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# ASSESSMENT OF THE GEOTHERMAL RESOURCE IN THE KARAHA - TELAGA BODAS AREA, INDONESIA

**VOLUME I: Text, Tables and Figures**

CONFIDENTIAL

*for*

**FPL ENERGY**

**North Palm Beach, Florida**

*by*

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# EXECUTIVE SUMMARY

FPL Energy has contracted GeothermEx to evaluate the exploration and wellfield development and assess the resource at the Karaha - Telaga Bodas geothermal field in western Java, Indonesia. FPL is a partner in Karaha Bodas Company LLC (KBC), which has undertaken exploration and drilling in a large concession area. Within the concession area, KBC has delineated the northern Karaha project area and the southern Telaga project area.

KBC initiated its exploration program after it obtained the concession from Pertamina in December 1994. A fluid chemistry survey was conducted, with collection and analysis of samples from surface thermal features (hot springs and fumaroles) and non-thermal waters. KBC reviewed the geophysical data collected by Pertamina, and later contracted additional resistivity surveys. KBC began its exploration drilling in May 1995 with a series of nine core holes drilled to depths ranging from 877 to 2,150 feet in the region around Kawah Karaha. On the basis of high temperature gradients observed in three of these holes, the first full-sized well (KRH1-1 ST1) was drilled near the Karaha fumaroles beginning in May 1996. The lack of production from this well led KBC to revise its program of core hole drilling. Subsequently, from September 1996 to November 1997, ten new core holes were drilled and one existing hole was deepened, with depths ranging from 3,340 to 6,621 feet.

During this program of deeper core hole drilling, two more non-commercial full-sized wells (KRH2-1 RD and KRH3-1 ST) were drilled and KRH1-1 was sidetracked again in an unsuccessful attempt to intercept a zone of commercial productivity. Drilling results improved as full-sized wells were sited further south. The next full-sized hole was KRH4-1, which is the shallowest and most productive well that has been drilled in the field. KRH4-1

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was sited primarily on the basis of results from core hole K-21, and it flows at a rate equivalent to 12.5 MW. A second full-sized well from the same pad (KRH4-2 RD) was drilled to the east and was non-productive. The next full-sized well, KRH5-1, offset KRH4-1 to the northwest and proved to be commercially productive, flowing at a rate equivalent to 4.2 MW after an acid stimulation.



Meanwhile, the core rig completed four more core holes further to the south in the Telaga area, two of which were productive (T-2 and T-8). KBC then drilled two successful production wells (TLG1-1 ST2 and TLG2-1) from surface locations adjacent to each of the productive core holes. TLG1-1 ST2 flowed at a rate equivalent to 5 MW, and TLG2-1 produced 2.6 MW with very high non-condensible gases. KBC also drilled another productive core hole (K-33) at the border between the two project areas, nearly 2 km south of KRH4-1. Then KBC sited and drilled its ninth full-sized well (TLG3-1) about 1.5 km southwest of K-33. TLG3-1 flowed at a rate equivalent to 7 MW during a month-long test.

Drilling and testing have demonstrated the existence of commercial productivity across a 7 km-long zone, from well KRH5-1 in the north to well TLG2-1 in the south. A total of 32.1 MW is available at the wellhead from five productive full-sized wells.

The Karaha - Telaga Bodas field is coincident with an axis of youthful volcanism. Gunung Galunggung, located a few miles south of the southern boundary of the concession area, erupted as recently as 1983. Age-dating indicates that most of the volcanic deposits that cover the project areas are younger than 1.75 million years, with one sample (from the Telaga Bodas crater) dated at 0.32 million years. At the surface and in drill holes, the lithology is dominated by andesitic pyroclastic units, which is typical for geothermal fields in western Java. Intrusive rocks have been logged in the deeper sections of a few wells. As in many volcanic areas, a correlation of subsurface geologic units from well to well has not been

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possible, so the geologic structure is interpreted from aerial photographs. Numerous lineaments cross the project area, some of which may represent faults that act as subsurface boundaries to fluid flow, as indicated by the subsurface temperature distribution and other data.



Gravity data show a positive anomaly coincident with the volcanic axis, which trends north-south throughout most of the Karaha - Telaga Bodas field. Resistivity data suggest that a thick subsurface conductive layer is present, also with a north-south trend. The temperature distribution has a similar trend, with higher temperatures in the Telaga area than to the north. Temperatures in excess of 650°F have been observed in the Telaga wells, and subsurface pressures are generally higher at Telaga than at Karaha. The central Telaga area is relatively gassy, the wells there produce hydrochloric acid (HCl) and some sulfur dioxide ($SO_2$), and similar HCl acid chemistry is noted at the fumaroles and hot springs. In contrast, wells in the northern Telaga area and in Karaha produce pH-neutral, less gassy fluids, and the surface features at Karaha, although steam-heated, lack HCl and $SO_2$.

The available data suggest that the heat source for the system is one or more cooling magma bodies or intrusions, and that the primary geothermal fluid has a significant magmatic component. Upflow of fluid into the system from a deep source occurs beneath Telaga, where gases have accumulated in a large steam cap. From Telaga, the reservoir fluids move northward, becoming neutralized and cooling along their flow path. It is possible that there is a subsidiary upflow in the Karaha area that provides pH-neutral water directly to the northern part of the field. If a Karaha upflow is present, it is distinctly less magmatic in character than the Telaga upflow.

The limits of the field have not been defined comprehensively, but several local boundaries of limited extent can be identified. Resistivity and temperature data, and the

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lack of success in KRH4-2 OH and KRH4-2 RD, suggest the presence of a fault boundary along the east side of the field. Another boundary to the reservoir is indicated around Kawah Karaha, because subsurface temperatures drop off rapidly to the north. The western boundary of the reservoir is less distinct, and no southern boundary has been determined. Within the field there appears to be a cross-cutting discontinuity, possibly related to WNW-trending structures, in the vicinity of well TLG3-1 and core hole K-33.

Well test results indicate that the degree of permeability in the reservoir is low to moderate, in comparison to other Indonesian geothermal fields. However, the results are comparable to permeabilities measured in exploration and early development wells in other projects, since an understanding of the permeability distribution typically improves as more wells are drilled. At Karaha - Telaga Bodas, permeable zones occur within both pyroclastic and lava units, and there is as yet no strong evidence for localization of permeability within particular structures or stratigraphic units.



Measurements in the deep wells and core holes have defined a large area of high temperature. The following estimates of average reservoir temperature, area, thickness, porosity and recovery factor have been made based on the conceptual model of the field. The available geothermal energy reserves have then been calculated separately for the Karaha and Telaga Bodas areas using a modified version of the methodology developed by the U.S. Geological Survey which incorporates Monte Carlo simulation to account for the uncertainties in parameter estimation.

| Parameter | Karaha | Telaga Bodas |
|---|---|---|
| *Average Temperature (°F)* | Minimum: 440<br>Maximum: 520<br>Most Likely: 480 | Minimum: 500<br>Maximum: 580<br>Most Likely: 540 |

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| | | |
|---|---|---|
| *Reservoir Area (square miles)* | Minimum: 1.5<br>Maximum: 7<br>Most Likely: 4 | Minimum: 3.5<br>Maximum: 12<br>Most Likely: 9 |
| *Reservoir Thickness (feet)* | Minimum: 2,500<br>Maximum: 4,000<br>Most Likely: 3,000 | Minimum: 2,500<br>Maximum: 4,000<br>Most Likely: 3,000 |
| *Porosity (%)* | Minimum: 4<br>Maximum: 10 | Minimum: 4<br>Maximum: 10 |
| *Recovery Factor (%)* | Minimum: 10<br>Maximum: 25 | Minimum: 10<br>Maximum: 25 |



Assuming a 30 year plant life and a 90% capacity factor, the available reserves at Karaha are estimated to range from 40 to 302 MW, with a most likely value of 135 MW. Reserves at Telaga are estimated to range from 100 to 670 MW, with a most likely value of 310 MW. At a confidence level of 90%, reserves at Karaha and Telaga are anticipated to exceed 72 and 188 MW, respectively, or approximately 260 MW for the two areas combined.

KBC's exploration and development program has been successful in defining a large geothermal system of considerable magnitude. The program balanced the use of core hole studies and full-sized well drilling quite effectively, except that the first tyhree full-sized holes did not get the full benefit of information from deep core hole drilling in the Karaha area. The deep core holes at Karaha were drilled after KRH1-1 ST1 and simultaneously with KRH2-1 RD and KRH3-1 ST. All three of these full-sized wells were non-productive (althrough the original hole in KRH 1-1 did flow during air drilling prior to being sidetracked due to stuck drill pipe). In contrast, later full-sized wells were drilled after completion of dceep core holes in their respective areas, and all of these later full-sized wells were successful except KRH4-2 RD. The availability of deep core hole data probably contributed to the greater success rate of the later full-sized wells.

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The combination of reserves and deliverability is critical to obtain bank financing for a geothermal project. KBC has been able to cover a large area with core holes and wells, and temperature data from these wells were used to estimate the reserves. Well testing has demonstrated commercial productivity across a 7 km-long zone. Detailed chemical sampling of surface features and deep core hole drilling has been done, and these are the two most useful exploration methods in volcanic settings, followed by certain geophysical methods. Therefore, in our opinion, KBC has pursued its exploration program well.

Our efforts to compile and integrate the database for our assessment required more time and effort than anticipated. This was primarily because drilling and well testing activities were continuing throughout the course of our work, and therefore new information continued to be generated. This information was transmitted to GeothermEx in a variety of formats from several sources. At the time this report was prepared, very little information on the conditions associated with fluid sampling was avalailable. As a result, it was sometimes difficult or impossible to make accurate estimates of fluid chemistry at reservoir condtions. In the information on well tests, there were some inconsistencies in file formats, unit labeling and conversion, atmospheric pressure corrections, and test set-up information. GeothermEx was able to resolve most data-related questions by follow-up with KBC personnel. The only well test data problem which introduced significant uncertainty into our analysis related to the pressure build-up tests. In several cases, the later portions of the build-up data may still have been affected by wellbore storage or may have been influenced by effects of changing temperature. For these build-ups, formation properties such as permeability-thickness product and skin factor should be considered rough estimates.

Fracture analysis logs were run in part of the production interval in two full-sized wells. Logging for fracture imaging is very expensive; as such, it may be more appropriately reserved for investigation of a specific aspect of geologic structure, rather than for general exploration or resource assessment. On the other hand, if a consistent suite of conventional logs is run in many wells, the results may be more useful in interpreting subsurface stratigraphy and structure, particularly in a volcanic pile, where stratigraphic units are difficult to distinguish using petrography. In GeothermEx's opinion, funds for downhole geophysics would be better spent on such a systematic program, even with a minimal logging suite, than on fracture analysis logs run in selected intervals in a few wells. However, it is not unusual for geothermal developers to forgo running a systematic set of geophysical logs, especially in remote areas where logging services are not readily available.

Detailed petrographic and petrologic studies were undertaken on a limited number of samples at Karaha - Telaga Bodas. Studies of this nature can be useful, and the level of KBC's expenditures on such studies appeared to be appropriate.

At three other Indonesian geothermal fields with which GeothermEx is familiar, which also began as exploration projects, deep core hole drilling was very effective in delineating zones of high temperatures across large concession areas. The most favorable zones for drilling were identified in this way. In one project about 10 core holes were completed and stable temperature data were obtained before any full-sized wells were drilled, and the success rate for full-sized wells was very high. In another field, the two types of holes were drilled at the same time, and initial success rates were lower but improved as the development drilling continued. The program at the Karaha - Telaga Bodas field has been more similar to the latter example than the former.

From the point of view of geothermal energy reserves, Karaha is similar to other successfully developed Indonesian fields. Temperatures are high along the volcanic axis and decline rapidly to either side. High non-condensible gas levels and corrosive steam are also observed in localized areas of other Indonesia fields. In one reservoir with which we are familiar, initial plans were made to exploit gassy zones, but it was later decided to step out and develop more benign areas. Likewise, corrosive areas at other fields (once defined) have been avoided, and corrosive wells have sometimes been plugged and abandoned for safety reasons.



The acid fluids at the central Telaga wells have a severe corrosion potential that is quite dangerous if not properly managed. The most dangerous condition exists when slightly superheated HCl-bearing steam condenses at points of heat loss in shallow casings, wellheads and flow lines, because extreme acidity can form in a thin condensate film that can corrode a pipe wall within hours. Production of acid steam wells is safely managed in other fields by injecting caustic soda downhole and into surface lines.

The relatively high total-flow enthalpies of the Karaha wells indicate that there is boiling in the reservoir under discharge conditions. This concentrates scaling in the formation rather than in the wellbore, and it tends to produce a high $CO_2$ pressure in the wellbore, which inhibits calcite scale formation. As a result, the Karaha wells should not experience major calcite scaling problems. Silica scaling is also not anticipated in the Karaha production wells, and neither silica nor calcite scaling is anticipated in the Telaga steam wells.

Non-condensible gas (NCG) concentrations in steam at the Karaha wells and at TLG3-1 are within the range commonly experienced elsewhere. $H_2S$ in the same wells (360 - 1,300 parts per million by weight at 116 psia) tends to be somewhat higher than is typical, and we do not know whether this exceeds allowable discharge limits under applicable regulations. If so, $H_2S$ abatement may be required. NCG in steam at the Telaga wells (except TLG3-1) ranges from 8 - 29 weight percent. Although gas levels may decrease with time as these wells are produced, it appears from current data that a power plant supplied from the wells drilled into the gassy zone at Telaga would have to be designed to handle more than the normal amount of NCG, which usually does not exceed about 5 weight percent in steam.

The overall extent of the productive reservoir, the location and extent of high-gas zones, the distribution of productive zones within the field, and the geometry of the corrosive steam zone at Telaga are incompletely defined, and any future development of the field should consider these issues. Downhole geophysical logs (including, at a minimum, resistivity and gamma ray logs) run routinely in newly drilled wells could facilitate stratigraphic and structural interpretations within the field. Additional geophysical surveys (particularly detailed gravimetry) can be run and the MT data can be re-interpreted in light of drilling results. Downhole temperature and pressure surveys in newly completed wells should be programmed to obtain systematic coverage during heat-up after drilling and during periods of injection.

The extent of the corrosive fluids and the high-gas zone at Telaga is probably limited, and can be delineated by a program of systematic core hole drilling and fluid sampling. Alternatively, considering the high rate of drilling success from Telaga north to K-33, one or two full-sized step-out wells can be drilled south of TLG3-1. These would not increase the known reserves of the field, but would help define the boundaries of the area affected adversely by fluid chemistry.

A staged development should be planned with initial capacity increments of perhaps 50 MW at Karaha and 80 MW at Telaga. As development wells are drilled for these two initial projects, additional drilling of deep core holes can be undertaken to determine the extent of the resource south of Telaga Bodas and east and west from the volcanic axis.

Ultimately, it should be possible to develop at least 260 MW from the Karaha - Telaga Bodas geothermal field.

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# 1. INTRODUCTION

FPL Energy has contracted GeothermEx to perform an independent assessment of the geothermal resource at the Karaha - Telaga Bodas field in western Java, Indonesia (figure 1.1). The field has been explored and developed by Karaha Bodas Company LLC ("KBC"), a partnership which includes FPL Energy and Caithness Resources. KBC holds the rights to develop up to 400 MW of generation from the geothermal resources within a large (> 400 km$^2$) concession area, and has delineated the Karaha and Telaga project areas within it, as shown on figure 1.2.



The scope of work for this report includes: 1) developing a conceptual hydrogeologic model of the Karaha - Telaga Bodas area using the results of drilling and available geological, geophysical and geochemical data; 2) compiling and analyzing well test data from slim and full-sized wells; 3) estimating the recoverable geothermal energy reserves; 4) reviewing KBC's exploration and drilling strategies, including an evaluation of the efficacy of slim hole drilling; 5) providing an opinion on the quality, reliability and completeness of the available data; 6) identifying possible resource-related constraints on field development for power generation; and 7) making recommendations for future development strategies.

The report is structured to address these issues in a logical succession. A history of development, with obvious emphasis on KBC's exploration and drilling activities, is included in Chapter 2. Chapter 3 provides a detailed description of the resource, as determined from analyses of data collected by KBC and its predecessors in interest in the area. The drilling and testing results of all full-sized wells and slim holes that were flow tested are included in Chapter 4. Chapter 5 presents the conceptual hydrogeologic model of the resource (synthesized from all of the forgoing) and the estimation of recoverable geothermal energy reserves. Chapter 6 is an analysis of the field development, including a review of the strategy utilized to date and options for continued development of the Karaha - Telaga Bodas geothermal resource.

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# 2. HISTORY OF DEVELOPMENT

Interest in the Karaha - Telaga Bodas area began in the 1980s, when Pertamina drilled four shallow gradient holes and contracted or performed geophysical exploration in the area, including magnetotelluric (MT) resistivity, DC resistivity, gravity, and microearthquake surveys. Following new legislation which enabled foreign companies to develop Indonesia's abundant geothermal resources, Caithness Resources and an Indonesian partner formed Karaha Bodas Company LLC (KBC) and obtained the Karaha - Telaga Bodas concession area shown in figure 1.2 in December 1994. Their exploration and development program began in May 1995. FPL Energy later took a partnership position in KBC.



KBC's exploration and development program included collecting and analyzing samples from hot springs, fumaroles and other surface water sources, and contracting additional resistivity (MT) surveys. The results are discussed extensively in the following chapter. In addition, KBC drilled numerous slim holes and full-sized wells, as described below. A detailed description of the results of testing these wells is included in Chapter 4. Tables 2.1 to 2.3 summarize the location and completion data for the core holes and full-sized wells, and figure 2.1 shows well locations.

Figure 2.2 shows the history of drilling in the Karaha - Telaga Bodas field in graphical form. The first phase of drilling concentrated in the northern part of the Karaha area, near Kawah Karaha, where KBC initially drilled eight core holes to measure subsurface temperatures. One year after beginning its exploration efforts, KBC began drilling full-sized wells near the Karaha fumarolic area based on encouraging temperature gradients observed in three of the shallow slim holes (K-2, K-3, and K-6). KRH1-1 was drilled simultaneously with the ninth of the shallow, northern core holes. The well was spudded on 18 May 1996,

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was side-tracked because of stuck drill pipe on 23 July 1996, and was completed at a total depth of 8,201 feet on 18 August 1996.

KRH1-1 ST1 was not a commercial success, and the rig was moved about 800m south to drill the second full-sized Karaha well (KRH2-1). The failure of KRH1-1 led KBC to revise their core hole program to site and drill deeper holes. Simultaneously with the drilling of KRH2-1, KBC drilled core holes K-20 and K-27 to depths of 3,340 and 4,505 feet, respectively. Core hole K-10, located about 500m NW of Kawah Karaha, was then deepened from 1,381 to 4,300 feet. After completing KRH2-1RD at a depth of 8,994 feet on 22 October 1996, the large rig moved to the KRH3-1 site and began drilling the third full-sized well. Core hole K-24 was then drilled on the west side of the volcanic axis, and K-21 was drilled on the northern slope of P. Julang. Meanwhile, another drilling rig was contracted to work over KRH1-1 ST1 to seal off a suspected zone of cool water entry; the well was eventually side-tracked again during this operation, and was completed at a depth of 9,973 feet on 23 March 1997. KRH3-1 ST was completed on the same day at a depth of 10,092 feet, and is the deepest well drilled in the area.



The first three full-sized holes (KRH1-1 ST2, KRH2-1 RD, and KRH3-1 ST) were not commercially productive, but results of successive wells improved as drilling progressed further south. KBC moved the core rig to the Telaga area and drilled productive core hole T-2, followed in succession by T-4, T-8 (also productive) and T-10. Meanwhile, the first commercial production well (KRH4-1) was completed in the Karaha area at a depth of 6,083 feet on 6 May 1997, with a currently estimated capacity of 12.5 MW. Following that success, KBC drilled a non-productive full-sized well (KRH4-2 RD, completed at a depth of 7,930 feet on 18 July 1997) toward the east from the 4 pad, then drilled a productive full-sized well (KRH 5-1, completed at a depth of 8,014 feet on 29 August 1997) offsetting KRH 4-1 to the northwest. While KRH5-1 was being drilled, the core rig drilled K-22, located about 1 km SW of KRH4-1.

The large rig was then moved to the Telaga area, where two productive core holes had been drilled. The first full-sized well (TLG1-1 ST2, completed on 11 November 1997 at a depth of 5,844 feet) was drilled from the same site as T-8. Simultaneously, the core rig drilled the productive core hole K-33, located near the boundary between the Karaha and Telaga areas. The second full-sized well at Telaga (TLG2-1) was then drilled from the T-2 site (figure 2.1); this well was completed at a depth of 8,490 feet on 30 December 1997. Finally, well TLG3-1 was drilled about 1 km south of the Karaha - Telaga boundary, and was completed on 8 February 1998 at a depth of 8,133 feet. All three of the full-sized Telaga wells are commercially productive.



In September 1997, KBC submitted its Notice of Resource Confirmation (NORC) to Pertamina, and updated it in December 1997 based on new drilling results. The Notice of Intent to Develop (NOID) for 210 MW was submitted to PLN in December 1997. In the wake of the Indonesian currency crisis, Presidential Decrees were issued in late 1997 and early 1998 which placed many infrastructure projects, including the Karaha - Telaga Bodas geothermal project, in an uncertain position. KBC finished drilling TLG3-1 and released the full-sized drilling rig (the core rig had been released earlier). TLG3-1 was then tested for about one month. KBC staff has since been reduced to a minimum following the return of most of the expatriate KBC personnel to the US.

