ORKUSTOFNUN

Evaluation of data obtained for the water and CO2 resource at Sillunchi, Ecuador

Ómar Sigurðsson

Greinargerð Ómar-99-01A

ORKUSTOFNUN
National Energy Authority

Verknr. 8-600051

Omar Sigurdsson

Evaluation of data obtained for the water and CO_2 resource at Sillunchi, Ecuador

Prepared for AGA S.A.

Report
Omar-9901 **March 1999**

ORKUSTOFNUN: Id. number 500269-5379 - Tel. +354 5696000 - Fax +354 5688896
E-mail os@os.is - Homepage http://www.os.is

LIST OF CONTENT

Evaluation of data obtained for the water and CO_2 resource at Sillunchi

INTRODUCTION

AGA S.A. owns and operates the CO_2 production plant at Aqua y Gas de Sillunchi located near the town Machachi south of the capital Quito in Ecuador. The CO_2 is produced by separation from saturated ground water, which is collected from natural springs and boreholes in the vicinity of the plant. The AGA property is about 200m wide strip that follows the eastern bank of the river Rio San Pedro. In south the property is marked by a small electrical power station just south of the gas plant and extends more than 2km to the north where another electrical power station marks the northern end.

Production of CO_2 started some 50 years ago where the early sources were gas rich springs along the Rio San Pedro river but drilling commenced in 1956. Location of at least 17 wells is known within or very near the AGA property. Today four wells and one natural spring are the main sources for the gas plant. The conditions of most of these wells was checked by measuring the downhole temperature and pressure during the field trip of Omar Sigurdsson on January 19th to 28th, 1999. Also looked at during that field trip was the distribution of natural springs and their temperature. Additional information and data was supplied by AGA personnel, especially on flow measurements made over the past three years.

In this report the emphasis is on evaluation of the data that has been supplied or collected during the latest trip by Omar Sigurdsson (1) and an earlier trip by Sverrir Thorhallsson (2). The main question is, if the data at hand can describe the longer term conditions of the water resource. Hence, conclusions could be drawn on what actions should be taken to insure the production from the gas plant. For description of the measurements and data the reader is referred to the field reports by the above mentioned persons (ref. 1 and 2).

MEASUREMENTS DURING FIELD TRIP

The temperature and pressure was measured in 13 wells and the gas flow rate in 3 wells. Of the 13 wells, one was outside the AGA property, well Marcela. Location of four additional wells is known, well Maria Fabiola and the three San Guillermo Bajo wells. Approximate location of the wells is shown on the location map in figure 1. Six of the thirteen wells are connected to the gas plant where four of them are main suppliers for the plant along with the natural spring at Tatatambo. Of the known 17 wells, 5 are more than 30 years old and thereof one is still in use for the plant. Then there are 4 wells that are between 15-20 years old and one of them is still in use but with little flow. The remaining 8 wells are less than 10 years old with the last well drilled 3 years ago. At least the younger wells are lined with 6" or 8" PVC-pipes and some are also completed with a gravel pack. The deeper part of the pipe has been perforated to allow flow into the pipe and up to the surface.

The downhole measurements revealed that all the wells measured were damaged and that the liners and boreholes had collapsed at different depth levels. Even during the measurements in well Margarita, one of the major producer for the gas plant, it was felt when stone fell into the well and blocked the measuring gauge in there. The gauge was freed with a fishing tool made by the personnel at the gas plant. The measurements demonstrate that the production interval has been severely reduced in many of the wells. Knowing the current depth of these wells, it can be compared with drilling and completion logs for each well to quantify this reduction. As an example the records for well Alborada B say that the well was drilled in 1993 to a total depth of 146m. It was lined with 6" PVC-pipe that was perforated from about 80m depth to bottom. After testing, the well was completed with a gravel pack placed in the annulus between the PVC-pipe and the borehole. Its current depth is 71m with small flow

rate. The well is blocked 10m above the well screen, which easily explains the small flow rate from the well. Another example is well Margarita, which was drilled to 105m depth in 1996. There drilling was stopped when the well started to discharge mixture of gas and water, indicating a good producer. The well is lined with 6" PVC-pipe and completed with gravel pack. The current depth of well Margarita is 83m and damages were felt on the liner at 78m depth. The liner is broken and stones are dropping into the well restricting the flow. This will cause a problem in the near future.

A failure occurred in the data logger used for the pressure gauge so pressure measurements made on January 21st and 22nd had to be recalibrated. Unfortunately it was not possible to correct the pressure measurement made in the San Guillermo Alto well while it was flowing. That measurement can therefore only be used for reference purpose. It was possible to correct the static measurement made in that well down to 90m depth, but from there the pressure profile can be extrapolated to greater depths. Pressure measurements made in other wells could be corrected. The temperature and pressure profiles along with the corrected profiles are shown on figures in the appendix.

During the field trip on January 19th to 28th, 1999 temperature and flow rates was measured for several natural springs along the riverbank of Rio San Pedro. Approximate location of these springs is shown on the location map in figure 1. The springs are marked with a character that corresponds with the ordering and description given in reference 1. For easier viewing and the purpose here the surface temperature for the natural springs and some of the wells is written next to their location in figure 2. Looking at figure 2 one can postulate that the temperature distribution near the gas plant points to a linear temperature anomaly with direction from the Spring by River Side (G) towards well Marcela. The anomaly could indicate a flow path of warmer water possibly along fracture or some other weakness in the formation. This need to be studied further with regard to future drillings in this area as it could be the target to aim for.

PRODUCTION HISTORY

History of flow rates from wells and natural springs was made available from March 1996 to December 1998. The production history for all the sources has been plotted on a single graph and measurements obtained during the field trip in January 1999 added to it. Measurements taken during the field trip in January 1999 indicate that the Alto wells, San Guillermo Alto and Tatatambo Alto, have been reported together as they flow to a common channel. The present major producers for the gas plant are the Alto wells (27 l/s) (San Guillermo Alto (20 l/s), Tatatambo Alto (7 l/s)), the natural spring at the Tatatambo A side (19 l/s), well Margarita (17 l/s) and well San Andrés 1 (7.5 l/s). Other wells and natural springs that are tapped have flow rates that are usually less than 3 l/s. These major sources supply over 70 l/s while other sources may add 10-15 l/s to that. The importance of these five major sources is therefore obvious as they supply over 80% of the water production and most likely the same ratio applies for the CO_2 gas production.

