermal site, on Dubti Woreda level, the following Common Wildlife are recorded which include: Hyena (*Crocutacrocuta*), Anubis Baboon (*Papioanubis*), Jackal (*Canisaureus*, *C. mesomelas*), Bush duiker (*Sylvicapra sp.*), Vervet monkey (*Cercopithecusaethiops*), Porcupine (*Hystrixcristata*), Leopard (*Pantherapardus*), Guenther's dikdik (*Rhynchotragusguentheri*), Genet (*Genetta* sp.), Soemmering's gazelle (*Gazellasoemmeringii*), and Warthog (*Phacochoerusaethiopicus*). According to the informants,

small mammals such as rats, different kinds of reptiles are found in the area. Some of the bird species found include: Ostrich (*Struthiocamelus*), Goose (*cyanochen sp.*), Francolin (*Francolinus sp.*), Pigeon (*Treton* sp.), Guinea fowl (*Acrylliu sp.*) and Dove (*Streptopelia sp.*). We believe that there are a lot more mammals as well as birds but it seems that there was no detailed survey carried out in the area.
The biodiversity in actual project site seems low as the area is arid- dry –windy flat land with little vegetation. The study team was able to observe only wild goats (local name) and some reptiles around the project area.

Potential tourist attraction or recreation sites: One of the objectives of national parks is to "set aside certain areas of outstanding scenic and scientific value for the enjoyment of present and future generations" and thereby, visit is an essential condition for the existence of national parks. With about 320 species of mammals, Ethiopia is one of Africa's most diverse countries for mammals. A great selection of the famous African mammals is still present in the country. This diverse wildlife, which includes 36 endemic species potentially, could make Ethiopia one of the top safari destinations in Africa. Species whose conservation state have been a global concern, include: 5 critically endangered 8 endangered 12 near-threatened species and 27 vulnerable species. For the survival of all those globally concerning species, Ethiopia plays a critical role.
The study area has also a number of spectacular scenic landscapes such as the sulphur springs at Lake Assale, Erte Ale Vocano; the Fenatle volcanic mountain, the traditional salt mining and camel caravan in Dallol which play a great role as tourist attractions. With this respect, the selected project site is does not serve as national park and not suitable for potential tourist attraction due to its harsh climate, flat topography and negligible diversity.

Possible impacts of the project on the ecology: There is a debate as to whether geothermal resource development and wildlife conservation are compatible. The key socio-economic impacts associated with developing these resources involved both positive and negative, opening up and modernizing sites on one hand, and loss of wildlife habitat as well as visual intrusion in scenic tourist areas on the other. Because capacity and areal coverage the geothermal plant to be developed is not yet determined, it is not possible to envisage the magnitude of the impacts of the project on the existing fauna and flora of the surrounding areas. In general however, it is an established fact that geothermal activities mostly affect vegetation by gaseous emissions, physical removal of vegetation to pave way for roads, drilling pads, and buildings and hot or cold geothermal brine flowing on the surface. Disposal of geothermal water on the surface can cause high metal concentrations in soils and vegetation.

Table 4.16: Regional Level National Parks, Wildlife Reserves, and Controlled Hunting Areas

National Parks			
Site	**Managed by**	**Established**	**Area in ha**
AbijataShala Lakes	Oromia	1963	88,700
Awash	Oromia & Afar	1958	75,600
Geralle	Somali	1998	385,800
YangudiRassa	Afar	1969	473,100
Wildlife Reserves			
Alledeghi	Afar		193,389
Awash west	Afar		415,000
Gewane	Afar		-
Mille Serdo	Afar		650,354
Controlled Hunting Areas			
Aluto	Oromia		28,000
Bilen Hertalie	Afar		109,000
MelkeSadi	Afar		-
TelalkDewe	Afar		72,000

(Data source: Different Publications)

4.4. Public Consultation and Stakeholders Meetings

4.4.1 Objectives of Public Consultation

During the field assessment, consultations were carried out with different stakeholders: This means, public consultation with the community and meetings with the rest of key stakeholders of the project. The different groups that participated in the consultation include, representatives of the community, woreda officials, kebele authorities, experts and officials from Geological Survey of Ethiopia (GSE). The following section deals with the whole issues of the consultations.

The objective of the consultations were:

- To create a platform for the key stakeholders to actively participate in the project, and what is more, to have a say in the planning and implementation of the project.
- To inform the concerned key stakeholders about the nature, scale and other features of the project.
- To discuss about the potential ion benefits and adverse impacts that may occur in the project cycle.
- To capture the attitude of the stakeholders particularly the community on the selected site.

4.4.2 Approaches to Consultation

All key stakeholder meetings were chaired by the concerned authorities. The consultation took place in different days in the offices of the stakeholders. All members of the study team attended the consultation program. Participants' pictures were taken while the consultation took place.

The other consultation was public consultation. Participants were representatives of the community from two villages that are found in Ayrolaf-Gebelaytu kebel. In each village two public consultation were conducted, the first with community representatives the other with elders. The entire public consultation took two days, one day for each village. The whole consultation process was audio taped, pictures taken and video recorded. The entire activity of the consultation and the result of the findings as mentioned above is presented here in different sub-titles.

4.4.4 Stakeholders' Consultation

Regional level consultation (February 13th 2016): The team of experts conducted meetings with the concerned regional bureaus, mainly with Afar Region water and energy bureau representatives (in Semera). The objective of the consultation was to explain all about the envisaged project. In addition, the meeting was meant to secure information about the status of the test well drilling, and other issues such as facilities, potential, and plans available in the regions. The other purpose of the consultation was to receive permission letter for the study team that would allow conducting the assessment and consulting concerned institutions. Many of the objectives of the consultations were achieved (see the names of officials participated in the consultations at Appendix).

Woreda consultation (14thFebruary2016): Consultation was conducted with Dubti Woreda officials. Different officials and experts including sector heads were present (see Appendix). The purpose of the discussion was to introduce them about the objective of the envisaged project, to capture their views over the project; to discuss about the adverse impacts of the project, if any, and seek alternate mitigation measure.

The consultation was indeed successful and achieved its objective. The woreda representatives confirmed that they would welcome the project to the extent that it would bring about adverse impact. In line to this, they had bad experience concerning geothermal projects. According to them, there was an explosion in one of the geothermal well (TD 6) in 2001, and yet they still hope the envisaged test well drilling wouldn't entail similar adverse impact. For them, Afar in general and Dubti woreda in particular are one of the least economically backward areas of Ethiopia. The prevailed pastoralist cultural value coupled with the harsh climate of the region attributed to limited attraction of investment. Participants also assured the study team that, not only the woreda administration but also the community in the project area would do their best and cooperate for the success and implementation of the project.

Photo 4.3: Consultation with Dubti Woreda Officials

Consultation with Geological Survey of Ethiopia (GSE), (8th February 2016): The study team conducted discussion with Geological Survey of Ethiopia (GSE), at their head office in Addis Ababa. Participants included concerned officials of the organization and Japanese experts from JICA (Appendix). The purpose of the consultation was to introduce the study team with both stakeholders, listen briefings of JICA on the existing status of the geological and other technical works so far done in the project site. The discussion carried out mainly through questions and answers. The consultation wound up when the required explanation was exhaustively done.

GSE staff stationed in Afar Region, at Semera town, was also consulted about how the study activity would go along the existing test well drilling activities. Following the consultation, representative of GSE at the site, facilitated the assignment of the study team. She also guided the team to visit the entire site and the surrounding areas. What is more she introduced the team members with the community who are settled at the far end of the site. The consultation made both in Addis and Semera with GSE staff was valuable and fruitful.

4.4.4 Public Consultation

Public consultations were undertaken in the two settlement areas of Ayrolaf-Gebelaytu, kebele. Both settlement areas are located within the kebele but far from the projected site. The participants of the meetings were: officials of the kebeles, elders and religious leaders; representatives of the community, and representatives of women and youth. The objective of the consultations were to (i) make aware the community about the project (ii) to capture their views on the project, i.e., their worries concerning negative impacts, if any, and their hopes and their expectation from the project (iii) solicit their views on the possible mitigation measures to be taken if they think of negative impacts.

4.4.4.1 Consultation with Boina village community (February 18/ 2016)

The consultation meeting was conducted in Sugar cane plantation workers camp. The meeting was chaired by the study team leader. About 25 persons attended the meeting. This includes two officials from Dubti woreda administration, all kebele leaders and community representatives as mentioned above. After the team leader introduced the agenda and the purpose of the consultation, participants actively engaged in the discussion. The summary of the discussion is as follows: The representatives in general were happy about the project. None of the participants were against the prospective test well drilling. According to them the project is free from human and animals. The area is totally abandoned due to the harsh climatic condition. In this respect therefore the introduction of the new project is a blessing. Villagers however expressed their worries over the project. According to them, similar project had been undertaken in the woreda some years back. The result was totally discouraging as it was blasted with a reason unknown to them. What is more the project is still suspended.

Photo 4.4: Consultations with Boina village community

Consultation with elders: Immediately after public consultation with Boina villagers wound up the study team had a session with selected persons involving community elders, and religious leaders of the same village. The discussion focused on the values of community, means of conflict resolution, and their views over development projects in general and test well drilling in particular; about ownership claim for site area. According to the elders the site has been deserted and known for no man land. The only thing that has been taken as valuable was the thermal smoke used by some people for medicinal purpose. And yet, the emission of the smoke is limited to a very small area; a maximum of a fourth of a hectare. According to them, if the area developed for geothermal project, the community would benefit the thermal hot water much better than the current use. The do nothing alternative is highly disadvantageous. In general, the elders and religious leaders were over joined on the project which would be launched on an area where it has been abandoned and deserted.

Photo 4.5: Consultations with Boina Elders

4.4.4.2 Consultation with Asboda village community (February 20/2016)

Similar to Boina villagers, consultation was undertaken with Asboda community in the kebele school compound. The same officials from both Dubti and Ayrolaf-Gebelyatu kebele were present in the meeting. Mainly, representatives of the community from different social groups attended. Points rose, and issues discussed were almost identical with Boina consultation session. For example, the

representatives were highly positives on the launching of the test well drilling. Similarly, their reservation geared to the past bad experience, i.e., the failure of similar geothermal project in 2011. Even if their past experience is gloomy, representatives reiterated that they have been optimist since then; according to them they wish the failed project would continue and what is more other new geothermal projects would be launched. As they said, the issue of the claim over Ayrolaf between two kebeles has been solved in the near past. Thus, project owner shouldn't get worry about ownership claim in both the site and the surrounding areas.

Photo 4.6: Consultations with Asboda Village Community

Consultation with elders: The public consultation with the villagers was followed by a meeting with representatives involving elders, and religious leaders of Asboda village. The theme of the session was around the values of community, means of conflict resolution, and their views over development projects in general and test well drilling in particular, and what is more, about ownership claim over the site. Similar to the views of elders from Boina, the site belonged to no one because it has been extremely unfavorable for people and livestock to live on. In fact, people even from distance areas go to certain location of the site to make use of the thermal smoke, which they believe would heal different ailments such as body ache. The study team assured the participants that the test well drilling has nothing to do with limiting the thermal smoke. One purpose of the project is to identify the extent and magnitude of the thermal power in the area. If the result of the test well drilling produced positive,

the next phase of the project would make the use of the thermal smoke easy and comfortable for users. The consultation was conducted with mutual agreement and understanding.

Photo 4.7: Consultations with Asboda elders

Public disclosure: The report of the study would make known to the concerned stakeholders and the public at large. The first action would be to put it in the website of the project owner. Then copies of the report would be sent to the concerned authorities/offices. In addition the project owner needs to open its door and allow users to make use of the report in all possible means prior to the processing of the project.

CHAPTER FIVE: IMPACT ASSESSMENT

5.1 Overview

As a rule of thumb, ESIA studies are usually carried out side-by-side or in parallel (or immediately after) with techno-economic studies. Both studies need to have harmonized data to share with. Basic data such as generation rates, plant size, amounts etc. that are considered as important inputs for ESIA are usually taken from techno-economic studies. However, in conditions of such data-gaps, assumptions generated from professional judgment are employed. It is strongly believed that these assumptions are not far from what might be expected after completion of techno-economic study findings and may not significantly affect the final outcome. To this effect, widely practiced geothermal technologies with moderate capacity have been chosen as a representative power plant so as to carry out the task of impact assessment.

5.2 Impact Rating Method

No single best assessment method is yet universally practiced. Thus, a combination of methods can be applied for impact assessment. Checklists and environmental guidelines along with locally accepted standards are generally applied for most of the cases. As much as possible all significant impacts are evaluated using appropriate parameters.

In this section, nature, extent, significance etc. of potential impacts is assessed using EPA national guidelines. This ESIA process includes prediction (e.g. duration, intensity, severity, status, reversibility) of impacts based on legal requirements. The purpose of this activity is to decide whether the project is likely to cause significant adverse environmental effects resulting from various project phases. The assessment is performed in three steps:

Step 1: Based on the nature of project and environmental baseline, a detailed matrix of project activities and environmental receptors is prepared and it is determined whether an interaction exists between an activity and a receptor.

Step 2: Based on the interactions in Step 1, potentially significant impacts due to the proposed changes are identified. These impacts may be beneficial/ adverse, direct/indirect, reversible/ irreversible and short-term/ long-term.

Step 3:Adverse impacts that are rated as “low” or “medium” or “high” are treated only qualitatively while all potentially *significant impacts* are quantitatively evaluated (Table 3.1).

Table .1: Criteria for impact assessment

Rating parameter	Definition	Scale	Description	Score
Duration	*Describes how long the impact persists*	Very short term	less than a month;	1
		Short term	Months but less than a year;	2
		Medium term	More than a year but less than the operational life of the project	3
		long term	Over the operational life of the project	4
		Residual	Permanent; remains after the closure	5
Extent	*Describes coverage of impacts*	Limited	Impact affects the immidiate site only	1
		Small	Impact affects immidiate site & surrounding	2
		Medium	Impact affects the entire project area	3
		Large	Impact affects including neighboring areas	4
		Very large	Impact that affects greater area than neighboring	5
Likelihood	*Describes the probability or chance a given impact could occur*	Highly unlikely	The impact is highly unlikely to occur	0.2
		Unlikely	The impact is unlikely to occur	0.4
		possible	The impact could possibly occur	0.6
		Probable	The impact will probably occur	0.8
		Definate	The impact will occur	1
Intensity	*Describes magnitude of the impact*	Insignificant	Impact is of a very low magnitude	1
		Low	Impact is of low magnitude	2
		Medium	Impact is of medium magnitude	3
		High	Impact is of high magnitude	4
		Very high	Imact is of of highest order	5
Consequence	*Quantitative approach used to describe combination effects of Severity & Extent*		Consequence = (Severity + Extent)/ 2	
Severity	*Quantitative approach used to describe combination effects of Intensity & Duration*		Severity = (Intensity + Duration) / 2	
Significance *(both for +ve &-ve impacts*	*A mathematical tool used to describe combination effects of Consequence & Probability*	Very low	Impact is negligeble; No mitigation required	≤ 1
		Low	Impact is of low order; Mitigation could be considered to reduce impact but does not affect environment acceptably.	> 1 & ≤ 2
		Moderate	Impact is real but not sustantial in relation to other impacts. Mitigation should be implemented to reduce the impact	> 2 & ≤ 3
	Signifi =(Conseq + Probability)/ 2	High	Impact is substantial. Mitigation is required to lower impacts to acceptable levels	> 3 & ≤ 4
		Very high	Impact is of the highest order possible. Mitigation is required to lower impacts to acceptable levels or other project option.	> 4 & ≤ 5

Source: Different documents

To quantify identified potential risks of the project, score range method can be used to provide distinction between risks. Impact rating is determined based on two parameters: the "significance of impact" and the "likelihood of impact occurrence". Significance depends mainly on the nature and size of the activity and the environmental sensitivity while the "likelihood of occurrence" depends mainly on nature of the activity and the control measures to be taken. Thus, impact assessment is an important pre-curser for effective impact evaluation. Thus, the beginning of this task starts from narration of

identified potential impacts from common geothermal plant development and particularly on test well drilling at various phases.

5.2 Geothermal Development Stages and Associated Environmental Impacts

Potential environmental impacts are associated with the different stages of geothermal energy development. The main stages of geothermal energy development involve:

- Reconnaissance Stage
- Prefeasibility Stage
- Feasibility stage
- Construction and operation of geothermal plant

The reconnaissance surface survey (geological, geochemical and airborne geophysical survey at a scale of 1: 500,000 and above) may not have any significant interaction with the environment.

The prefeasibility stage involves:

- Semi Detailed Surface Exploration (geological, geochemical, and geophysical) at a scale of 1: 100,000 to 1: 250,000 scale. No significant interaction, unless road construction is required
- Detailed Surface Exploration (geological, geochemical, and geophysical) at a scale of 1: 50, 000 or lower scale. No significant interaction, unless road construction is required
- Temperature Gradient Drilling (wells usually 50- 300m are drilled for measurement). Road construction and drilling fluids interact with the environment.
- Exploratory Drilling (2-3) deep wells are drilled per target to a depth up to 3000m using a deep drilling rig

Potential environmental impacts during the prefeasibility stage are associated with the following activities:

- Road construction
- Excavation of drill site, back filling with selected material, leveling and compaction for drill pad preparation (200mx200m)
- Grouting with cement of the drill pad surrounding with small rig by drilling about 20 wells of 30m depth
- Drill cellar preparation with concrete and Iron bars
- Mobilization
- Drilling (Drilling fluids include: Fresh water (3500 Cubic m/day), bentonite mud, Soap and air, chemical additives)
- Well testing vertical discharge to clear wells
- Production testing

The Feasibility Stage involves:

- Appraisal drilling
- Delineation of the boundary,
- Detailed further resource evaluation
- Production drilling
- Power plant design
- Design of other physical structures

The feasibility study stage may cause some environmental impacts if not conducted with due consideration of the environmental systems.