To summarize, KBC collected and analyzed fluid samples from wells and surface features over a broad area, performed an electrical resistivity survey, and completed a major drilling campaign. Nine full-sized wells have been drilled, of which five have produced geothermal fluids at commercial rates and pressures, to depths ranging from 6,082 to 10,092

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feet. Most have been completed with 13⅜-inch cemented surface casing, with 9⅝-inch casing cemented at intermediate depths, and with either open hole or slotted liners in the production interval. In addition, KBC has completed nine shallow slim holes ranging in depth from 488 to 2,150 feet and eleven deep slim holes ranging in depth from 3,340 to 6,623 feet. Most of the slim holes have 4½-inch casing cemented surface casing with uncemented 2⅜-inch tubing run to bottom. Three of the deep slim holes were productive.

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# 3. DESCRIPTION OF THE RESOURCE

## 3.1 Geologic Setting

The Karaha - Telaga Bodas area lies at the eastern end of a chain of young volcanic complexes that dominate the topography of western Java and host a number of geothermal fields, many of which are in various stages of exploration, development and commercial operation. The Patuha, Wayang Windu, Kamojang and Darajat fields are all situated to the west of Karaha - Telaga Bodas, within a distance of 150 km (figure 1.1).

A massif that consists of a series of overlapping volcanic edifices occupies the central part of the Karaha and Telaga Bodas project areas. In the southern (Telaga Bodas) area, the axis of the volcanic centers trends northward to NNE, but within the Karaha area, the trend changes to northwestward (figure 2.1). The volcanic deposits that have been erupted from the centers and make up the massif are described as being predominantly andesitic to dacitic in composition, and include lavas, tuffs and tuff breccias, debris flow deposits and volcanic-derived sediments. These characteristics are typical of the volcanoes of western Java.

Age dating of a limited number of volcanic rocks has been carried out by Pertamina and KBC. The results of this dating indicate that many or most of the exposed volcanic deposits were erupted within the last 1.75 million years, and that the age of the volcanic activity decreases from north to south. The youngest age date of 0.32 million years has been obtained from within the Telaga Bodas crater. South of the concession area, the volcanic massif continues, reaching the active volcano Gunung Galunggung a few miles to the south of the concession boundary (figure 1.2).

The lithology observed in the core holes and exploration wells drilled by KBC is summarized in the downhole summary plots for the various wells, included as Appendices A and B. Based on this information, the rocks found in the subsurface to depths of at least 10,000 feet are for the most part similar to those exposed at the surface. Pyroclastic rocks (tuffs, tuff breccias and tuffaceous sediments) are substantially more abundant than lavas in the drillholes, with maximum uninterrupted thicknesses of lava typically not exceeding a few hundred feet. Limited intervals of intrusive rocks, classified as quartz diorite, have been observed in several of the wells (KRH1-1 ST2, KRH2-1, KRH3-1 ST, TLG2-1 and TLG3-1) below depths of 7,500 feet. Some of these intervals are quite thin (less than 50 feet), whereas some exceed at least 400 feet. The intrusives are probably related to the young volcanism in the area; their occurrence indicates that some are in the form of dikes, but more massive and extensive intrusions may also be present.



Definition of a volcanic stratigraphy from observed drillhole lithologies is frequently difficult or impossible in young volcanic terrains, due to repetitive lithology, a lack of distinctive marker units, and a lack of lateral continuity in lithologic units. This situation exists at Karaha - Telaga Bodas, and has prevented the classification of a consistent stratigraphy that can be correlated between wells. The lack of stratigraphic correlation also limits the degree to which geologic structure can be interpreted from subsurface data. Gamma ray logs, which can sometimes be used to differentiate units in a thick pyroclastic section were run in KRH2-1 RD and KRH3-1 ST. These are included in Appendix B, and show a considerable amount of character in the logged interval. However, the three-dimensional coverage is too limited to permit well-to-well correlations.

Structural characteristics of the area must be interpreted mainly from analysis of aerial photographs, due to the stratigraphic problems mentioned above, and to the limited extent of surface exposures of rock units. GeothermEx has independently identified

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prominent lineaments in the concession area by examining air photos of approximately 1:50,000 scale, obtained from KBC; these lineaments are shown in figure 3.2. Only those lineaments whose physiographic expression ranged from fairly strong (reliable) to very strong are shown. The identification of air photo lineaments is to some degree subjective. Although the interpretation shown in figure 3.2 differs in detail from KBC's, there is a similarity in the overall patterns and trends.

It is likely that the identified lineaments are an expression of recent faulting, although the degree of offset, if any, on such structures cannot be determined. The most predominant structural trend is approximately WNW, with a northeastern trend also common. A few structures trend close to north-south. The density of identified structures is somewhat greater in the south (Telaga Bodas) than in the north (Karaha). This may imply that the Telaga Bodas area is more active tectonically, particularly as the lesser age of the rocks there would tend to obscure older structures.

The hydrothermal alteration observed in the drillholes is fairly typical of geothermal fields hosted by volcanic rocks of andesitic to dacitic composition, with a normal sequence of alteration assemblages, coinciding with increasing depth and temperature, reported in most wells. It is noteworthy that a number of different high-temperature alteration minerals, including epidote, biotite, tourmaline, hydrothermal amphibole and hydrothermal garnet, have been reported in several of the deep wells. For the most part, the alteration assemblages at depth reflect alteration by near-neutral pH fluids. However, several of the Telaga Bodas drillholes (TLG 1-1 ST2, T-2 and T-8) have within limited intervals assemblages that are the products of high-temperature acidic fluids, which is consistent with the observed production of acid fluids from some wells in that area.

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## 3.2 Thermal Manifestations

The locations of surface thermal activity are shown on figure 3.1. Active thermal features occur mainly in two areas: at Kawah Karaha in the north; and in the vicinity of Telaga Bodas in the south.

Thermal features at Kawah Karaha are described as fumaroles, hot springs and mud pots located within and near an area of altered ground with dimensions of several hundred feet. Most of the hot water discharges at Kawah Karaha are of acid-sulfate composition, indicating that they are derived from steam-heated meteoric water. Several gas seeps and acid-sulfate cold springs also occur in the Karaha project area, not far from Kawah Karaha.

Fumaroles, mud pots and hot springs are present in the Telaga Bodas area. The hot springs are located at lower elevations (mostly about 100 m below the other features), with discharge temperatures up to about 60°C and low-pH, sulfate-chloride compositions.

A few hot springs have been identified on the eastern flank of the volcanic massif, outside the project areas but within the concession area. These springs discharge neutral-pH mixed cation bicarbonate thermal waters.

The chemistry of the surface thermal features is discussed in detail in section 3.5.

## 3.3 Geophysics

Results of geophysical surveys in the Karaha - Telaga Bodas area have been presented in a number of documents, which were reviewed for this study:

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- three reports of magnetotelluric (MT) surveys, prepared by GENZL (1996a, 1996b and 1997);

- the two Notices of Resource Confirmation, or NORCs (KBC, 1997a and 1997b); and

- the Notice of Intent to Develop, or NOID (KBC, 1997c).

The essential information regarding the geophysical surveys undertaken within the project areas is contained in the three GENZL reports. The NORCs and NOID for the most part re-state this information.

The GENZL reports are for the Karaha area (1996a), the Telaga Bodas (T. Bodas) area (1996b), and for these two areas combined (1997). The 1997 report makes a synthetic presentation which supersedes the 1996 reports, and is the basis for most of the following discussion. Therefore, unless otherwise noted, the 1997 report is the source of data discussed herein. The great majority of data available for review are MT data, hence the emphasis here is on the MT results.

### 3.3.1 MT and TDEM Data Acquisition

The first MT survey within the project areas was conducted on behalf of Pertamina by CGG in the 1980s. It covered a broad area and used wide station spacings (2 to 3 km). During 1996-97, under contract to GENZL, Geosystem conducted a detailed MT/TDEM survey in three phases. Geosystem digitized, modeled, and incorporated 12 of the reported CGG soundings into its 1996 MT work (GENZL, 1996a,b), but apparently did not include them in the 1997 effort, which covers the entire Karaha - Telaga Bodas region (GENZL,

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1997). During the recent work, an area of approximately 90 km$^2$ was covered by 179 station sites, although some of these did not include H-field measurements.

The first phase of the MT survey covered the Karaha area, using the hybrid MT-EMAP method (described above) along four traverse lines, each 3 to 4 km in length. In addition, soundings were made at 10 MT stations (KM01 through KM10) to the north and south of the clustered traverse lines. The second phase covered the Telega Bodas area, and included one long hybrid EMAP-MT profile as well as 11 scattered stations (TM01 through TM11). Finally, the third phase of the survey covered the entire Karaha - Telaga Bodas region, utilizing 43 sites. For the purpose of statics corrections, TDEM was performed at each of these 43 sites, as well as at nine of the scattered 1996 sites. All sites and traverse lines are shown in figure 3.3.



In all, 103 regular MT stations comprise the three surveys. Of these, 65 were distributed over the broad area surveyed, while 38 were located along five curvilinear profile lines. Each of the 38 profiling stations incorporated E-field measurements at two adjacent locations, thus forming a series of three-site arrays, each one spanning 500 m, with the H field measured at one site in each array. GENZL has designated the E-field-only sites (76 in number) as "MT" stations, under the presumption that the H field varies slowly enough in space that it is substantially the same at two adjacent line locations (within 500 m), thus arriving at a total of 179 "MT" stations.

The described linear array technique for E-field measurement is often referred to as "EMAP" (electromagnetic array processing), and has the advantage that statics corrections may be estimated by means of low-pass spatial filtering along a profile line. When combined with MT, it is called a hybrid MT-EMAP method. Statics corrections at distributed stations relied upon TDEM soundings (carried out at 52 of the 65 MT sites).

Data were recorded overnight at each site for a period of 18 hours, using frequencies from 100 to 0.001 Hz. Remote referencing was employed among three EMI MT-1 recording systems, and data were quality-checked each morning before moving to the next site. Noise was variable and depended on local cultural activity, including unregulated and leaky power transmission lines. Natural signal levels were variable but adequate throughout the survey period, and signal-to-noise ratios were good. No repeat MT soundings were necessary. Data quality was reportedly considered to be good at all stations (KBC, 1997a).

In addition to performing these MT surveys, GENZL reprocessed and presented previously acquired geophysical exploration results for the area, including MT, DC resistivity, gravity, and microearthquake data. These surveys were performed by or for Pertamina. Data from a few of the Pertamina MT stations were incorporated by GENZL into its presentations. Information concerning previous investigations is limited but is described below.

### 3.3.2 Gravity Survey

Pertamina conducted a gravity survey across the Karaha volcanic massif, as well as the massif to the north. GENZL (1996a) reprocessed the raw gravity data, using a DTM to obtain better terrain corrections, and contoured the resulting Bouguer anomaly for several terrain densities. Maps for a terrain density of 2.3 g/cc are included in the GENZL reports (1996a and 1996b).

A larger-scale Bouguer anomaly map covering the project areas, with a reduction density of 2.3 g/cc, is included here as figure 3.4. As this map indicates, a gravity high follows generally the trend of topography through both the Karaha and Telaga Bodas area. In the south a strong, crudely elliptical high trending N35°E passes about 1 mile SE of lake

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Telaga Bodas. Further north, in the vicinity of wells KRH4-1 and KRH5-1, there appears to be an intersection of three high-gravity axes, which trend NW, NE, and N. There do not appear to be any conspicuous gravity discontinuities clearly related to structural features within the project areas.

Two-dimensional modeling of the gravity data suggests that the volcanic pile, when assigned a density 0.4 g/cc greater than that of surrounding sedimentary rocks, has a maximum thickness of 3,000 m (GENZL, 1996b).

#### 3.3.3 Microearthquake Survey

Natural seismic activity was recorded by a network of five portable seismographs in the Karaha area for a period of 95 days. More than 200 microearthquakes were detected, of which 83 were large enough (magnitude 0.2 to 2.4) to record at three stations and have epicenters determined. Most of the 83 events were located south of the Karaha fumarole field and only 10 lay to the north. The epicenters could not be correlated with any known geological structures (KBC, 1997a). However, P.T. Geoservices identified three target areas northwest and southeast of the Karaha fumarole field, based on seismicity, focal mechanism (tension axes), and relationship to mapped structures.

#### 3.3.4 DC Resistivity Survey

The Geophysical Section of Pertamina measured resistivity at 214 locations at 500 m intervals along several profile lines in 1985. The Schlumberger array configuration was employed, with AB/2 of 250, 500, 750, and 1000 m (KBC, 1997a). In addition, six vertical soundings with AB/2 up to 2000 m were conducted at scattered locations. The overall quality of the data is considered good (GENZL, 1996a). Because this work was performed prior to development of many local roads, the survey lines were concentrated on the northern slopes and in the valleys to the northwest and east of Karaha.

Figure 3.5 presents a map of apparent resistivity for AB/2 = 1000m, for which the approximate probing depth is 300 - 400 m. A well-developed low, within minimum resistivity values below 5 ohm-m), can be seen in the Telaga Bodas field. The 7 ohm-m contour encloses nearly all of the surface thermal features in the vicinity. A weaker low, with minimum resistivities of about 15 ohm-m, is centered less than one mile NNE of Kawah Karaha.

### 3.3.5 MT Modeling and Results

The report for the 1997 regional survey incorporates the data gathered in 1996, and provides a comprehensive set of 1D and 2D models of the resistivity structure of the region. Therefore, it is discussed first, in some detail, before the more limited analyses (all 1D) of the two 1996 reports.

The data were first "static-stripped," to remove offsets between $rho_{xy}$ and $rho_{yx}$ (apparent resistivity curves for the two electrode pairs), followed by recalculation of impedances. The TDEM data were used to predict MT $rho_{xy}$ and $rho_{yx}$, and the static-stripped results were shifted to fit these predictions. Shift factors ranged from 0.5 to 4.5. One-dimensional modeling was performed on invariant resistivity, $(rho_{xy} \cdot rho_{yx})^{1/2}$, using the Bostick method (yielding a continuous variation of resistivity with depth). TE and TM modes were identified, and further 1D modeling was carried out on the TE mode if structures appeared to be "clearly 2D." The criteria for recognition of two-dimensionality are not stated. Electrical strike was hard to determine because it seems to rotate from N-S to E-W with increasing depth, and some structures appear to have a strong 3D character.

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Therefore, 2D modeling was performed in three orientations (NS, EW and NE-SW) by choosing the appropriate impedance tensor components.

Figures 3.6 and 3.7 present Bostick resistivity at elevations of 400 m (1,312 feet) and 0 m above mean sea level. These maps show the lowest resistivities (down to 3 ohm-m) in the western Telaga Bodas area, west of lake Telaga Bodas. This low extends northward as far as the village of Cinta, in the southern part of the Karaha project area. Figure 3.6 shows a low (5 ohm-m) centered on G. Karaha, and a belt of higher resistivity (15-20 ohm-m) trending nearly east-west across the southern Karaha area. Figure 3.6 reveals a rather different pattern in the Karaha area, with a high ridge trending NNW and passing west of G. Karaha, while G. Karaha remains the locus of a 5-ohm-m low.



The Bostick inversions clearly identified a strong conductive layer ("conductor") at most MT sites. This is depicted in four figures (3.8 through 3.11), which show, respectively, the conductor's top elevation, thickness, base elevation, and resistivity. These maps are discussed in some detail because the configuration of the conductor is commonly considered to have a close relationship to the geothermal temperature regime, and the conductor base may coincide with an isotherm in the range of 150-200° C. These relationships are discussed more fully below.

The elevation of the top of conductor (figure 3.8) shows a strong high (1,600 m) centered on lake Telaga Bodas, which corresponds to a top-of-conductor depth of 100 m at that location. This high is part of a ridge in the conductor that trends northerly to the western Karaha area. The conductor ridge closely follows the topographic high that runs northerly from Telaga Bodas to G. Putri, and depths to the conductor are between 100 and 400 m along the length of the ridge.

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The conductor thickness map (figure 3.9) reveals a trend of minimum thickness that closely parallels that of top elevation, though it is different in detail. From south to north, this thickness axis turns northeasterly just south of G. Putri, and almost reaches G. Karaha. The minimum thickness is 400 m, within a NNE trending zone located adjacent to G. Karaha on the southwest; the next smallest thickness is 600m, in a tight anomaly positioned about 1 mile south-southeast of lake Telaga Bodas. A narrow belt of thick (1,600 - 2,200 m) conductor runs east-west through lake Telaga Bodas. Pronounced local thickening is centered just NW of G. Batu Rahang.



Not surprisingly, the map of conductor base elevation (figure 3.10) has a pattern generally similar to that of the previous two maps. The conductor base has a maximum elevation of about 500 m (1,640 feet) in a north-trending belt passing through lake Telaga Bodas, as well as in a narrow, northwest trending zone adjacent to G. Karaha on the southwest.

The resistivity of the conductive layer (figure 3.11) is very low (about 3 ohm-m) at lake Telaga Bodas, and values of 2-3 ohm-m occur in a V-shaped belt which opens to the west and is located north of Telaga Bodas. To the north, a narrow, NE-trending low (5 ohm-m) has its north end at G. Karaha. Maximum resistivity is 20 ohm-m north of G. Batu Rahang (station K136), but this may be high due to an incorrect measurement.

Two-dimensional modeling was performed along profile lines oriented east-west (5 lines), SW-NE (6 lines), and north-south (3 lines), using the WinGlink system to invert the data beginning from a model with uniform resistivity of 50 ohm-m. The minimum elevation shown in the models is -4 km (maximum depth of about 5-1/2 km). The east-west profiles are about 8 km long and cover a region extending from 1 km south of lake Telaga Bodas to G. Batu Rahang. All five east-west profiles show an arched conductor that thins

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dramatically at the arch's axis, in good agreement with the 1D modeling represented in figures 3.8 to 3.11. The conductor is overlain by a thin layer of higher resistivity (20 to 1,000 ohm-m) in most places, although it disappears near the crest of the arch in three of the profiles. The underlying medium-high resistivity rock appears as a very steep-sided ridge. This structure is represented schematically in figure 3.12.



Three of the SW-NE profiles indicate a structure very similar to that of the EW lines. However, the two most southerly SW-NE profiles show a conductor configuration that is asymmetrical or broken. The three north-south profiles show that, at elevations below sea level, resistivity is higher beneath North Karaha (20-50 ohm-m) than it is to the south of G. Putri (10-20 ohm-m).

The DC resistivity survey covers only the western part of the area covered by MT data, and it has a probing depth of around 300 m, reaching only into the shallowest portion of the conductive layer defined by MT. The DC results generally confirm those of MT, except that the DC resistivity lows are higher in value and are generally centered about 0.5 mile north or northwest of those interpreted from MT. The Bouguer gravity high (figure 3.4) coincides closely with the MT conductive layer. The high-gravity axis runs northward from a point about 1 mile south of Telaga Bodas to near G. Putri, and closely follows the axis of the top-of-conductor high (figure 3.8).

The configuration and resistivity of the conductor described above is believed to have a close relationship to the active or recently active geothermal flow regime. In geothermal areas, conductive materials at shallow depths usually consist of hydrothermally altered rocks, whose alteration minerals (especially kaolinite) are stable at temperatures less than about 150-200° C. Although pore-fluid chemistry (salinity) and temperature are important factors influencing bulk resistivity, experience indicates that the type and degree of alteration is

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more important in andesitic volcanic areas such as this one. Typically a shallow conductor with resistivity less than 10 ohm-m is formed by alteration resulting from upflow or outflow of fluid from a high-temperature reservoir. Hence, the presence and configuration of a shallow conductor is often useful in locating geothermal drilling targets, although such a conductor may also represent relict alteration caused by ancient flow that no longer is occurring. The base of the conductor often marks an isotherm of about 150-200°C. Furthermore, because the degree of alteration tends to reflect the strength of upflow/outflow, zones of lower conductor resistivity may be considered more attractive for geothermal fluid production.

The MT modeling results clearly indicate the presence of a strong conductor, with a convex-upward shape to form a ridge that trends northward from north of Telaga Bodas to G. Putri. Base-of-conductor elevations range between about -250 and 500 m (msl) in this north-trending zone, and its width ranges from about 1 to 4 km. The trend of lowest conductor resistivities roughly follows this zone, with the two exceptions:

- a narrow, V-shaped belt of 2 to 3 ohm-m, opening to the west, centered north of Telaga Bodas; and
- a low of 2 ohm-m near proposed core hole T-5.

These off-axis lows may indicate zones of outflow. At elevations below sea level, resistivity is lower to the south of G. Putri than to the north. This may indicate the presence of greater temperature or salinity at reservoir depths south of G. Putri.

The Bouguer gravity anomaly has a north-trending high whose axis coincides with that of the top of the conductor (figure 3.8). The high begins at least 1 mile south of Telaga

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Bodas and terminates about 0.75 mile east of G. Putri. The thickness of the conductor thickness correlates less closely with the gravity anomaly. These relationships suggest that shallow alteration (less than 1,500 feet deep) and related densification (due to deposition in pores) may be strongly reflected in the gravity data. However, on a regional scale, the gravity anomaly appears to reflect the position of the volcanic massif.

### 3.3.6 Conclusions

The Karaha - Telaga Bodas prospect area is characterized by a strongly conductive layer (conductor) present at shallow depths, and by a positive gravity anomaly. Both of these features are observed commonly in the geothermal fields of Indonesia. The top surface of the conductor is shallowest along a north-south axis which closely follows the axis of maximum Bouguer gravity anomaly. The highest elevation of the conductor and the strongest Bouguer anomaly occur together in the immediate vicinity of Telaga Bodas. This part of the concession area also has the densest occurrence of natural geothermal manifestations (hot springs and fumaroles) and recent faulting.