Looking at the available production history, which is shown in figure 3, it can be seen that the flow rate from the natural spring at Tatatambo has some seasonal fluctuation, but on average it has about the same flow rate over the measured period. The smaller fluctuation can be caused by measurement errors, which can be limited with the installation of a permanent weir flow meter. The stability in the flow from this natural spring, taking into account the seasonal fluctuation, is fundamental to the following interpretation of the production history and the corresponding remedial suggestions.

The combined Alto wells show a decline in production in late 1996 from about 32 l/s to 27-28 l/s, but the wells have been stable at that level for the past two years. When well

Margarita starts to discharge in late May or early June 1996 at a rate of 32 l/s the production from the Alborada wells was reduced by about 7 l/s. For one year the Margarita well discharges at that rate, but then something happens in the well and the flow rate declines to 27 l/s and remains such for another year. In April or May 1998 something happens again in the well and the flow rate starts to decline again. Presently the flow rate from Margarita is about 17 l/s. Most likely the failure in the PVC-liner and possible collapse near the bottom of the well has caused this nearly 50% reduction in flow rate from this well. As the flow rate from well Margarita has declined a small increase is observed in the discharge rate from the Alborada wells.

The discharge from the San Andrés 1 well has been fairly stable during the measured period. A gradual decline is in the discharge from well Tatatambo B during the period from about 4 l/s to about 1 l/s. At the same time the much bigger discharge from the natural spring at Tatatambo located only few meters away remains stable. This indicates that the cause for the rate decline is in the Tatatambo B well itself. A minimal decline of about 1 l/s is observed in discharge at the natural springs at Santa Teresa.

The general picture points to that the regional flow potential has remained stable for the past three years or over the measured period. It is therefore concluded that the observed production decline over the same period is a result of problems in the production wells themselves.

DISCUSSION

Near the gas plant the static water level is at less than 1m depth (wells Alborada, Margarita, Marcela). The wells are selfflowing or artesian because of gas lift caused by CO_2 coming out of solution in the upper part of the water column. The discharge produces a drawdown in the wells. The drawdown is 3.7m in well Marcela and there the separation or boiling starts at about 15m depth. In well Margarita the drawdown appears to be about 9m with separation starting near 25m depth. At San Guillermo Alto the static water level is at greater depth. After the flow from the San Guillermo Alto well was quenched during the measurements on January 22nd, 1999 the water level was at about 21m depth. The static water level is most likely higher, as the large discharge from the well prior to the measurements had left some drawdown in the well. In San Guillermo Alto the separation starts between 50-60m depth and drawdown due to regular discharge is more than 10m.

The reason for mentioning this is that the balance between a flowing and static well is weak. In January 1999 it was observed when flow was quenched from two wells, i.e. Marcela and San Guillermo Alto. The procedure leading to the quenching was similar for both wells. When the surface pipes were disconnected from their wellheads, the small back pressure applied by the surface equipment was reduced, allowing their flow rates to increase some due to more degassing in the water column as the pressure had been decreased. Reconnecting the surface equipment to the Marcela well increased the backpressure enough to quench the flow from that well. The increased degassing in the more permeable San Guillermo Alto well continuously increased the discharge rate from that well until the boiling or separation reached the depth of the aquifer feeding the well. Then for some time the discharge rate stayed about the same while degassing spread into the formation. At some point degassed water flowed into the well and quenched its discharge. The wells start to flow again when water saturated with CO_2 has filled the wellbore and degassing in the upper most portion of the water column reduces the weight or the pressure inserted by the water column on the aquifer, hence creating a small drawdown that initiates flow.

For the wells at Sillunchi that have small flow rates (<5 l/s) a relatively small fluctuation in the back pressure in the gas collection system can quench the flow from those wells. It has

less effect on the more permeable sources with the higher flow rates as long as their discharge will not become uncontrolled due to broken surface pipes. The San Guillermo Alto well seams to be operated near but below its optimum flow rate. It is likely that its discharge could be increased to about 30 l/s without risking quenching of the well. That can either be done by lowering the wellhead and surface pipes from the well or by the use of a submersible pump.

As pointed out earlier is the PVC-liner in well Margarita damaged and its damage is growing. The current state for the damage is that the depth of the well has been reduced by more than 20m from the drilled depth, 105m to 83m. This has resulted in almost 50% reduction in the output from the well. The condition of the liner now is that it is broken at 78m depth so in the nearest future it can collapse there reducing the depth of the well by another 5m, but more seriously reduce its output considerably more. Loosing the production from this well will reduce the production capacity of the gas plant by about 20% or 150 kg/hr of liquid CO_2. Action should be taken as soon as possible to secure this production.

The highest temperature measured in wells near the gas plant point to a thermal anomaly with a linear trend laying in direction with well Marcela and the natural spring called Spring by River Side. The Spring by River Side was one of the first production sources used when the gas plant started. It is worth while to define this structure better, but the production wells Margarita and San Andrés 1 are close to it. This structure could be a fracture acting as a conduct for upflow of warmer water in this area.

In the last week of January 1999, the personnel at the gas plant started cleaning well Manuel. For the job they used their own drilling rig Deep Rock, Model DR 150 and their compressor Atlas Copco, XAH(S) 175 for air lifting cuttings and debris from the hole. The initially drilled depth of well Manuel is not clear, but at about 14m depth they encountered obstacles and from there the well had to be redrilled. On January 28th the depth of the well was 19m and the people operating the rig starting to get the feel for its operation. The outcome from that operation decides how capable the people are to undertake such tasks in the future and how well the rig is suited for maintenance work on the Sillunchi boreholes. Furthermore, well Manuel could be well suited for testing of downhole pumps and it could also give information the existence of a linear flow structure near that well.