The construction and operation stage involves:

- Construction of drilling plant and other components
- Construction of camp
- Monitoring

Most of the environmental damages associated with the test well drilling will be short term, if there is. To capture all potential impacts, it is necessary to have a completed techno-economic feasibility study. However, the current ESIA study is at a preliminary stage where potential impact assessment can be qualitative based on secondary information and experiences of similar projects in other countries. Therefore, in the absence of a complete techno-economic feasibility study of the project, the study team can only undertake a preliminary ESIA. From discussion made in the previous chapter of project description, the following potential impacts may need further elaboration for credible assessment and evaluation.

5.3 Identified Impacts on Natural Environment

5.3.1 Gaseous emissions

Gaseous emissions result from the discharge of non-condensable gases (NCGs) that are carried in the source stream to the power plant. For hydrothermal installations, the most common NCGs are carbon dioxide (CO_2) and hydrogen sulfide (H_2S), although species such as methane, hydrogen, sulphur dioxide, and ammonia are often encountered in low concentrations. Emissions of H_2S – distinguished by its "rotten egg" odor and detectable at 30 parts per billion – are strictly regulated to avoid adverse impacts on plant and human life. Studies conducted at the geothermal prospect sites in Ethiopia showed that the H2S concentration is relatively high.

Emissions can be managed through process design. In steam and flash plants, naturally occurring NCGs in the production fluid must be removed to avoid the buildup of pressure in the condenser and the resultant loss in power from the steam turbine. The vent stream of NCGs can be chemically treated and/or scrubbed to remove H_2S, or the NCGs can be recompressed and injected back into the

subsurface with the spent liquid stream from the power plant. Both of these solutions require power, thereby increasing the parasitic load and reducing the plant output and efficiency. Binary plants avoid this problem because such plants only recover heat from the source fluid stream by means of a secondary working fluid stream. The source geo-fluid stream is re-injected without releasing any of the non-condensable.

The selection of a particular H_2S cleanup process from many commercially available ones will depend on the concentration of contaminants in the geo-fluid stream and on the established gaseous emissions standards at the plant site.

So far in Ethiopia, there are no standards to be met for the emission of CO_2 and H_2S. Nevertheless, geothermal steam and flash plants emit much less CO_2 on an electrical generation basis (per megawatt-hour) than fossil-fueled power plants, and binary plants emit essentially none. The concentrations of regulated pollutants – nitrogen oxide (NOx) and sulfur dioxide (SO_2) – in the gaseous discharge streams from geothermal steam and flash plants are extremely minute.

5.3.2 Water pollution

Liquid streams from well drilling, stimulation, and production may contain a variety of dissolved minerals, especially for high-temperature reservoirs (>230°C) which may not be the case in similar projects. Some of these dissolved minerals (e.g., boron and arsenic) could poison surface or ground waters and also harm local vegetation only in some locations. Liquid streams may enter the environment through surface runoff or through breaks in the well casing. Surface runoff can be controlled by directing fluids to impermeable holding ponds and by injection of all waste streams deep underground.

To guard against fluids leaking into shallow fresh-water aquifers, well casings should be designed with multiple strings to provide redundant barriers between the inside of the well and the adjacent formation. Nevertheless, it is important to monitor wells during drilling and subsequent operation, so that any leakage through casing failures can be rapidly detected and managed.

5.3.3 Solids emissions

There is practically no chance for contamination of surface facilities or the surrounding area by the discharge of solids *per se* from the geo-fluid. The only conceivable situation would be an accident associated with a fluid treatment or minerals recovery system that somehow failed in a catastrophic manner and spewed removed solids onto the area. There are no functioning mineral recovery facilities of this type at any similar project elsewhere.

5.3.3.1 Noise pollution, dust and vibration

Noise from geothermal operations is typical similar to many industrial activities. The highest noise levels are usually produced during the well drilling, stimulation, and testing phases when noise levels ranging from about 80 to 115 decibels. A-weighted (dBA) may occur at the plant fence boundary.

During normal operations of a geothermal power plant, noise levels are in the 71 to 83 decibel range at a distance of 900 m. Noise levels drop rapidly with distance from the source, so that if a plant is sited within a large geothermal reservoir area, boundary noise should not be objectionable. If necessary, noise levels could be reduced further by the addition of mufflers or other soundproofing means but at added cost.

During normal operations, there are three main sources of noise: the transformer, the power house, and the cooling tower. Because the latter is a relatively tall structure and the noise emanates from the fans that are located at the top, these can be the primary source of noise during routine operation.

Air cooled condensers employ numerous cells, each fitted with a fan, and are worse from a noise perspective than water cooling towers, which are smaller and use far fewer cells for a given plant rating. The air cooled systems may not be recommended in the Ethiopian context as ambient temperature is relatively high in the prospected Ayrobera site.

However, it should be noted that test well drilling plants will likely be located in locations where water may be in short supply, they may require air-cooling, and proper attention may be needed to muffle the sound from their air-cooled condensers.

Drilling activities and movement of trucks carrying heavy load machineries cause dust and vibration. On top of that and in the absence of project intervention, topography //land scape// of the Ayrobera project site by itself is a wide-flat and sandy with ash. The prevalent strong wind in the area is capable of creating visual intrusion and induces health risks. Thus, the proposed drilling activity will have cumulative effect with respect to dust. As the project area is susceptible for seismic, huge vibrations may also exacerbate the seismic risk.

Soil contamination and degradation: Soil contamination due to geothermal energy development during its different stages is very minimal. However, soil erosion could be a problem if the various activities are not managed properly.

5.3.3.2 Land use

Land footprints for test well plants vary considerably by site because the properties of the geothermal reservoir fluid and the best options for waste stream discharge (usually reinjection) are highly site-specific. Typically, the power plant is built at or near the geothermal reservoir because long transmission lines degrade the pressure and temperature of the geo-fluid. Although well fields can cover a considerable area, typically 5 to 10 km^2 or more, the well pads themselves will only cover about 2% of the area. With directional-drilling techniques, multiple wells can be drilled from a single pad to minimize the total wellhead area. However, it is important to note that availability of land is not a major challenge in the Ayrobera geothermal prospect area; it is a no man's land.

Gathering pipelines are usually mounted on stanchions, so that most of the area could be used for farming, pasture, or other compatible use. The footprint of the power plant, cooling towers, and auxiliary buildings and substation is relatively modest. Holding ponds for temporary discharges (during drilling or well stimulation) can be sizeable but represent only a small fraction of the total well field.

5.3.3.3 Land subsidence

If geothermal fluid production rates are much greater than recharge rates, the formation may experience consolidation, which will manifest itself as a lowering of the surface elevation, i.e., it may lead to surface subsidence. This was observed early in the history of geothermal power at the Wairakei field in New Zealand where reinjection was not used. Subsidence rates in one part of the field were as high as 0.45 m per year. Wairakei used shallow wells in a sedimentary basin. Subsidence in this case is very similar to mining activities at shallow depths where raw minerals are extracted; leaving a void that can manifest itself as subsidence on the surface. After this experience, other geothermal developments adopted actively planned reservoir management to avoid this risk.

Most of geothermal developments are likely to be in granitic-type rock formations at great depth, which may contain some water-filled fractures within the local stress regime at this depth. After a geothermal well is drilled, the reservoir is stimulated by pumping high-pressure water down the well to open up existing fractures (joints) and keep them open by relying on the rough surface of the fractures. Appropriate precautions should be considered concerning the depth as well as reinjection of the geothermal fluid. In particular case of Dubti, the shallow reservoir is estimated at the depth of 300 to 500m, so the ground subsidence may not occur.

5.3.3.4 Water use

Geothermal projects, in general, require access to water during several stages of development and operation. Water use can be managed in most cases to minimize environmental impacts. The upcoming feasibility study shall clearly identify and evaluate the availability and potential of water supply sources at Ayrobera site. Two options are sited: One, from Dubti irrigation pond through pipelines; the second one is by drilling sub surface ground water and abstract the resource using electrical pump.

Access to potable (treated) water is still a priority. Water resource competition from currently growing (expanding) sugar industries is pessimistically perceived by the community. Respondents were asked about the negative impact of the project on water in terms of pollution, water supply/ system; the possible competition of the project for the existing water resources; and options to reduce or avoid the impacts. The finding reveals that the community believed the project would bring about no negative impact. However in terms of the critical shortage of water all community in all sites required the supply of water at least in their respective kebele.

5.3.4 Other Impacts

5.3.4.1 Resource competition

It is a collective term used to evaluate pressure on existing land use; competition on farm site and grazing land; clearing of bushes; pressure on existing flora & fauna; increased price on locally available products and services; water resource competitions. Impacts on each of these socio-environmental components are discussed in the subsequent section.

5.3.4.2 Fauna, flora and biodiversity

Ayrobera project site is arid area covered mainly with sand ashes. Few bushes are found here and there. Desert goats (local name) and reptiles are observed in the area. Fauna and flora found in the Dubti Woreda are discussed in the Baseline chapter. Even though productive well fields can cover considerable area, gathering pipe lines are mounted on stanchions so that most of the available area remains unaffected (even in the production phase). Thus, the existing biodiversity may not be disturbed. The impact on biodiversity during test well drilling phase is almost negligible.

5.3.4.3 Local warming

Geothermal steam releases heat along with CO_2 to the surrounding. Other secondary heat sources are condensers (heat exchangers), air fans; lengthy transmission pipe lines etc. These heat sources are suspected to enhance local warming contributing to the global. Sufficient reference literature may not be available to determine significance of this issue.

5.3.4.4 Deforestation

With respect to energy in few households, kerosene lamps and solar cells have been used, particularly in health posts and schools. However, the assessment reveal that the main source of energy both for cooking and light is fuel wood, coal and dung. Thus, existing pressure on natural resources and consequent degradation of environmental quality needs to be assessed. The impact of wide use of wood and coal would be not significant as the number of rural community is few and scattered, compared to the available resource and its regenerative capacity. In addition to this, energy consumption per capita of the community is very low. Social impacts such as unnecessary time and labor wastage should also be addressed.

5.3.4.5 Occupational Safety and Health

Out of many, major safety issues during test well drilling phase are: Safety on Rig operation; Gas blow outs; and hydrogen sulphide emission. Safety issues for power plant development are too technical and are not included in the scope of this study; it requires an institutional arrangement during operational phase through monitoring and auditing activities.

Uncontrolled well blowouts may bring injuries or loss of life, environmental damage, wasting of resources, and loss of equipment. Blow-out-prevention equipment (BOPE) capable of shutting in the well during any operation shall be installed on the surface casing tested, and maintained ready for use at all times. Fig 3.1 depicts such representative controlling equipment.

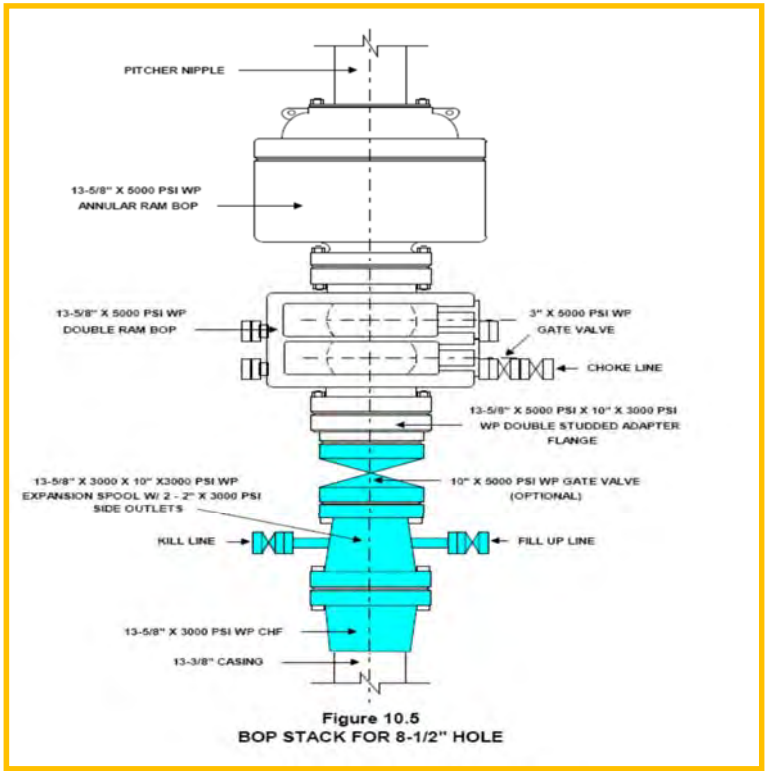


Fig 5.1: Representative controlling equipment

5.3.4.6 Community Safety and Health

As the project area is arid zone with water scarcity the surrounding community and cattle might be forced to consume pond water that is supposed to be disposed. The other community health risk emanates from gaseous emission, noise and increased traffic movements.

5.3.4.7 Waste disposal of Cuttings and Mud Products

Huge amount of waste is expected from this activity, particularly if the number of test wells is more. Percolation of this fluid will contaminate ground water resources. No recharge wells might be expected on test well drilling phase. Thus, professionally designed waste disposal structure (pond) need to be constructed, preferably to dispose waste after air-dried.

5.3.4.8 Environment related components to be affected

Environmental components most likely affected include ambient air quality; water bodies; soil (land use); fauna and flora; eco-system; natural noise levels. Social components most likely affected, on the other hand, include change in life pattern; livelihood; culture; heritage etc. of the surrounding communities. In addition to these, resource competition, safety and health, community development etc. are among joint issues to be addressed in light of existing national and international guidelines as socio-environmental effects. The subsequent section presents major findings of the field survey for the candidate site.

5.3.5 Impacts from Site Selection and Land Acquisition

Due to various negative repercussions of geothermal power plants on man and environment, it is not possible to set up such facilities anywhere. Selection of a site that fits best for the proposed projects was pre-determined in the scientific or technical studies at reconnaissance study using relevant professional parameters/criteria. Thus, there is no room for alternative site analysis.

The candidate site, from socio-environmental point of view, however, was also further screened using standard check-list methods and parameters to assess level of its impacts. These parameters consider both physical and biological data. The physical data emphasizes on climate, soil, water and associated risks such as flood, erosion, seismic and storm water handling. On the other hand, biological data deals with fauna, flora ecosystems, etc.

The project site and its surrounding were surveyed by the ESIA study team to carry out the task. This study, however, does not include assessment on project area of influence as there was no prior plant lay-out available.

Thus, issues/or parameters/ such as project area of influence; core process area; area for supportive facilities; expansion area; protected green belt; alignment/symmetry/ for point and area sources of pollutant emissions, heavy load of traffic on affected roads and surroundings etc. are not treated. This is because the scope of the study is limited on test well drilling. As it is explained above in this chapter, the proposed project site at Ayrobera is a no man land; arid climate; flat land covered with sand and ash. Thus, impacts from site selection and land acquisition are at minimal.

Site analysis

- Findings from document review at Regional and/or Zonal levels do not reveal any directives that prevent the geothermal plant from establishment along the proposed site;
- The inquiry/interview/ we made with legally authorized institution/ Regional & Woreda EPA/ for this particular site do not indicate that the surroundings of the proposed project site is either declared or reserved;

- More than 100% of directly affected households in the area express their willingness for establishment of the plant in the proposed site provided that they earn compensation as per indicated in guidelines and secure equivalent resettlement area near their town;
- All of key stakeholders do not have compliant in the proposed project site. In addition to this, they have also explained that their office do not have any planned development activity in the surrounding of the project sites.
- According to Federal Environmental Guideline of EPA, 2003, the proposed site is not classified as environmentally sensitive;
- No preliminary hydro geological data is obtained to confirm that the proposed site is relatively safe and stable from natural hazards of seismic, subsidence. Further work need to be carried out after during implementation;
- In addition to the above mentioned facts, professional observation and judgment of the study team is that the proposed site is not environmentally sensitive but arid climate for the work force;
- The study team strongly believes and as usually practiced, public disclosure and official reviewing are best instruments for further investigation of few unforeseen dimensions so as to arrive on a sound decision before implementation.

5.3.6 Findings from Relevant Guidelines

For this study major guidelines selected as relevant are: Federal and Regional guidelines of Environmental Protection Authority, EPA: According to these guidelines, geothermal power plant development industries which process mine products are treated under Category I (Schedule III) and they require full EIA. With regard to site selection processes; the federal guideline; environmental impact assessment procedural guideline, May, 2003,(Annex VI) stress that adverse projects shall be sufficiently far or out from environmentally sensitive sites.

From this guideline, description of environmentally sensitive sites relevant to the proposed plant is summarized as follows.