Other features of the resistivity structure, including the thickness and resistivity of the conductor, are less clearly expressed and interrelated than those just described. The axis of minimum conductor thickness trends northward, but is positioned about 1 mile to the west of the axis of highest elevation, north of Telaga Bodas. The conductor's mapped resistivity pattern is complex and not simply related to its other characteristics: lowest conductor resistivities (2 - 3 ohm-m) occur in a broad arc, convex to the west, passing through Kawah Saat, Telaga Bodas, the town of Pangancongan, and G. Candramerta.

## 3.4 Subsurface Temperatures

Downhole temperature profiles measured in the various wells and coreholes drilled by KBC can be used to interpret the subsurface distribution of temperature in the project areas. All temperature surveys available to GeothermEx have been plotted in the downhole summary plots for the various drillholes, presented as Appendices A and B. These have been used to interpret a stable temperature profile for each drillhole. The stable profiles have then been used to develop a three-dimensional model of subsurface temperatures.

The accurate interpretation of temperature in the subsurface is limited by several factors:

- The density of drillholes is low over much of the area, due to both the relatively large extent of the project areas (more than 6 miles north to south) and the pattern of drilling. Coverage is greatest in the north-central Karaha area (in the vicinity of Kawah Karaha); in this area, no significant data gaps exist. The area of lowest drillhole density within the zone of interest is in the approximately 3-mile-long corridor between wells KRH4-2 and TLG1-1. In this area, substantial interpolation of temperatures is required.

- For a few recently drilled wells (*e.g.*, TLG1-1, TLG2-1, TLG3-1) the number of temperature surveys is limited, and the available surveys may not reflect fully equilibrated temperatures. For most drillholes, however, the available surveys are adequate.

- A number of wells are affected by wellbore phenomena that cause measured downhole temperatures to deviate from true formation temperatures. These phenomena include flow between permeable zones, convection around liners, and, probably most importantly, two-phase conditions or steam/gas conditions in the wellbore. Examples of holes that are likely affected by these phenomena are wells KRH1-1 ST2 and KRH4-1, and core hole T-8. In some cases it is possible to correct for the effects and estimate formation temperatures with reasonable accuracy; in other cases the degree of uncertainty may be high.

In addition to these factors, the data generally indicate a high degree of temperature heterogeneity in the Karaha - Telaga Bodas area, with strong vertical and lateral gradients occurring locally, especially at shallow depths. This tends to make it more difficult to differentiate extraneous phenomena such as wellbore effects from actual spatial variations in subsurface temperature, and also limits the reliability of interpolations between wells. At this stage of field development, therefore, the broad pattern of subsurface temperatures can be interpreted with some confidence, but it should be expected that local details may change as more wells are drilled.

Level maps of subsurface temperature have been prepared based on GeothermEx's interpreted stable temperature profiles for the Karaha - Telaga Bodas drillholes. These maps are presented as figures 3.13 through 3.19, representing 1,000-foot intervals of elevation from +3,000 to -3,000 feet (msl). Only a few wells penetrate below the latter elevation.

Figures 3.13 and 3.14 reveal two significant areas of high temperatures at shallow depths; these areas generally coincide with the areas of surface thermal features at Karaha and Telaga Bodas. The available data suggest that the Karaha temperature anomaly is or more limited extent as well as cooler than the Telaga Bodas anomaly. The Karaha anomaly appears to trend ENE, whereas the Telaga Bodas high-temperature zone may trend north to

NNE. A zone of moderately elevated temperatures appears to be present in the vicinity of Pasir Julang (well KRH4-1 and core hole K-21).

The Telaga Bodas temperature anomaly, and to some degree the Pasir Julang anomaly, persist with increasing depth, whereas the Karaha anomaly migrates southward and becomes less distinct. The area of high temperatures generally broadens with depth; however, measurements from KRH4-1 and KRH4-2 indicate a steep temperature gradient along the east-central margin of the field.

The axis of highest temperatures coincides closely at all levels with the zone of highest topographic elevation, from the Telaga Bodas area in the south to the Kawah Karaha area in the north. North of Karaha, the high-temperature zone ends fairly abruptly, along what appears to be a NE-trending boundary. At shallower depths there is some extension of higher temperatures northeastward from Karaha, but it is uncertain whether this persists to deeper levels. The overall pattern of subsurface temperatures also coincides rather closely with the more well-defined geophysical anomalies, discussed in section 3.3.

Maximum temperatures in the Telaga Bodas area reach at least 660°F. Temperatures generally decrease to the north at any given level, but temperatures exceeding 620°F have been measured in the deeper Karaha wells.

The shape of the high-temperature geothermal reservoir can be assessed by means of contour maps of particular isothermal surfaces. The elevation of the 400°F and 480°F isotherms are shown in figures 3.20 and 3.21, respectively. These maps indicate that the reservoir has the shape of a gently dipping arch, trending NE to NNE from Telaga Bodas to the vicinity of Pasir Julang, then turning northwestward to Karaha, beyond which there is no evident extension.

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## 3.5 Subsurface Pressures

Static reservoir pressures are significantly higher in the Telaga project area than in the Karaha project area. In the region between the KRH4-1 and TLG1-1 pads, K-33 is the only well for which a survey showing a static liquid level is available. The reservoir pressure in K-33 is intermediate between pressures measured in permeable wells at the centers of the two project areas. This suggests that, in the reservoir's natural state, geothermal fluids enter the reservoir from an upwelling under the Telaga project area and migrate laterally to the north. However, the observed distribution of static reservoir pressures does not rule out the possibility of several areas of upwelling along the north-south axis of the productive reservoir.

Figure 3.22 shows representative pressure surveys from all wells which have flowed or in which static liquid levels have been measured. The surveys are plotted at equivalent elevations with respect to sea level. The wells plotted with symbols are believed to have low permeability, and liquid levels in these wells appear to represent static columns of water that are not in good pressure communication with the reservoir.

Figure 3.23 shows an expanded plot of the pressure surveys with most of the low-permeability wells removed. At a given elevation, the wells near the center of the Karaha project area show reservoir pressures within the liquid column clustered within a range of about 150 psi, with the highest pressures in KRH4-1. Pressures in K-33 (estimated based on a calculated hydrostatic gradient after a pressure build-up) are about 100 psi higher than those in KRH4-1. The selected surveys for the two Telaga wells in which static liquid levels have been measured (TLG1-1 ST2 and TLG2-1) are roughly 400 psi above the pressure in K-33 and are within about 100 psi of each other. It should be noted that other surveys in these two Telaga wells showed a range of pressures for a given elevation within the liquid column (see the downhole summary plots for these wells in Appendix B), but these pressures were generally above the pressures in K-33 at a corresponding elevation.

Surveys for KRH4-2 OH and KRH4-2 RD are included in figure 3.23 for comparison. These wells show pressures in the liquid column comparable to pressures measured in TLG1-1 ST2 and TLG2-1. It is possible that the KRH4-2 wells show pressures in a fault block that is hydrologically isolated from the reservoir tapped by KRH4-1. However, it is more likely that the liquid levels in the KRH4-2 wells simply reflect water remaining after drilling operations, isolated from the reservoir by the low permeability of the surrounding formation. Similarly, the short liquid column in slim hole T-8 probably represents an isolated accumulation of water below the permeable zones in the well.

## 3.6 Fluid Chemistry



### 3.6.1 Background

Chemical and isotope analyses of water and steam samples from shallow wells and gradient holes, deep slim holes, deep production tests, springs, fumaroles and surface waters have been assembled into a comprehensive database that is reproduced as Appendix C. Data sources are cited therein. Most are raw laboratory reports, although some analyses have been obtained from narrative reports by KBC and others. There is a large well-to-well difference in quality and quantity of chemical data. At the time this report was prepared, only limited data were available from the two newest wells, TLG2-1 and TLG3-1.

Most of the raw analyses do not include information about the methods or conditions of sample collection. KBC has provided some general comments about method, and we have culled the relevant flow data (pressure, temperature and enthalpy) from flow test data

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files and sample collection notes. We also have calculated steam fractions at sample collection conditions, as permitted by the data. There are many gaps in these data, and some contradictions (see comments in Appendix C, table C-1 part 4, and table C-2 part 3). These uncertainties added to the time needed for data interpretation, but they do not have a significant impact on the general conclusions of this study.

The sample locations of Appendix C, with temperature, Cl and pH at springs and shallow wells, are shown on figures 3.24 (for the Karaha and Telaga project areas) and 3.25 (for the entire concession area).

Table 3.1 is a summary of fluids chemistry at the deep core holes and full-sized wells in both areas. This includes: total non-condensible gases (NCG) and $H_2S$ in steam as sampled and at 8 bar-abs (116 psia); water sample pH, Cl and Mg; calculated reservoir liquid Cl; classified water type; and the Na-K-Ca and quartz ($SiO_2$) geothermometers. Mg is included because it rarely exceeds about 1 mg/l in deep, chemically equilibrated sodium-chloride (Na-Cl) thermal water. Higher Mg suggests that cool groundwater or acidic thermal water is present, alone or mixed into normal geothermal water. An abbreviation of the data in table 3.1 is included in table 4.1, which summarizes well test results.

Table 3.2 is a detail of data from the non-commercial well KRH2-1 RD and table 3.3 is a summary of fluids chemistry at shallow holes and points of surface discharge. The term "mixed cation" in table 3.3 indicates that Ca, Mg, Na and K all contribute significantly to the ion balance of the sample.

Figure 3.26 is a schematic summary of fluids chemistry in the two project areas, plotted for reference over the temperature contours at sea level from figure 3.16. Most deep well production is from below sea level.

3.6.2 Telaga Project Area

Deep wells at the center of the Telaga project area have tended to produce acidic chloride water (TLG1-1 ST2) or dry steam that carries gaseous HCl, which appears in condensate as hydrochloric acid and is highly corrosive (TLG1-1 ST2, T-2, and T-8). Hydrothermal systems show a general association of liquid HCl with recent or active magmatism (volcanism or intrusion), and gaseous HCl is associated with superheat (*i.e.*, steam at higher temperature than liquid saturation at the prevailing pressure), with active or recent magmatism, with very high temperature, and/or with boiling of acidic, high-Cl water. Some HCl gas may form when dry steam flows over the dry sodium chloride (NaCl) that has been deposited in rock fractures when a wet system boils and dries out. This dry reaction mechanism may explain acid steam at a superheated production well, but it does not easily explain the acid-Cl water that was produced by well TLG1-1 ST2 (pH about 4 as sampled), or the HCl acidity at fumaroles and associated springs. Well TLG2-1 produced a sodium chloride (Na-Cl) water at pH 6.3 with high levels of Ca and Mg, low Fe (no wellbore corrosion) and evidence of $SO_2$ (sulfur dioxide), before drying to 100% steam. This pH is near-neutral, but the level of Ca and Mg suggests recent acidity, and the $SO_2$ can only have a magmatic source.

There are waters at surface features in the central Telaga area that carry several hundred to several thousand mg/kg of Cl and high $SO_4$ at low pH (table 3.3). This kind of water, found at a high elevation, forms when HCl and $H_2S$-bearing steam condenses into groundwater and the $H_2S$ is oxidized to sulfuric acid ($H_2SO_4$). Salinity may be increased and pH lowered by evaporation, and rock alteration may neutralize some acidity, but the ratio of Cl to $SO_4$ is much higher than in hydrothermal settings where HCl is absent (*e.g.,* in the Karaha area), and at two locations (TEL-3 and -8) the pH is so low (relative to $SO_4$) that HCl must be present. The KBC Hot Spring is notable, because it is only warm (116°F), has

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the isotope composition of rainwater (figure 3.27) and flows at some 400 gpm (KBC estimate), yet has pH 2.3, 4,680 mg/kg Cl and 584 mg/kg $SO_4$. The amount of dilution that is implied by these conditions also implies that the acid steam component carries a high level of HCl.

Away from the center of the Telaga area, there is evidence of less acid and pH-neutral conditions. The "recently acidic" water from well TLG2-1 (see above) was essentially pH-neutral, probably as a result of water-rock reactions, and the steam that was subsequently produced had a near-neutral condensate pH 6 (although the condensate was apparently not analyzed to detect corrosion products that could have neutralized the pH). Further north, well TLG3-1 has recently produced a small, steady flow of pH-neutral water during sampling over a week of flow during February 1998. Field tests of this water (subsequently confirmed by lab analysis) indicated a pH of about 7 and total salinity at 5,000 - 8,000 ppm, so a neutral Na-Cl water is indicated.

The central Telaga springs, the recent volcanic setting, active volcanism at G. Galunggung 6 km to the south of Telaga Bodas, and isotope data (see below) all suggest that recent volcanism or magmatic intrusion is the general source of the central Telaga HCl acidity, and that some acidic water is present at depth in the central Telaga area.

The possible sources of HCl are not constrained enough to infer that magmatic conditions currently exist directly beneath the central Telaga area, that the HCl is a direct, active, magmatic emanation, or that acid conditions are widespread at depth. HCl and $H_2SO_4$ acid conditions in geothermal systems are often highly localized and disappear over horizontal and vertical distances of a few hundred meters and less, both near the surface and at reservoir depth, as a result of rock alteration and hydrologic barriers. Hence, the observation of near-neutral water at TLG2-1 and neutral water TLG3-1 is not surprising.

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Worldwide, the superheated fumaroles of active volcanoes tend to carry HF (hydrofluoric acid) and $SO_2$ (sulfur dioxide) as well as HCl, but significant levels of HF are not always found, and only some related acid hot springs carry anomalous F. The springs at Telaga have low levels of F, but there is high F in two early water samples from well T-2 (15 - 22 mg/kg F at 2,200 - 2,600 mg/kg Cl and pH 3.7). $SO_2$ is a very common volcanic emanation, but this sulfur species will hydrate to sulfite (sulfurous acid) in the presence of liquid-phase water, and it is detected reliably only in samples that are collected with methods designed for $SO_2$ analysis. At Karaha and Telaga there is evidence of low-level $SO_2$ at fumaroles TB-01 and KRH-03, and a report of sulfite at well TLG2-1, but $SO_2$ was below detection in the KBC Hot Spring. KBC reports that these are the only samples in which a $SO_2$ or sulfite analysis was performed.

### 3.6.3 Karaha Project Area

In contrast to Telaga, deep wells at the Karaha project have produced pH-neutral, Na-Cl waters. The highest reservoir Cl, *c.* 7,500 mg/kg, has been found at deep production zones in the south in well KRH5-1. At higher elevations, further north, and at the margins of the temperature anomaly, reservoir Cl is 1,000 to 2,000 mg/kg. Chemical geothermometers applied to the waters from these wells range from 530° - 560°F at KRH5-1 (logged downhole temperature 530°F) down to 430° - 460°F at KRH1-1 ST2 (non-commercial, fluid source temperature not well-constrained by well logs).

Wells that have been tested and sampled repeatedly during more than a few days show a progressive clean-out of drilling fluids, for example at KRH2-1 RD (table 3.3) and at KRH4-1. The last sample collected at KRH2-1 RD (12 June 1997) had higher Mg and was more dilute than earlier samples, indicating that the flow probably included a relatively shallow, cool casing leak (table 3.2). Samples from a 10-day test of KRH5-1 show somewhat

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higher Mg relative to Cl than at the other Karaha deep holes (table 3.1). This also suggests a casing leak, but the evidence is less compelling than at KRH2-1 RD.

The only indication of acid-Cl water from a well in the Karaha area was from samples taken at KRH3-1 ST within 24 hours of the start of flow, while the well was flowing at a low rate. KBC reports that flow from the well subsequently increased, as though another productive interval opened up, and a later sample showed a lower Cl concentration and near-neutral pH. It is possible that the well produces from two zones with different chemistries: acidic steam or a condensate of acid-steam contributes a small percent of the total flow, and a neutral-Cl water that resembles the water at well KRH2-1 RD produces most of the total flow.



Otherwise, the only acidity reported at Karaha is from steam-heated acid sulfate springs, which carry about 10 mg/kg of Cl. These are made acidic only by the oxidation of hydrogen sulfide, as the level of Cl is too low to suspect that HCl is present.

### 3.6.4 Non-Condensible Gases

Non-condensible gases (NCG) in steam at 116 psia are *c.* 7 - 27 wt.% at the central Telaga deep holes (except TLG1-1 ST2) and at slim hole K-33 near the southern boundary of the Karaha project area, and *c.* 0.5 - 4.4 wt.% at the Karaha deep holes plus TLG3-1 at the northern end of the Telaga area.

Considering experience elsewhere, the very high gases at the central Telaga wells are probably higher than would be found with long-term flow, though it has also been found that gas levels which decrease during flow may quickly increase again after the well is shut in.

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The high total non-condensible gases are accompanied by high $H_2S$, at about 1,150 to 5,000 ppm-wt at 116 psia.

Well TLG1-1 ST2 produced steam with about 2.5 wt.% NCG and 660 ppm-wt. $H_2S$ when it was tested during drilling. At total depth, however, a single sample contained only about 1.1 wt.% NCG, a very high concentration of $H_2S$ (2,820 ppm-wt), and a high fraction of nitrogen ($N_2$). The high $N_2$ indicates probable contamination by drilling air and oxidation of some $H_2S$, so the true $H_2S$ in the gas fraction must exceed the reported level of 15 vol.%. This composition, relatively low gases in steam but high $H_2S$, has been found in volcanic settings elsewhere.

The best data from Karaha suggest that water-dominated mixtures of deep water and deep steam will produce (at KBC's reference separator pressure of 116 psia) about 2.5 wt.% NCG and 400 ppmw $H_2S$ (as at well KRH5-1), whereas mixtures with a higher steam fraction from shallower zones will produce (at 116 psia) about 4.4 wt.% NCG and 1,300 ppmw $H_2S$, as at well KRH4-1. According to comparisons of measured enthalpy with the enthalpy of the quartz geothermometer, well KRH4-1 produces a mixture of about 30% boiled reservoir liquid and 70% reservoir steam. The wellhead steam fraction is higher than 70% because the liquid fraction has boiled en-route to the surface. At the north end of the Telaga project area, well TLG3-1 produced a very high steam fraction with only 0.54 wt.% total non-condensible gases and 360 ppm-wt $H_2S$ (only one sample has been reported). This low level, after three days of flow, suggests that the deep southern end of the Karaha area will have lower gases than estimated from KRH5-1 and KRH4-1. Deep slim hole K-33, only 1 km north of TLG3-1, produced roughly 13 - 15 wt.% NCG and 2,800 ppmw $H_2S$ (at 116 psia), but from elevations up to 1,000 feet above those produced at well TLG3-1.

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### 3.6.5 Discussion

The chemical contrast between the Telaga and Karaha areas suggests upflow of fluid in the south, with progressive dilution and neutralization of acidity along a northerly flow path. This pattern is supported by subsurface temperature and pressure data (see sections 3.4 and 5.1), and by stable isotope data for hydrogen and oxygen.



Figure 3.27 (part A) shows the raw isotope sample data, with thin lines that connect samples of steam and water that are related. Part B shows approximate total flow compositions, along with a suggested mixing line that connects most of the data points. Fumarole KRH-03 is considered not likely to represent deep fluid and so is not included on part B. Total flow compositions for some of the wells can only be approximated because collection data are sketchy and waters were often collected at a lower pressure than steam. Some samples represent rig tests and therefore possibly unstable flow. Overall, the total flow data clearly allow the Karaha fluids to be mixtures of Telaga fluids and local meteoric water.

The composition at the extension of the part B mixing line that is considered "magmatic" results from complete isotope exchange between (originally) meteoric water and either a magma or young, fresh, unaltered igneous rock at a very high temperature and a relatively low water/rock mass ratio. The suggested Telaga-Karaha mixing appears to include this "magmatic" composition as an end-member, but this does not prove the presence of "magmatic" fluid. The Telaga steam could be an end-member, or the Telaga steam could itself be a mixture which includes "magmatic" fluid.

In May 1995, KBC conducted a helium (He) isotope gas survey in which nine springs and fumaroles were sampled: three in the central Karaha thermal area (KR-1, -3 and -7);

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three in the central Telaga thermal area (TEL-A, -2 and -5); and three in the outlying concession area to the south and east (TAK-3, -4 and -7). All nine samples had isotope ratios $^3He/^4He$ at 5 to 7.7 times higher than in the atmosphere, and this is considered to represent the presence of $^3He$ from the earth's mantle or from magma (which forms in the mantle). This influence could be active (current magmatic intrusion) or passive (leaching of He from volcanic rocks). There was no difference of $^3He/^4He$ between the Karaha and Telaga areas (ratios to atmosphere of 7.1 - 7.7). Ratios in the outlying samples were lower (5.1 - 5.9), which can be caused by a higher contribution of $^4He$ from radiogenic disintegration of rock materials, and by mixing with air that may be dissolved in groundwater.

Ratios of total He to $CO_2$ in the gas samples used for the He isotope analyses are higher at the Telaga thermal manifestations than at the Karaha thermal manifestations. Since He is much less soluble in water than is $CO_2$, this can mean that the Telaga manifestations are closer to a source of upflow, and the Karaha manifestations represent outflow affected by prior boiling and loss of He beneath the Telaga area. The $He/CO_2$ ratio is even lower at outlying springs TAK-3 and -4 (the ratio at TAK-7 was not determined).

### 3.6.6 Concession Area



Away from the central axis between Telaga and Karaha and outside the two project areas (figure 3.25), most of the waters obtained from gradient holes, other wells and springs have a mixed cation - bicarbonate composition. Most carry 500 to 1,100 mg/kg bicarbonate alkalinity and 10 to 170 mg/kg Cl, with higher Cl at warm springs TAK-9 (220 mg/kg) and TAK-10 (470 mg/kg) near Ciapas (also called the Ciapas basin).