Monitoring of production and temperature is important for evaluating the potential of the sources available for the gas production. The evaluation becomes more reliable as the data time series becomes longer. A monitoring program is currently implemented by the personnel at the gas plant and that should be continued. Flow rate and temperature is measured at several wells and springs every 15 days. This measuring frequency is in order and should not be decreased. Reporting for the Alto wells needs to be checked, regarding if they are currently reported together or not. In future they should be reported separately. Additionally the gas production should be reported for the same days as measurements are taken in the field. Where possible, permanent weir flow meters should be installed to minimize measurement errors.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendation are based on interpretation of data collected during two field trips to the gas plant Aqua y Gas de Sillunchi in Ecuador and on production history data submitted by AGA S.A. The order of the recommendation does not necessary reflect their importance or time order.

Immediate action needs to be taken to insure the production capacity of the gas plant. The reason being the pending loss of production from well Margarita, which is one of the major

sources for the gas plant. It is not possible to predict for how long the well will maintain its current output, but one should be prepared to see it decrease further by mid year 1999.

Based on initial interpretation of the past three years production history for the water sources at Sillunchi, the observed production decline is traced to damages in the production wells. Indications are that the potential of the water source within the AGA property at Sillunchi has remained stable during the same time, implying that the production could be increase from the source in the future by drilling new production wells.

- Determine the existence of a thermal anomaly near the gas plant and delineate it by drilling few shallow (20-25m) exploratory wells. The drill rig owned by the gas plant could possibly be used for this job.
- After delineating the thermal anomaly, site a production well to intersect it at some depth. The site for that production well will likely be between wells San Andrés 1 and Manuel.
- When production has been initiated from the new production well, the rig should be moved to well Margarita for redrilling and recompleting that well. That operation should increase the output from the well to 27 l/s.
- It was said that a large stone had been dropped on top of the 6" PVC-liner in well Tatatambo Alto. If true this stone is at about 2m depth and is restricting the flow from that well. It is recommended to dig down to that depth around the well and remove the stone. Water can be diverted from the well through a dug out channel or by pumping. After removing the blockage the wellhead can be recompleted with an 8" PVC-pipe.
- A geological study should be made to site production wells in the vicinity of the Alto wells and in the vicinity of the Santa Terese springs.
- Permanent weir flow meters should be installed for the natural spring at Tatatambo (A) and for the Tatatambo Alto well. The small concrete channel made at the Margarita well and resembles a rectangular weir should be fixed and made such that it will become a permanent flow meter.
- Collection of flow rate and temperature data for the water sources at Sillunchi should be continued at the minimum frequency of every second week.

With the current data and detailed map of the area near the gas plant, Orkustofnun can make recommendations, as to the number and location of exploratory wells needed to delineate the thermal anomaly.

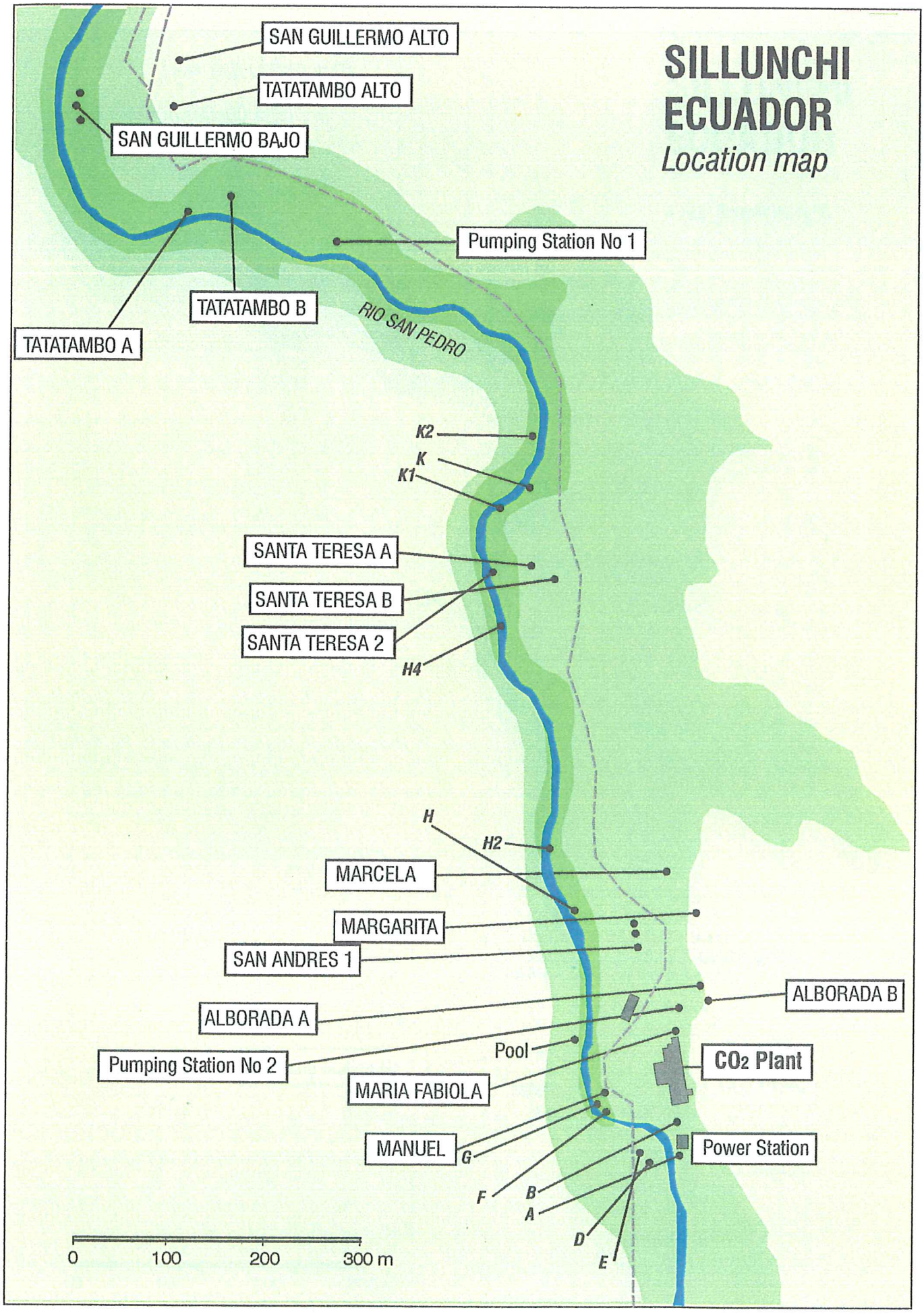
Orkustofnun can make a design for the drilling of the production well and its completion as well as advice on equipment needed for successful implementation of the drilling operation. The same applies for the recompletion of well Margarita.