Environmentally Sensitive Areas and Ecosystems

- Areas prone to natural disasters (geological hazards, floods rain storms, earthquakes, landslides, volcanic activity, etc.).
- Wetlands: - flood plains, swamps, lakes, rivers etc.
- Mangrove swamps characterized by one or any combination of the following conditions;
    - With primary pristine and dense growth;
    - Adjoining mouth of major river systems;

- Near or adjacent to traditional fishing grounds;
- Which act as natural buffers against shore erosion, strong winds and storm floods

- Areas of unique socio-cultural history archaeological or scientific importance and areas with potential tourist value

- Areas declared as: National parks, Watershed reserves, forest reserves, wildlife reserves and sanctuaries, sacred areas, wildlife corridors, hot - spring areas

***Potential impacts*:** It can be observed from the discussion of the previous section that potential impacts of the project naturally emanate from major drilling processes and related activities. These impacts are identified as follows:

a. Predicted impacts from project concept formulation (screening);
b. Predicted impacts from site selection and land acquisition;
c. Impacts due to plant lay-out (setting), design aspect;
d. Impacts due to construction and development phase;
e. Impacts from raw material handling, storage and feed supply;
f. Impacts from major plant processes;
g. Impacts from handling, storage and feed supply of hazardous input materials/chemicals/;
h. Impacts from utilities and infrastructure services;
i. Occupational safety of workers (in-plant);
j. Community safety and health (out-plant);
k. Effects and benefits to local community;
l. Impacts from generation and disposal of liquid process-wastes;
m. Impacts from non-condensable gaseous wastes;
n. Impacts from generation and disposal of domestic wastes;
o. Impacts from infra-transport phenomenon;
p. Impacts from resource competition and issues of cleaner production methods;
q. Nature of water resource utilization and its options;
r. Energy source and its utilization;
s. Optimized raw material utilization

For convenience, each of the above impacts on the corresponding sensitive socio-environmental receptors is usually and meaningfully grouped phase-by-phase of the project development. These receptors are then squeezed to few but main categories. Finally, impact evaluation is performed on main receptors for easy decision making.

Summarized environmental receptors include:

- Natural environment: (1) Topography and geological features including seismic, (2) Soil erosion, (3) , Hydrological & seismic situation, (4) Flora, fauna and biodiversity,(5)Protected Area, (6) Global warming

- Pollution control: (1) Air pollution and dust, (2)Water pollution, (3) Waste generation, (4) Bottom sediment, (5) Noise and vibration, (6) Odour

For instance, a representative development project has the following phases: (1) concept formulation (inception) phase; (2) construction phase; (3) operation phase; (4) decommissioning phase etc. In a similar approach the "test well drilling project" can be perceived as having the following phases:

- Pre drilling phase (survey & conceptual modeling);
- Construction phase (civil & non-civil works);
- Drilling phase (development & commissioning phase);
- Testing phase (operation phase);
- Decommissioning phase.

5.3.7 Experience Learnt from Aluto-Langano

The Aluto-Langano geothermal field is located on the floor of the Ethiopian Rift Valley about 200 km south east of Addis Ababa. It is regarded as advanced prospect area. Eight deep exploratory wells were drilled to a maximum depth of 2500 m between 1981 and 1985, of which four are potentially productive. The maximum reservoir temperature encountered in the productive wells is about 350ºC.

A 7.3 MW pilot geothermal plant was installed in 1999 on the basis of the exploration wells that had been drilled. Binary system was installed and operated for many years. However, the plant was not fully operational mainly due to technical limitations inappropriate, field and plant management skills.

Recently, techno-feasibility study of the power development at the Aluto-Langano geothermal field has been conducted as part of FY2009 Studies for Economic Partnership Projects in Developing Countries promoted by the "Ministry of Economy, Trade and Industry of Japan (METI)" and that was entrusted to West Japan Engineering Consultants Inc. (West JEC) through Ernst & Young Shin Nihon LLC and the Japan External Trade Organization (JETRO).
The geothermal power development project is divided into the following two kinds of development: underground geothermal resource development and surface power generation facilities. The outlines of each development are as follows:

(a) Underground geothermal resource Development

The 3D numerical model was constructed based on the geothermal conceptual model. Using this numerical model, 30 years forecast simulations with several development scenarios were carried out. It was concluded that the optimum scenario is 35MW development with steam pressure of 10 bars. In this case, it is forecasted that 8 production wells and 4 reinjection wells will be required at the

commissioning of the 35MW power plant. It is also forecasted that 5 make-up production wells and 2 make-up reinjection wells will be necessary to maintain the rated output for 30 years. The produced steam and brine will be separated at a separator station, and the separated steam will then be sent to the power station and the brine to reinjection wells in the southern part of the field. All of the required pipelines and other facilities will be constructed.

(b) Surface power generating facilities

The geothermal power facilities consist of the geothermal fluid transportation system (Gathering System), power plant, transmission and substation. Main specifications of the facility shown below were determined taking account the results of resource evaluation and the pressure drop of pipeline of the geothermal fluid.

- Capacity 35 MW gross × 1 unit
- Power plant type Single flashed steam cycle with condensing turbine
- Steam condition 10 bar(abs)/179.9 Deg. C (saturated) at plant inlet
- Non-condensable gas in steam 8 wt %

Currently, two test wells are drilled each about 1951 meters depth and about 150 meters apart. It generates steam at 1350 and the brine solution is relatively clean. Interview made with the site engineer, Ato Habtamu Germew, revealed that boundary cases and compensation were and still are critical social issues for the last thirty five years. The project area is about 44 Hectare; 33 households were compensated each household gaining about ETB 400,000.00; giving rise a total cost of ETB13, 200,000.00.

As the site recommends that any new geothermal development plants shall pro-actively establish clear boundary map considering future expansion and green belt development. The project shall also secure approval from Regional and Federal Authorities. Copies of approved document with site plan shall be officially issued to the local administrators so as to minimize unnecessary negotiation and unwise cost.

The following table summarizes phase-by-phase, identified impacts of the project on sensitive socio-environmental receptors.

5.4 Social Impact Analysis

5.4.1 Findings from Directly Affected People

The findings of the public consultation have been highly encouraging. The participants were, more or less termed as <directly affected people>, though they are settled very far away from the proposed site, Ayrobera. They were people drawn from the community, women and youth, the elderly and religious leaders, among others. In fact the finding confirms similar positive scenario and view to that end. The issue is thoroughly discussed in the coming chapters.

Photo 5.1: Site Visit

5.4.2 Findings from Other Key Stakeholders' Participation

The assessment follows and employed the concept of the International Association for Impact Assessment (IAIA) which considers social impacts as changes to all aspects of social variable. This among others includes their health and wellbeing, services and facilities, quality of the air and water people use; the level of hazard or risk, dust and noise they are exposed to; physical safety, access to and control over resources. Pertaining to the project site, Ayrobera is the best and only alternative location that is presumed to be rich in thermal power. Fortunately, the site/ is not only inhabitable but hostile to life. If the test well drilling proves positive, the future geothermal production will be a promising venture. Stakeholders view on the appropriateness of the site is fully positive. Starting from the concerned community (Ayrolaf-Gebelaytu kebele) to region, woreda and local officials, the site and the project fit well with nearly no adverse impact affecting the community directly. In general there is no social, economic, or other legal issue that imposes, the implementation of the test well drilling project.

Perception of key stakeholders on the impact: *T*his section discusses the major social impacts identified by stakeholders. The entire household heads interviewed hoped to gain benefits from the establishment of the project. However few respondents worried about the success of the project. This is because that they had bad experience which resulted in not only in failure but also accident.

The two prioritized benefits that the community hoped to secure are the expansion of development projects in the area and access to electric power that may be distributed in the future.

The big majority of interviewed officials expressed their support for establishment of the project by providing with what is required of them. There are no policies, regulations and directives that prevent the test well activity from launching on the proposed site. The only obligation is that project owners go through legal process and procedures as required by the federal and regional governments. In line to this, findings from other stakeholders too, reveal that they didn't have objection, rather happy, in that the unexplored resource of Afar Region in general and Ayrolaf-Gebelaytu kebele in particular is to be exploited. It will be, thus, justifiable to launch the proposed project on Ayrobera site.

5.4.3 Impact on heritages and scenery

Heritages: The other aspect of the impact is concerned with cultural, historical, and natural heritages. In terms of its proper definition of heritages, there have been no heritages located within or close to the site. Thus impact analysis pertaining to this has been left out due to the absence of the elements.

Scenery: The test well drilling activity at Ayrobera site would be situated within the empty deserted section of the kebele. Thus the construction and activity of the proposed test well drilling would not affect the natural and geological features of the area. Rather the effect would be positive. It is positive because the proposed area is so harsh, sandy, and no single vegetation is growing. As the result, no human being prefers to cross the area, let alone living within. Very few temporarily settled pastoralists neighbor the site; however, they are off the site, far away, and found in relatively vegetated areas. In terms of this therefore, the activity and construction of a camp, and other appurtenance buildings such as maintenance workshop, lounges, lodgings, new facilities and infrastructures for example roads, supply of water, energy, would rather boost the amenity of the harsh landscape. This in other words mean, implementing the project would undoubtedly result in significant positive effect**.**

5.4.4 Change in land use pattern and zoning

It is assumed that the launching of test well drilling would attract other business sectors towards Ayrolaf and Gebelytu in general and Ayrolaf site in particular. This is so, because once the project launched others began to look into business alternative closely tied or associated with the drilling project. The unpopulated vast land of Ayrobera could slowly attract small businesses or pastoralists willing to settle, though in a lesser extent. One pull factor for settlement might be the availability of water supplied within the site.

Overall economic impact: The impact of the project revolve around the socio-economic impacts at higher level, particularly at National and Region level in general and at Dubti woreda level in particular. The impact in these areas has been taken one of the two significant positive effects. The analysis compares the extent of the effect at all levels, in terms of employment, local capital, and increase in capacity of the energy sector.

Other socio economic impact: The socio economic benefits of the project would be immense, explained by direct and indirect, short term and long term. In fact the analysis has covered impacts that are related to adverse social issues. However, a few of the variables are not decisive and thus left out from discussion in this report.

Sources of adverse impacts: Impacts are sourced from different factors, activities and conditions. Identifying the sources of adverse impacts would help to identify the real mechanisms of mitigation and management.

Table 5.2: Major sources of adverse impacts

Major impacts sources	Activities/situation	
Accidents	Personal; equipment, and vehicular	
Personal factors	Lack of skill; worker physical and mental ailments.	
Unsafe activities	Operation without safety and authority.	
Unsafe condition	Absence of safety tools	
Job factors	Make use of below standard equipment; wear and tear of tools and materials	
Items, equipment	Electricity; motors; gases; chemicals, walk ways; ladders, mast and/or derricks;	

Generic impacts will be the major characteristics of the project. This means adverse occupational health and safety impacts related to personal accident or injury all projects particularly that involve construction and production. There are also likely negative impacts derived from workers-management relationships. According to the study team judgment, due to the nature of the project/site nearly all adverse impacts will be related to generic (Table 5.2).

5.4.5 Occupational accident and hazards

During construction phase, heavy equipment would move from Semera town to Ayrobera site. After arrival, the same machines are to move from one corner of the site to the other. Construction of camps and stores, installation of equipment, storage activities, movement of vehicles, and physical activities of workers, among others, are intense. During operation phase too, wells are drilled, gases and vapors are emitted, tools and machines are moving from place to place, and chemicals are loaded and unloaded, or carried from one corner to another, the function of machines and vehicular movements etc., enhanced. All these process and activities are sources of accidents and hazards; what is more, the occurrence of such irregularities is most likely. Possible accidents and hazards associated with test well drilling projects are indicated at Table 5.3.

Table 5.3: Phase, and sources of accident and hazard in test well drilling

Likely Phase	Sources of accident	Sources of hazard
Construction and operation phases	Over exertion,	Burning
Construction and operation phases	Slips and falls	Explosion
Construction	Openings	Ignition
Construction and operation phases	Struck by objects	Fire
Construction	Work in heights	Gases/ vapor
Implementation	Drilling activity	Shock
Construction and operation phases	Equipment movements	
Construction and operation phases	Movements of vehicles	
Operation/Implementation	Operating machines	

The key and most likely adverse impacts of the project therefore are the following:

Injuries: The following are the common types of injury usually sustained by workers during test well drilling: injuries from a violent blow; injuries involving breathing; injuries of scrapped; injuries having jagged or hole by a sharp object; sprain and fracture; burns of skin or eye; and spinal injury etc.

Dust:-Due to the nature of the site, emission of dust is quite uncontrollable. The blowing of wind in and around the site is common which carries tones of dust across the site and travel long way, sometimes violently. The staff and workers around the site will definitely be affected incessantly. In line to this, the occurrence of adverse impact during exposure to dust is critical.

Hearing disorder:-Impact of noise is the other sensitive issue during test well drilling. As experienced elsewhere, for example in Aluto site, noise emitted from during and after drilling is nauseating. Even the blowing of steam after the drilling wells emit incessant noise which can be heard one to two km away. In terms of this, therefore, the adverse impact of the noise particularly on the staff and other workers around the site is serious, and thus labeled as major. As already indicated, as most of these noise sources cannot be prevented, control measures should include the use of personal hearing protection for exposed personnel. The allowable exposure time according to the ILO or Ethiopian standard for different sound level is given in Table 5.4.

Table 5.4: Sound level with allowable exposure time

S/N	Ethiopia/ILO/ standard[dB(A)]	Allowable exposure time (hr)
1	90	8
2	92	6
3	95	4
4	97	3
5	100	2
6	102	1.5
7	105	1
8	110	0.5
9	115	0.25

Source: Ethiopia/ILO/ standard [dB(A)]

Duration of the test well drilling activity is anticipated to last over 12 months. The required number of workers in all phases is about 70-90. The following are presumed impacts that are closely associated in all phases. In general, the staff and temporary workers exposure to unsafe work setting will be moderate; as it is expected that the concerned body will take measure to that end. In addition to exposure to improper equipment will also be moderate. On top of this, exposure to harsh environment would be high.

5.5 Economic Impact

5.5.1 Impact of Road Construction

As the area is totally free from residence and vegetation, there is no need to worry about displacement cost and deforestation risks. In other words, it doesn't result in adverse impact on agriculture, and fertility of the land. In addition, it does not result in displacing or affect private property. In line to this, therefore the cost of constructing the road will be relatively cheap because some of the raw materials are available in the area; what is more the landscape is evenly flat which would make the cost minimal. As the project site is free from any human settlement, the activity of the project will have no impact related to noise and dust, at least on the community.

5.5.2 Impact of project vehicles/transportation

There is generally a higher traffic on the road from Addis Ababa all along Semera town to Djibouti. The road transports heavy trucks carrying imported items to all parts of the country. Thus, as the result of the project activities, traffic will increase in the area mainly during the transportation of the rig and its accessories to the drill site. This additional increase traffic might have some unfavorable impact however it is insignificant. The increased traffic may also lead to an increase in dust, noise and

vehicular emissions; however, since there are no communities living around the main road there will be no impact in that respect. This doesn't however mean that there is no adverse impact. During drilling, dust and noise resulting from movements of service trucks most likely affect the entire staff/workers. Since increased traffic activity will be temporary and normality is restored after the drilling is completed, expected impacts would be lesser and lesser.

5.5.3 Impact of the Project on Employment Opportunities

The test well drilling project will create temporary jobs for different activities. Some of the employment opportunities, especially the technical part demands the use of foreign experts while some others can be covered by local workforce. And yet, the large part of operation will be covered by the local community.

The test well drilling project is expected to create an employment opportunity for 13 local professionals and laborers and semi-skilled workers. In addition the project will involve about 10 foreign experts at different stages (see Table 5.6).

Work force and experts' involvement: At this drilling and testing phase of the project a number of professionals and non-professionals will be employed /assigned. Of this, during drilling a total of 121 workers are required. Of this 8 are local professionals, 7 of them are foreign experts. During the testing phase too, 8 highly skilled workers are required. Of the total 121 workers, additional labor force, a minimum of 60 workers is required for the construction of the road from the main road to the site. In general, a total of 129 skilled and non-skilled workers will be involved through-out the phases (Table 5.6).

Table 5.5: Project labor force required

Nº	**Labor Force Type**	**Drilling phase**	**Testing phase**	**Total**
1	Foreign experts	7	3	10
2	Local experts	8	5	13
3	Laborers and semi-skilled workers	46	-	46
4	Laborers during road construction	60	-	60
	G. total	**121**	**8**	**129**

The community in the potential project site is semi-pastoralist. Due to the recent severe drought, and the incorporation of the fertile land into sugarcane plantation, the community is becoming dependent on wage labor available. In this regard the project will serve as a source of additional income for the

surrounding community. To build a positive image of the project related to the job opportunities, project owner has to give due attention to ensure equity in recruitment and selection. Involving community leaders at the early stage of the recruitment therefore will be best approach to that end. The available job opportunity for the community during test well drilling is mainly labor works. The projects' requirement for unskilled labor indeed meets the need of the local community. This is therefore one of the positive impact in terms of economic benefits of the community.

5.5.4 Impact on Disposable Income and Business Activities

Most development interventions create job opportunities that involve the local community. The additional income that some members of the community earn from the employment will increase their disposable income. Besides, migrant workers who might access the job opportunity will secure adequate money to satisfy their basic needs. This in other way means injecting additional money in the economy. The level of benefit maximized from the increased disposable income and business activity largely depend on readiness of the local community to consume and deliver the required goods and services. In this regard Semera town is expected to benefit far more than the project site kebele and other towns such as Logia and Dubti.