All of these outlying sample points have measured temperatures below 150°F and some are below 80°F (see figure 3.16). Silica temperatures range from about 100°F, if determined by volcanic glass (amorphous silica), to 300°F, if determined by chalcedony. K-Mg temperatures are below 200°F and the Na/K and Na-K-Ca-Mg geothermometers are invalidated by very high Mg, which indicates relatively low temperatures.

Mildly thermal waters such as these are often found in areas of moderate heat flow at the margins of volcanic systems. The high bicarbonate is a result of rock alteration that is promoted by mixing of $CO_2$ from depth with meteoric groundwater. Temperatures in the aquifers that most immediately feed these sources are not likely to exceed 200° to 300°F. Deeper temperatures could be higher, but there are no data to prove this.

None of these outlying waters clearly represents outflow from the deep thermal system beneath the Telaga - Karaha axis. However, a high-Cl component could be present, mixed 1:10 to 1:20 with local bicarbonate water. The highest Cl (TAK-9 and -10) is discharged at elevations of 480m and 495m, which probably is slightly below the liquid level beneath Karaha and Telaga. Therefore, the presence of outflow is possible. The lowest elevation sampled is 450m at warm spring TAK-6 in the far north, where Cl is 130 mg/kg.

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# 4. RESULTS OF DRILLING AND WELL TESTING

## 4.1 Summary of Well Test Results

Currently available productive wells at Karaha have demonstrated a combined capacity of 32.1 MW (17.5 MW from the Karaha project area and 14.6 MW from the Telaga project area). Table 4.1 presents the results of all well tests conducted at Karaha, and table 4.2 summarizes current estimates of performance characteristics for productive wells. For the purposes of this study, productive capacity has been estimated assuming a minimum flowing wellhead pressure of 110.0 psig (122.5 psia), a design separator pressure of 103.5 psig (116.0 psia), and steam conversion factor of 16,000 pounds per hour per megawatt (16 kph/MW).



The productive wells in the Karaha project area have yielded two-phase fluid with enthalpy values in the range of 600 to 1,000 British thermal units per pound-mass ($Btu/lb_m$). Non-condensible gas (NCG) levels in these wells have been moderate to high: expressed as weight percent (wt%) in steam at the design separator pressure, NCG concentrations are estimated at 4.4 wt% in KRH4-1, 2.4 wt% in KRH5-1, and 13.4 wt% in K-33. Hydrogen sulfide ($H_2S$) levels, expressed as parts per million by weight (ppmw) in steam at the design separator pressure, have also been moderate to high: 1,329 ppmw in KRH4-1, 366 ppmw in KRH5-1, and 2,786 ppmw in K-33. For comparison, NCG and $H_2S$ levels in steam are considered moderate up to about 5 wt% and 1,500 ppmw, respectively. Water samples from the Karaha project wells have been neutral to slightly basic in pH, with generally moderate salinity.

The productive wells in the Telaga project area have yielded steam with little to no water on discharge to atmosphere. Enthalpy values for these wells have been in the range of

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1,040 to 1,150 Btu/$lb_m$. NCG and $H_2S$ levels in steam have showed a wide range of values. Two of the full-sized wells have low NCG (1.1 wt% in TLG1-1 ST2 and 0.5 wt% in TLG3-1), while the third full-sized well (TLG2-1) has a very high NCG value of approximately 27 wt%. NCG values for T-2 and T-8 have been in the range of 7 to 10 wt%. H2S values in the Telaga wells have ranged from a low of 360 ppmw in TLG3-1 to a high of 5,100 ppmw in T-8. The small amounts of produced water have tended to be acidic, with pH values of about 4 for TLG1-1 ST2 and T-2, and as low as 2 for T-8. The salinity of the produced water has generally been low to moderate, with the exception of T-8 which produced water with a chloride concentration in the range of 58,000 to 180,000 milligrams per liter (mg/l).



The above estimates of NCG and $H_2S$ levels give more weight to samples toward the end of each flow test in cases where several samples are available. It is common for NCG and $H_2S$ to decline in geothermal wells over longer production periods, and declining levels were in fact observed during testing of KRH4-1. Therefore, it is possible that long-term levels of NCG and $H_2S$ in the Karaha field may be lower than those observed during initial testing.

## 4.2 Results of Pressure Build-Up Tests

The permeability of the reservoir in the Karaha field is low to moderate based on pressure build-up tests conducted in five of the wells. For this report, seven build-up tests have been analyzed, including double tests in KRH4-1 and KRH5-1. Table 4.3 summarizes the data used in these analyses, and table 4.4 presents the calculated results. Build-up analyses were performed both by the Horner straight-line method and by trial-and-error matching using an analytical model of reservoir fluid flow, wellbore storage and skin (Earlougher, 1977). The most productive well (KRH4-1) had permeability-thickness (kh) values in the range of 24,000 to 45,000 millidarcy-feet (md-ft). These are moderate values in comparison with geothermal wells in other Indonesian geothermal fields. The other Karaha wells had kh values in the range of 900 to 6,500 md-ft. For three of the wells (KRH5-1, TLG1-1 ST2, and T-2), the later portions of the build-up data may have been affected by wellbore storage or may have been influenced by effects of changing temperature, which means that the calculated results from these tests should be considered only rough estimates.

Most of the build-up tests yielded negative values of skin (s), indicating a stimulated condition of the wellbores. This is typical for geothermal wells because of the effects of natural fractures. Two of the build-ups indicated positive skin values in KRH5-1 and TLG1-1 ST2, which may indicate wellbore damage (*i.e.*, a near-wellbore restriction in permeability). However, the late-time data from both of these build-ups are suspect (as discussed above), so indications of damage are not considered conclusive. A second build-up in KRH5-1 (also suspect) yielded a negative skin value. After the second build-up in KRH5-1, an acid stimulation was performed on the well; no build-up data was available in the preparation of this report to assess the effect of the acid stimulation on the well's skin value.

## 4.3 Drilling and Testing Data From Individual Wells



### 4.3.1 Well KRH1-1 ST2

KRH1-1 was spudded on 18 May 1996. Directional drilling was initiated at a depth of 1,445 feet, directing the well toward the southeast. Partial losses of circulation were noted below 5,188 feet, and a total loss zone was encountered at 5,739 feet, at which point air drilling began. During air drilling, the well encountered several fractures and was reported to flow strongly. After a total of 66 days of drilling, the well had reached a total depth of 7,293 feet where the drill pipe became stuck. After several attempts to free the stuck pipe,

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the well was plugged back to 5,198 feet and side-tracked around the fish. Air drilling began at 5,372 feet in the side-track. After the well reached a depth of 7,124 feet, a 7-inch slotted liner was run, and a flow test was attempted. The slotted liner was then pulled out of the hole, and drilling continued. A total loss of circulation was noted at 8,046 feet. Drilling continued to a total depth of 8,201 feet, and the slotted liner was run in the hole again. Drilling ceased on 18 August 1996, for a total drilling time of 92 days. After another unsuccessful flow test attempt, the well was shut in.



KBC's evaluation of the failure of KRH1-1 ST1 indicated that there was a relatively cool entry at 5,400 feet. Therefore, on 18 January 1997, a rig was moved back on the hole to cement off the unwanted zone. Most of the 7-inch slotted liner was pulled out, and the zone at 5,400 feet was cemented off. On 9 February, the well was side-tracked again from a depth of 6,918 feet, and directionally drilled to 7,507 feet. A 7-inch blank liner was run and cemented from 4,796 to 7,505 feet. Drilling proceeded with a 6-1/8-inch bit to 9,973 feet, with air-assisted drilling from 7,458 feet. Several unsuccessful attempts were made to initiate flow by air-lifting at various depths. The second side-track was completed on 21 March 1997, after 62 days of drilling operations.

Several nitrogen lifts were performed on the second side-track during June 1997, but these also failed to induce flow. The well has a high bottom-hole temperature of about 600°F (316°C) but apparently insufficient permeability to produce. The well may eventually be useful as an injector in an area north of the productive reservoir.

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### 4.3.2 Well KRH2-1 RD

KRH2-1 was spudded on 26 August 1996, after the drilling was moved off KRH1-1 ST1. The well was drilled vertically to the 13⅜-inch casing point at approximately 3,100 feet, at which point it was drilled directionally to the SSE. Severe losses of circulation began at 3,300 - 3,600 feet, and numerous cement plugs were required in the 12¼-inch hole. Aerated drilling began at 4,625 feet, and the well reached a depth of 6,100 feet on 2 October 1996. A 9⅝-inch liner was then hung and cemented from 2,904 to 6,089 feet. Drilling then proceeded with an 8½-inch bit to a TD of 10,050 feet using aerated fluids. A total of 62 days were spent drilling the well.



On 25 October 1996, the well was air-lifted and flowed unassisted for a day or two, but at relatively low rates and temperatures. On 27 October the well was plugged back to 6,104 feet and kicked off directionally toward the SW. An 8½-inch hole was drilled with air to a total depth of 8,994 feet, which was reached on 24 November 1996. After several days of air-lifting, the well flowed on its own, but at sub-commercial conditions. The well was then deepened to 9,063 feet and the rig was released on 2 December 1996.

During two flow tests in June 1997, the side-track produced two-phase fluid with an estimated enthalpy of 500 Btu/$lb_m$. However, wellhead pressures were sub-commercial, and the flow showed "cycling" behavior, *i.e.*, wide oscillations in wellhead pressure due to slugs of water alternating with steam. Figures 4.1 to 4.3 show the James tube measurements and calculated flow rates from these two flow periods. Based on this testing, KRH2-1 RD is considered non-productive. The well has a high bottom-hole temperature of about 580°F (304°C) and, like KRH1-1 ST2, it may ultimately be useful as a northern injector.

4.3.3 Well KRH3-1 ST

After completing KRH2-1 RD, the rig was moved further to the south and west to begin drilling KRH3-1 on 13 December 1996. Severe losses of circulation were encountered in the shallow part of the well (shallower than 500 feet). After resolving these, the well was drilled to the 20-inch casing point at 1,158 feet, and directional drilling toward the east began at 1,212 feet on 10 January 1997. Directional drilling proceeded to 3,596 feet, and the 13⅜-inch casing was set and cemented at 3,529 feet on 22 January. Mud drilling with a 12¼-inch bit proceeded to 4,512 feet, at which point aerated drilling was initiated. A total loss of circulation was encountered at 6,572 feet, and the well was drilled with foam and intermittent returns to 6,887 feet. After a rig test and wireline surveys indicated that the loss zone at 6,572 feet was non-commercial, 9⅝-inch casing was set and cemented from 3,454 to 6,887 feet on 15 February 1997.

An 8½-inch hole was then drilled with mud to 7,560 feet where a partial loss of circulation occurred and the decision was made to switch to aerated drilling. At 7,568 feet, however, the drill pipe twisted off and fishing operations began. After 5 or 6 days of fishing, a cement plug was set and a side-track was attempted starting at 7,443 feet. This side-track did not build sufficient angle, and the fish in the original hole was re-encountered at 7,532 feet. Another cement plug was set, and the well was then kicked off from 7,386 feet and directionally drilled with mud to 7,545 feet. Aerated drilling of an 8½-inch hole proceeded (with brief uses of the mud motor to correct hole direction) to a total depth of 10,092 feet, which was reached on 20 March 1997.

KRH3-1 ST is the deepest well to date at Karaha. A flow test from 10 to 11 June 1997 (figures 4.4 and 4.5) showed fairly steady two-phase flow and an enthalpy of about 600 Btu/$lb_m$, but the wellhead pressure was sub-commercial. In addition, the produced water was

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reported to have high salinity (chlorides of 40,870 mg/l) and a low pH (2.2). On the second day of flow, a surge brought up rocks and damaged the muffler, bringing the test to a halt. Subsequent wireline surveys indicated that the well had bridged in the open-hole section at 7,500 feet (2,286 meters).

During a second period of flow from 13 to 15 June (figure 4.7), the well began cycling with progressively wider oscillations in wellhead pressure, and the well died after 36 hours. Interestingly, a brine sample during this period showed moderate salinity (chlorides of 1,260 mg/l) and a basic pH (8.3), suggesting that flow during the second test was dominated by a different zone than during the first test. The temperature at total depth (before the hole bridged off) was measured at a high value of 633°F (334°C). The best use of this well in the long run may be for deep injection, especially considering the unfavorable chemistry of the fluids produced during the first period of flow.



#### 4.3.4 Well KRH4-1

KRH4-1 was spudded on 11 April 1997 from a surface location 400m east of the K-21 core hole. It was completed after only 32 days of drilling on 6 May 1997 at a total depth of 6,083 feet (1,854 meters). The 13⅜-inch casing was set on 16 April 1997 at a relatively shallow depth (1,007 feet), and the 12¼-inch hole was then directionally drilled toward the WSW with some losses of circulation to 4,503 feet (with air from 2,271 feet). On 1 May 1997, a 9⅝-inch liner was run and cemented in the hole from 887 to 4,501 feet. A few days were then spent squeezing cement into the liner lap, and on 4 May drilling of the 8½-inch hole began. A loss of circulation was encountered at 4,737 feet, where aerated drilling began. There were additional complete losses of circulation at 5,486 and 5,877 feet. The well reached a total depth of 6,083 feet on 6 May 97. A rig test was performed, and the well was completed on 14 May 97.

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During the rig test from 10 to 13 May 1997 (figure 4.8), the well produced two-phase fluid at a total mass rate of about 300 kph with wellhead pressures of up to 360 psig. The enthalpy of flow during this short-term test was approximately 1,000 Btu/$lb_m$, yielding a steam rate at 116 psia of 237 kph, equivalent to a power output of 14.8 MW.

At the end of the test, the build-up in pressures and temperatures was recorded at a depth of 5,300 feet (figure 4.9), with the sensor above the static liquid level (later measured at about 5,680 feet). Out of a total pressure drawdown of 240 psi during flow, the well recovered 96 psi (40%) in the first ten minutes after shut-in. The downhole temperature rose correspondingly, as would be expected during a pressure build-up with the sensor suspended in saturated steam. The temperature declined slightly from 40 minutes to 1 hour after shut-in, apparently due to condensation of steam in the wellbore as pressure continued to rise.

A log-log plot of the pressure build-up (figure 4.10) does not show a period of data with unit slope, so the duration of wellbore storage is not clearly defined. However, the latter portion of the data does appear to reach infinite-acting conditions, when the effects of phase changes and other wellbore storage effects become negligible. A semilog straight line through the latter portion of the data on a Horner plot (figure 4.11) indicated a kh value of 44,340 md-ft and a skin value of -0.7. An analysis of the same data by trial-and-error matching with an analytical model yielded a kh value of 29,076 md-ft and a more negative skin value (-3.7). The analytical model used was the line source solution with storage and skin, as described by Earlougher (1977), not incorporating temperature effects. Both techniques extrapolated to values of static reservoir pressure (P*) that were in reasonable agreement with the actual static pressure measured three months later (797 psia at the sensor depth of 5,300 feet). Thus, the build-up test indicated a moderate kh value in the range of 29,000 to 45,000 md-ft and a negative skin value (indicating a stimulated or fractured condition near the wellbore).

KBC conducted a long-term test of KRH4-1 from 21 August to 18 September 1997. Flow measurements were made using both a James tube with a weir (figure 4.12) and an orifice (figure 4.13). During the first five days of the test, the well produced dry steam. After five days, the well began to produce a small amount of water. On 27 August, the well was shut in briefly to change the James tube and the orifice, and the well was flowed for several hours thereafter on a 3-inch bleed. When the well was opened back up, water production resumed within one day. The well produced two-phase fluid for the remainder of the test, with enthalpy values generally in the range of 950 to 1,050 Btu/$lb_m$ , depending on wellhead pressure. Figures 4.14 and 4.15 show the calculated results of the flow test vs time, and figures 4.16 through 4.19 show plots of total mass rate, enthalpy, steam rate, and power output vs pressure on the flow line (wellhead pressures were not recorded).

At an extrapolated line pressure of 110 psig, KRH4-1 is estimated to produce at a total mass rate of 275 kph, an enthalpy of 950 Btu/$lb_m$, and a steam rate of 200 kph, equivalent to a power output of 12.5 MW. The concentration of NCG in steam declined from 9.6 wt% initially to 4.5 wt% at the end of the test (figure 4.15). Based on the shape of the decline trend during the test, it is possible that NCG concentrations would have continued to decline over a longer flow period.

The plot of enthalpy vs line pressure (figure 4.17) suggests that producing the well at lower pressures yields fluids with a lower enthalpy (*i.e.*, a higher liquid fraction). As shown in figure 4.20, the water level in KRH4-1 was higher with the well on bleed than with the well shut in, and still higher with the well flowing full open. The main source of production in the well appears to be a dry steam zone at a measured depth of about 5,430 feet. Under full production, the pressure drawdown in this zone induces a rise of the liquid level in the wellbore and the entrainment of a certain amount of liquid from lower zones into the production stream.

Figure 4.21 shows a match of measured pressure and temperature profiles during flow on 27 August with profiles from wellbore simulation. A good match was achieved using the measured total mass rate of 171 kph, of which 123 kph came from the main steam zone at 5,430 feet, 41 kph of liquid came from a zone at 5,931 feet, and an additional 7 kph of steam came from an upper zone at 4,810 feet. The enthalpy of fluids produced at the wellhead was 1,018 Btu/$lb_m$ in the simulation. Figure 4.22 shows a similar result from simulation of a flowing survey conducted on the last day on the long-term test (18 September 1997). In this case, the pressure and temperature sensors could not get below 5,371 feet, possibly due to a ledge in the wellbore wall in combination with the force of upward flow at a higher rate than the earlier survey.

At the end of the long-term test, KBC measured the pressure build-up at a depth of 5,370 feet (figure 4.23). A log-log plot of the build-up (figure 4.23) suggests that the end of the data set did extend into the infinite-acting period. A straight-line interpretation on a Horner plot (figure 4.25) yielded a kh value of 25,130 md feet and a skin value of -1.8. Trial-and-error matching with an analytical model yielded a very similar result: a kh value of 24,308 md-ft and a skin value of -3.9. As before, both techniques yielded estimates of P* that were in good agreement with the measured static pressure at the sensor depth (798 psia). These consistent results give a high degree of confidence that the kh value for KRH4-1 is about 25,000 md-ft and that the productivity of the well is enhanced by near-wellbore fractures.

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Maximum downhole temperatures with the well shut in have been measured at about 505°F (263 °C) in intervals above and below the main production zone at 5,430 feet. Within the main production zone itself, temperatures have been slightly lower at about 500°F (260°C), possibly due to residual cooling by fluid lost during drilling.



4.3.5 Well KRH4-2 RD

After KHR4-1 was completed, the rig was skidded to drill a second well from the 4 pad. KRH4-2 was spudded on 21 May 1997. The 20-inch casing was set and cemented at 893 feet, and directional drilling toward the east began at 1,473 feet. Circulation was lost at 2,996 feet, and drilling continued with partial losses to about 4,000 feet. The well was drilled ahead to 4,505 feet, where the 13⅜-inch casing was set and cemented on 10 June 1997. A 12¼-inch hole was drilled with air to 7,087 feet. Tight spots were noted below 5,200 feet in this interval, and the drill pipe eventually became stuck at 6,720 feet on 26 June 1997 and could not be freed.

The well was then plugged back, and the re-drill was kicked off at 4,500 feet on 30 June 1997. The re-drill began with 12¼-inch hole directionally drilled to the NNE. Circulation was lost at 5,629 feet; cement plugs were set, and drilling continued with partial losses to the 9⅝-inch casing point at 6,000 feet. The casing was run and cemented from 4,370 to 6,000 feet on 10 July 1997. An 8½-inch hole was drilled with aerated fluid, reaching a total depth of 7,930 feet on 17 July 1997, with some losses of circulation in the interval.

Static surveys in KRH4-2 RD on 19 July 1997 (36 hours after last circulation during drilling) showed pressures within the standing water column that were about 500 psi higher than pressures at corresponding elevations in the water column in KRH4-1. KRH4-2 RD appears to have very low permeability, and the standing water column probably represents circulation fluuids that had not equilibrated with the formation. KRH4-2RD does not appear to have any direct hydrologic connection to the productive reservoir tapped by KRH4-1. The maximum measured temperature in KRH4-2 RD was 480°F (249°C) at a depth of 7,700 feet (2,347 meters). Temperature surveys have shown no isothermal interval that would indicate convection in either the wellbore or the formation.

During the long-term test of KRH4-1, KRH4-2 RD was used for injection of produced water. It was able to dispose of water at rates of up to 163 kph with the water level rising to just below the wellhead at the highest rates. KRH4-2 RD is another candidate for long-term injection when the Karaha field goes on production.

### 4.3.6 Well KRH5-1

KRH5-1 was drilled at a location offsetting KRH4-1 to the west. Like KRH4-1, it was drilled relatively quickly, reaching a total depth of 8,015 feet in about 34 days. After spudding on 29 July 1997, a 17½-inch hole was drilled to 1,500 feet, and the 13⅜-inch casing was set and cemented with returns to the surface on 2 August. A 12¼-inch hole was drilled to 4,500 feet where the 9⅝-inch liner was hung and cemented from 1,384 to 4,500 feet on 10 August. Circulation losses in the upper part of the hole were minor and well-managed. The 8½-inch hole was then drilled with mud to 4,737 feet and with air to 5,085 feet, where the drill string twisted off. The drill string was fished out of the hole and drilling with aerated fluid continued to 8,000 feet, at which point the well began to flow on 20 August. A core was then taken from 8,000 to 8,015 feet, and a 7-inch slotted liner was run from 4,428 to 7,984 feet. Flow was initiated with air lifting on 25 August, and the rig was released on 29 August 1997.