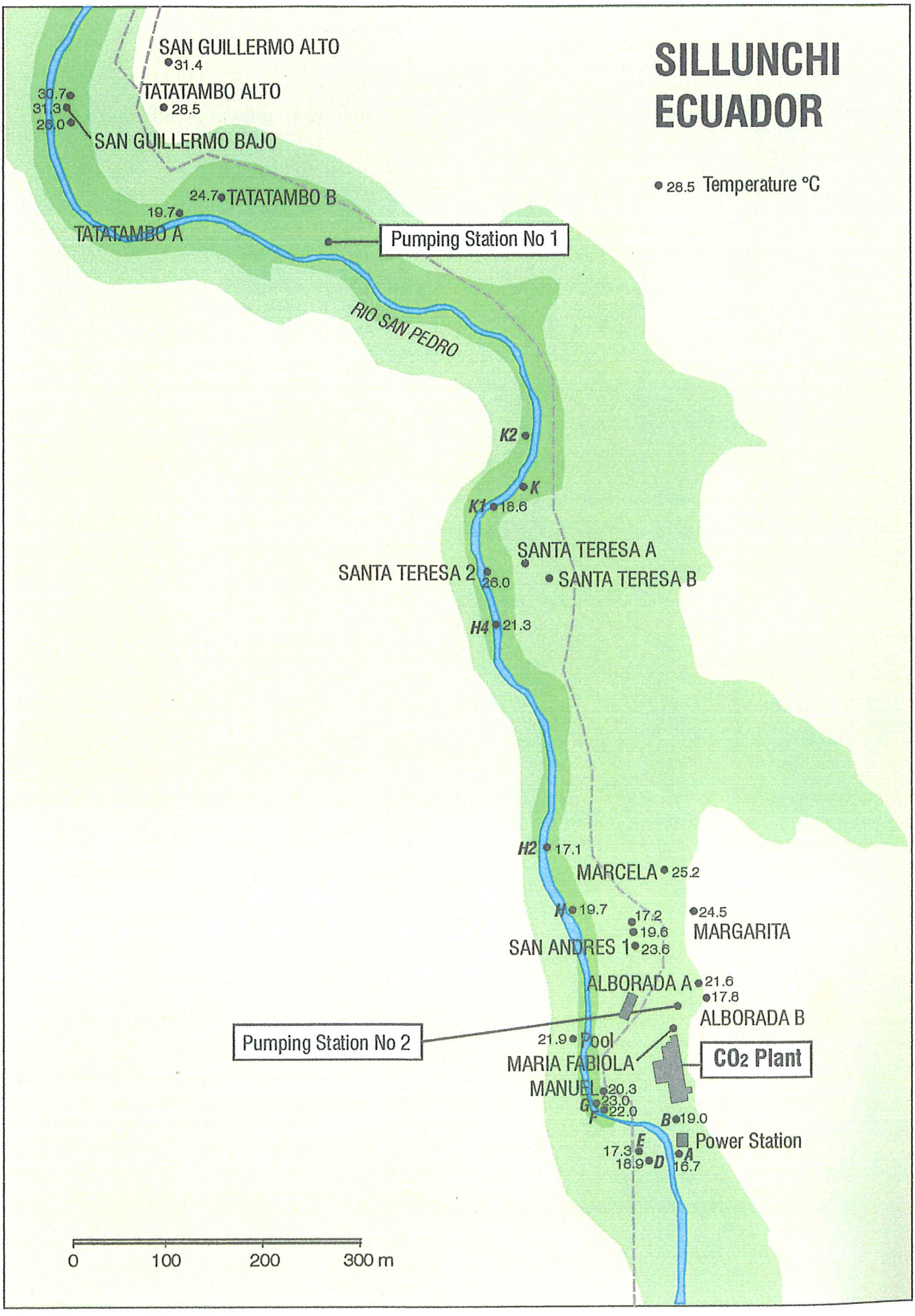
Orkustofnun has trained field and borehole geologist that could be supplied for monitoring the drilling of the production well and advice on drilling procedures for the formation encountered. While monitoring the drilling operation, the geologist could study the AGA-property for the purpose of siting new production wells in the vicinity of the Alto wells and near the natural springs at Santa Teresa.