The additional demand created as the result of the test well drilling intervention will bring about development in the local business activities and thereby contribute to the improvement of the economy at the Kebele, Woreda, Region and National level. The project will contribute to the increase in the number and types of business in the area. Each new business creates new job opportunity, additional revenue for the local Government bodies in the form of profit tax and employee income tax.

In addition, the implementation of the test well drilling project is expected to inject cash inflow through job opportunity and enhance marketing for livestock outputs. The project staff might indirectly boost income of the community through exchanging sheep, goats, ox, and milk supplied by the surrounding community. In this regard the implementation of test project will have moderate favorable impact both on increasing the number and types of businesses in the area.

5.5.5 Impact on Cost of Living

When new development project is established in rural communities like Ayrolaf and Geblaytu, one of the major socio economic impacts is the increasing migrant workers appearing around the project site; which indirectly bring about an increase on cost of living. In addition to that, the increase in population, due to migrant workers, may cause a strain on the available resources and thus may result in conflicts. In terms of the test well drilling project in Ayrobera, however, the pressure of migrant workers on the local community will be insignificant. This is because that, most of the facilities and services project workers need may be obtained from Semera town rather than the project Kebele.

Semera is not only near to the project site but also supply better services and facilities needed to the project staff/workers. The impact of migrant workers on the existing services and facilities of Semera will be negligible when compared with the size of laborers employed in the project. Besides, the

increase in the demand for facilities and services during the drilling phase will be temporary. Once the drilling operation is over, the demand may return to its previous level. Moreover, the drilling project may not significantly affect housing facilities adversely in the kebele, since the staff/workers will be camping within the site. Consequently, the project's impact on the cost of services and facilities either on the kebele and/or on the local community would be minor.

5.5.6. Impact on Cultural and Social Norms

Ayrobera site is located away from the local villages where the kebele community settled. However there are very few people living within 10 Kilo meter radius from the potential test well drilling site. Thus the establishment and operation of the project will have some kind of impact with limited range of intensity. The impact of migrant workers on the culture, language, religion, and style of life of the community will be insignificant on the nearby few residents and lesser impact on Asboda and Boina villages, the two big settlement villages in the project kebele. Similarly, the impact on socio cultural norms of Semera town will be insignificant too, because the town has already been mixed with migrants for a long time. The issue of gender would not be a point of discussion here. This is because that as already mentioned, the site is devoid of human settlement.

5.6 Conflict History and Minority Issue

Conflict:-The area is not known for witnessing tribal conflict within and/or without. No report of conflict has been reported by respondents during data collection. In addition to that, there is no official recorded data on history of conflict in the area. Possible conflict of interest (claiming the site to be included in their respective kebele) however might arise among the same kebele dwellers when drilling activity begins in the near future. According to Focus Group Discussants, three neighboring villagers began to claim Ayrobera when the news of the drilling project was heard. However, through intermediaries' of all sides, the issue was being discussed. Although the site is characterized by sandy terrain and incessant wind, according to informers, the southern part of Ayrobera is claimed by a tribe called Tiou Henteba. Other people who have settled at the far end (northern part) of Ayrobera also claim that the area belongs to them. Nearly all Kebele residents of Ayrolaf-Gebelaytu are resettled by the Afar Regional government. The settlement area is far away/ opposite the site. And yet according to some respondents, the same resettled people think of benefiting from the future geothermal project, if any. From this angel therefore conflict of economic interest (just to get a kind of benefit from the project) might occur when the actual test well drilling activity begins.

In fact, the tendency of individuals claiming project land (even though the land is no man land and has never been serving for either grazing or settlement), is common among the Afar. The previous study made by the same team (on Master Plan for Geothermal sites in Ethiopia) confirms this very fact, per-se. Any person/s from somewhere might come and claim a plot of land assigned to any project. Since the Afar culture doesn't encourage certificate of any kind for owning/inheriting land, a mere oral claim is taken for granted. In line to this therefore, land claim might arise from three directions. The first is from people who are neighboring or living at the far end of the site. The second claimers might be those who are already settled on the opposite side of the site. The third one could be individual

person/group of people who might claim that the site belonged to their father or grandfathers. Thus the issue need to be given due consideration. The shortest cut is to let the higher body of Afar Regional State process and clear the future land claim that may arise by one or all of the groups mentioned above.

Minority and Indigenous Issues: - In general, minorities (non-Afar) living in Afar face difficulties in possessing land. The Afar believes that their land belongs to no other except the Afar people. Due to this, none-Afar individuals don't have the right to own land. Following observation and informal interviews, in rural areas minority group may be denied of possessing land. Minorities in big tows such as Semera, Dubti and Logia however seemed to have the right to possess land as long as they passed through legal process in their respective Municipality. The best example could be certain non-Afar minority groups, for instance, business people, such as hotel owners have been able to possess land and built houses.

The case of investors is totally different. Land for big investors is processed by the Regional government. Since the federal government also has concern on investment, accessing land for large venture such as modern farming and geothermal projects would be simple, and relatively none bureaucratic. And yet the issue of compensation might be a bit irritating.

Ayrolaf-Gebelaytu residents belonged to mainly to Asobakari, other three tribes, namely, Bedewaita, Mandit, and Hintiba are also residing in the area. In line to this therefore the indigenous people are none other than these four mentioned tribes. In other words, there are no other indigenous people known among the area. The four tribes belonged to the bigger clan-The Afar. The above mentioned tribal groups are more or less treating each other equally and what is more, they are socially and economically tied together. Minority within the Afar are not discriminated. In light of this there is no history of discrimination against any Afar minority group in the kebele.

5.7 Quantitative Evaluation of Identified Impacts

From discussions made above the following impacts are considered useful for quantitative evaluation and then for the corresponding management plan. Here, as much as possible, similar impacts that may occur in different phases of project development are treated together using their generic name. However, few impact parameters such as nature; sensitivity; reversibility etc. are explained using descriptive statements.

Assumption for the scoping result

As the scope of the present study is limited to test well drilling, scoping results of operation phase may not be adequately addressed using the above mentioned parameters, such as generation rate, spatial coverage, intensity etc. Thus, scoping results of operation phase need detailed investigation after production capacity of the power plant is determined. Hence, rate given on operation phase shall be perceived only as indicative value in the context of test well drilling.

Note:

Pre:-During preparation,
Con:-During construction,
Ope:-During well testing
A+/-: Significant positive/negative impact is expected.
B+/-: Positive/negative impact is expected to some extent.
C+/-: Extent of positive/negative impact is unknown (further examination is needed, and its impact could be clarified as the study progresses)
D+/-: Miner impact is expected.
E : No impact is expected.

Table 5.6: Quantities evaluation of identified impacts

Quantitative evaluation of identified impacts (Scoping)						
Category	*No.*	*Items*	*Rating*			*Basis for rating*
			Pre	*Con*	*Testing*	
Policy framework	1	National policy of the country	A+	.....	.....	***Pre・Con :*** Inter allignment of policies and guidelines needs verivication
	2	International conventions				
	3	Guidelines of financial institutions				***Ope.*** Energy from geothermal power plant is among national priorities
	4	Policy of funding organization				Considered as renewable and also reduces greeen house gas emission
Pollution	5	Air Quality	E	D-	D-	**Pre・Con :** By production test, generation of the containing hydrogen sulfide (H_2S) is expected. In addition, emission gases are discharged by operation of heavy machines during well drilling and facility construction. **Ope :** H_2S is expected to be released along with steam.
	6	Water Quality	E	D-	D-	**Pre・Con :** Muddy water is expected to be generated due to well drilling. **Ope :** Wastewater is expected to be discharged from the facilities.
	7	Waste generation	E	D-	D-	**Pre・Con :** Drilling sludge, construction waste soil, and scrap wood are expected to be generated by well drilling activities. **Ope :** Wastes (sludge, waste oil) are expected to be generated at the facilities.
	8	Soil Pollution	E	D-	D-	**Pre・Con :** Discharging of geothermal fluids and muddy water will contaminate surface soil with heavy metals
	9	Noise/ Vibration	E	D-	D-	**Pre・Con :** Blowout of geothermal fluid by well drilling and noise from operation of heavy machines are expected. **Ope :** Noise from operation of the facilities (power generator, steam turbine, cooling tower, etc.) is expected.
	10	Ground Subsidence	E	E	D-	**Pre・Con**: Collection of geothermal fluid during well drilling and facilities construction is limited. **Ope :** Although ground subsidence is expected by collection of geothermal fluid, detail examination is required.
	11	Offensive Odor	E	D-	D-	**Con * Oper**: Offensive odor is expected due to harmful H2S gas emission **Pre* Con**: Construction of link roads and other facilities are planned
	12	Sediment Quality	E	D-	D-	**Oper**-Discharge of contaminated sludge and slurry is part of the planned activity
Natural Environment	9	Protected Area	E	E	E	No protected area is regestered with in and around project site
	10	Ecosystem/Flora and Fauna	E	D-	D-	***Con* Oper***: Minor negative impacts on local ecosystem and flora and fauna are expected due to disturbance of the land, operation, and existence of the facilities.
	11	Hydrology	E	D-	D-	**Pre・Con :** Surface water or groundwater is planned to be used. **Ope :** The amount of surface water or groundwater planned to be used is limited.
	12	Topography/ Geology	E	D-	D-	**Pre :** Impacts are negligible as large-scale well drilling is not planned. **Con :** The land is expected to be disturbed by construction of facilities (generator building, steam and hot fluid transport pipe, cooling tower, etc.). **Ope :** No activities which may cause impacts on topography/geology are planned.

Cont'd

Category	No.	Items	Rating			Basis for rating
			Pre	Con	Testing	
	13	Involuntary Resettlement	E	E	E	Since there are no residents at the project site, involuntary resettlement would be out of question.
	14	Ethnic Minority/ Indigenous People	E	E	E	There are no indigenous people in the area, and no ethnic minorities except clans within the Afar.
	15	Local economy (the poor)	D+	C+	C+	**Pre :** Creation of employment opportunities are limited at this stage. **Con・Ope :** Positive economic impacts would occur in terms of local employmnet, however limited.
	16	Land use and utilization of local resources /resource competion such as water and energy/	E	E	E	No impacts on land use, utilization of local resources and conflict are expected as the site is left baren and the project will use its own source of water and energy
	18	Infrastructures and social services	E	E	E	Although there are social infrastructures such as health centers, schools and others around the project site kebele, the staffs will use the thses services away from the kebele such as Semera town.
	19	Social institutions and local decision-making institutions	E	E	E	There are no such institutions within the site that could be affected due to the project in all phases.
Social Environment	20	Misdistribution of benefits	E	E	E	No unequal distribution of benefit and damage is expected during all phases.
	21	Local conflicts of interest	D-	D-	D-	Minor local conflict of interest is expected among villagers to include the site in their repective kebele.
	22	Diffussion of local culture & norm	E	D-	C-	**Co・Op**:Minor impact could occur as limited number of local people interact with project staff; what is more, the limited number of skilled staff (camped) are little access to diffuse among the community.
	23	Increased cost of living	E	D-	C-	**Co・Op**: Minor impact would occur that aggravate cost of living on the area
	24	Landscape	E	D-	D-	**Pre・Con :** Since no large scale construction work is planned, impacts on landscape are temporal and limited. **Ope :** Some impact on landscape is expected by the existence of plant facilities (power generator, steam turbine, cooling tower, etc.).
	25	Gender and children's rights	E	E	E	No impact is expected as the site is dvoid of settlement.
	26	Community saftey and infectious Diseases	E	D-	C-	**Pre・:** There would be no possibility for infectious diseases at this stage. **Co・Ope :** Since the number of workres at the project facilities is limited, impact due to infectious disease would be minor.
Industrial safety	27	Occupational safety and accidents	D-	B-	C-	***Con・Op***: Since the project site is located at harsh environment; what is more since construction and drilling activities involve accidents occupational safety are required. Accidents are expected during test drilling, facility construction, and operation, respectively. Thus requires special consideration
Socio-economic	28	Contribution to the national economy	E	E	A+	**Ope**: Lack of alternative and renewable power would be addressed; hard currency earned from sale of eltric poweris likely expected.
Others	29	Climate change	D	D	A+	**Pre・Con :** Since no large-scale construction work is planned, impact on climate change is temporal and limited. **Ope :** This project could contribute to reduce greenhouse gas emission.

Summary of overall findings

As can be observed from results of the identified impacts (Table 5.6), socio-environmental components with rating value greater than-1.25 are considered as having adversely significant impacts. Thus, *pollution, safety and health, waste generation, changes in life pattern are* among the top priorities for the corresponding mitigation measure and management plan that will be dealt in the next chapter. Geothermal technologies in general, test well drilling in particular are environmentally advantageous because there is no combustion process. The potential environmental impacts of conventional hydrothermal power generation are widely known. Several articles and reports have documented various potential impacts from geothermal dry-steam, flash-steam, binary energy, combined energy conversion systems. The general conclusion from all studies is that emissions and other impacts from geothermal plants are dramatically lower than other forms of electrical generation. Thus, the lessons learned from a number of existing geothermal power plants can be used to ensure that future geothermal systems will have similar or even lower environmental impacts.

CHAPTER SIX: MITIGATION MEASURES AND MANAGEMENT PLAN

6.1 Overview

This section presents major adverse effects only on natural and social environment due to significant impacts identified in the previous sections; then provides mitigation measures if possible with alternatives. For harmonized reviewing, these impacts can be presented parallel to the drilling activities but at various project phases.

These phases can be presented as follows;

- Pre drilling phase (survey & conceptual modeling);
- Construction phase (civil & non-civil works);
- Drilling phase (development & commissioning phase);
- Testing phase (operation phase);

Most of identified potential impacts can either be avoided or reduced through mitigation. These mitigation measures are proposed in sequence of: technology/design/ option; careful choice of location; proper timing; suitable season; material and best practices.

Mitigation measures and management plan for air emission depends on practices to be adopted to eliminate or reduce air emissions. Such practices include both prevention practices and pollution control measures, preferably at a lower cost. Prevention and control techniques may include various methods of treatment depending on:

- Regulatory requirements;
- Significance of the source;
- Location of the emitting facility relative to other sources;
- Location of sensitive receptors;
- Existing ambient air quality;
- Technical feasibility and cost effectiveness of the available options for prevention, control, and release of emissions;

Emissions from the test wells, according to the information gathered during the preliminary drillings carried out by Aquater and the relevant field assessment, contain 99% steam and the remaining 1 % is constituted by CO_2, H_2S, ammonia and other non-condensable gases. Furthermore, test well drilling is a short term activity and localized in the project site which is almost no man's land. Therefore, technology option to adsorb emission is considered as not a viable option.

6.2 Social Impact Mitigation Measures and Management

6.2.1 Design for workers' camp

As discussed in the socio impact analysis part of this report, most expected adverse impact of the project would be on the staff/workers of the project. To avoid and/or manage the negative impacts the first step would be to arrange and prepare the project site in a manner that adverse impacts would be easily controlled. To that end, workers' camp needs to be built in a way that fits the harsh environment of the site/area. The following precaution should be considered while building the camp.

Permanent and recurrent places of work should be designed and equipped with:

- Temporary but standardized buildings that are structurally safe, and provide appropriate protection against the harsh Ayrobera climate should be set.
- Surfaces, structures and installations should be easy to clean and maintain, and not allow for accumulation of hazardous compounds;
- The buildings of the camp and temporary offices should be equipped with fire resistant, noise-absorbing materials, following the nature of the project.
- The entire buildings should be equipped with AC and ventilators.

Potable water:

- Adequate lavatory facilities (toilets and washing areas) should be provided according to the number of work force available at the site. Particularly cold shower is highly required since Ayrobera site is so hot almost throughout the year. Toilet facilities should also be provided with adequate supplies of cold running water, soap, and hand drying devices.
- Adequate supplies of potable drinking water should be provided from a fountain with an upward jet or with a sanitary means of collecting the water for the purposes of drinking.
- Water supplied to areas of food preparation or for the purpose of personal hygiene (washing or bathing) should meet drinking water quality standards.

6.2.2 Facility Design for Work Areas

Risk management: To control and/or avoid adverse impacts of the project, the contractor should assign personnel and/or sections. As discussed in Chapter 5 there would be potential adverse impacts but limited to around the site and on workers of the project. The potential for occupational accidents and hazard would be imminent, among others. Health threat, vehicles movements and functioning of machines, fire sound and dust effects have been the treated as sources of adverse impacts. In fact, as long as proper mitigation and monitoring measures taken, the said negative impacts could be controlled.

The risk of fire for example could be controlled following Environmental Health and Safety (EHS) guideline and standards which involve occupational health and safety rules. According to other similar test well drilling projects no damaging fire hazard occurred. However, there is a possibility of fire accident; thus the concerned body should consistently adhere to the prescribed requirements and the readiness of fire extinguishers and related equipment; across all parts of the site, camps and drilling areas, among others.

In terms of traffic accidents too, all prevention methods should be in line with international guidelines (particularly, IFC's Guidelines, 3.4 Traffic Safety). As per the agreement that would be reached between project owner and the contractor, all test drilling phases should be given due emphasis in accordance with relevant statutory requirements, abiding regulations standards.

Similar to the staff camp, work areas are mainly sources of adverse impact. In line to that, drilling spots and associated areas need to be arranged in a way that they would minimize, control and avoid adverse impacts. The following points should be considered to mitigate/manage negative impacts before project implementation.