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On an initial rig test from 27 to 28 August 1997 (figure 4.26), KRH5-1 produced two-phase fluid at a total mass rate of about 130 kph, but the wellhead pressure during flow was sub-commercial. Flowing surveys during the rig test indicated that flashing was occurring to the bottom of the wellbore. Static surveys showed that water level in the well stood at about 5,400 feet with shut-in wellhead pressures of about 100 psig.



Temperature and pressure surveys suggest that KRH5-1 produces from zones both above and below the static water level, *i.e.*, from both vapor-dominated and liquid-dominated zones (see the downhole summary plot in Appendix B). Under flowing conditions, the draw-down in pressure induces reservoir boiling in the liquid-dominated zones and causes fluids from these zones to enter the wellbore as a two-phase mixture. This contrasts with the performance of KRH4-1, in which flow causes a rise in the water level and production of single-phase liquid from zones below the main steam zone. The difference in performance reflects both lower permeability and higher temperatures in KRH5-1. The maximum temperature in KRH 5-1 under static conditions has been measured at 534°F (279°C) at total depth.

On a flow test from 23 September to 3 October 1997 (figures 4.27 and 4.28), KBC tested KRH5-1 over a range of wellhead pressures, including a period of about three days when the well sustained flow at wellhead pressures of 120 psig. Stabilized total mass rates during this test were in the range of 80 to 90 kph (figure 4.29), and stabilized enthalpy values were in the range of 690 to 730 Btu/$lb_m$ (figure 4.30). Injection tests were performed on the well from 22 to 24 October 1997. During a subsequent flow test from 4 to 11 November 1997 (figures 4.31 and 4.32), flowing wellhead pressures were again sub-commercial (90 psig or less).

KBC performed an acid stimulation on the well on 27 November 1997, followed by another flow test from 3 to 17 December 1997 (figures 4.33 and 4.34). The acid job appears to have stimulated greater production from liquid-dominated zones. Stabilized total mass rates increased to 180 - 210 kph (figure 4.35), and stabilized enthalpy values decreased to 560 - 605 Btu/$lb_m$ (figure 4.36). At a wellhead pressure of 110 psig, KRH5-1 is currently estimated to produce 67 kph of steam (figure 4.37), equivalent to a power output of 4.2 MW (figure 4.38).

KBC conducted two pressure build-up tests on KRH5-1: one after the rig test from 27 to 28 August (figure 4.39), and a second after the flow test from 23 September to 3 October (figure 4.42). On log-log plots of the two build-ups (figures 4.40 and 4.43), the data do not extend far enough beyond fluctuations associated with phase changes to be confident of reaching the infinite-acting period. In the second build-up (figure 4.43), the early data show a clear period of unit slope, indicating wellbore storage. When such a unit slope is present, infinite-acting behavior is not expected to start until 1-1/2 log cycles later, which is past the end of the data set in this case. Therefore, values of kh and skin calculated from straight lines through the ending portions of these data sets should be considered rough estimates, as discussed in section 4.2.

A Horner plot of the first build-up (figure 4.41) indicates a kh of 4,929 md-ft and a skin of +8.3. The extrapolated value of P* (1,265 psia) is in only fair agreement with the actual static pressure at the sensor depth (1,400 psia). The plot for the second build-up (figure 4.44) indicates a kh of 1,012 md-ft and a skin of -0.5. The extrapolated value of P* (2,078 psia) is a poor match to the actual static pressure at the sensor depth (1,430 psia). In principle, the trial-and-error matching technique could take storage into account in estimating kh and skin. However, for the first build-up, the trial-and-error technique did not converge, and for the second, the extrapolated P* value was 2,241 psia, an even poorer match than the straight-line extrapolation.

Therefore, the most one can conclude from the two build-ups is that KRH5-1 has low permeability (roughly in the range of 1,000 to 5,000 md-ft) and that the evidence for positive or negative skin (*i.e.*, damaged or stimulated conditions near the wellbore) is ambiguous. The improvement in the well's output after the acid job suggests that there was in fact some near-wellbore damage at the time the build-ups were conducted.



4.3.7 Core Hole K-33

Core hole K-33 was completed on 25 November 1997 at a total depth of 6,621 feet (2,018 meters). The well's location at the southern boundary of the Karaha project area makes it important in demonstrating the continuity of productive reservoir between the two project areas. KBC conducted a flow test of K-33 from 30 November to 5 December 1997 (figures 4.45 and 4.46). The well flowed with a steady wellhead pressure of about 130 psig. The total mass rate declined gradually during the test, but remained essentially constant at 19 kph for the last two days. The enthalpy of the produced fluid rose during the test from 650 to 875 Btu/$lb_m$. A single steam sample on the second day of the test indicated a high NCG concentration of 13.4 wt% in steam (adjusted to flash conditions at 116 psia); it is likely that this concentration would have declined with further flow. The steam rate at the end of the test was about 12 kph, equivalent to a power output of 0.8 MW.

KBC measured the downhole pressure build-up at the end of the flow test (figure 4.47). A log-log plot of the build-up indicates that the data set did extend beyond the effects of wellbore storage (figure 4.48). A Horner plot of the data (figure 4.49) yields a low kh value of 930 md-ft and a skin of -1.9 (indicating a stimulated wellbore). The low permeability suggests that a larger wellbore at this location would not be a prolific producer. However, the permeability contrast between KRH4-1 and KRH5-1 illustrates that the permeability of wells at adjacent locations can vary widely. The fact that K-33 was able to flow and that it encountered a formation temperature of at least 493°F (256°C) suggests that there is a good possibility of higher permeabilities in the vicinity of this well.

### 4.3.8 Core Hole T-2

T-2 was the first of four core holes that KBC drilled in the Telaga project area. It was completed on 30 April 1997 at a total depth of 4,536 feet (1,383 feet). Uncemented 2⅜-inch tubing was run to total depth, with slots from 3,500 feet to bottom. Maximum temperatures recorded during coring showed cooling by drilling fluids (indicating permeability) over an interval from about 3,700 to 4,200 feet. Stabilized temperatures with the well shut in were about 550°F (288°C) over this interval, increasing to a maximum of about 610°F (321°C) on bottom (see the downhole summary plot in Appendix A).

KBC conducted a flow test of T-2 from 8 to 11 June 1997 (figures 4.50 to 4.51). The well produced mainly steam with a small amount of water. At the end of the test, with a wellhead pressure of 47 psig, the well produced about 12 kph of steam at atmospheric conditions. The NCG and $H_2S$ concentrations in the steam were 9.5 wt% and 1,830 ppmw, respectively. The pH of the produced water was relatively low at 3.8.

On 13 October 1997, KBC pulled the 2⅜-inch tubing from T-2. A second flow test of the well was conducted from 17 to 18 October 1997 (figures 4.52 to 4.53). Wellhead pressures and flow rates were significantly higher during this test. The flowing wellhead pressure stabilized at about 220 psig, with a corresponding flow rate of 27 kph of dry steam,

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equivalent to a power capacity of 1.7 MW. The slim hole was plugged and abandoned on 12 November 1997.

The pressure build-up after the second flow test was recorded for one hour at a depth of 1,400 feet (figure 4.54). The data set was analyzed using the pressure-squared approach for a dry-steam well. A log-log plot of the data indicated that the measured pressures were probably affected by storage throughout the test (figure 4.55). A semilog straight line fit through the last portion of the data on a Horner plot (figure 4.56) indicated a kh value of 6,472 md-feet and a very negative skin factor (-4.6), suggesting fractures near the wellbore. Because of the effects of wellbore storage, these values of kh and skin are considered only rough estimates.



4.3.9 Core Hole T-8

KBC completed slim hole T-8 on 6 July 1997 at a depth of 4,352 feet (1,326 meters). Cooling as recorded by maximum reading thermometers during coring suggested permeability in several intervals below about 3,200 feet. Uncemented 2⅜-inch tubing was run to total depth, with slots from 3,105 feet to bottom. A temperature survey two days after completion indicated nearly isothermal temperatures of about 543°F (284°C) from 3,200 feet to 4,100 feet, increasing to 551°F (288°C) on bottom.

KBC conducted two flow tests of T-8: the first from 10 to 13 July 1997 (figures 4.57 and 4.58), and the second from 20 to 26 July 1997 (figures 4.59 and 4.60). On both tests the well produced mostly steam, with water production starting at about 1 kph and tapering to barely measurable rates. The small amount of produced water had a high salinity (chlorides in the range of 58,000 to 180,000 mg/l) and a low pH (2 to 3). The flowing wellhead pressure during the first test was in the range of 65 to 75 psig, with total mass rates in the range of 14 to 16 kph. During the second test, the wellhead pressure reached as high as 104 psig and was still rising at the end of the test. The total mass rate at the end of the test was 22 kph, with an enthalpy of about 1,140 $Btu/lb_m$.

No power capacity has been assigned to the well, because the wellhead pressure during the tests did not reach 110 psig. However, the well did indicate the presence of productive reservoir conditions, subsequently confirmed by the drilling of TLG1-1 ST2 near the same location.

#### 4.3.10 Well TLG1-1 ST2

After the drilling rig was released from the KRH5-1 well, it was moved south to the Telaga area, and well TLG1-1 was spudded from a site adjacent to productive core hole T-8 on 15 September 1997. The 17½-inch hole was drilled quickly to 1,362 feet, where the 13⅜-inch casing was set and cemented. A 12¼-inch hole was then drilled directionally to 3,037 feet, where a 9⅝-inch casing was run and cemented back to the surface on 22 September. The 8½-inch section of the hole was then drilled to 4,622 feet, with some sloughing and bridging problems. A 7-inch slotted liner was hung from 2,726 to 4,433 feet on 1 October, but could not be run to bottomhole, presumably because of fill in the hole. Attempts to push the liner to bottomhole were partially successful and it was moved down more than 100 feet (2,841 - 4,548 feet).

The well was then allowed to heat up for several days and a flow test was made on 5 and 6 October. The results were not encouraging, and the well was deepened using a 6⅛-inch bit to 4,895 feet. The 7-inch liner was then removed and the well was plugged back to 3,086 feet, and directional drilling of ST1 began on 13 October 1997. An 8½-inch hole was drilled with losses to 4,665 feet, where the drill pipe twisted off on 17 October. Fishing

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operations ensued for several days, and on 23 October, the decision was made to side-track again. The well was plugged back to 4,134 feet. When running in the hole with the directional tools to kick off ST2, the drill pipe became stuck temporarily. An 8½-inch hole was then drilled to 4,800 feet, and a 7-inch blank liner was hung and cemented from 2,940 to 4,786 feet on 1 November 1997. Cement was subsequently squeezed into the liner lap. A 6⅛-inch hole was drilled to 5,844 feet with some losses, and a 5-inch slotted liner was hung from 4,745 to 5,844 feet. A rig test was run on 10 and 11 November 1997, and the rig was released on 12 November 1997.

The rig test from 10 to 11 November 1997 (figure 4.61) showed that the second side-track flowed with a wellhead pressure of 130 psig. It produced about 60 kph of steam (equivalent to a power output of 3.8 MW), and a small amount of water (possibly a return of drilling fluid). Wellbore simulation was used to match a flowing pressure survey conducted during the rig test (figure 4.62). A good match was achieved using an enthalpy of 1,100 Btu/$lb_m$ and a total mass rate of 65 kph. In the simulation, 37 kph two-phase flow was estimated to enter the wellbore at the base of the 5-inch liner, with single-phase steam entering the wellbore at upper zones (14 kph at 5,080 feet and another 14 kph through the liner top at 4,744 feet).

After the rig test, KBC measured the pressure build-up at a depth of 5,200 feet (figure 4.63). The build-up was monitored for 10 hours, but a log-log plot (figure 4.64) suggests that the data did not extend beyond the period of wellbore storage. It is also possible that the late-time data was influenced by the effects of temperature changes on the Kuster tools. Fitting a semilog straight line on a Horner plot through the last portion of the data (figure 4.65) yields rough estimate of kh (5,325 md-ft) and skin (+10.2). The high positive skin value suggests possible wellbore damage, but is not considered conclusive due to the possible influence of wellbore storage and temperature effects.

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KBC conducted a flow test of TLG1-1 ST2 from 29 November to 1 December 1997 (figures 4.66 and 4.67). The well produced dry steam throughout the test and was throttled in the last half of the test to raise the wellhead pressure. At the end of the test, the wellhead pressure was 198 psig, and the steam rate was 80 kph, equivalent to a power output of 5.0 MW.



### 4.3.11 Well TLG2-1

The drilling rig was moved from the TLG1-1 location to a site adjacent to core hole T-2, and TLG2-1 was spudded on 19 November 1997. After setting the 20-inch casing at 1,068 feet, a 17½-inch hole was drilled to the kick-off point at 1,633 feet. The well was then drilled directionally to 2,371, where the mud motor broke apart and had to be fished from the hole. Directional drilling then proceeded to 3,300 feet, where the drill pipe became stuck. After freeing the pipe, the well was deepened to 3,314 feet and the 13-3/8-inch casing was run and cemented from the surface to 3,308 feet on 2 December. A 12¼-inch hole was then drilled with some torquing problems to 4,650 feet where the drill pipe stuck again. After freeing the pipe, a 9⅝-inch liner was hung and cemented from 3,120 to 4,645 feet.

Mud drilling continued with an 8½-inch bit to 5,095 feet, where aerated drilling began. The well came in at 5,700 feet, and drilling continued to 8,490 feet. A 7-inch slotted liner was hung from 4,576 to 8,490 feet on 26 December 1997, the well was tested, and the drilling rig was released on 30 December 1997.

During the rig test from 28 to 29 December 1997 (figures 4.68 and 4.69), TLG2-1 produced steam with a decreasing amount of water (probably returning drilling fluid). By the end of the rig test, the well was flowing dry steam at a rate of 64 kph, with wellhead

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pressures throttled to about 130 psig. The well produced relatively high concentrations of NCG (10.3 wt% in steam), with moderate concentrations of $H_2S$ (844 ppmw).

KBC conducted a flow test of TLG2-1 from 3 to 21 February 1998 (figures 4.70 and 4.71). The well produced dry steam throughout the test. Figure 4.72 shows the variation in flow rate with wellhead pressure. The calculated steam rate has been adjusted downward to account for the well's very high NCG level (approximately 27 wt%). At an interpolated wellhead pressure of 110 psig, the well has a flow capacity of 42 kph steam, equivalent to a power capacity of 2.6 MW (figure 4.73). However, the high NCG concentration will make it difficult to use TLG 2-1 in a conventional geothermal flash plant, unless steam from this well can be diluted by mixing with steam from other wells with lower NCG. 

On 4 March 1998, KBC performed a temperature and pressure survey in TLG2-1 with the well shut in. The survey showed a maximum temperature of 667°F (353°C), the hottest temperature measured to date in the Karaha field. Isothermal sections from 3,000 to 6,200 feet and from 7,000 to 7,850 feet suggest that cross-flow of steam is occurring in both intervals with the well shut-in (see the downhole summary plot in Appendix B).

#### 4.3.12 Well TLG3-1

After completing TLG2-1, the drilling rig was moved north. A productive core hole had been drilled just north of the boundary between the two areas, and KBC sited vertical well TLG3-1 to further investigate the productivity of the region between the Telaga and Karaha areas.

TLG3-1 was spudded on 7 January 1998. After setting the 20-inch casing at 1,919 feet, a 17½-inch hole was drilled to 4,204 feet with some losses of circulation. The 13⅜-inch

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casing was hung and cemented from 1,727 to 4,200 feet on 22 January 1998. A 13⅜-inch tie-back string was cemented to the surface on the following day. Drilling of the 12¼-inch hole proceeded to 7,747 feet, where a rig test was run on 4 February 1998. Drilling proceeded to 7,981 feet, and a 10-3/4-inch slotted liner was hung from 4,175 to 7,981 feet on 6 February. The well was then tested again briefly, and the rig was released on 8 February 1998. The two rig tests run prior to completion indicated that the well was productive, with a power capacity preliminarily estimated at 8 MW.

KBC conducted a 30-day flow test of TLG3-1 from 16 February to 18 March 1998 (figures 4.74 and 4.75). The wellhead pressure was raised in steps during the test; figure 4.76 shows the relation between stabilized total mass rates and flowing wellhead pressure. The only chemical sample available from the test (taken on 18 February 1998) shows low NCG and $H_2S$ values (0.5 wt% and 360 ppmw, respectively). A plot of enthalpy versus flowing wellhead pressure (figure 4.77) suggests that the well produces higher-enthalpy fluid at lower wellhead pressures. Figures 4.78 and 4.79 show the variation in steam rate and power output with wellhead pressure. At a wellhead pressure of 110 psig, the test indicates that the TLG3-1 produces steam at 112 kph, equivalent to a power capacity of 7.0 MW. A static survey on 20 March 1998 showed temperatures nearly isothermal at about 520°F (271°C) to 6,000 feet, then gradually increasing to 564°F (296°C) at 7,800 feet.

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# 5. CONCEPTUAL MODEL AND GEOTHERMAL ENERGY RESERVES

## 5.1 Conceptual Model

A conceptual model of the Karaha - Telaga Bodas geothermal system can be developed based on the results of the drilling and other investigations discussed in previous chapters. Such a model can serve as a framework for understanding and interpreting the system in light of existing information, and for planning future development activity. Because the combined project areas comprise an overall area that is large, the detail of investigation of the geothermal field is still limited, despite the number of wells and core holes drilled to date. Future drilling and other development work is likely to result in modifications and refinements to the model presented here.



The available evidence shows that an extensive, high-temperature geothermal system underlies much of the Karaha and Telaga Bodas project areas. Measured temperatures up to nearly 670°F have been measured in the Telaga Bodas area, and temperatures greater than 620°F have been measured in the deepest Karaha wells. The trends of the temperature profiles in the deeper wells suggest that still higher temperatures are likely to be present, at least locally, at greater depths.

The geothermal system discharges to the surface at two widely separated locations: a fumarole area at and near Telaga Bodas, and another to the north at Kawah Karaha. Although there is no apparent surface expression of the system between these two sites, subsurface data indicate that the geothermal reservoir is essentially continuous from Telaga Bodas to Kawah Karaha. Mapping of subsurface temperatures shows the reservoir to have the shape of a broad arch that dips generally northward, in close coincidence with the axis of the volcanic massif. The shape of the reservoir can be visualized through the isothermal

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surfaces presented in figures 3.20 and 3.21. Figures 5.1 and 5.2 show cross sections of temperature and other features, along the south-to-north length of the field, and west-to-east across the Karaha area, respectively; these sections further illustrate the form of the geothermal reservoir.

The ultimate source of heat for the geothermal system probably consists of one or more cooling intrusions or magma bodies, related to the young volcanism within the project area (and to the active volcanism a short distance to the south). The heat source has not been specifically identified. It is possible that the intrusive rocks encountered in the deepest wells are connected directly with the heat source, but this cannot be confirmed from available data.



Except for the deep intrusives noted, the system is hosted by volcanic rocks typical of the volcanic complexes of western Java, with pyroclastic units predominating over lavas. The shape of the reservoir and the heterogeneous nature of the rocks suggest that reservoir permeability is distributed broadly, rather than being confined to specific stratigraphic units or structural zones. Permeable zones occur within pyroclastics as well as lavas and intrusives, indicating that secondary permeability has developed as rocks have become altered (and therefore competent) and then fractured in response to ongoing tectonic and/or hydraulic stresses.

Temperature, pressure and chemical data show that fluid within the geothermal reservoir moves generally northward, from the Telaga Bodas area toward Karaha. This indicates that the location of the most important upflow into the explored reservoir from deeper levels is near or south of Telaga Bodas. However, the data do not preclude the existence of a second zone of upflow within the Karaha area, perhaps in the vicinity of KRH4-1 and KRH5-1 (see figures 3.21 and 5.1), or further to the south.

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The fluid entering the system in the Telaga Bodas area consists largely of water of meteoric origin, but it also contains a significant magmatic component, which may have been acquired either by incorporation of magmatic fluid, or by interaction with recently emplaced intrusive rocks. The magmatic component yields a fluid composition that causes acidic steam to be produced in the southern Telaga Bodas wells. As the reservoir fluid migrates northward, the tendency toward acid production is neutralized by dilution and water-rock interaction, so that production from the northern (Karaha) wells is neutral to alkaline.



The fluid in the deeper part of the geothermal reservoir is liquid-phase water, but at shallower levels the presence of a two-phase or steam-dominated zone, at least locally, is indicated by production enthalpies, chemical data, and temperature profiles measured in some of the wells. The distribution and thickness of the steam zone are difficult to quantify, because various phenomena can affect phase conditions within wellbores, obscuring the phase distribution in the adjacent reservoir. Two wells that appear to have well-defined steam zones are KRH4-1 (at about 4,500 to 5,500 feet depth) and TLG2-1 (at about 4,000 to 5,000 feet depth). Depending on their location and completion depth, wells drilled into the reservoir may produce from the steam zone, the liquid zone, or both.

As noted above, the shape of the geothermal system coincides in a general way to the shape and trend of the volcanic massif. Gravity and electrical anomalies also conform to this general trend. The available data are insufficient to determine whether the localization of the geothermal system is due more to lithological, structural, or heat-source-related factors. Several observations can be made, however, regarding specific local characteristics of the system:

- The southern boundary of the geothermal system has not been defined by drilling so far. Subsurface temperatures increase toward Telaga Bodas and Kawah Saat, and it is probable that the reservoir extends at least as far south as Kawah Saat.

- The pattern of subsurface temperatures suggests the presence of a WNW-trending discontinuity somewhere in the vicinity of well TLG3-1 and core hole K-33. The discontinuity appears to separate a broad zone of high temperatures in the south from a narrower high-temperature zone in the Karaha area north; it also represents a zone in which temperatures are slightly depressed, thereby separating the southern upflow zone from the possible northern upflow zone. The exact position and nature of the discontinuity are uncertain; however, several NW to WNW-trending lineaments are present near the boundary between the project areas (figure 3.2). One or more faults in this zone may partially restrict and localize the movement of fluid from south to north, without creating enough of a barrier to create two chemically distinct reservoirs.