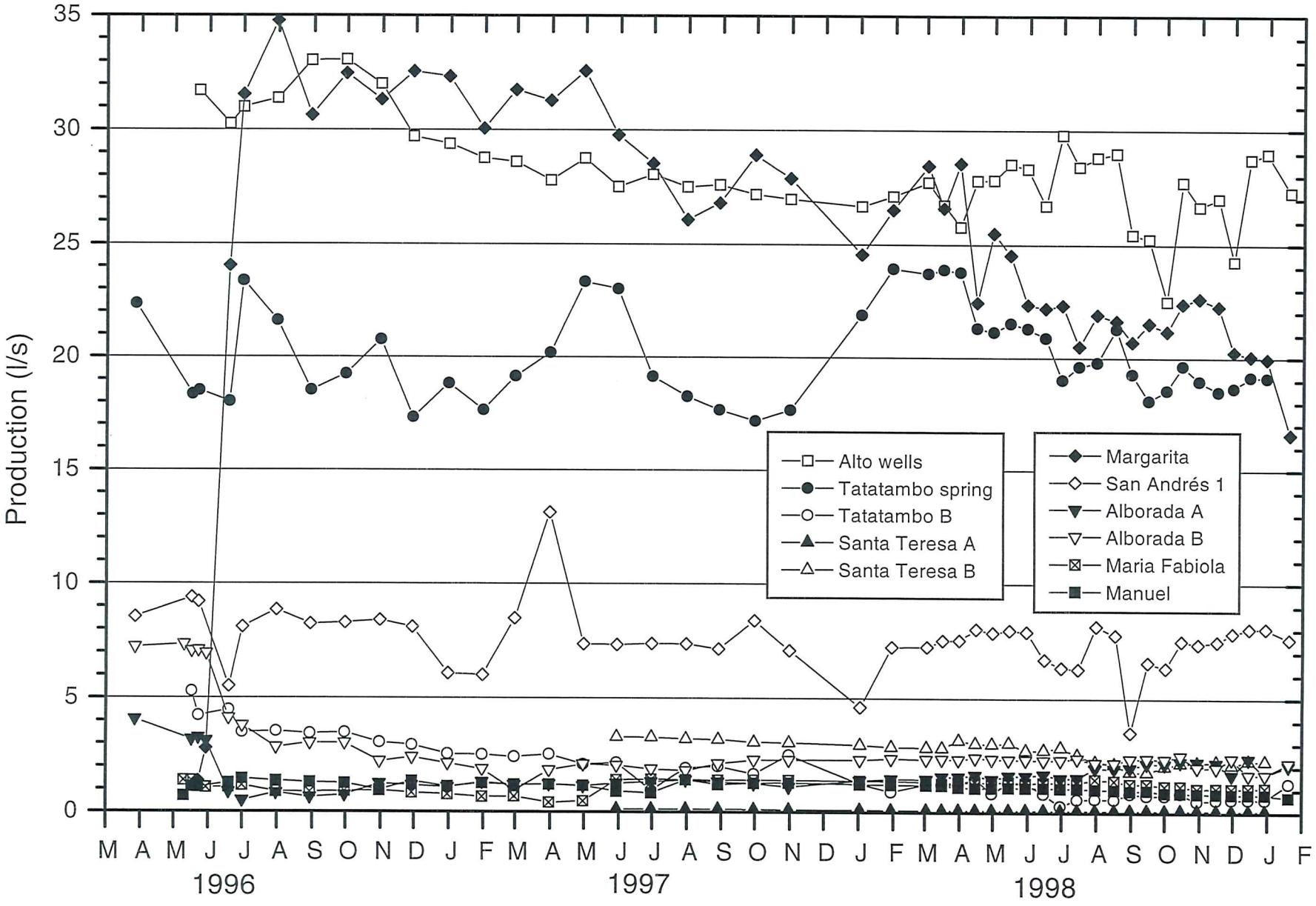
REFERENCES

1. Preliminary report on data collected for wells and springs at Sillunchi. Field report of Omar Sigurdsson, January 19th to 28th, 1999.
2. Fact-finding and assessment of the CO2 source of Sillunchi. Field report of Sverrir Thorhallsson, November 10th-15th, 1997.

Reykjavik 19. February 1999
Omar Sigurdsson


SILLUNCHI
ECUADOR
Location map
SAN GUILLERMO ALTO
TATATAMBO ALTO
SAN GUILLERMO BAJO
Pumping Station No 1
TATATAMBO B
TATATAMBO A
RIO SAN PEDRO
K2
K
K1
SANTA TERESA A
SANTA TERESA B
SANTA TERESA 2
H4
H
H2
MARCELA
MARGARITA
SAN ANDRES 1
ALBORADA B
ALBORADA A
Pool
Pumping Station No 2
CO2 Plant
MARIA FABIOLA
MANUEL
G
F
B
A
D
E
Power Station
0
100
200
300 m


SILLUNCHI
ECUADOR
28.5 Temperature °C
SAN GUILLERMO ALTO
31.4
TATATAMBO ALTO
28.5
30.7
31.3
26.0
SAN GUILLERMO BAJO
24.7 TATATAMBO B
19.7
TATATAMBO A
Pumping Station No 1
RIO SAN PEDRO
K2
K
K1 18.6
SANTA TERESA A
SANTA TERESA 2 26.0
SANTA TERESA B
H4 21.3
H2 17.1
MARCELA 25.2
H 19.7
17.2
19.6
24.5
MARGARITA
SAN ANDRES 1 23.6
ALBORADA A 21.6
17.8
ALBORADA B
Pumping Station No 2
21.9 Pool
MARIA FABIOLA
CO2 Plant
MANUEL 20.3
G 23.0
F 22.0
B 19.0
Power Station
E
17.3
18.9 D
A
16.7
0
100
200
300 m

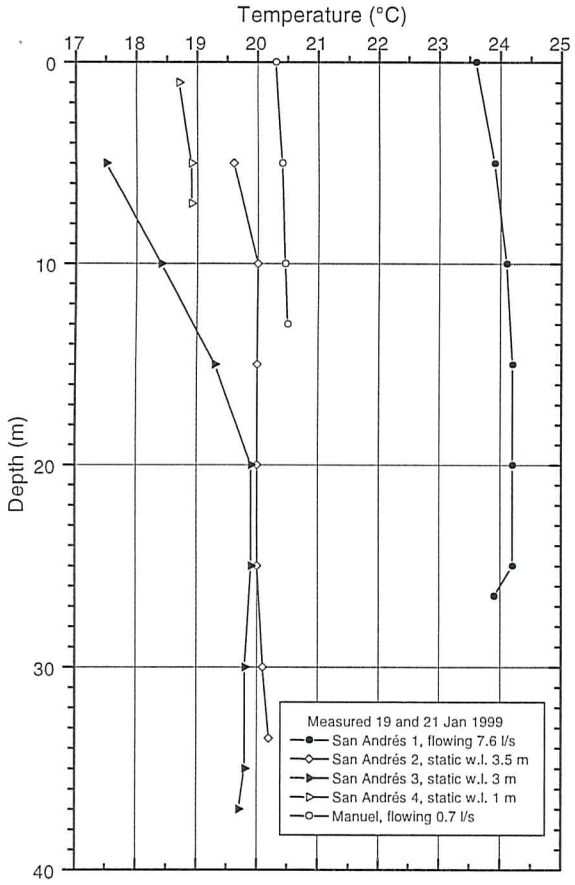

Production (l/s)
35
30
25
20
15
10
5
0
M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F
1996
1997
1998
Alto wells
Tatatambo spring
Tatatambo B
Santa Teresa A
Santa Teresa B
Margarita
San Andrés 1
Alborada A
Alborada B
Maria Fabiola
Manuel

APPENDIX

Figures of temperature and pressure profiles.