6.2.3 Health and Safety around the Site

Project owner in general and the contractor in particular need to follow and ensure the stipulations indicated here under during construction phase:

- Availing health and safety equipment such as First Aid kits, protective clothing and boots.
- Controlling huge discharge of dust.
- Implementing noise abatement mechanisms to minimize inconvenience to current staff and site workers.
- Ensuring the cleanness of the site, for instance free from mud and debris; and dumping excavated materials and scraps at a preset and approved location.
- Implementing traffic system for vehicles entering and exiting the site.
- Qualified health professionals with necessary medical tools and drugs should avail 24 hours for emergency, at least victims under serious accident or hazard transferred to an appropriate medical facility.

Space and Exit:

- The space provided for activity of workers should be wide enough for safe execution of all assignments. This refers to all buildings required for the project, for example, offices, laboratories, lodgings and lounges, including storage of materials, among others.
- The number of stores needed for the project is determined by the number of wells to be drilled. One store for each well, according to experience elsewhere, may be required. Stores for silica and bentonite are mandatory. These temporary stores may be constructed from cheaper materials but need to be wide and long enough to accommodate thousands of silica/bentonite sacks. A single stores used for the same propose at Aluto Langano, for example, is nearly 20x10 meter wide and 5mter height. Other standardized stores in some countries are wide enough to accommodate big trucks to facilitate loading and unloading.
- All stores, rooms and halls need passages emergency exits and should be unobstructed at all times. Exits should be clearly marked to be visible in total darkness. The number and capacity of emergency exits should also be wide enough for safe and orderly evacuation of the staff and workers.

Fire precautions:

- The test well drilling camp should be designed to prevent the start of fires through the implementation of fire codes applicable to industrial settings. Other essential measures include:
- Equipping facilities with fire detectors, alarm systems, and fire-fighting equipment. The equipment should be maintained in good working order and be readily accessible. It should be adequate for the dimensions and use of the premises, equipment installed, physical and chemical properties of substances present, and the maximum number of people present.
- Provision of manual firefighting equipment that is easily accessible and simple to use
- Fire and emergency alarm systems that are both audible and visible.
- Following the nature of the test well drilling, workers may be exposed to poisonous smokes/vapors, eye and skin irritating substances. Thus all safety tools should be availed at the camp and check workers use them without failure.

Safe access:

- Passageways for movements of vehicles, machines, and workers within and outside the camp should be segregated and provide for easy, safe, and appropriate access.
- Drilling and other related equipment, tools and installations requiring servicing, inspection, and/or cleaning should have unobstructed, unrestricted, and ready access.
- Hand, knee and foot railings should be availed while working on steam pipes, stairs, ladders, platforms, permanent and interim ramps, etc.
- Hazardous areas during drilling or during testing should be marked to prevent unauthorized access.

Work Environment

As already mentioned, the site is so hot, windy and dusty except few days (in two months) when there is little rain and cooler temperature. Thus, the temperature in all work rooms, rest, eating and sleeping rooms should be at a temperature appropriate for the climatic condition of the area.

- Sufficient fresh air should be supplied for indoor and confined work spaces. Factors to be considered in ventilation design include physical activity, substances in use, and process related emissions. Air distribution systems should be designed so as not to expose workers to heat and suffocation.
- All work areas of the drilling should receive natural light and if there is a need artificial light (which of course doesn't aggravate the hot climate of the site) to promote workers' safety and health, and enable safe equipment operation.
- Emergency lighting of adequate intensity should be installed and automatically activated upon failure of energy to ensure the continuation of the entire drilling activity and/or cooling system, among others.

Noise Mitigation Measure: As already mentioned, the site is relatively far from the neighborhood. And yet, it is likely the impact of sound could be felt throughout the site. Thus, measure for the mitigation should ensure minimize noise caused by vehicle movements, excavations, drilling, heavy machines activities, and pit related works. Therefore two basic measures need to be considered:

- Applying equipment mufflers particularly to heavy construction machines; and,
- Evaluating the level of noise every week particularly by consulting groups (staff of the contractor) that may likely affected by the sound.

Labor rights

In terms of labor and employment too, the contractor as well as project owner will be committed to respect human right issues, national and international policies and conventions involving workers that will be engaged in the project.

Summary of mitigation measure: The above discussions briefed the mitigation measures required for the identified impacts so far discussed. In line to that Table XX summarizes the mitigation measures proposed.

Table 6.1: Mitigation measures for adversly significant impacts

Impact type	*Mitigation measures*
Air pollution	When possible, dust producing activities should be reduced in presence of particularly windy conditions.
	The working area and site roads shall be sprayed with water during and immediately after operations so as to maintain the entire surface wet.
	Heights from which materials are dropped shall be restricted as far as practicable to minimize the fugitive dust arising from unloading /loading.
	Stockpiles of friable material must be properly treated to prevent wind throw and sediment run-off to the rivers during wet weather, alternatively coverings, enclosures or wind fences can be used to protect storage piles or vegetation can be grown on and around the storage piles to limit fugitive dust emission.
Surface and ground water pollution	Sufficient settling ponds equipped with an overflow system, and a further settling basin equipped with filters, this being the final point before the abstraction point for recycled water.
	Good maintenance of these storage ponds and treatment system is required.
	Impose best practice methods of storage, regular monitoring and development of appropriate responses for spills from fuels; chemicals etc.
	As much as possible, drill re-injection well after the first test well is developed.
Waste generation	Appropriate storage of general waste and regular disposal to landfill.
	Storage of mud in lined ponds and of cuttings in dedicated houses.
	Disposal of hazardous waste by a licensed contractor.
	Segregation and monitoring of waste streams in view of reducing, reusing recovering and recycling waste.
	Liaison with the community to identify reuse and recycle options.
	Identification of appropriate site(s) for excavation material disposal, away from sensitive surface or ground water features.
	Implementation of measures to avoid silt run off to surface water from excavated material.
	Regular removal of mud from the settling ponds and treatment of the mud as hazardous waste thus requiring safe disposal to approved landfill site.
	A Waste Management Plan should be developed and adopted by the Contractors
Soil contamination and degradation; (Surface & sub-surface changes in geology; morphology; subsidence; land slide; seismicity etc.)	Landfill and level surfaces after their disturbance in excavation or drilling
	Re-vegetation of disturbed areas by draught resistant plants
	Continuous monitoring of steam cavities and hot springs around the project site
	Set up a network of seismometer around the project area
	As much as possible use environment friendly mud additives for drilling
	Develop immediate clean up strategy for spills
	Construct professionally designed drainage and sufficient settling ponds for cuttings and mud products that have no linkage to surrounding water body
	Hazardous chemicals, oils and lubricants shall be stored in bundle at safe locations
	Spent oils, lubricants and other wastes shall be stored at safe and isolated site until regular disposal

Cont'd

Impact type	*Mitigation measures*
Noise and vibration	Workers nearest to high noise source shall be equipped with ear drum safety
	All site employees should be trained to adopt the quietest work practices, where appropriate.
	General working hours should be restricted to avoid/ minimize/ exposure to sensitive receptors;
	Machines and plant equipment that may be in intermittent use should be shut down between work periods or throttled to a minimum.
	stockpiles and other wide structures should be effectively utilized, where practicable, to screen sensitive receptors from noise due to on-site construction activities.
	Plant with directional noise features should be positioned so as to minimize the potential for noise disturbance.
	Appropriate construction methods should be used where possible so as to minimize noise levels at source.
	Advising villagers in advance of particularly noisy work.
Ecology; fauna; flora	Drill mud must be contained in appropriately lined ponds, equipped with overflow and solid retention system. These should be maintained throughout the drilling phase and periodically until the mud are removed. Incidents such as uncontrolled spill /overflow should be avoided through appropriate civil works and working practices
	Brines need to be contained in retention ponds that are sufficiently large and lined with corrosion and heat-resistant material, and contained until reinjection is possible.
	During test well drilling, dev't of re-injection well may not be feasible. In such cases, brine or mud solutions need to be treated physicochemical using flocculants at or nearly normal pH before released to either land fill or soil or water bodies and at a temperature that is not more than 3 °C higher than that of the water into which it is released.
	Retention ponds need to be sufficiently large and properly fenced to protect against accidents.
	Domestic and human waste effluents need to be fully treated (involving at least primary and secondary treatment) before being released into soil and local surface waters, or treated with septic tanks.
	Vegetation and green belt development around the project area (cascade)
	Noise and traffic mitigation measures shall also be maintained here for local fauna and flora
Occupational health and safety	Initial and continuous training of concerned staff prior to working (i.e Human Resource Development,HRS;)
	Design aspects of industrial safety shall be in place such as emergency exit, fire fighting systems etc.
	Assignment of roles and responsibilities to employees
	Strict management on delivery and usage of safety tools
	Identification of locations of concern and most sensitive areas.
	Establish clinic for waterborne diseases and malaria.
	Equip with fire detectors, alarm systems, and fire-fighting equipment.
	Set water points for fire-fighting; powder and foam for chemicals substances.
	Orient staff and workers with the use and mechanism of firefighting
	Minimum exposure time for those workers near hazardous activities.
Employment	Priority to local labor force, particularly, none skilled, and if possible semi skilled
Community safety	Remind/aware community on likely areas of health threats
	Posting signs and/or fencing around hazard areas within the site.
Vehicular and machine movements	Set maximum speed limit for vehicles particularly within the site; monitor and enforce rules and regulations.

6.3 Management Plan

Environmental and Social Management Plan (ESMP) is prepared on the basis of identified impacts and their level of significance. The objective of this ESMP is to identify project specific environmental and social actions that will be undertaken to manage impacts associated with the development and operation of test well drilling. Thus, it focuses on:

- Specific measures that will be taken to prevent, reduce or manage the socio-environmental impacts of the development
- Where it is not possible to specify these at this stage what level of environmental performance will be expected of the operation
- Developing proposals for monitoring and audit of ESIA implementation process.

Significant impacts that are detailed in the previous section shall be mitigated through proposed methods and then subjected to mechanisms of environmental management plan using monitoring and auditing as instrument.

However, in parallel to the general ESMP, a number of specific documents are required. GSE shall develop additional plans, policies and procedures to ensure adequate management and monitoring of social and environmental aspects. It is assumed that these plans will be elaborated by GSE to complement existing Environmental, Health and Safety Management System specifically for the Project. Where relevant and under respective contracts, drilling contractors should be required to implement the corresponding arrangements.

This management plan has been developed to clearly identify mitigation measures that should be implemented to minimize, reduce, or eliminate moderate and major adverse impacts identified in the ESIA. In addition, the ESMP also identifies best management practices (BMPs) and other mitigation measures that will minimize, reduce, or eliminate some negligible and minor impacts that could escalate to become more important if they are not handled properly.

Implementation of the ESMP is usually and effectively practiced through establishment of an Environmental Management Unit (EMU). In particular, implementation of the ESMP requires that:

- The detailed final design (plans and specifications) for the project incorporates all mitigation measures specified in the approved ESIA;
- The contract for the project implementation includes all mitigation measures;
- The drilling contractors' performance is duly monitored for compliance with the ESMP by competent inspectors;

- On completion of the works, inspection takes place to check that the completed work meet all significant environmental requirements before the project is officially accepted;
- The operations stage monitoring program is implemented as specified in the ESMP.

- There is effective reporting mechanism by the EMU (Environmental Monitoring Unit), through Project Implementation Unit, to demonstrate that the ESMP is being properly managed;

During drilling stage, the focus is on ensuring that the drilling contract requirements include basic health and safety requirements as well as mitigation measures are environmentally sound. To a considerable degree, drilling contractors will be responsible for implementing mitigation measures but, in any case, the ultimate responsibility for ensuring that environmental and social protection elements are being carried out properly is of GSE. Most of the impacts which occur during the drilling phase can be reduced or avoided through the application of sound construction management guidelines.

6.4 Institutional arrangement

The project office will ensure that socio-environmentally critical actions are undertaken as per recommended mitigation measures, various standard guideline requirements and applicable Ethiopian legislations. There shall be an assigned high level Management Body for overseeing all environment and safety responses to ensure the implementation of ESMP.

Thus, organizational Unit shall be instituted with defined roles, responsibilities, and authority to implement the ESMP. This Unit will focus on assessing current environmental practices, developing an internal audit system, reviewing environmental monitoring reports, identifying required control measures, initiating public relations campaigns to report, maintaining a clear environmental procedure, and establishing a transparent communication with governmental and non-governmental agencies concerned in environmental management.

The social set up within the Unit will form an important part of the Environmental management. There might not be institutional capacity at the woreda and PA levels for implementation of social development schemes in the project area. Thus, this set up in the Project Office will implement these programs. The Social Officer will coordinate with the Municipality of the Town, the woreda officials and the local community to address the social issues in the project surrounding. Community liaison and implementation of various education, health, employment, and infrastructure schemes proposed will be its important function.

A permanent organizational set up charged with the task of ensuring effective implementation of the Socio-environmental Management Plan shall be established in the Project Office. Thus, it may have a department consisting of Experts from various disciplines to co-ordinate activities concerned with the management and implementation of the socio-environmental mitigation measures of the proposed test well drilling operation. Thus, the following professional mix is recommended to establish Environmental Management Unit (EMU).

- Senior Environmentalist-one;
- Chemical Engineer or Chemist-one;
- Senior Sociologist-one.

6.5 Monitoring and Auditing

Monitoring is required prior to, during and after the drilling is completed. The purpose of this activity is to make periodic checks on the environmental impacts during different phases of the project, comparing them with those foreseen during the first phases of ESIA process. Monitoring provides a very useful feedback, which permits to correct at the right moment any environmental problem due to the project and meanwhile to acquire experience in planning future projects. The Federal EPA, the Regional EPA or Woreda level offices may not have facilities to undertake some part of the monitoring or auditing activities. Therefore, the project owner, GSE, shall establish Socio-environmental Management unit/section to address the issues.

The audit program will include pre-commissioning audits of the facilities focusing on the compliance of equipment and procedures to deliver the specified level of performance to ensure that all socio-environmental requirements are met. The above said monitoring shall be carried out by either creating in-house facilities or by hiring an external consultant. This ESIA study, after its approval, will be submitted to concerned bodies; Federal & Regional EPA, local administrators and communities, etc. Thus, this document shall only serve as a bench mark for auditing. It should be dynamic, interactive and participatory with regulatory bodies, project owner, local administrators, and communities through its institutional arrangement. Limiting values of EPA's guideline discussed in Chapter 3 on industrial emission (or effluent) need to be adapted here in test well monitoring and auditing activities.

Table 6.2: Monitoring and auditing plan

Monitoring and auditing plan for all phases of activities										
No.	*Items*	*Method*	*Parameters //Indicators//*	*Frequency*			*Prime Responsibility*			
				Pre	*Con*	*Ope*	*Pre*	*Con*	*Ope*	
1	Air Quality	Measurement /sampling/	PM/ PM10, CO2, H2S, Temperature, Oxygen level,	Quarterly	Monthly	Weekly	GSE project office	Contractor	GSE project office	
2	Water Quality	Surface and ground water sampling	Temperature, pH, Oil content Suspended solids, COD, Heavy metal concentration	Quarterly	Monthly	Monthly	GSE project office	Contractor	GSE project office	
3	Waste generation	Audits, photographic documentation, and interviews	Generation, storage, recycling, transport and disposal	Monthly	Weekly	Monthly	GSE project office	Contractor	GSE project office	
4	Soil Pollution	Sampling	Moisture content, pH, salinity, Nitrogen, Phosphate, Chloride, Potassium, Sodium Heavy metal content such as Mn, Fe , etc.	Monthly	Monthly	Monthly	GSE project office	Contractor	GSE project office	
5	Noise/ Vibration	Measurement Leq	(dB(A))	Monthly	Monthly	Biannually and upon complaints	GSE project office	Contractor	GSE project office	
6	Ground Subsidence	Site inspection; seismometer reading around the project area	Changes observed in steam cavities and hot springs around the project site	Quarterly	Monthly	Monthly	GSE project office	Contractor	GSE project office	
7	Offensive Odor	Steam sampling	Concentration of NH3; H2S	No need	Monthly	Weekly	GSE project office	Contractor	GSE project office	
8	Hydrology	Surface and ground water sampling	Temperature, pH, Oil content; Suspended solids; COD; Heavy metal concentration; Generation rate	Quarterly	Quarterly	Monthly	GSE project office	Contractor	GSE project office	
9	Occupational safety	Health and Safety survey	Proper use of PPE & other safety equipments;, presence of safety signs, first aid kit, fire fighting devices, Injury/ illness records. Emergency exits and plans; Accident statistics recording in accordance with ILO standards, including recording of Lost-Day- Accidents per Million-man hours (LDA/MMH)	Quarterly	Weekly	Monthly	GSE project office	Contractor	GSE project office	
10	Local economy (the poor)	Economic survey	Monthly income and level of business activities such as demend and supply trends	End of the phase	Semi-annually	Annually	GSE project office	GSE Project Office,Woreda Economic and Finanace Office	GSE Project Office,Woreda Economic abd Finanace Office	
11	Local conflicts of interest	Interview, observation and conflict report	Number of conflict incidents reported	End of the phase	Semi-annually	Quarerly	GSE project office	GSE Project Office,Woreda comm. Reprsentatives	GSE Project Office,Woreda comm. Reprsentatives	
12	Diffussion of local culture & norm	Survey and observation	Observed way of life style	End of the phase	Annualy	Annually	GSE project office	Culture & Tourism Office &GSE	Culture & Tourism Office &GSE	
13	Increased cost of living	Economic survey	Price trends and scarcity of supply and increased demend	End of the phase	Semi-annually	Semi-annually	GSE project office	GSE & Woreda Economy and Finance Office	GSE & Woreda Economy and Finance Office	
14	Community saftey and infectious Diseases	Health and safety survey and reports	Number of infected patients	Monthly	Monthly	Monthly	GSE project office	GSE & Health Office	GSE & Health Office	

6.6 Cost for Mitigation and Management

It is understood that test well drilling is a transition (or an intermediate) study having neither techno-economic nor engineering estimate studies that corresponds to this level of ESIA study. Thus, determining complete cost for implementing this ESMP might be unrealistic or misleading except perhaps cost estimate for human resource development in the project office and associated expenses for nearby community mobilization in the task of awareness creation and collective monitoring. For a full-fledged project, it is a common practice that 5 up to 7 % of the total project cost is allocated for ESIA implementation. However, the implementation cost for test well drilling is expected much lower. The following table presents annual cost estimate for ESMP implementation, being conservative and hoping that it serves only as bench mark to be further developed when techno-economic studies are finalized.