- Over most of the project area, the eastern and western boundaries of the field have not been defined by drilling; therefore it is not know whether, in general, they are diffuse or distinct. In the vicinity of P. Julang, however, a sharp reservoir boundary is indicated by the contrast in temperatures, well productivities and rock alteration between wells KRH4-1 and KRH4-2. As cross section 5.2 shows, a localized temperature high coincides with the high productivity of well KRH4-1 on the western side of the boundary, whereas temperatures then fall off steeply to the east at KRH4-2 and beyond. A strong lineament identified along the east side of P. Julang suggests that a fault may be responsible for limiting eastward movement of fluid in this area.

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- A temperature high similar to that near KRH4-1 occurs in the vicinity of Kawah Karaha, in this case culminating in the surface discharge of steam (figure 5.1). The steep drop in temperatures to the northeast, representing the effective northern limit of the geothermal field, again suggests that a fault or other dipping planar feature may create a permeability barrier.

To summarize the above, there are local indications of impermeable faults or other barriers that may act as lateral boundaries east of P. Julang and at the nothern end of the temperature anomaly; however, no lateral boundaries are clearly defined at the western or sourthern margins.

The temperature profiles measured in the various wells and coreholes do not indicate the presence of a widespread, well-defined "caprock" limiting upward movement of fluid; similarly, there is no strong stratigraphic evidence for such a cap. The strongest evidence for the existence of a widespread caprock is the shape of the conductive layer defined by geoelectrical investigations, which shows a correlation, particularly at its upper surface, with the shape of the geothermal reservoir (figures 3.8 and 5.1). In most fields, the conductive layer is thought to be represent a zone of clay alteration, which is likely to be impermeable. However, as can be seen in figure 5.1, the deduced base of the conductor is irregular and does not conform to the top of the reservoir zone, and therefore the real significance of the geophysical feature is uncertain.

## 5.2 Reserve Estimation

### 5.2.1 Methodology

In the early stages of development of a geothermal field, a volumetric approach is usually used to estimate the energy reserves. This method begins with estimates of reservoir volume and the average temperature within a specified volume of rock to calculate the heat-in-place. The next parameter to be estimated is the recovery factor, which is the fraction of the heat-in-place that can be recovered at the surface. Then a utilization factor to convert the heat energy of the recovered fluid to electrical energy is used to calculate reserves in terms of MW-years.

We have used, with some modifications, the volumetric reserve estimation methodology introduced in the mid-1970s by the U.S. Geological Survey. We have improved this method to account for uncertainties in some parameters by using a probabilistic approach. The details of this method are given below.

In our method, the maximum sustainable capacity of a geothermal system (the reservoir and the plant considered together) is given by:

$$E = \frac{AhC_v(T-T_o) \cdot R}{F \cdot L} \tag{1}$$

where
- $A$ = areal extent of the reservoir,
- $h$ = thickness of the reservoir,
- $C_v$ = volumetric specific heat of the reservoir,
- $T$ = average temperature of the reservoir,
- $T_o$ = base temperature (equivalent to the average annual ambient temperature),

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| | | |
|---|---|---|
| R | = | overall recovery efficiency (the fraction of thermal energy in place in the reservoir at a temperature of $T_o$ or more that is converted to net electrical energy at the power plant), |
| F | = | power plant capacity factor (the fraction of time the plant produces power on an annual basis), and |
| L | = | power plant life. |

The parameter R can be determined as follows:

$$R = \frac{W \cdot r \cdot e}{C_f \cdot (T - T_o)} \qquad (2)$$

ENTIAL

| | | | |
|---|---|---|---|
| where | r | = | recovery factor (the fraction of thermal energy in place that is recoverable at the surface as thermal energy), |
| | $C_f$ | = | specific heat of reservoir fluid, |
| | W | = | maximum available work from the produced fluid, and |
| | e | = | utilization factor, which accounts for mechanical and other losses that occur in a real power cycle. |

The parameter $C_v$ in (1) is given by:

$$C_v = \rho_r \, C_r \, (1-\phi) + \rho_f \, C_f \, \phi \qquad (3)$$

| | | | |
|---|---|---|---|
| where | $\rho_r$ | = | density of rock matrix, |
| | $C_r$ | = | specific heat of rock matrix, |
| | $\rho_f$ | = | density of reservoir fluid, and |
| | $\phi$ | = | reservoir porosity. |

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The parameter W in (2) is derived from the First and Second Laws of Thermodynamics as follows:

$$dW = dq\,(1-T_o/T), \text{ and} \quad (4)$$

$$dq = C_f\, dT \quad (5)$$

where q represents thermal energy.

### 5.2.2 Estimation of Parameters

The following parameters required for reserves estimation can be assumed for the Karaha - Telaga Bodas geothermal field with little uncertainty:

| | | |
|---|---|---|
| Volumetric Specific Heat of Rock | = | 34 Btu/ft$^3$ °F (based on representative rock types at Karaha - Telaga Bodas) |
| Base Temperature | = | 68°F (average ambient temperature at Karaha - Telaga Bodas) |
| Utilization Factor | = | 0.45 (typical for modern geothermal plants) |
| Plant Capacity Factor | = | 0.90 (typical for modern geothermal plants) |
| Plant Life | = | 30 years (typical amortization period for a geothermal power plant). |

The remaining parameters required for reserve estimation were considered to have significant uncertainty. In order to estimate the reserves within the Karaha - Telaga Bodas field in a probabilistic way, we have used the Monte Carlo simulation method. Separate Monte Carlo simulations were run for the Karaha and Telaga Bodas project areas. The following estimates of the uncertain parameters were used, as derived from the conceptual model of the field and the temperature distribution described above:

| | |
|---|---|
| Average Temperature: | Karaha - ranges from 440 to 520°F with a most-likely value of 480°F; |
| | Telaga Bodas - ranges from 500 to 580°F with a most-likely value of 540°F; |
| Reservoir Area: | Karaha - ranges from 1.5 to 7 square miles with a most-likely value of 4 square miles; |
| | Telaga Bodas - ranges from 3.5 to 12 square miles with a most-likely value of 9 square miles; |
| Reservoir Thickness: | ranges from 2,500 to 4,000 feet with a most-likely value of 3000 feet (same for both projects); |
| Porosity: | ranges from 0.04 to 0.10 with equal probability (same for both projects); and |
| Recovery Factor: | ranges from 0.10 to 0.25 with equal probability (same for both projects). |



5.2.3 Results

For both project areas, values within the specified ranges of the uncertain parameters were sampled randomly 1,000 times, and reserves were calculated for each sampled set of parameters assuming a 30-year plant life. For the Karaha project area, figures 5.3 and 5.4 show the histogram and the cumulative probability graphs, respectively, of the gross MW capacity calculated by Monte Carlo simulation. Figures 5.5 and 5.6 show the corresponding figures for the Telaga Bodas project area.

Based on these simulations, the gross MW capacity of the Karaha project area ranges from about 40 to about 320 MW, with a most likely value of 135 MW for a project life of 30 years (equivalent to available energy reserves of 4,200 MW-years). For the Telaga Bodas project area, the gross MW capacity ranges from about 100 to about 670 MW, with a most

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likely value of 310 MW for a project life of 30 years (equivalent to available energy reserves of 9,300 MW-years). Figures 5.4 and 5.6 show that there is a 90% probability that the capacities of the Karaha and Telaga Bodas project areas will exceed 72 MW and 188 MW, respectively, for 30 years. Thus, at the 90% level of probability, the 30-year capacity of the entire Karaha - Telaga Bodas field is 260 MW.

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# 6. EVALUATION OF DEVELOPMENT OPTIONS

## 6.1 Review of Exploration and Drilling Strategy

KBC has pursued an aggressive exploration program at Karaha - Telaga Bodas over approximately 2-1/2 years. As indicated from the data provided to GeothermEx, the essential elements of this program have been: 1) sampling and chemical analysis of fluids from wells and surface discharges; 2) resistivity surveying using the magnetotelluric (MT) method; 3) drilling 19 shallow and deep core holes, of which three were flow tested; and 4) drilling nine full-sized wells, of which five flowed at commercial rates and pressures.



Fluid sampling for chemical analysis was undertaken in many areas of KBC's concession, and was effective in characterizing thermal and non-thermal surface discharges. Samples collected during flow tests of core holes and full-sized wells were useful in developing the conceptual model of the field presented in the preceding chapter. The sampling methods and data quality were problematic in some cases, as discussed in section 6.2. However, these problems did not significantly hinder the resource assessment.

The MT resistivity survey area coincides with the drilled area, which is about 40 $km^2$. The interpreted base of the subsurface "conductor" outlines, in a general sense, areas of higher reservoir temperature; however, it is unclear how much KBC relied upon the MT data for well siting, as the drilling campaign and the MT data collection/interpretation were undertaken simultaneously. At this stage, the deduced shape of the conductor, and other geophysical anomaly data, can be helpful (in conjunction with other data) for interpreting the geothermal system, but they do not provide enough detail for specific well siting decisions. For example, it would be difficult (if not impossible) to distinguish the

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non-productive well KRH4-2 from the highly productive KRH4-1 on the basis of geophysics alone.

The initial series of nine core holes (K-1/1A, K-2, K-3, K-4, K-6, K-7, K-9, K-10 and K-11, figures 2.1 and 2.2) was drilled in the region around Kawah Karaha, and good information on shallow subsurface temperatures and heat flow was obtained. However, the core holes were too shallow to penetrate the reservoir, and the first full-sized well was subsequently sited in a zone that proved to be unproductive. In hindsight it can be said that if the core holes had been drilled deeper, KBC might not have drilled KRH1-1 and its sidetracks. However, drilling near a fumarole area often yields good results, and it was certainly reasonable to site the first well where KBC did, given the available geological, geophysical and geochemical information.

KBC had already begun drilling the second full-sized well when core hole drilling was resumed, and simultaneous drilling of the two types of holes continued thereafter. The low drilling success rate for full-sized wells over the next six months or so (through the first quarter of 1997) may be attributed to the fact that core hole data could not be fully assimilated prior to siting full-sized wells. Drilling success was higher later in the drilling campaign; for example, wells KRH4-1 and KRH5-1 were drilled near core hole K-21, and two of the productive full-sized wells at Telaga (TLG1-1 ST2 and TLG2-1) were drilled adjacent to productive core holes (T-8 and T-2, respectively).

Unlike at Karaha, drilling of the Telaga full-sized wells began about one month after the nearby core holes had been completed (see figure 2.2). Furthermore, well TLG3-1 was sited between two wells that were both productive, although widely spaced (TLG1-1 ST2 and core hole K-33). While this siting strategy does not guarantee success, it certainly improves the odds. The drilling of the first four full-sized wells at Karaha is best characterized as

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exploration drilling. By the time the Telaga full-sized wells were drilled, enough was known about the resource to say that development wells (as opposed to exploration wells) were being drilled, although the characteristics of the central Telaga wells make them problematic as commercial producers. The high gas content and acidity suggested by analysis of fluids from surface discharges and core holes did not preclude the possibility that more benign conditions might be encountered in deeper, full-sized wells, as such conditions often have limited extent (both laterally and with depth). However, the risk that full-sized wells at Telaga would also encounter these conditions clearly existed.



The core holes were drilled relatively quickly, and although GeothermEx did not receive cost information, we assume that they were drilled at reasonable cost. Deep core holes that did not encounter commercial production provided very useful information about reservoir boundaries at considerably less cost than full-sized wells. The core holes, particularly the deep ones, provided information on the distribution of subsurface temperatures that has been critical in developing the conceptual model and estimating the available reserves of the Karaha - Telaga Bodas resource. The magnitude of the available geothermal energy reserves is one of the important criteria for bank financing of a geothermal development. As discussed in Chapter 5, the reserves in the Karaha - Telaga Bodas are 260 MW or more. This could not have been determined without covering a large area; hence the utility of core holes.

Commercial deliverability at the wellhead must also be demonstrated before bank financing can be obtained. From April 1997 to February 1998, KBC drilled six full-sized wells, of which five were commercially productive at an average of 6.4 MW per well. This implies a drilling success rate of 83%, which is excellent for the initial development drilling phase of a geothermal project. Drilling times (and therefore costs) improved as the program

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continued (figure 2.2). The wells were drilled with state-of-the-art drilling techniques, and KBC particularly managed the air drilling program very well.

To summarize, KBC has effectively balanced the use of slim holes and full-sized holes to demonstrate the existence of a substantial geothermal resource in a timely manner. Detailed chemical sampling of surface features and deep core hole drilling (primarily to obtain subsurface temperature information) are the two most useful exploration methods in volcanic settings, followed by certain geophysical methods. Therefore, in our opinion, KBC pursued its exploration program well, and has defined an exploitable geothermal resource of considerable magnitude.

## 6.2 Available Database

FPL has asked for comments on the completeness, quality and reliability of KBC's database from the Karaha - Telaga Bodas project. Our efforts to compile a complete database were hindered by two factors. The first was that drilling and well testing activities were continuing throughout the course of our work, and therefore new information continued to be generated. The second was the variety of data formats and sources. Information was held by various individuals in the U.S. and Indonesia, each with their own system of recording and archiving. This comment applies particularly to the well test and chemical data, for which a comprehensive compilation and integration required more time and effort than anticipated. KBC was extremely cooperative in providing information to us, and the quality of the data was generally good, with the following exceptions.

At the time this report was prepared, very little information on the conditions associated with fluid sampling was available in the chemistry database, and well test information did not always make up for this. As a result, the pressure, enthalpy and flow

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conditions associated with a number of the samples were unknown or uncertain. Early in the exploration program, some steam samples were apparently collected at a pressure lower than the flowline pressure, which can allow an unquantified dilution of gases in steam if water enters the separator. Later in the program, steam samples were collected at line pressure. Most water samples were apparently collected from the weirbox, but it was not always clear if this was the case, and the information received was sometimes contradictory.

With steam samples collected at line pressure and water samples collected at atmospheric pressure, it is possible to determine gases in steam and concentrations of chemical species such as Cl and $SiO_2$ in the water phase, and most total flow concentrations can usually be calculated without making potentially erroneous assumptions. However, it is sometimes difficult to back-calculate the concentration values to reservoir conditions with desired accuracy, and parameters such as calcite saturation indices are then not easily determined. KBC's sampling did not enable a determination of the gases that are dissolved in the water phase. Although this problem is usually minor, it can become important for decisions regarding abatement of $H_2S$ gas and/or plant design. Isotopes should also be determined in samples of water and steam that are collected simultaneously at the same pressure, because the water isotopes shift during boiling and weirbox samples for isotopic analysis can be affected by condensation or excess evaporation.



Most geothermal wells are sampled at 125 - 140 psig to avoid such problems, and sampling pressures less than 80 psig are usually avoided. KBC's sampling methods increased the uncertainty of the data, making the process of calculating back to reservoir conditions cumbersome and error-prone. While this does not affect the overall analysis of the geothermal system, some of the finer points of the system chemistry cannot be determined.

Similar problems were noted in the well-test database. The format of the spreadsheets containing the test data changed from test to test, probably because several individuals were responsible for compiling the test data. The reported units varied, and there appeared to be some errors in converting between metric and English units and in converting from gauge to atmospheric pressures. In a few cases, the units were incorrectly or incompletely labeled. The value of atmospheric pressure used in the reported calculations varied from test to test. In GeothermEx's experience, atmospheric pressures in the range of 12.2 to 12.7 psia would be expected for the range of elevations at Karaha - Telaga Bodas. Our calculations assumed a constant value of 12.5 psia.

In some cases, GeothermEx's estimates of MW capacity were as much as 10% lower than the values calculated by KBC. GeothermEx's calculations of flow rates and MW capacities typically included a correction fro NCG based on sampling during the flow period in question. KBC's calculations usually did not included a correction for NCG due to the uncertainty of stabilized NCG concentrations. This accounts for some of the differences between the calculated results. Differing assumptions about atmospheric pressures may also have contributed, though this effect would be expected to be minor. For some well tests, a non-standard V-notch weir (82° rather than 90°) was used; while this does not affect the accuracy of the results, it took some time to verify which weir applied to which test.

None of the above significantly hindered our analysis, as we were able to resolve most data-related questions with KBC personnel. However, as with the chemical data, it took longer than anticipated to organize the data and resolve inconsistencies so that an analysis of flow test results could be made.

The only well test data problem which introduced significant uncertainty into our analysis was related to the pressure build-up tests. In several cases, collection of build-up data was appeared to have been terminated before the end of the period of wellbore storage effects. For the Kuster tools that KBC had available, it is not clear that allowing longer build-ups would have solved this problem, because of limited clock times and the possibility of temperature effects on the tools. For the build-ups in which wellbore storage or temperature effects are significant, formation properties such as permeability-thickness product and skin factor should be considered as rough estimates.

Two aspects of the geological database merit discussion here: geophysical logs, which were rarely run; and petrologic analyses, various types of which were undertaken in some of the core holes and full-sized wells.



As mentioned in Chapter 3, very few geophysical logs were run in the Karaha - Telaga Bodas wells. Fracture imaging logs were run in portions of the production intervals in two wells. Gamma ray logs were also run in the same intervals for these two wells, as indicated on the plots in Appendix B. Logging for fracture imaging is very expensive; as such, it may be more appropriately reserved to investigate a specific aspect of geologic structure rather than as a general exploration or resource assessment tool. At some geothermal fields, developers have attempted to use fracture imaging in one well to target additional wells, with mixed success. The main problem is that such a log has a depth of investigation of a few inches; therefore, extrapolation of the dip and strike of a fracture identified by logging over hundreds or thousands of feet may not be reliable.

On the other hand, a consistent suite of conventional logs run in many wells may be more useful in interpreting subsurface stratigraphy and structure, particularly in a volcanic pile, where stratigraphic units are difficult to distinguish petrographically. Gamma ray, resistivity and perhaps caliper, neutron or density logs, run routinely in each well, may provide a means of correlating units from well to well, and of identifying fault offsets

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between wells. This type of fundamental understanding of subsurface geology is important to the development of an accurate conceptual model of the field, which can then be used with confidence to predict subsurface conditions in new wells. In GeothermEx's opinion, funds for downhole geophysical logging would be better spent on such a systematic program, even a minimal suite, than on fracture analysis logs run in selected intervals in a few wells. However, it is not unusual for geothermal developers to forgo running a systematic set of geophysical logs, especially in remote areas where logging services are not readily available.

KBC performed detailed petrographic and petrologic analyses of a limited number of core and cutting samples from selected wells. Most commonly, x-ray diffraction (XRD) analyses were performed, with a lesser number of petrographic descriptions of thin sections and a few fluid-inclusion analyses. The analyses undertaken on core samples and cuttings from core holes and full-sized wells are illustrated in figures 6.1 and 6.2, respectively.

Detailed petrographic/petrologic analysis has been found to be useful in a number of geothermal fields for making specific drilling or development decisions. Examples of this include (most frequently) identifying the onset of reservoir conditions while drilling (allowing optimum casing points to be selected), and identifying potential zones of acidic fluid production. Petrographic/petrologic data can also help refine and improve the conceptual model of the geothermal system. The economic benefit of such information is difficult to quantify, and it is not clear that results from some of the analyses (such as fluid-inclusion studies) would have had any significant impact on development planning. Still, the cost of petrographic/petrologic analysis is a small fraction of the total cost of drilling a well, and the level of expenditure which KBC put into such studies appeared to be appropriate.

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## 6.3 Comparison With Other Indonesian Geothermal Fields

Unlike some other Indonesian geothermal prospects, the Karaha - Telaga Bodas area was not well known or explored in much detail before KBC obtained its concession. Therefore, considering its initial status as an exploration project, it was necessary to drill holes over a large area, for two primary reasons: 1) to identify targets for full-sized wells; and 2) to demonstrate that significant reserves are present within the concession area.

At three other Indonesian geothermal fields with which GeothermEx is familiar, which also began as exploration projects, deep core hole drilling was very effective in delineating zones of high temperatures across large concession areas. The most favorable zones for drilling were identified in this way. In one project where about 10 core holes were completed and stable temperature data were obtained before any full-sized wells were drilled, the success rate for full-sized wells was very high. In another field, the drilling of the two types of wells overlapped, and initial success rates were lower but improved as the development drilling continued. The timing of drilling and types of wells at the Karaha - Telaga Bodas field are more similar to the latter example.



From the point of view of geothermal energy reserves, Karaha is similar to other successful developed Indonesian fields. Temperatures are very high along the volcanic axis and decline rapidly to either side. High non-condensible gas levels and corrosive steam are also observed in localized areas of other Indonesia fields. In one reservoir with which we are familiar, initial plans were made to exploit gassy zones, but it was later decided to step out and develop more benign areas. Likewise, corrosive areas (once defined) have been avoided, and corrosive wells have sometimes been plugged and abandoned for safety reasons.

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## 6.4 Resource Development Issues

### 6.4.1 Corrosion

The acid steam produced by the central Telaga wells has a severe corrosion potential that is quite dangerous if not properly managed. The most dangerous condition exists when slightly superheated HCl-bearing steam condenses at points of heat loss in shallow casings, wellheads and flow lines, because extreme acidity can form in a thin condensate film which can corrode pipe walls within hours. Production of acid steam carrying up to about 150 mg/kg of Cl is safely managed in other fields by injecting caustic soda downhole and into surface lines. It remains to be determined whether this would be possible for the Telaga wells. Proper evaluation requires steam sample collection using techniques appropriate to the measurement of HCl and other species in the steam alone, avoiding samples contaminated by sidewall condensate, and factoring out the effect of entrained water, if present.