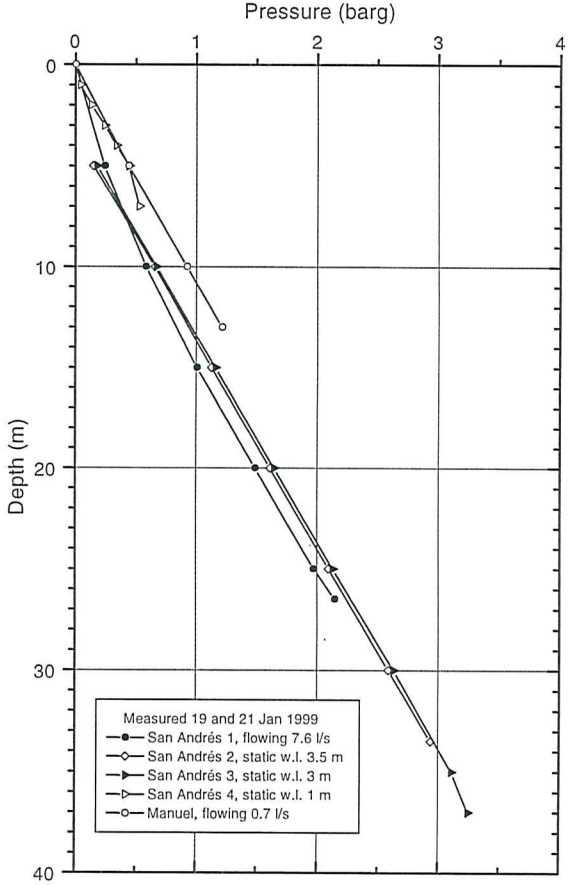
Orkustofnun For AGA S.A.

San Andrés and Manuel wells



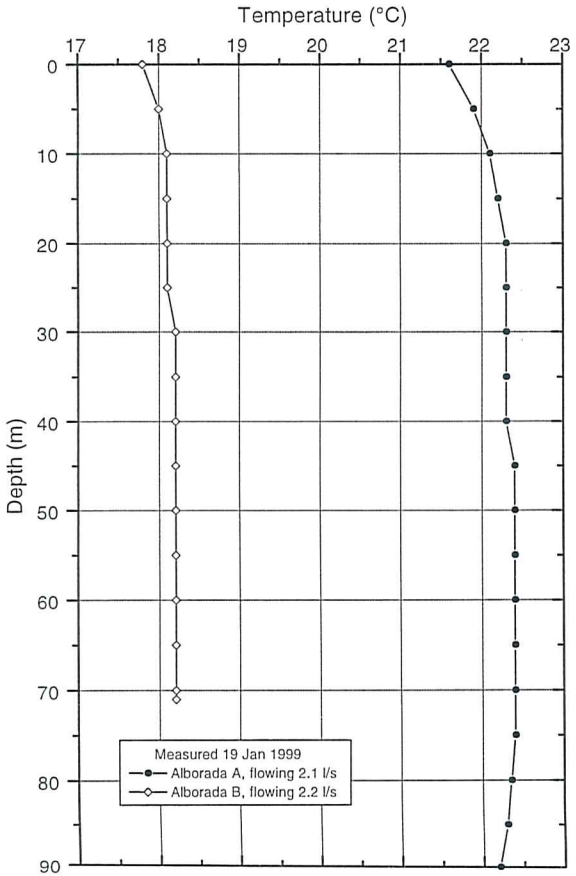
Orkustofnun For AGA S.A.

San Andrés and Manuel wells



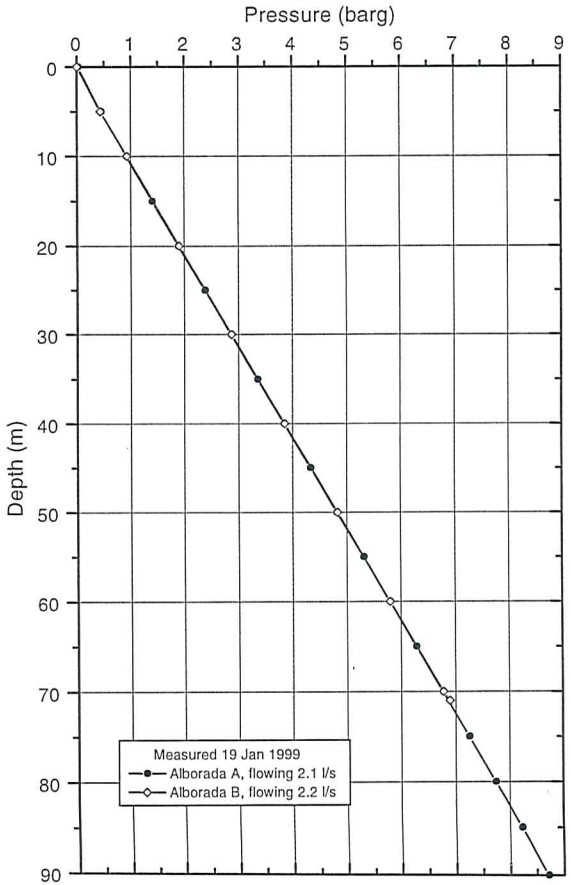
Orkustofnun For AGA S.A.