Table 6.3: Cost estimate for ESMP implementation (in USD)

No	*Item*	*Unit*	*Amount*	*Unit price (Cost/month)*	*Annual cost*
1	Professional fee	Person	3	600.00	7200.00
2	Supportive staff	Person	1	400.00	4800.00
3	Laboratory equipment & chemicals	Pcs	LS	1000.00	12000.00
4	Community mobilization	No of meetings /workshops/	12	2000.00	24000.00
5	Miscellaneous expenses	Ls	LS	300.00	12000.00
6	***Total***				***60000.00***

CHAPTER SEVEN: CONCLUSIONS AND RECOMMENDATION

7.1 Conclusion

This ESIA report is developed as a continuation of the "Master plan study for geothermal power plant development in Ethiopia". The objective of the Master Plan study was prioritization from fifteen potential geothermal sites found in Ethiopia. Accordingly, Tendaho-2, Dubti Woreda, Ayrobera site becomes at the frontier. However, geothermal power plant development by its very nature is complex with high coefficient of uncertainty. On top of that, the cost of well drilling is too high. Thus, it is quite reasonable that the selected site need to be supplemented (verified) by finer scientific investigation and test well drilling within the selected Ayrobera site. It is with this understanding that the scope of the project is limited to "ESIA study for test well drilling".

From the nature of the project, it can be concluded that geothermal energy conversion equipment in general and test well drilling in particular is relatively compact, making the overall footprint of the entire system small. With geothermal energy, there are no atmospheric discharges of nitrogen oxides or particulate matter, no need to dispose of radioactive waste materials, does not require large land area. The available and near-term geothermal energy technologies generally present much lower overall environmental impact than do conventional fossil-fueled, nuclear power plants and even hydropower energy system. For example, the power plant is located above the geothermal energy resource eliminating the need to:

a) physically mining the energy source (the "fuel") in the conventional sense, and in the process, to disturb the earth's surface, and;

b) process the fuel and then use additional energy to transport the fuel over great distances while incurring additional environmental impacts;

There are, however, certain impacts that must be considered and managed if geothermal energy is to be developed as a larger part of a more environmentally sound, sustainable energy portfolio for the future. Most of the potentially important environmental impacts of geothermal power plant development are associated with ground water use and contamination, and with related concerns about land subsidence and induced seismicity as a result of water injection and production into and out of a fractured reservoir formation. Issues of air pollution, noise, safety, also merit some consideration.

Findings of the project from policy perspective were studied by considering a number of elements: alignment of the project from policy perspectives; energy policy of the country verses geothermal; project perspective from guidelines of financial institutions; and alignment of JICA's guidelines with national policies. To this effect, national policies and regulation were reviewed; guidelines of relevant Federal and Regional Offices were studied; sufficient numbers of officials were also interviewed. It was understood that the entire legislative framework applicable to the proposed project is governed by the laws of Federal Democratic Republic of Ethiopia (FDRE). The ESIA study team has also concluded

that the proposed project could be fully materialized in alignment with national regulations and international conventions.

In terms of social aspects, the project brings almost no adverse significant impact upon the neighborhood in general and the community in particular. This is because that the project site is totally deserted, even grazing is unthinkable. What is more, there is no permanent settlement, even around the site. Likely adverse impacts could occur on the projects staff and temporary workers at large. This will happen due to the expected occupation accidents and hazard. In this respect, sources of adverse impacts could be observed particularly in the last two phases. These are related to person factors, unsafe activities, unhealthy weather conditions and job factors. These are explained by ill operations, absence of safety tools, lack of skill, failure of machines and equipment, availability of chemicals and movement of vehicles and machines, among others. This doesn't however mean that all the adverse impacts will 100% occur. As long as proper caution and care taken, and all safety mitigation measures are implemented prior to launching the project, the said adverse impacts would either be avoided or minimized, in one or another way.

Concerning economy, the project will result in a number of favorable benefits. The case in point is the fact that the project will definitely provide job opportunity for the unemployed section of the community; this will be true in all phases of the project. For instance, during construction of roads, and drilling or testing phases, most workers might be temporary. And yet, some other workers could enjoy permanent work if the drilling test result indicates positive. Additional income generated through employment in the form of wage will also result in injecting additional cash flow in the project kebele and the surrounding towns. This in turn will contribute to the expansion of the existing market and boost new small businesses, though not significantly. Semera town is expected to benefit more from additional market related to the project workers. On top of that the Federal, regional and woreda Government Revenue and Custom offices will benefit from the different withholding and profit taxes arising from the flow of cash from the project. In fact, the project may have minor adverse impacts related to heavy traffic, influence on the culture and style of life of the community around the project area.

7.2 Recommendation

In terms of environmental aspects, geothermal power projects are relatively eco-friendly, and are results of comparative analysis and possibilities of accessing Best Available in-process Technology, (BAT). This helps to fix potential environmental problems and thus encourages the realization of the test well drilling project. It is also to be noted that the proposed mitigation measures and management plans serve only as a bench mark for auditing. It is supposed to be dynamic, interactive and participatory with Regulatory Bodies, project owner, local administrators and nearby communities through its institutional arrangement.

In addition to this, justification of the project is adequately demonstrated in terms of: project rational; consistency with national policy; attractive scoping result from stakeholders' feedback in the project

site; manageable negative impact; contribution to the national development; access for job opportunities and better livelihoods, among others. Thus, as long as the proposed mitigation measures and institutional arrangements are implemented, the test well drilling project is feasible from socio-environmental perspectives.

Hard and soft copies of approved documents of ESIA study along with agreed up-on auditing plan shall be submitted to the respective legal and administrative institutions in a way that ensures easy access for their auditing purposes. It is with this approach that relevant institutions legally responsible can crosscheck its compliance with existing environmental laws and national standards. As the proposed geothermal project and its pre-requisite test well drilling is classified in Category A of EPA guideline, the status and responsibility of this Unit shall be higher to incorporate the following objectives:

- record project impacts during construction and operation;
- evaluate the effectiveness of the mitigation measures;
- meet legal and community obligations;
- update mitigation measures to further reduce impacts;
- elaborate mitigation measures to deal with unforeseen issues;
- develop mitigation measures to face changes in operations;
- let the international lenders verify that loan requirements are being met.

Pertaining to the social impact assessment, the success of the project will be determined by two measures that project owner and the contractor should consider. The first is to closely work with Afar Regional government and Dubti woreda administration. This is decisive, because they are the two government bodies that could react and respond to those individuals who would try to claim belongingness over the deserted and uninhabited site. Experiences from the region show that individuals who don't have legal right might accidentally claim possession over the deserted project sites. The other recommendation is the need to strictly follow up the mitigation measures as presented in last Chapter. Generic adverse impacts arising from occupation health risks, accidents and hazards will likely occur in all phases of the test well drilling project. Thus, the only means to avoid or control the negative effects would be to assign responsible section that would take serious measure and strictly implement mitigation measures before and during project operation.

For further success of the project, public disclosure and official reviewing are best instruments to further investigate unforeseen dimensions so as to arrive on a sound decision before implementation.

The employment opportunities that will be created by the project should be equally accessible for all, but fairly. To that end, recruitment and selection procedures should be done by the involvement of the elderly, tribe leaders and kebele officials; this approach has been found effective in other projects. Considering those who didn't get prior opportunity of employment would be a plus not only in improving the economic wellbeing of individuals but also in ensuring fairness and secure trust among the community. If possible the application of gender mainstreaming, would be advisable to further

facilitate the existing societal change in the area. Finally it will be wise to visit socioeconomic services of the project kebele. The project could provide support to the schools and water supply that are suffering from a number of challenges. The project could win the maximum cooperation of the community if the existing schools get support and the defective water pump gets repaired.

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APPENDIX-7

掘削計画

Appendix-7　掘削計画

A7.1　掘削計画坑跡

以下の表に AY-1 および AY-2 の坑跡計算結果を示す。

表 A7.1.1　AY-1 (A 基地)計画坑跡計算結果

No	掘進長	傾斜	方位			垂直深度	南北偏距	東西偏距	坑底方位			偏距	DLS
	m	dd.mm	dd.mm			m	m	m	dd.mm			m	dg/30m
1	0.00	0.00	N	E	82.00	0.00	0.00	0.00	N	E	82.00	0.00	0.00
2	100.00	0.00	N	E	82.00	100.00	0.00	0.00	N	E	82.00	0.00	0.00
3	200.00	0.00	N	E	82.00	200.00	0.00	0.00	N	E	82.00	0.00	0.00
4	300.00	0.00	N	E	82.00	300.00	0.00	0.00	N	E	82.00	0.00	0.00
5	400.00	0.00	N	E	82.00	400.00	0.00	0.00	N	E	82.00	0.00	0.00
6	450.00	0.00	N	E	82.00	450.00	0.00	0.00	N	E	82.00	0.00	0.00
7	480.00	0.30	N	E	82.00	480.00	0.02	0.13	N	E	82.00	0.13	0.50
8	510.00	1.30	N	E	82.00	509.99	0.09	0.65	N	E	82.00	0.65	1.00
9	540.00	3.00	N	E	82.00	539.97	0.25	1.81	N	E	82.00	1.83	1.50
10	570.00	5.00	N	E	82.00	569.90	0.55	3.89	N	E	82.00	3.92	2.00
11	600.00	8.00	N	E	82.00	599.70	1.02	7.25	N	E	82.00	7.32	3.00
12	630.00	9.30	N	E	82.00	629.35	2.45	17.44	N	E	82.00	11.88	1.50
13	660.00	12.30	N	E	82.00	658.80	3.46	24.62	N	E	82.00	17.61	3.00
14	690.00	15.30	N	E	82.00	687.90	4.68	33.31	N	E	82.00	24.86	3.00
15	720.00	18.30	N	E	82.00	716.59	6.11	43.47	N	E	82.00	33.63	3.00
16	750.00	21.30	N	E	82.00	744.77	7.74	55.07	N	E	82.00	43.89	3.00
17	780.00	24.30	N	E	82.00	772.39	9.57	68.10	N	E	82.00	55.61	3.00
18	810.00	27.30	N	E	82.00	799.35	11.59	82.50	N	E	82.00	68.76	3.00
19	840.00	30.30	N	E	82.00	825.58	13.81	98.24	N	E	82.00	83.31	3.00
20	870.00	33.30	N	E	82.00	851.02	16.20	115.28	N	E	82.00	99.20	3.00
21	900.00	36.30	N	E	82.00	875.59	24.53	174.53	N	E	82.00	116.41	3.00
22	1000.00	37.00	N	E	82.00	955.72	32.90	234.12	N	E	82.00	176.24	0.15
23	1100.00	37.00	N	E	82.00	1035.58	41.28	293.72	N	E	82.00	236.42	0.00
24	1200.00	37.00	N	E	82.00	1115.45	49.65	353.31	N	E	82.00	296.60	0.00
25	1300.00	37.00	N	E	82.00	1195.31	58.03	412.91	N	E	82.00	356.78	0.00
26	1400.00	37.00	N	E	82.00	1275.17	66.41	472.50	N	E	82.00	416.97	0.00
27	1500.00	37.00	N	E	82.00	1355.04	74.78	532.10	N	E	82.00	477.15	0.00
28	1600.00	37.00	N	E	82.00	1434.90	83.16	591.70	N	E	82.00	537.33	0.00
29	1700.00	37.00	N	E	82.00	1514.76	91.53	651.29	N	E	82.00	597.51	0.00
30	1800.00	37.00	N	E	82.00	1594.63	99.91	710.89	N	E	82.00	657.69	0.00
31	1900.00	37.00	N	E	82.00	1674.49	108.28	770.48	N	E	82.00	717.87	0.00
32	2000.00	37.00	N	E	82.00	1754.35	0.00	0.00	N	E	82.00	778.06	0.00

※磁北基準にて検討

表 A7.1.2　AY-2 (B 基地)計画坑跡計算結果

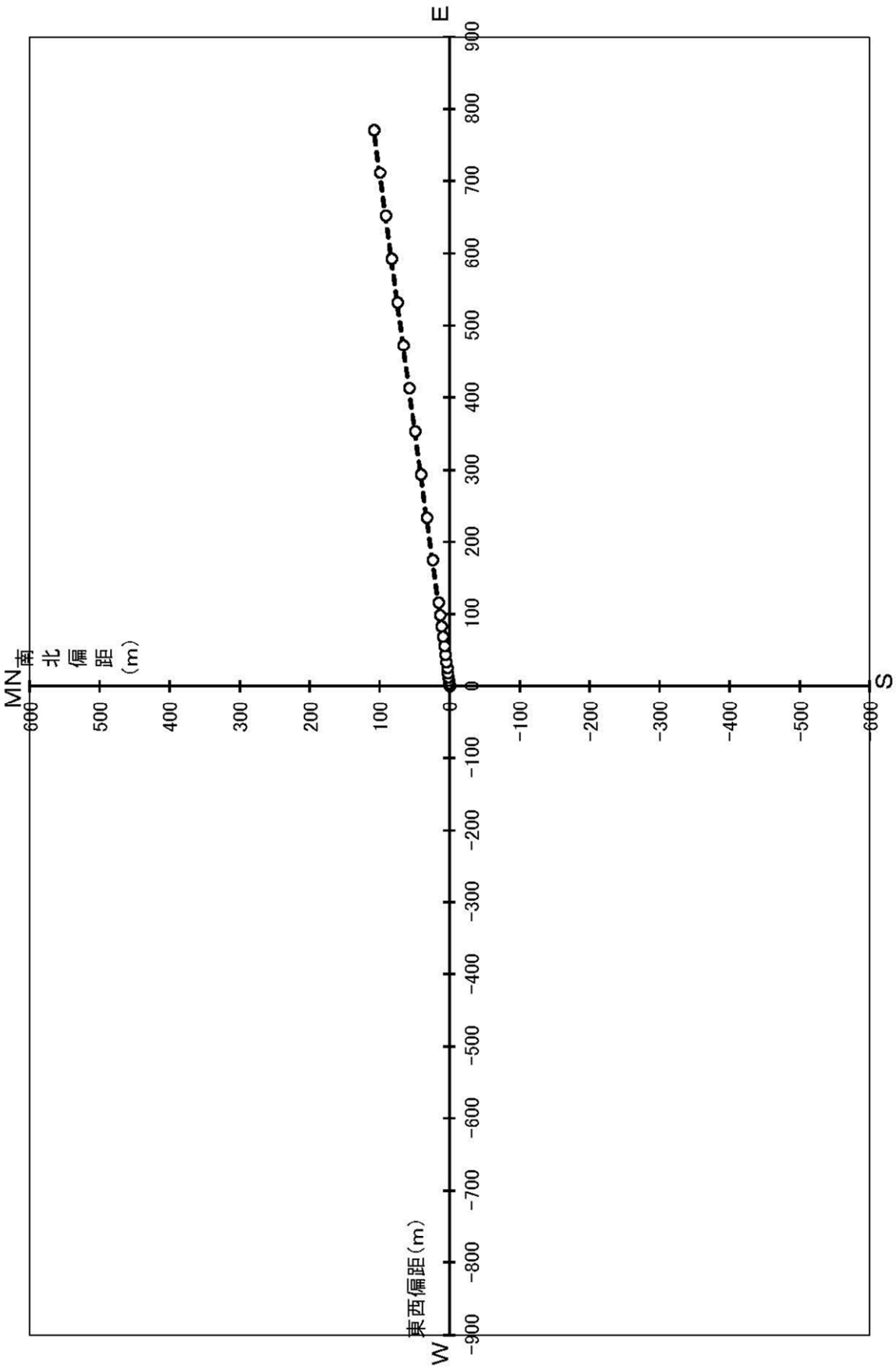
No	掘進長	傾斜	方位			垂直深度	南北偏距	東西偏距	坑底方位			偏距	DLS
	m	dd.mm	dd.mm			m	m	m	dd.mm			m	dg/30m
1	0.00	0.00	N	E	84.00	0.00	0.00	0.00	N	E	84.00	0.00	0.00
2	100.00	0.00	N	E	84.00	100.00	0.00	0.00	N	E	84.00	0.00	0.00
3	200.00	0.00	N	E	84.00	200.00	0.00	0.00	N	E	84.00	0.00	0.00
4	300.00	0.00	N	E	84.00	300.00	0.00	0.00	N	E	84.00	0.00	0.00
5	400.00	0.00	N	E	84.00	400.00	0.00	0.00	N	E	84.00	0.00	0.00
6	450.00	0.00	N	E	84.00	450.00	0.00	0.00	N	E	84.00	0.00	0.00
7	480.00	0.30	N	E	84.00	480.00	0.01	0.13	N	E	84.00	0.13	0.50
8	510.00	1.30	N	E	84.00	509.99	0.07	0.65	N	E	84.00	0.65	1.00
9	540.00	3.00	N	E	84.00	539.97	0.19	1.82	N	E	84.00	1.83	1.50
10	570.00	5.00	N	E	84.00	569.90	0.41	3.90	N	E	84.00	3.92	2.00
11	600.00	8.00	N	E	84.00	599.70	0.77	7.28	N	E	84.00	7.32	3.00
12	630.00	9.30	N	E	84.00	629.35	1.24	11.82	N	E	84.00	11.88	1.50
13	660.00	12.30	N	E	84.00	658.80	1.84	17.51	N	E	84.00	17.61	3.00
14	690.00	15.30	N	E	84.00	687.90	2.60	24.73	N	E	84.00	24.86	3.00
15	720.00	18.30	N	E	84.00	716.59	3.52	33.45	N	E	84.00	33.63	3.00
16	750.00	21.30	N	E	84.00	744.77	4.59	43.65	N	E	84.00	43.89	3.00
17	780.00	24.30	N	E	84.00	772.39	5.81	55.31	N	E	84.00	55.61	3.00
18	810.00	27.30	N	E	84.00	799.35	7.19	68.39	N	E	84.00	68.76	3.00
19	840.00	30.30	N	E	84.00	825.58	8.71	82.85	N	E	84.00	83.31	3.00
20	870.00	33.30	N	E	84.00	851.02	10.37	98.66	N	E	84.00	99.20	3.00
21	900.00	36.30	N	E	84.00	875.59	12.17	115.77	N	E	84.00	116.41	3.00
22	1000.00	37.00	N	E	84.00	955.72	18.42	175.27	N	E	84.00	176.24	0.15
23	1100.00	37.00	N	E	84.00	1035.58	24.71	235.13	N	E	84.00	236.42	0.00
24	1200.00	37.00	N	E	84.00	1115.45	31.00	294.98	N	E	84.00	296.60	0.00
25	1300.00	37.00	N	E	84.00	1195.31	37.29	354.83	N	E	84.00	356.78	0.00
26	1400.00	37.00	N	E	84.00	1275.17	43.58	414.68	N	E	84.00	416.97	0.00
27	1500.00	37.00	N	E	84.00	1355.04	49.88	474.53	N	E	84.00	477.15	0.00
28	1600.00	37.00	N	E	84.00	1434.90	56.17	534.39	N	E	84.00	537.33	0.00
29	1700.00	37.00	N	E	84.00	1514.76	62.46	594.24	N	E	84.00	597.51	0.00
30	1800.00	37.00	N	E	84.00	1594.63	68.75	654.09	N	E	84.00	657.69	0.00
31	1900.00	37.00	N	E	84.00	1674.49	75.04	713.94	N	E	84.00	717.87	0.00
32	2000.00	37.00	N	E	84.00	1754.35	81.33	773.79	N	E	84.00	778.06	0.00