The pH-neutral Na-Cl waters at the Karaha wells and apparently at TLG3-1 have a conventional geothermal chemistry which has very low corrosion potential for contemporary geothermal equipment.

### 6.4.2 Scaling

Nearly all thermal waters such as those produced in the Karaha area have a theoretical calcite scaling potential which can be calculated. However, the uncertainties in the data and conditions of sample collection at Karaha effectively preclude useful calculations. Other geothermal reservoirs with similar temperature ranges tend to have a high calcite scaling potential. On the other hand, the relatively high total-flow enthalpies of

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the wells indicate reservoir boiling, which concentrates scaling in the formation rather than in the wellbore, and tends to produce a high $CO_2$ pressure in the wellbore, which inhibits scale formation. As a result, the Karaha wells should not experience major scaling problems, unless boiling occurs inside the wellbore of wells yet to be drilled. To the extent that wellbore scaling occurs, it should be possible to inhibit the scale with chemicals, at acceptable cost. Calcite scaling in the formation may have a production impact, which can be managed using acidization and re-drilling, but in many geothermal fields, formation scaling has been found to have no significant effect on production.

Given the temperature of the Karaha resource, it is very unlikely that downhole silica scaling will occur in any of the production wells. Furthermore, silica scaling is not an issue at the Telaga steam wells. In surface facilities, silica scaling is controlled by the temperature and pressure of steam separation and subsequent cooling of the water fraction. From a resource temperature of 500° - 530°F, saturation with scale-forming amorphous silica will occur at about 320°F / 90 psia. Scaling at lower temperatures can be controlled using acidization, scale inhibitor, gas injection, or some combination of these technologies.

### 6.4.3 Management of Non-Condensible Gases

NCG in steam at the Karaha wells (*c.* 2.5 - 4.4 wt.% at 116 psia), and at TLG3-1 (0.5 wt.%), is within the range commonly experienced elsewhere. $H_2S$ in the same wells (360 - 1,300 ppmw at 116 psia) tends to be somewhat higher than is typical, and we do not know whether this exceeds allowable discharges under applicable regulations. If so, $H_2S$ abatement would be required.

NCG in steam at the Telaga wells is as high as 8 - 10 wt.% at slim holes T-2 and T-8, 15 wt.% at slim hole K-33 along the Karaha - Telaga border, and 25 - 29 wt.% at TLG2-1.

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These concentrations, and 1,000 - 5,000 ppmw of $H_2S$, are much higher than found at most geothermal developments. It is common to find that gases in steam zones decrease during long-term production, but none of the Telaga wells has been produced long enough to establish a trend. The potential economic impact of this is outside the objectives of this study, but it is clear that a power plant supplied from the wells drilled into the gassy zone at Telaga would have to be designed to handle more than the normal level of NCG, which usually does not exceed about 5 wt.% in steam.

### 6.5 Recommendations for Future Exploration and Development

Exploration and development at Karaha - Telaga Bodas have demonstrated the presence of a commercially productive geothermal reservoir over a large area, with available energy reserves of 260 MW or more and a productive capacity of 32 MW available from five commercial producers. However, there are certain aspects of the reservoir which remain unknown or incompletely defined. The most important of these are: the overall extent of the productive reservoir; the location and extent of high-gas zones; the distribution of productive zones within the field; and the geometry of the corrosive steam zone at Telaga. Any future development of the field should consider these issues.

Improvement and refinement of the conceptual model of the field will be possible as development activities proceed. Several specific data-gathering activities might be considered to maximize the understanding of the system. Downhole geophysical logs (including, at a minimum, resistivity and gamma ray logs) run routinely in newly drilled wells could facilitate stratigraphic and structural interpretations within the field. Additional geophysical surveys (particularly detailed gravimetry) could be run and the MT data could be re-interpreted in light of drilling results. In planning downhole temperature and pressure surveys in newly

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completed wells, systematic coverage during heat-up after drilling and during periods of injection should be emphasized.

The extent of the corrosive fluids and the high-gas zone at Telaga is probably quite limited, and could be delineated by a systematic core hole drilling and chemical sampling program. Alternatively, considering the high rate of drilling success from Telaga north to K-33, one or two full-sized step-out wells could be drilled south of TLG3-1. These would not increase the reserves of the field, but would help define the boundaries of the area affected adversely by fluid chemistry.

A staged development should be planned with initial power increments of perhaps 50 MW at Karaha and 80 MW at Telaga. As development wells are drilled for these two initial projects, additional drilling of deep core holes could be undertaken to determine the extent of the resource south of Telaga Bodas and east and west from the volcanic axis. Ultimately, it should be possible to develop at least 260 MW from the Karaha - Telaga Bodas geothermal field.

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# TABLES

## Table 2.1 Shallow Slim Holes, Karaha - Telaga Bodas Geothermal Field

*1998, GeothermEx, Inc.*

| Well name | Wellhead location [a] Northing (meters) | Easting (meters) | Ground level elevation (feet, msl) | Kelly bushing elevation (feet, msl) | Spud date | Completion date | Total depth (feet) | Maximum temperature (°F) | Notes |
|---|---|---|---|---|---|---|---|---|---|
| ***KBC shallow slim holes*** | | | | | | | | | |
| K-1 | 9,212,069 | 177,587 | 3,578 | 3,586 | 24-Nov-95 | 26-Nov-95 | 488 | NA | Replaced by K-1A |
| K-1A | 9,212,069 | 177,587 | 3,578 | 3,586 | 8-Dec-95 | 13-Jan-96 | 2,037 | 161 | P&A - 5 December 1997 |
| K-2 | 9,211,407 | 177,261 | 3,896 | 3,904 | 2-Nov-95 | 26-Nov-95 | 1,819 | 343 | P&A - 28 November 1997 |
| K-3 | 9,211,267 | 176,489 | 4,005 | 4,013 | 16-Jan-96 | 25-Jan-96 | 877 | 224 | P&A - 3 December 1997 |
| K-4 | 9,212,300 | 175,770 | 4,037 | 4,045 | 20-Feb-96 | 11-Mar-96 | 1,224 | 110 | |
| K-6 | 9,210,556 | 176,228 | 4,359 | 4,367 | 11-Mar-96 | 8-Apr-96 | 2,015 | 258 | |
| K-7 | 9,210,800 | 177,664 | 3,880 | 3,888 | 20-Dec-95 | 28-Jan-96 | 2,141 | 150 | |
| K-9 | 9,211,531 | 176,030 | 4,125 | 4,133 | 2-Feb-96 | 25-Feb-96 | 2,106 | 177 | P&A - 3 December 1997 |
| K-10 | 9,211,888 | 176,498 | 3,902 | 3,911 | 22-Apr-96 | 9-May-96 | 1,381 | 156 | Deepened in December 1996 (K-10D) |
| K-11 | 9,213,221 | 176,360 | 3,632 | 3,640 | 8-Feb-96 | 8-Mar-96 | 2,095 | 116 | |
| ***Pertamina Gradient Holes*** | | | | | | | | | |
| KR-01 | 9,212,238 | 179,668 | 2,660 | - | 12-Jan-87 | 6-Feb-87 | 492 | 110 | Within Karaha project area |
| KR-02 | 9,209,393 | 187,373 | 1,535 | - | 12-Jan-87 | 29-Jan-87 | 394 | 103 | East of Karaha project area |
| KR-03 | 9,203,905 | 174,308 | 4,462 | - | 30-Jan-87 | 8-Mar-87 | 820 | 122 | Within Telaga project area |
| KR-04 | 9,214,808 | 181,551 | 3,058 | - | 7-Feb-87 | 8-Mar-87 | 755 | 93 | Northeast of Karaha project area |

Notes [a] All shallow slim holes drilled by KBC are located within the Karaha project area.

## Table 2.2. Full-Sized Wells and Deep Slim Holes, Karaha - Telaga Bodas Geothermal Field - Location and Drilling Results

*1998, GeothermEx, Inc.*

| Well name | Well type | Spud date | Completion date | Wellhead location Northing (meters) | Wellhead location Easting (meters) | Bottomhole location Northing (meters) | Bottomhole location Easting (meters) | Maximum temperature (°F) | Productive with wellhead pressure > 110 psig? | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Karaha project area*** | | | | | | | | | | |
| K-10D | slim hole | 19-Dec-96 | 5-Jan-97 | 9,211,888 | 176,498 | - | - | 294 | No | Deepening of shallow slim hole K-10. |
| K-20 | slim hole | 25-Sep-96 | 24-Oct-96 | 9,210,019 | 176,316 | - | - | 356 | No | |
| K-21 | slim hole | 21-Feb-97 | 28-Mar-97 | 9,209,060 | 177,395 | - | - | 499 | No | |
| K-22 | slim hole | 18-Aug-97 | 27-Sep-97 | 9,208,420 | 176,440 | - | - | 455 | No | |
| K-24 | slim hole | 10-Jan-97 | 16-Feb-97 | 9,208,865 | 174,475 | - | - | 362 | No | |
| K-27 | slim hole | 31-Oct-96 | 12-Dec-96 | 9,211,206 | 175,759 | - | - | 302 | No | |
| K-33 | slim hole | 2-Oct-97 | 25-Nov-97 | 9,206,956 | 177,646 | - | - | 493 | Yes | |
| KRH 1-1ST1 | full-size | 18-May-96 | 18-Aug-96 | 9,211,584 | 176,180 | 9,211,235 | 176,950 | 455 | No | Side-tracked during initial drilling. Subsequently sidetracked again. |
| KRH 1-1ST2 | full-size | 2-Feb-97 | 23-Mar-97 | 9,211,584 | 176,180 | 9,211,076 | 176,931 | 600 | No | Workover started 18 Jan 97; parted liner; 2nd sidetrack started 4-Feb-97. |
| KRH 2-1OH | full-size | 26-Aug-96 | 22-Oct-96 | 9,210,421 | 176,373 | 9,210,077 | 176,561 | 522 | No | Original hole plugged back for re-drill. |
| KRH 2-1RD | full-size | 29-Oct-96 | 12-Dec-96 | 9,210,421 | 176,373 | 9,210,424 | 176,323 | 580 | No | Flowed at wellhead pressure less than 110 psig. |
| KRH 3-1ST | full-size | 13-Dec-96 | 23-Mar-97 | 9,209,716 | 175,577 | 9,209,726 | 176,284 | 633 | No | Side-tracked during initial drilling; flowed at wellhead pressure < 110 psig. |
| KRH 4-1 | full-size | 21-Apr-97 | 6-May-97 | 9,208,962 | 177,803 | 9,208,871 | 177,502 | 505 | Yes | |
| KRH 4-2OH | full-size | 21-May-97 | 28-Jun-97 | 9,208,898 | 178,367 | 9,208,871 | 178,318 | 409 | No | Original hole plugged back for re-drill. |
| KRH 4-2RD | full-size | 30-Jun-97 | 18-Jul-97 | 9,208,898 | 178,367 | 9,209,142 | 178,286 | 480 | No | |
| KRH 5-1 | full-size | 30-Jul-97 | 29-Aug-97 | 9,209,107 | 177,273 | 9,209,259 | 177,358 | 534 | Yes | |
| ***Telaga project area*** | | | | | | | | | | |
| T-2 | slim hole | 6-Apr-97 | 30-Apr-97 | 9,202,898 | 175,784 | - | - | 610 | Yes | P&A - 12 November 1997. |
| T-4 | slim hole | 7-May-97 | 6-Jun-97 | 9,202,163 | 177,442 | - | - | 436 | No | |
| T-8 | slim hole | 13-Jun-97 | 6-Jul-97 | 9,203,656 | 176,179 | - | - | 551 | No | Flowed at wellhead pressure less than 110 psig. P&A - 20 September 97. |
| T-10 | slim hole | 10-Jul-97 | 8-Aug-97 | 9,203,341 | 174,250 | - | - | 505 | No | |
| TLG 1-1ST2 | full-size | 15-Sep-97 | 11-Nov-97 | 9,203,626 | 176,187 | 9,203,722 | 176,491 | 550 | Yes | Side-tracked twice during initial drilling. |
| TLG 2-1 | full-size | 19-Nov-97 | 30-Dec-97 | 9,202,885 | 175,795 | 9,202,715 | 174,766 | 667 | Yes | |
| TLG 3-1 | full-size | 7-Jan-98 | 8-Feb-98 | 9,205,865 | 176,860 | 9,205,907 | 176,897 | 564 | Yes | |

## Table 2.3. Full-Sized Wells and Deep Slim Holes, Karaha - Telaga Bodas Geothermal Field - Completion Data

*1998, GeothermEx, Inc.*

| Well Name | Ground elevation (feet) | Kelly bushing elevation (feet) | Drilled Depth (feet) | Vertical Depth (feet) | Surface Casing | | Upper Liner | | Lower Liner | | Open Hole Size (inches) | Completion Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth (feet) | Size (inches) | Top-Bottom Depths (feet) | Size (inches) | Top-Bottom Depths (feet) | Size (inches) | | |
| *Karaha project area* | | | | | | | | | | | | |
| K-10D | 3,902 | 3,911 | 4,300 | - | 345 | 4-1/2 | 0-1,381 | 3-1/2 (HQ) | 0-4,293 | 2-3/8 | 3.03 | Unslotted 2-3/8" tubing hung from surface |
| K-20 | 4,222 | 4,232 | 3,340 | - | 982 | 4-1/2 | - | - | 0-3,300 | 2-3/8 | 3.8 | Unslotted 2-3/8" tubing hung from surface |
| K-21 | 4,633 | 4,342 | 5,425 | - | 791 | 4-1/2 | - | - | 0-5,324 | 2-3/8 | 3.8 | Slots from 4,724 ft to bottom |
| K-22 | 4,632 | 4,642 | 5,926 | - | 2,855 | 4-1/2 | 2,830-5,337 | 3-1/2 (HQ) | 5,290-5,924 | 2-3/8 | 3.03 | 3-1/2" liner uncemented; 2-3/8" slotted 5,890 to bottom |
| K-24 | 3,763 | 3,773 | 4,565 | - | 1,030 | 4-1/2 | - | - | 0-3,300 | 2-3/8 | 3.8 | Unslotted 2-3/8" tubing hung from surface |
| K-27 | 4,485 | 4,495 | 4,505 | - | 816 | 4-1/2 | - | - | 0-4,502 | 2-3/8 | 3.8 | Unslotted 2-3/8" tubing hung from surface |
| K-33 | 4,528 | 4,538 | 6,621 | - | 2,465 | 4-1/2 | 2,420-5,345 | 3-1/2 (HQ) | 2,420-5,345 | 2-3/4 | 2.98 | 3-1/2" lnr uncmtd w/ slots below 5,000 ft; 2-3/8" slotted throughout |
| KRH 1-1ST1 | 4,134 | 4,155 | 8,201 | 7,504 | 3,280 | 13-3/8 | 3,163-5,074 | 9-5/8 | 5,025-8,201 | 7 | 8-1/2 | Slots from 5,815 ft to bottom |
| KRH 1-1ST2 | 4,134 | 4,155 | 9,973 | 9,279 | 3,280 | 13-3/8 | 3,163-5,074 | 9-5/8 | 4,796-7,505* | 7 | 6-1/8 | Kicked off from ST at 6,918 ft |
| KRH 2-1OH | 4,381 | 4,402 | 10,050 | 9,322 | 3,087 | 13-3/8 | 2,600-6,089 | 9-5/8 | - | - | 8-1/2 | |
| KRH 2-1RD | 4,381 | 4,402 | 9,063 | 8,668 | 3,087 | 13-3/8 | 2,600-6,089 | 9-5/8 | - | - | 8-1/2 | Kicked off from OH at 6,104 ft |
| KRH 3-1ST | 4,600 | 4,621 | 10,092 | 9,740 | 3,539 | 13-3/8 | 3,451-6,887 | 9-5/8 | - | - | 8-1/2 | |
| KRH 4-1 | 4,528 | 4,549 | 6,083 | 5,962 | 1,007 | 13-3/8 | 887-4,501 | 9-5/8 | - | - | 8-1/2 | |
| KRH 4-2OH | 4,528 | 4,549 | 7,087 | 6,810 | 4,466 | 13-3/8 | - | - | - | - | 12-1/4 | |
| KRH 4-2RD | 4,528 | 4,549 | 7,930 | 7,598 | 4,466 | 13-3/8 | 4,370-6,000 | 9-5/8 | 5,989-7,930 | 7 | 8-1/2 | Kicked off from OH at 4,500 ft |
| KRH 5-1 | 4,605 | 4,626 | 8,014 | 7,989 | 1,492 | 13-3/8 | 1,338-4,498 | 9-5/8 | 4,428-7,983 | 7 | 8-1/2 | |
| *Telaga project area* | | | | | | | | | | | | |
| T-2 | 4,633 | 4,642 | 4,536 | - | 1,203 | 4-1/2 | 1,103-3,375 | 3-1/2 (HQ) | 0-4,499 | 2-3/8 | 3.03 | 3-1/2" lnr cmtd 3,020-3,375 ft only; 2-3/8" slots 3,500 ft to bottom |
| T-4 | 5,062 | 5,072 | 5,125 | - | 2,455 | 4-1/2 | - | - | 0-5,082 | 2-3/8 | 3.8 | Unslotted 2-3/8" tubing hung from surface |
| T-8 | 5,340 | 5,349 | 4,352 | - | 2,516 | 4-1/2 | - | - | 0-4,321 | 2-3/8 | 3.8 | Slots from 3,105 to bottom |
| T-10 | 4,779 | 4,789 | 5,205 | - | 2,317 | 4-1/2 | - | - | 0-5,182 | 2-3/8 | 3.8 | 2-3/8" slots 3,989-4,143 ft; 4,634-4,757 ft; and 4,998-5,119 ft |
| TLG 1-1ST2 | 5,304 | 5,332 | 5,844 | 5,713 | 3,836 | 9-5/8 | 2,845-4,800 | 7 | 4,744-5,844 | 5 | 6-1/8 | |
| TLG 2-1 | 5,249 | 5,277 | 8,490 | 7,486 | 3,308 | 13-3/8 | 3,120-4,645 | 9-5/8 | 4,576-8,490 | 7 | 8-1/2 | Slots from 4,936 ft to bottom |
| TLG 3-1 | 4,560 | 4,588 | 8,133 | 8,127 | 4,200 | 13-3/8 | - | - | 4,175-7,981 | 10-3/4 | 12-1/4 | 9-7/8" open hole below shoe of 10-3/4" liner |

Notes:
Upper liners are cemented unless otherwise indicated. Cemented lower liners are indicated with an asterisk (*) following the liner depths.
Uncemented lower liners are all slotted unless otherwise indicated.