Alborada wells



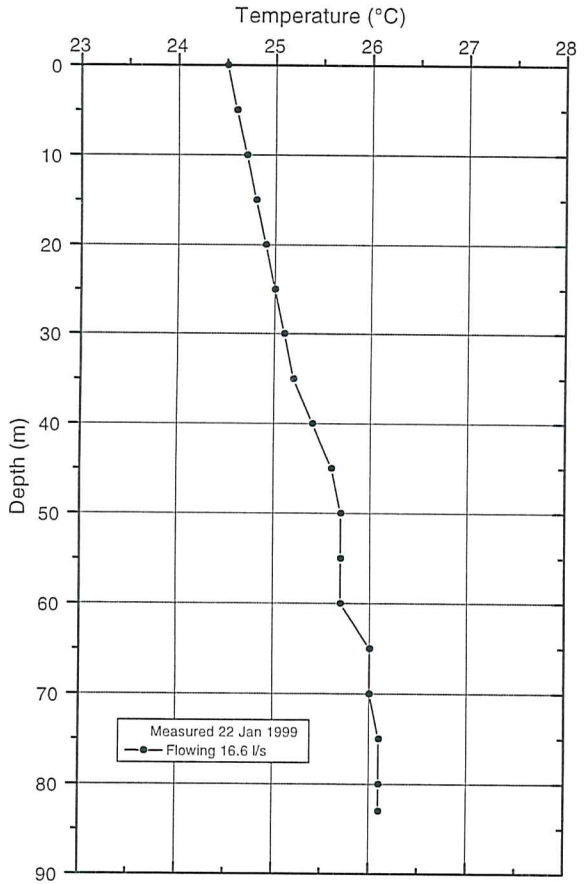
Orkustofnun For AGA S.A.

Alborata wells



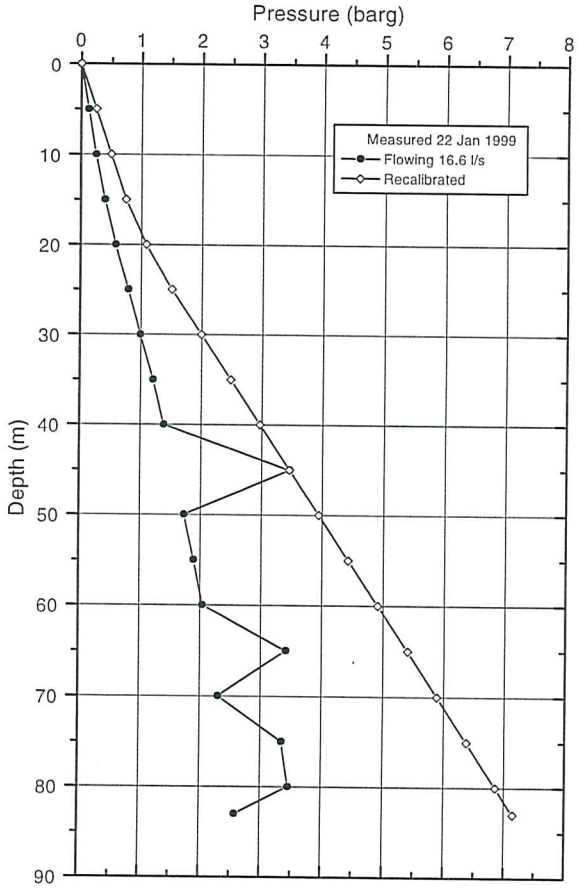
Orkustofnun For AGA S.A.

Well Margarita



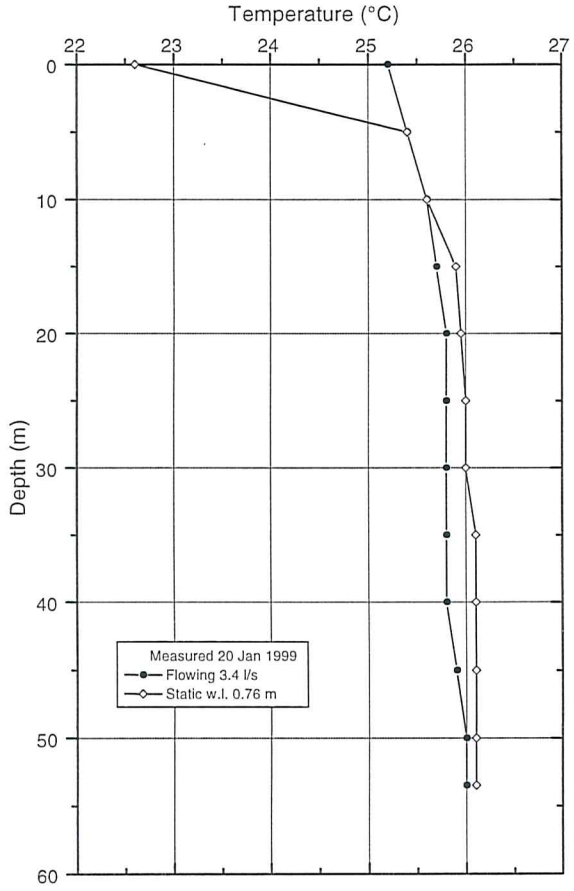
Orkustofnun For AGA S.A.

Well Margarita



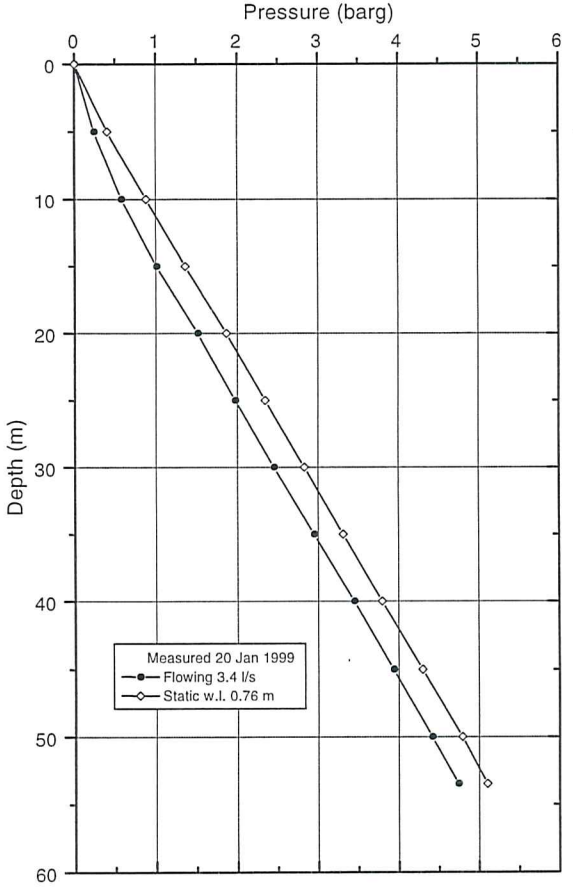
Orkustofnun For AGA S.A.