※磁北基準にて検討

表 A7.1.2　AY-3 (C 基地)計画坑跡計算結果

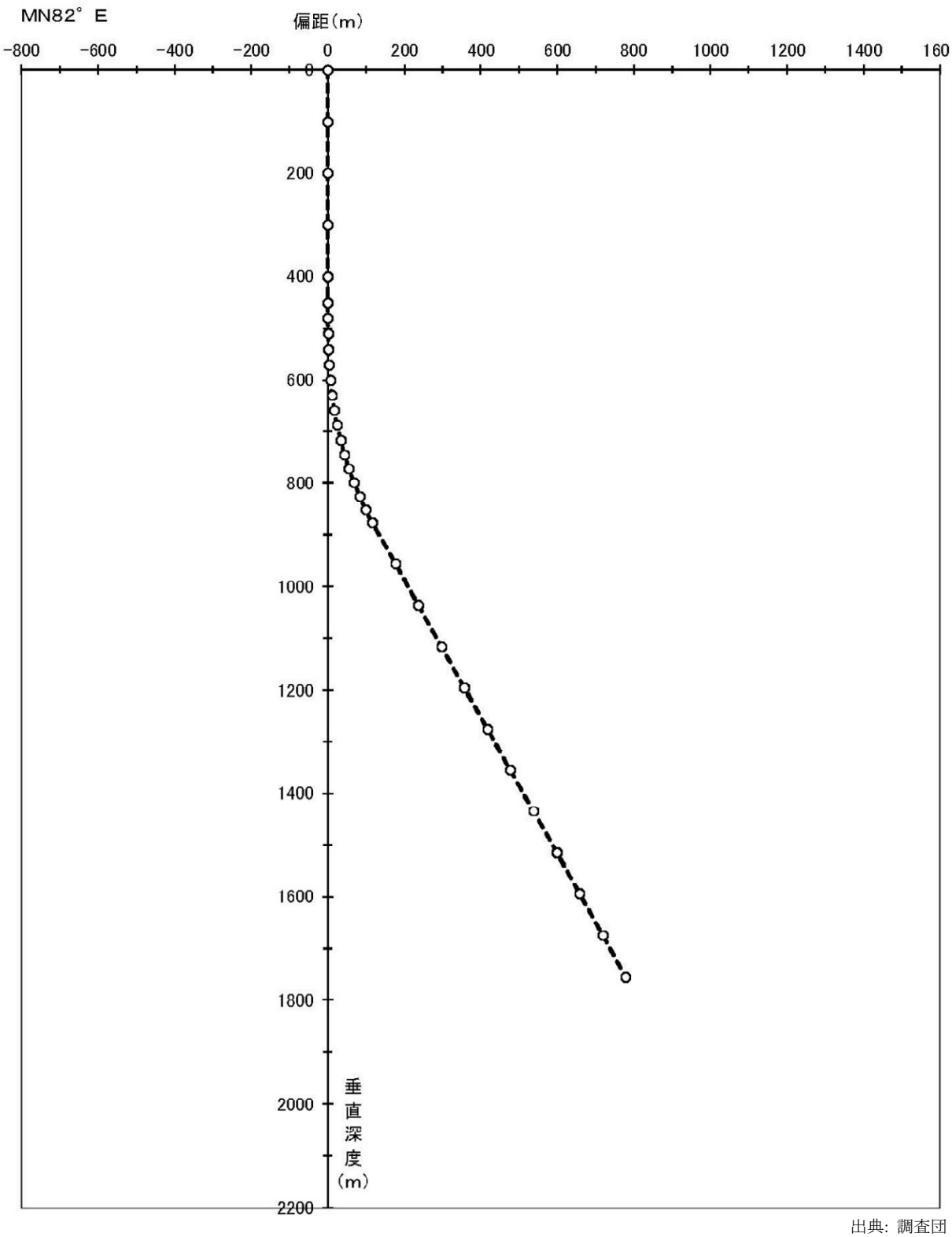
No	掘進長	傾斜	方位			垂直深度	南北偏距	東西偏距	坑底方位			偏距	DLS
	m	dd.mm	dd.mm			m	m	m	dd.mm			m	dg/30m
1	0	0	N	E	49.00	0	0.00	0.00	N	E	49.00	0.00	0.00
2	100	0	N	E	49.00	100.00	0.00	0.00	N	E	49.00	0.00	0.00
3	200	0	N	E	49.00	200.00	0.00	0.00	N	E	49.00	0.00	0.00
4	300	0	N	E	49.00	300.00	0.00	0.00	N	E	49.00	0.00	0.00
5	400	0	N	E	49.00	400.00	0.00	0.00	N	E	49.00	0.00	0.00
6	500	0	N	E	49.00	500.00	0.00	0.00	N	E	49.00	0.00	0.00
7	530	0.3	N	E	49.00	530.00	0.09	0.10	N	E	49.00	0.13	0.50
8	560	1.3	N	E	49.00	559.99	0.43	0.49	N	E	49.00	0.65	1.00
9	590	3	N	E	49.00	589.97	1.20	1.38	N	E	49.00	1.83	1.50
10	600	3.4	N	E	49.00	599.95	1.58	1.82	N	E	49.00	2.41	2.00
11	630	5	N	E	49.00	629.87	3.07	3.53	N	E	49.00	4.68	1.33
12	660	8	N	E	49.00	659.67	5.30	6.10	N	E	49.00	8.08	3.00
13	690	11	N	E	49.00	689.26	8.55	9.83	N	E	49.00	13.03	3.00
14	720	14	N	E	49.00	718.54	12.81	14.73	N	E	49.00	19.52	3.00
15	750	17	N	E	49.00	747.45	18.07	20.78	N	E	49.00	27.54	3.00
16	780	20	N	E	49.00	775.89	24.31	27.96	N	E	49.00	37.05	3.00
17	810	23	N	E	49.00	803.80	31.52	36.26	N	E	49.00	48.05	3.00
18	840	26	N	E	49.00	831.10	39.68	45.65	N	E	49.00	60.49	3.00
19	870	29	N	E	49.00	857.71	48.77	56.10	N	E	49.00	74.34	3.00
20	900	32	N	E	49.00	883.55	58.76	67.59	N	E	49.00	89.56	3.00
21	930	33.3	N	E	49.00	908.78	69.41	79.84	N	E	49.00	105.79	1.50
22	1000	33.3	N	E	49.00	967.15	94.75	109.00	N	E	49.00	144.43	0.00
23	1100	33.3	N	E	49.00	1050.54	130.96	150.66	N	E	49.00	199.62	0.00
24	1200	33.3	N	E	49.00	1133.93	167.17	192.31	N	E	49.00	254.81	0.00
25	1300	33.3	N	E	49.00	1217.32	203.38	233.97	N	E	49.00	310.01	0.00
26	1400	33.3	N	E	49.00	1300.71	239.59	275.62	N	E	49.00	365.20	0.00
27	1500	33.3	N	E	49.00	1384.10	275.80	317.28	N	E	49.00	420.39	0.00
28	1600	33.3	N	E	49.00	1467.49	312.01	358.93	N	E	49.00	475.59	0.00
29	1700	33.3	N	E	49.00	1550.87	348.22	400.59	N	E	49.00	530.78	0.00
30	1800	33.3	N	E	49.00	1634.26	384.43	442.24	N	E	49.00	585.98	0.00
31	1900	33.3	N	E	49.00	1717.65	420.65	483.90	N	E	49.00	641.17	0.00
32	2000	33.3	N	E	49.00	1801.04	456.86	525.55	N	E	49.00	696.36	0.00