Well Marcela



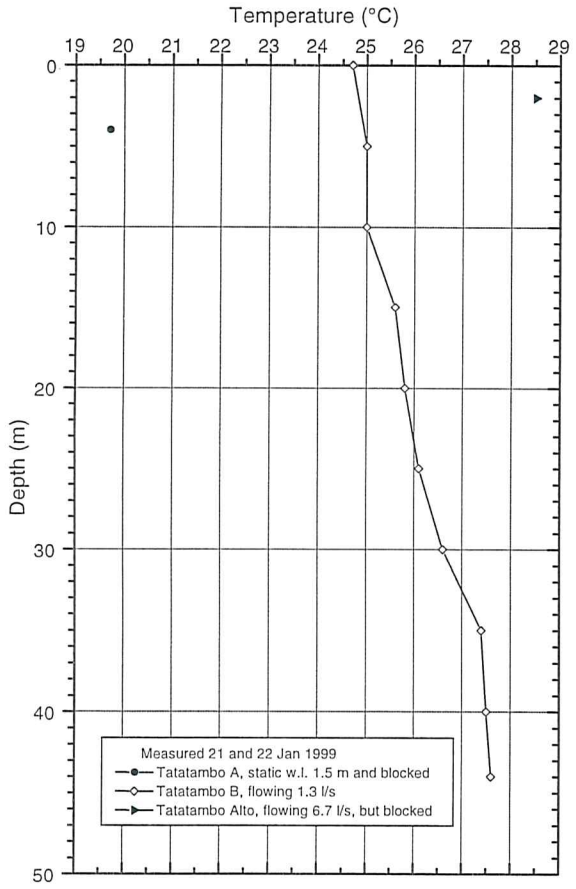
Orkustofnun For AGA S.A.

Well Marcela



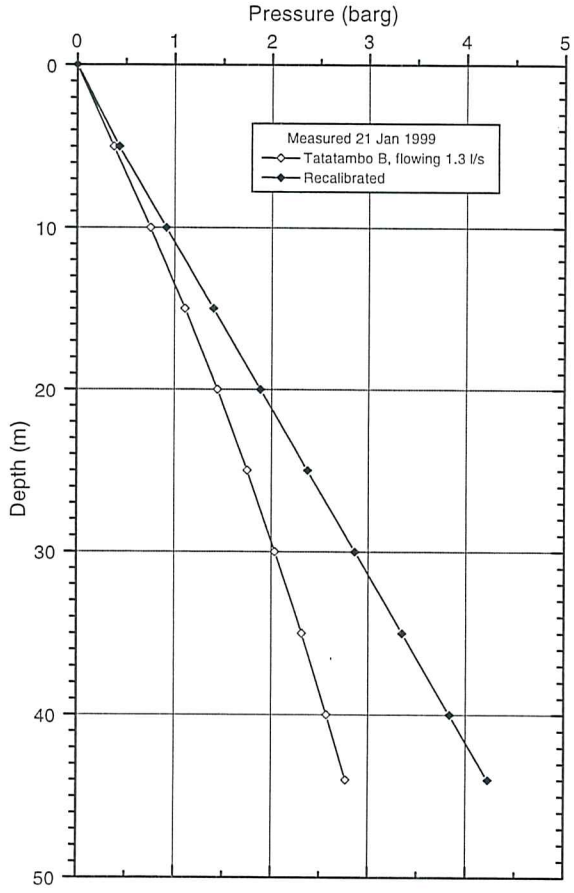
Orkustofnun For AGA S.A.

Tatatambo wells



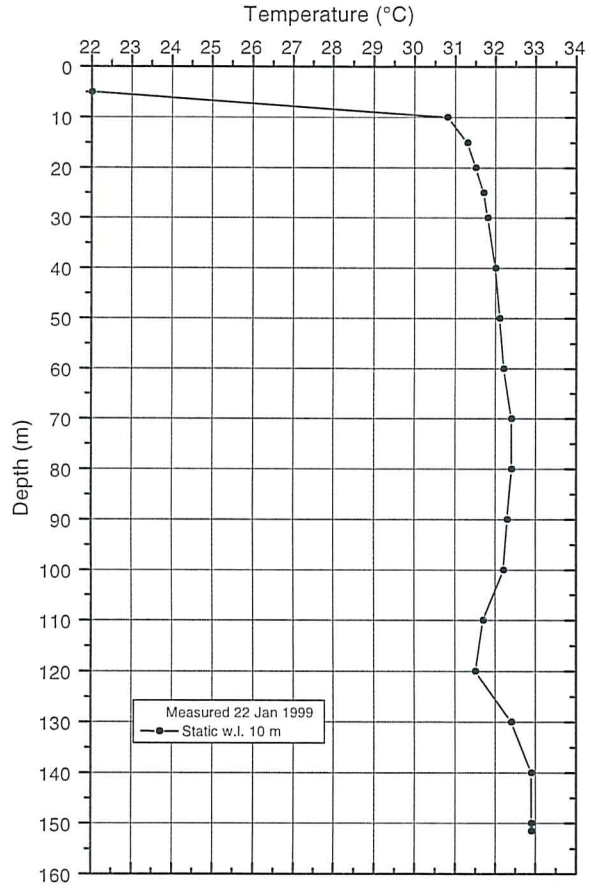
Orkustofnun For AGA S.A.

Well Tatatambo B



Orkustofnun For AGA S.A.

Well San Guillermo Alto



Orkustofnun For AGA S.A.

Well San Guillermo Alto