※磁北基準にて検討



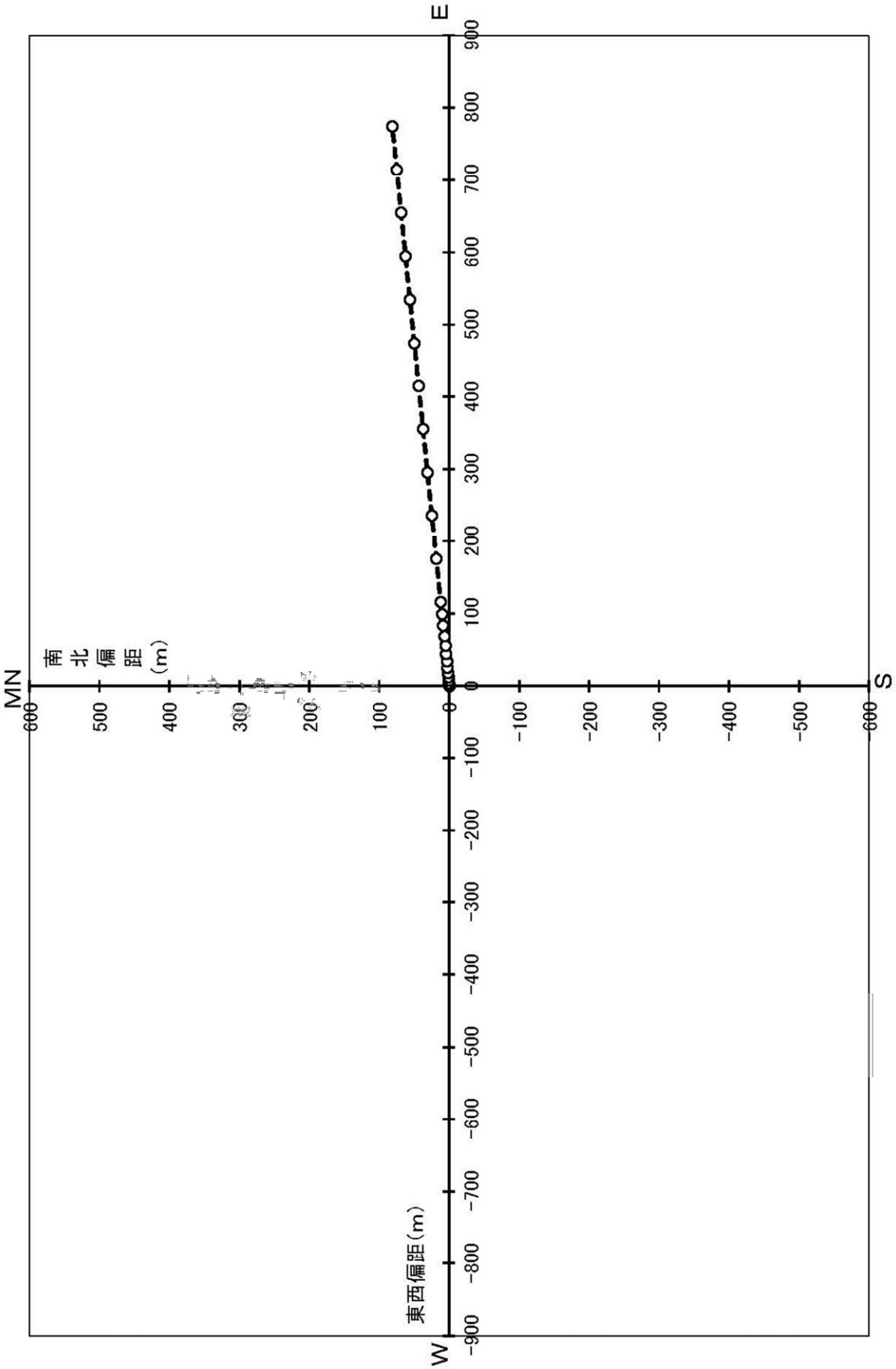
出典: 調査団

図 A7.1.1 AY-1 (A 基地)磁北基準坑跡平面図



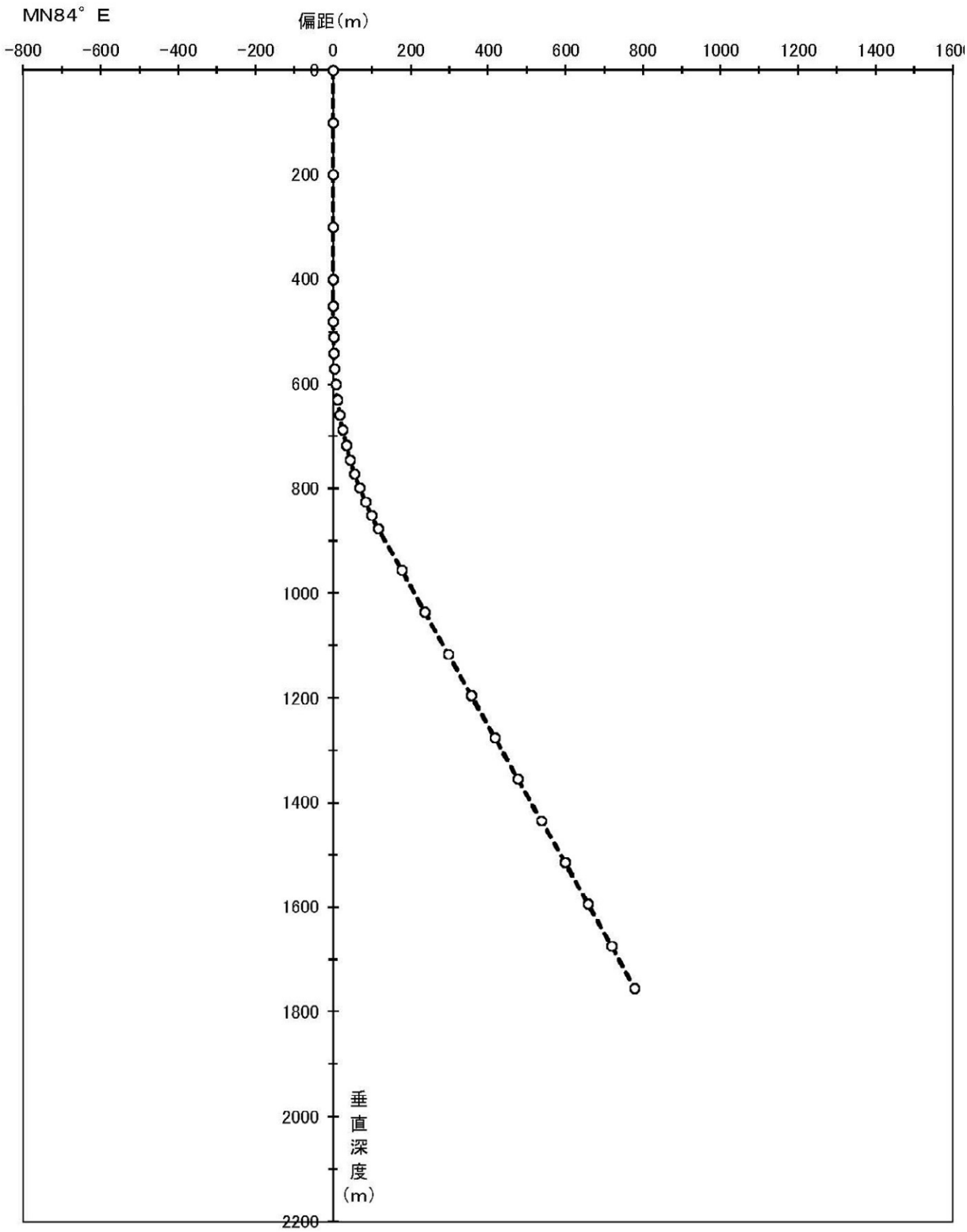
出典: 調査団

図 A7.1.2　AY-1 (A 基地)磁北基準坑跡断面図



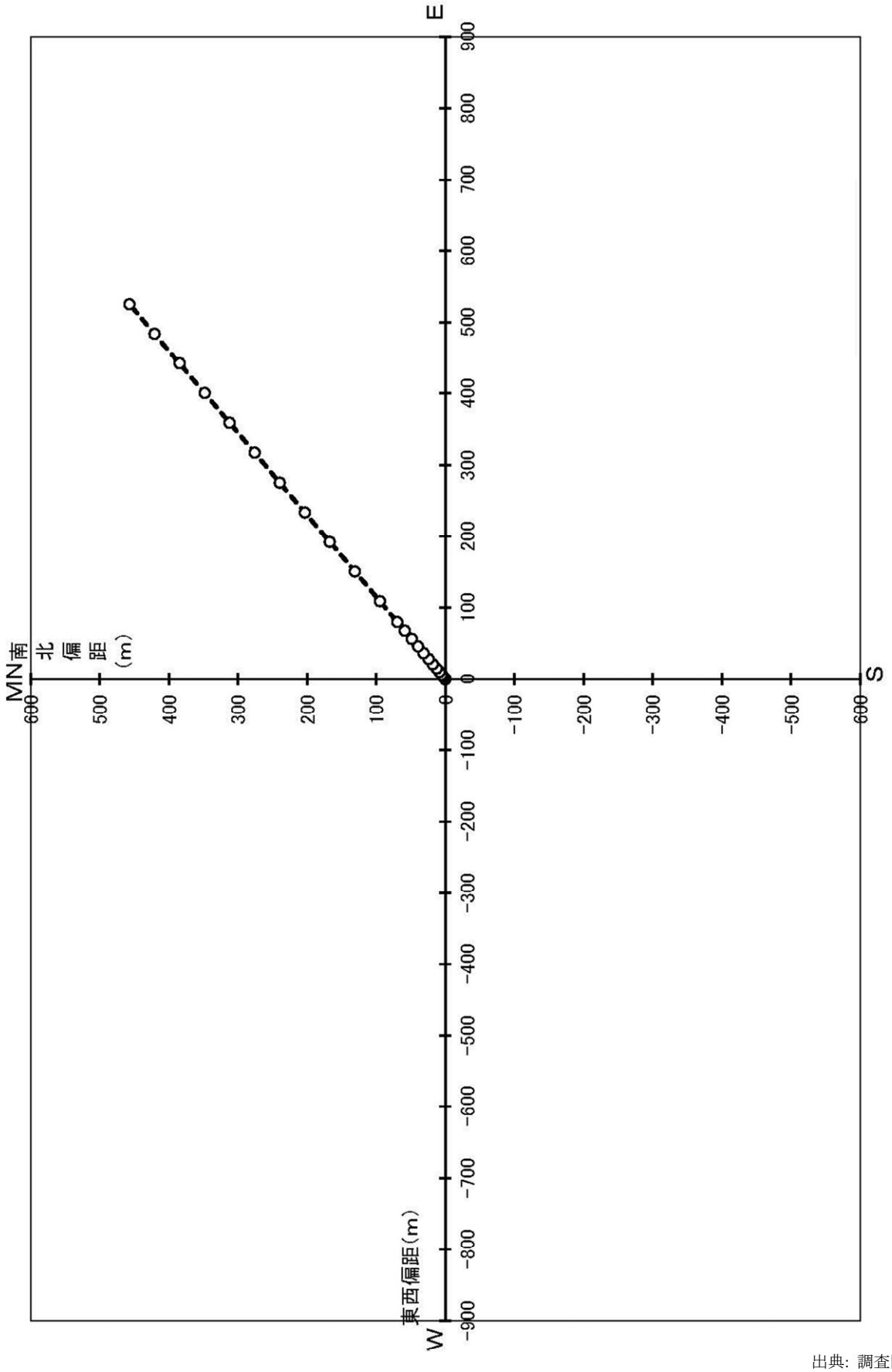
出典: 調査団

図 A7.1.3　AY-2 (B 基地)磁北基準坑跡平面図



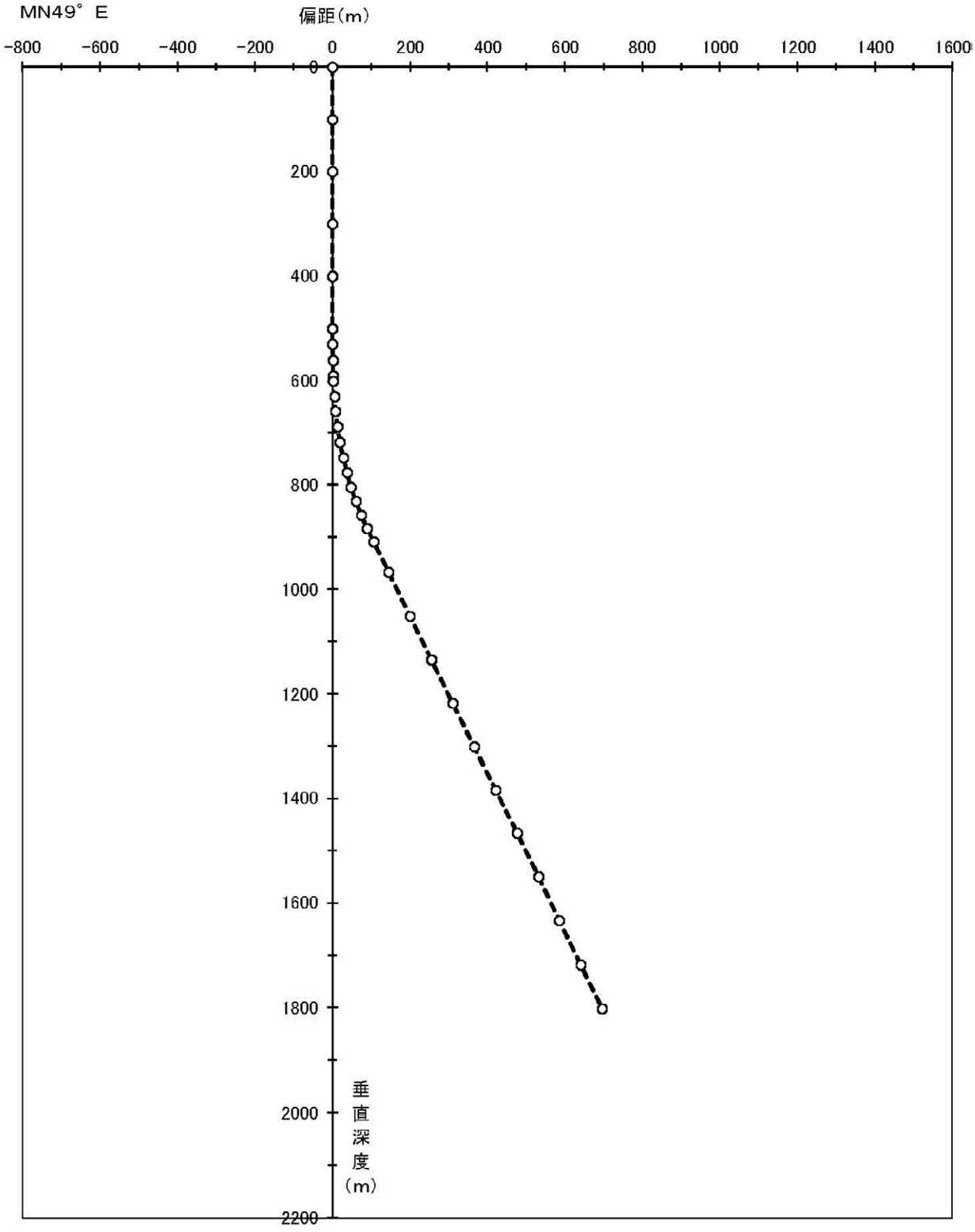
出典: 調査団

図 A7.1.4 AY-2 (B 基地)磁北基準坑跡断面図



出典: 調査団

図 A7.1.5　AY-3 (C 基地) 磁北基準坑跡平面図

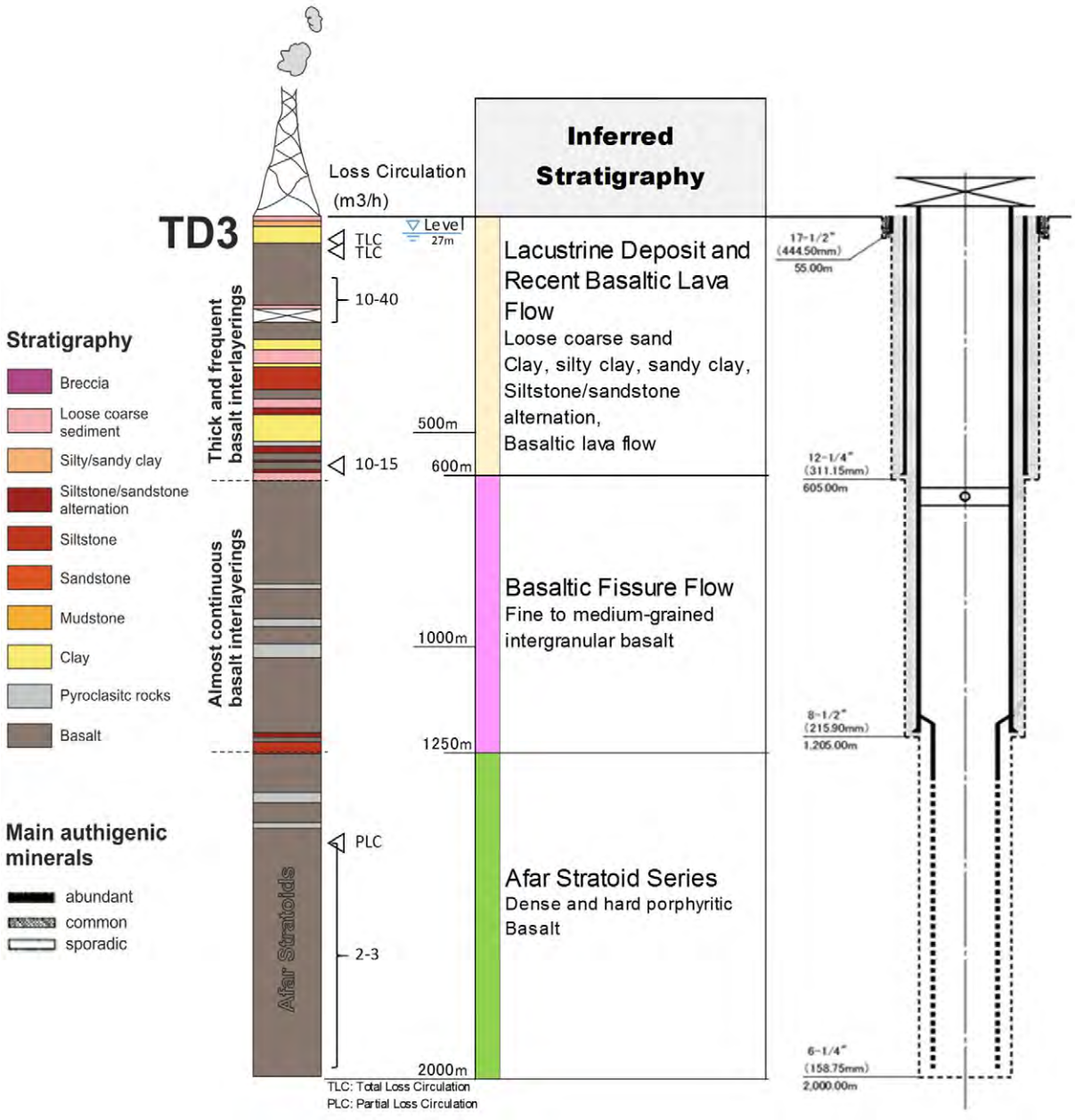


出典: 調査団

図 A7.1.6　AY-3 (C 基地)磁北基準坑跡断面図

A7.2 想定地質柱状図

以下の図に、既存坑井 TD-3 を基にした想定地質柱状図を示す。

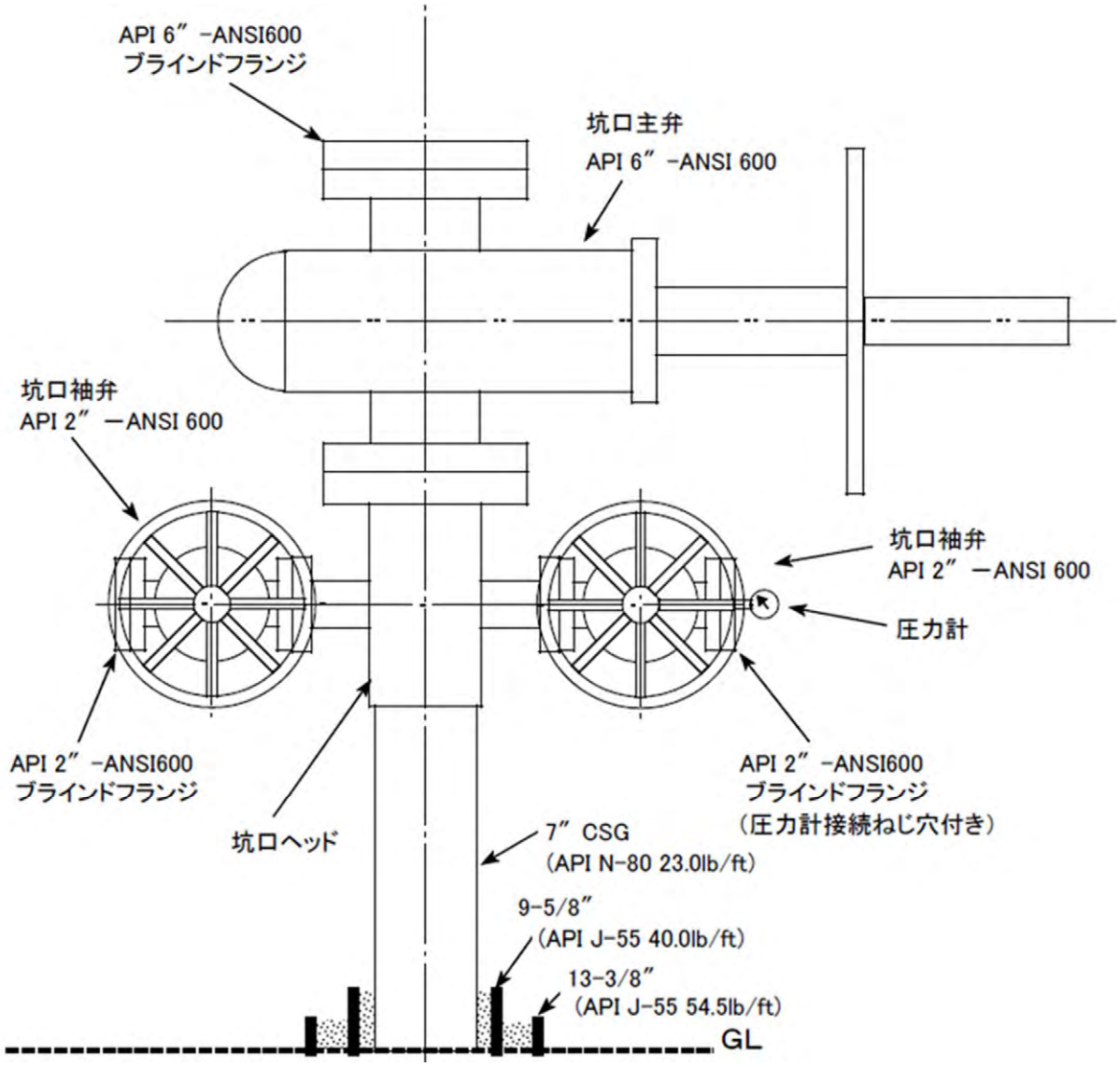


出典: 調査団

図 A7.2.1 想定地質柱状図

A7.3　坑口装置

以下の表に AY シリーズの坑井に取り付ける坑口装置の計画を示す。



出典: 調査団

図 A7.3.1　坑口装置図