## Table 3.1: Summary of Fluids Chemistry at Deep Holes

| | | | Gases | | | | | | Water | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Reservoir | Total Flow | Steam Sample | | | 8 b.a. (116 psia) | | | Sample | | | | Reservoir | | | Chemical Geothermometers,°F | | | |
| Name | Temp. °F | Enthalpy BTU/Lb | Total NCG ppmw | H2S ppmw | Press. psia | Total NCG ppmw | H2S ppmw | N. | pH | Cl mg/l | Mg mg/l | at | Cl mg/l | N. | Water Type | Na-K-Ca | SiO2 | N. | Comment |
| **Karaha Deep Holes** | | | | | | | | | | | | | | | | | | | |
| *KRH 1-1 ST2* | - | N2 lift | - | - | - | - | - | 1 | 7.8 | 1,520 | 0.5 | wbx | 1,180 | 1a | neutral Na-Cl | 450 | 460 - 430 | 1b | 19 June 1997. Nitrogen lift, would not sustain flow. |
| *KRH 2-1* | 520 | c.1,000 | - | - | - | - | - | 1 | 7.8 | 1,425 | 0.1 | wbx? | 930 - 1,010 | 2a | neutral Na-Cl | 460 | 470 | 2b | Rig test 26-27 Oct. 1996. Low wellhead pressure, later re-drilled. |
| *KRH 2-1 RD* | 514 | large water flow | 7,800 | 25 | c.30-40? | - | - | 3 | 8.1 | 2,960 | 0.1[3a] | wbx? | 2,040 | 3b | neutral Na-Cl | 500 | 490 | 3c | Waters: rig test 29-30 Nov. 1996. Gases: Single sample on 12 June 1997 when water is more dilute and shows signs of low temperature entry into well. |
| *KRH 3-1 ST* | 480 | cycles 500 - 700 | - | - | - | - | - | 1 | 2.2 | 40,870 | 0.2 | ? | - | | acid Na-Cl | - | - | | Sample dated 9 June 1996. Relation to flow test on 10-11 June not documented. |
| | | | 5,400 | 70 | c.30-40? | - | - | 4 | 8.3 | 1,260 | 0.03 | ? | 830 | 4a | neutral Na-Cl | 525 | 515 | 4b | One sample, 14 June 1996. |
| KRH 4-1 | 500 | 950 | 45,500 | 1,380 | 222 | 44,100 | 1,340 | 5 | 7.8 | 4,000 | 0.044 | wbx | 2,100 | 5a | neutral Na-Cl | 475 | 450 | 5b | Flow test 21 August - 18 September 1997. |
| KRH 5-1 | 530 | 770 | 25,500 - 19,800 | 300 - 430 | <90 | - | - | 6 | 7.0 | 11,600 | 1.7 | ? | ~7,500 | 6a | neutral Na-Cl | 560 | c.530 | 6b | Flow test 23 September - 3 October 1997 |
| **Karaha Deep Slim Hole** | | | | | | | | | | | | | | | | | | | |
| *K-33* | 493 | 875 | 200,000 | 4,150 | <130 | - | - | 7 | c.7.5 | - | - | - | - | 7a | neutral | - | - | - | Flow test 30 November - 5 Dec. 1997. pH + gases only |
| **Telaga Deep Holes** | | | | | | | | | | | | | | | | | | | |
| TLG 1-1 ST2 | | 1,160 | 10,900 | 2,820 | <130 | 10,900 | 2,820 | 8 | 4 | 8,240 | 57.8 | <130 psig | - | 8a | acid Na-Cl; acid-Cl condensate | - | - | 8b | Rig test November 10. November 26 - December 1 produced superheated steam with condensate pH < 3.0 |
| | | c.100% stm | | | | | | | 6.3 | 15,700 | 57.3 | wbx | ? | 9a | "neutral" mixed cation-Cl | c.540 | - | 9b | Rig test December 28-29, 1997 |
| TLG 2-1 | >600 | 100% stm | c.270,000 | c.1,280 | <130 | c.270,000 | c.1,280 | 9 | 6.1 | - | - | <130 psig | - | 9 | neutral condensate | - | - | - | Flow test February 3 - 21, 1998 |
| TLG 3-1 | >=520 | c.1,100 | 5,400 | 360 | c.100 | 5,400 | 360 | 13 | c.7 | TDS c.5,000-8,000 | | wbx | - | 13a | neutral Na-Cl probable | - | - | | Flow test February 16 - March 18, 1998; sample data from February 17 - 23. |
| **Telaga Deep Slim Holes** | | | | | | | | | | | | | | | | | | | |
| *T-2* | 570 | wet steam | 94,500 | 1,830 | 46 | 97,300 | 1,880 | 10 | 3.8 | 2,170 | 0.2 | =<34 psig | - | 10a | acid-Cl condensate | - | - | - | Flow test June 8 - 11, 1997 |
| | 570 | dry steam | 78,400 | 1,150 | - | 78,400 | 1,150 | 11 | - | - | - | - | - | - | - | - | - | - | Flow test October 17 - 18, 1997 |
| *T-8* | 540 | c.100% stm | 70,900 | 5,100 | <90 | 70,900 | 5,100 | 12 | 2-3 | 58,000 - 180,000 | 8 - 170 | wbx? | - | 12a | acid-Cl condensate | - | - | - | Flow test July 10 - 13, 1997 |

**Names in italics are wells which are not commercial producers**

wbx = weirbox (atmospheric pressure)

**Notes to table 3.1:**

| | |
|---|---|
| 1 | No gas data. |
| 1a | Average of two samples. Correction to reservoir is based on quartz geothermometer, assuming maximum steam loss during nitrogen lift. This probably overestimates steam fraction and underestimates reservoir Cl. |
| 1b | Averages of two samples. Range for quartz represents assumptions of no steam loss (high value) to maximum steam loss (low value), during nitrogen lift. |
| 2a | Sample on 27 Oct.. Range represents estimates for steam loss from downhole logged temperature at production zone (low value) to silica temperature (high value). |
| 2b | Sample on 27 Oct.. Silica temperature assumes maximum steam loss at atmospheric pressure. |
| 3 | One sample. Low oxygen but high nitrogen; implies significant contamination by air from drilling and destruction of $H_2S$. |
| 3a | Sample on 29 Nov.. Mg at 1.2 mg/l on 30 Nov. is assumed to be a reporting error. |
| 3b | Average of two samples. Correction to reservoir is based on quartz geothermometer, assuming maximum steam loss. |
| 3c | Average of two samples. Silica temperature assumes maximum steam loss at atmospheric pressure. |
| 4 | One sample. Low oxygen but high nitrogen; implies significant contamination by air from drilling and destruction of $H_2S$. |
| 4a | One sample. Cl assumes maximum steam loss at atmospheric pressure from enthalpy of silica geothermometer. Higher pressure sampling will yield higher Cl concentration. |
| 4b | Silica temperature assumes maximum steam loss at atmospheric pressure. Higher pressure sampling will yield higher silica temperature. |
| 5 | Samples were collected through a portable separator throttled to discharge at 25 psig, attached to the top port on a flowline at significantly higher pressure. If water entered the portable separator, then gases have been diluted by a second-stage flash.<br>Gas/steam decreased during test, probably stable at end. Data shown are average of 2 samples, 13 Sept. |
| 5a | Average of 8 weirbox samples, 30 Aug - 13 Sept. |
| 5b | Average of 8 samples. Silica temperature assumes maximum steam loss at atmospheric pressure, with correction for high total flow enthalpy. Reservoir Cl given by this silica temperature averages 2,240 mg/l. Silica temperature uncorrected for total flow enthalpy averages 490°F. |
| 6 | Range, 2 samples taken Sept.25 and 1 taken Oct.2. $CO_2$ and nitrogen levels suggest some contamination by air in drilling fluid, loss of $H_2S$. Upper $H_2S$ level is minimum. Wellhead pressures below 116 psia. |
| 6a | Sample 2 Oct.. Sampling conditions not clearly documented so correction to reservoir is approximate, based on probable range of conditions. Somewhat high Mg suggests either contamination by cooler groundwater, or near-acid condition in reservoir. |
| 6b | Silica is uncertain due to unclear documentation of sampling conditions, but a temperature close to downhole log temperature is indicated. |
| 7 | One sample, collection conditions not specified but lower than wellhead pressure. |
| 7a | Field measurements reported to indicate neutral pH, low TDS. |
| 8 | One sample, collection conditions not specified but lower than wellhead pressure. Enthalpy indicates c.95% steam and minimal effect of pressure on gas concentration. 37.9 vol.% $N_2$ in dry gas implies significant contamination by air from drilling, with oxidation of some $H_2S$. |
| 8a | One sample. Very low $SO_4$ implies acid-Cl, not acid-$SO_4$ composition. Earlier rig test and downhole sampling in shallower well also yielded water with pH c.4, but higher salinity and lower $SiO_2$. |
| 8b | Anhydrite saturation temperature and quartz geothermometer imply >400°F. |

| | |
|---|---|
| 9 | Average of one sample at day 6 and one sample at day 14 of flow test. Gases higher in second sample. Condensate pH 6.1 from field measurements. Condensate Cl, Fe not reported. |
| 9a | Well was drying out during the rig test and the single weirbox sample apparently was collected at a steam fraction close to 100%. Possibly affected by strong evaporation and/or condensation. High levels of Ca and Mg suggest recent acidity. Report of sulfite in brine implies the presence of volcanic SO2. |
| 9b | Na-K-Ca temperature includes Mg correction. Quartz temperature not possible due to uncertain sampling conditions. |
| | |
| 10 | One sample. |
| 10a | One sample. Water composition indicates condensate of acid-Cl steam. |
| | |
| 11 | One sample. |
| | |
| 12 | Average of three samples, all similar |
| 12a | Three samples, all highly concentrated by excess evaporation at low pressure, all indicate condensate of acid-Cl steam. |
| | |
| 13 | One sample, after 3 days of flow. |
| 13a | Only field data are available (samples at labs, April 1998). Three samples all have neutral pH. TDS is probably from conductivity measurement. Report of white water in weirbox implies high silica, perhaps concentrated by excess evaporation. |

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**Table 3.2:**
**Water samples collected during tests of well KRH 2-1 RD (non-commercial)**

| Date | Time | Depth ft | Activity | Sample Port | pH | Ca | Mg | K | Na | Li | T.Alk as HCO3 | SO4 | Cl | As | B | SiO2 | Ion Bal. % Dif. | Na/K | T.Alk/Cl | SO4/Cl | 1000* Mg/Cl | 100* B/Cl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Analytical Values, mg/l | | | | | | | | | | | | Ion Ratios | | | | |
| 06-Nov-96 | | 7,489 | rig test | ? | 8.34 | 32 | 0.08 | 138 | 619 | 0.28 | 198 | 143 | 859 | 0.64 | 69 | 315 | 2.64 | 4.49 | 0.23 | 0.166 | 0.09 | 8.03 |
| 06-Nov-96 | | 7,489 | rig test | ? | 8.31 | 32 | 0.08 | 147 | 640 | 0.29 | 173 | 159 | 893 | 0.82 | 67 | 321 | 2.96 | 4.35 | 0.19 | 0.178 | 0.09 | 7.50 |
| 16-Nov-96 | 0500 | 8,840 | rig test[1] | ? | 7.50 | 48 | 0.05 | 74 | 368 | 0.12 | 247 | 233 | 355 | 0.22 | 35 | 164 | 3.58 | 4.97 | 0.70 | 0.656 | 0.14 | 9.86 |
| 17-Nov-96 | 1600 | 8,840 | rig test[1] | ? | 7.96 | 26 | 0.12 | 130 | 824 | 0.42 | 131 | 128 | 1224 | 2.0 | 79 | 664 | 1.51 | 6.34 | 0.11 | 0.105 | 0.10 | 6.45 |
| 17-Nov-96 | 1900 | 8,840 | rig test[1] | ? | 7.47 | 35 | 0.06 | 135 | 861 | 0.36 | 127 | 128 | 1313 | 1.6 | 92 | 529 | 1.11 | 6.38 | 0.10 | 0.097 | 0.05 | 7.01 |
| 29-Nov-96 | 2200 | 8,994 | rig test | ? | 8.06 | 50 | 0.14 | 335 | 1775 | 4.8 | 101 | 101 | 2969 | 4.4 | 129 | 730 | 0.85 | 5.30 | 0.03 | 0.034 | 0.05 | 4.34 |
| 30-Nov-96 | 0100 | 8,994 | rig test | ? | 8.17 | 52 | 0.11 | 198 | 1176 | 1.3 | 96 | 117 | 1945 | 1.6 | 118 | 436 | 0.13 | 5.94 | 0.05 | 0.060 | 0.06 | 6.07 |
| 30-Nov-96 | 0200 | 8,994 | rig test | ? | 8.16 | 64 | 1.21[2] | 330 | 1760 | 5.3 | 101 | 91 | 2958 | 4.6 | 117 | 676 | 1.19 | 5.33 | 0.03 | 0.031 | 0.41 | 3.96 |
| 12-Jun-97 | | 8,994 | flow tst | portsp | 8.15 | 5.0 | 0.42 | 70 | 573 | 0.98 | 265 | 173 | 722 | 1.5 | 45 | 471 | -1.22 | 8.19 | 0.37 | 0.240 | 0.58 | 6.18 |

Notes:
1. Reported contamination by drilling fluid with increasing Cl during test (S.Petty memo 18 Nov. 1996).
2. Reported Mg is anomalously high with respect to other components of the analysis. Suspect true Mg is lower.

## Table 3.3: Summary of fluids chemistry at shallow holes and points of surface discharge

| Map Code | Name or Location | Temp °F | pH | HCO3 | SO4 | Cl | Description |
|---|---|---|---|---|---|---|---|
| **Karaha Shallow Slim Hole** | | | | | | | |
| K2 | W.side G.Karaha | steam | - | - | - | - | 700m temperature gradient well. BHT 165°C/329°F, no water column, discharges steam with =< 2,000 ppm-wt gases. Two samples highly contaminated by air. |
| **Karaha Thermal Manifestations** | | | | | | | |
| KR-1 | Jenkin's Seep | 72 | 3.8 | <1 | 27 | 5 | Dilute acid SO4 water sample from small spring adjacent to gas seep with strong H2S smell. |
| KR-2 | Kp.Bakom spring | 72 | 3.8 | <1 | 184 | 4 | Dilute acid SO4 |
| KR-3 | Karaha fumarole | 205 | 2.3 | <1 | 965 | 3 | Dilute acid SO4 water at fumarole |
| KR-4 | Karaha fumarole | 196 | 6.6 | 33 | 208 | 11 | Dilute SO4 - mixed cation water at fumarole |
| KR-5 | Kp.Ciselan spring | 72 | 7.2 | 41 | 6 | 3 | Dilute, cool bicarbonate - mixed cation |
| KR-6 | Sawah Cipanas spring | 100 | 6.3 | 167 | 38 | 6 | Dilute, warm bicarbonate - mixed cation |
| KR-7 | Karaha mudpot | 198 | 6.4 | 33 | 370 | 4 | Sulfate - mixed cation water |
| KR-A | Kp.Bakom spring | - | - | - | - | - | Sulfur spring discharges in a rice paddy, uncontaminated sample not possible |
| KRH-03 | Karaha fumarole | steam | - | - | - | - | Most vigorous steam vent in karaha fumarole area; adjacent to water sample location KR-4. 14.8 wt.% gases in steam, 4,700 ppm-wt H2S. Analysis report includes SO2. |
| **Pertamina Shallow Slim Holes** | | | | | | | **(all areas)** |
| KR-01 | NE corner of Karaha Project Area | - | 7.5 | 170 | 7 | 7 | Karaha Ciawi, apparently gradient hole KR-01, 150m deep. Dilute, cool bicarbonate - mixed cation, pH 7.5. |
| KR-02 | Outside of Karaha Project Area to E | - | 6.4 | 1098 | 3 | 129 | Gradient hole KR-02, 120m deep. Dilute, cool bicarbonate - mixed cation water |
| KR-03 | 2 miles NW of Telaga Bodas | - | 6.2 | 113 | 3 | 132 | Gradient hole KR-03, 250m deep. Dilute, cool Cl - bicarbonate - mixed cation water |
| KR-04 | Outside of Karaha Project Area to NE | - | 6.2 | 1120 | 3 | 143 | Gradient hole KR-04, 230m deep. Bicarbonate - mixed cation water |
| **Telaga Thermal Manifestations** | | | | | | | |
| FM-3 | warm spring | 118 | 2.9 | <2 | 346 | 824 | Flow 24 L/min. Acid Cl - SO4 - mixed cation water |
| FM-4 | fresh water spring | - | - | - | - | - | Sampled for isotopes only. |
| KBC | KBC spring | 116 | 2.3 | <2 | 584 | 4680 | Acid Cl - SO4 - mixed cation water. 247ppm SiO2. Flows 400 gpm at 116°F |

## Table 3.3: Summary of fluids chemistry at shallow holes and points of surface discharge

| Map Code | Name or Location | Temp °F | pH | HCO3 | SO4 | Cl | Description |
|---|---|---|---|---|---|---|---|
| TB-01 | Telaga Bodas fumarole | 200 | - | - | - | - | Apparently dry fumarole (not flooded) on S. side of lake; adjacent to location TEL-3. 10. Wt.% gases in steam, 7,300 ppm-wt H2S. Analysis report includes SO2. |
| TB-03 | acid spring SE of weak fumarole field, E of lake. | - | - | - | - | - | Sampled for isotopes only. |
| TEL-1 | Telaga Bodas lake | 162 | 3.8 | <1 | 216 | 62 | Dilute acid SO4 - Cl - mixed cation water |
| TEL-2 | Telaga Bodas fumarole | 199 | 2.8 | <1 | 2050 | 16 | Acid SO4 - mixed cation water at one of three major thermal manifestations around edges of Telaga Bodas |
| TEL-3 | Telaga Bodas mudpot | 194 | 0.8 | <1 | 5016 | 3072 | Acid SO4 - Cl - mixed cation water at one of three major thermal manifestations around edges of Telaga Bodas Acidity exceeds SO4, HCl indicated. |
| TEL-4 | Resurgent fumarole | 162 | 1.8 | <1 | 1560 | 26 | SO4 - mixed cation water at small fumarole field. |
| TEL-5 | Cipanas sping | 142 | 2.8 | <1 | 622 | 288 | Acid SO4 - Cl - mixed cation water. Acidity does not exceed SO4. |
| TEL-6 | Cikahuri spring | 118 | 2.7 | <1 | 438 | 2129 | Acid Cl - SO4 - mixed cation water. Acidity does not exceed SO4. |
| TEL-7 | Ciateul spring | 109 | 2.3 | <1 | 298 | 322 | Acid Cl - SO4 - mixed cation water. Acidity slightly less than SO4. |
| TEL-8 | Cikajaya spring | 120 | 1.8 | <1 | 614 | 2204 | Acid Cl - SO4 - mixed cation water. Acidity exceeds SO4, HCl indicated. |
| TEL-9 | Fire Mountain spring | 115 | 3.9 | 58 | 221 | 5 | Acid SO4 - mixed cation |
| TEL-10 | Mixed - Fe (iron) spring | 91 | 5.5 | 99 | 360 | 172 | Acid SO4 - Cl - mixed cation water |
| TEL-A | Kawah Saat | steam | - | - | - | - | Dry gas fumarole, sampled for He isotopes only. |
| TEL-B | Telaga Bodas fumarole | steam | - | - | - | - | Water at one of three major thermal manifestations around edges of Telaga Bodas; high discharge temperature, low pH, large flow, high Ec. Narrative description only, no quantitative data. |
| TEL-C | Panyipuha | =<142 | - | - | - | - | Area of low pH and high conductivity springs, 118-142°F. Narrative description only, no quantitative data. |
| TEL-D | Cienagang | =<142 | - | - | - | - | Area of low pH and high conductivity springs, 118-142°F. Narrative description only, no quantitative data. |
| Not on map | Telaga Bodas spring | - | 2.5 | <2 | 96 | 2 | Dilute acid - SO4-Cl-mixed cation water. Location unknown. |
| Not on map | Telaga Bodas spring | - | <1 | <2 | 30500 | 8850 | Concentrated Acid SO4 - Cl - mixed cation water. Location unknown. |
| **Concession Area and regional** | | | | | | | **(Outside of Project Areas (except TAK-2))** |
| Not on map | Ciawi Artesian well | 113 | 6.6 | 916 | 8 | 115 | 1.2 km N of KBC Ciawi house. Clear, 105°F water from abandoned well. Pertamina data: 108 lpm, 160 m deep, 113°F BHT. Bicarbonate - Cl - mixed cation water |

## Table 3.3: Summary of fluids chemistry at shallow holes and points of surface discharge

| Map Code | Name or Location | Temp °F | pH | HCO3 | SO4 | Cl | Description |
|---|---|---|---|---|---|---|---|
| TAK-1 | "Kp.Sumur" W.of Karaha Project Area | 100 | 7.1 | 166 | 11 | 54 | Spring at topographic break between central volcanic range and lower lying basin. Dilute, cool, bicarbonate-mixed cation water |
| TAK-2 | Kp.Cinta. SW corner of Karaha Project Area | 79 | 6.3 | 55 | 8 | 7 | Dilute, cool bicarbonate - mixed cation water |
| TAK-3 | Panoyana. E. of Karaha Project Area | 115 | 6.1 | 656 | 2 | 11 | Spring at topographic break between central volcanic range and lower lying basin. Bicarbonate - mixed cation water |
| TAK-4 | Kp.Salaa. NE of Karaha Project Area. | 72 | 2.5 | 0 | 191 | 11 | Dilute acid SO4-mixed cation water |
| TAK-5 | Kp.Salaa. NE of Karaha Project Area. | 73 | 6.1 | 44 | 3 | 5 | Dilute bicarbonate-mixed cation water |
| TAK-6 | Ci Peles. NW of concession boundary | 140 | 6.7 | 980 | - | 131 | Bicarbonate - mixed cation water |
| TAK-7 | Galunggu. S of concession boundary | 149 | 6.7 | 545 | 1110 | 194 | SO4-bicarbonate-Cl-mixed cation water. Silica temperature >300°F |
| TAK-8 | Kp.Cipacing. E edge concession area. | 122 | 6.4 | 1080 | - | 167 | Bicarbonate - mixed cation water |
| TAK-9 | Tanjungkerta. E of concession boundary | 100 | 6.4 | 703 | - | 224 | Bicarbonate - Cl - mixed cation water |
| TAK-10 | Cicilap. E of concession boundary | 104 | 6.4 | 1070 | - | 462 | Bicarbonate - Cl - mixed cation water |
| TAK-11 | Panoyana. E side concession area. | 109 | 6.3 | 881 | 2 | 103 | Bicarbonate - Cl - mixed cation water |

# Table 4.1 Summary of Well Test Results, Karaha - Telaga Bodas Geothermal Field

*1998, GeothermEx, Inc.*

| | | | | Representative test results | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well | Well type | Test dates | Test type | Wellhead pressure (WHP) (psig) | Total mass rate (kph) | Enthalpy (BTU/lbm) | Water rate at atmospheric pressure (kph) | Steam rate at 116 psia (kph) | Non-condensible gas (NCG) (weight % in steam) [a] | Hydrogen sulfide ($H_2S$) (ppm-wt in steam) [a] | Power capacity (MW) [b] | Comments |
| **Karaha project area** | | | | | | | | | | | | |
| KRH 1-1ST2 | full-sized | 6, 14, 19 Jun 97 | nitrogen lifts | | | | | | | | | Would not sustain flow. |
| KRH 2-1RD | full-sized | 16-17 Nov 96 | rig test | 36 | | | 280 | 0 | | | 0.0 | Flow contaminated by drilling mud throughout test. |
| | | 29-30 Nov 96 | rig test | 27 | | | | 0 | | | 0.0 | |
| | | 9-10 Jun 97 | flow test | 20 - 60 | 250 - 800 | 500 | 150 - 550 | 0 | (1.0) [c] | (34) [c] | 0.0 | Cycling flow. Sub-economic flowing WHP. |
| | | 12 Jun 97 | flow test | 0 - 50 | | | | | | | | Cycling flow. Sub-economic flowing WHP. |
| KRH 3-1ST | full-sized | 10-11 Jun 97 | flow test | 32 | 160 | 600 | 90 | 0 | | | 0.0 | High chlorides (40,870 mg/l), low pH (2.2). |
| | | 13-15 Jun 97 | flow test | 20 - 60 | 120 -300 | 500 - 700 | 60 - 200 | 0 | (0.7) [c] | (92) [c] | 0.0 | Cycling flow. Bridged at 7,500 feet at end of test. |
| KRH 4-1 | full-sized | 7 May 97 | rig test | ~250 | | | | | | | | Lip pressures on James tube not considered reliable. |
| | | 10-13 May 97 | rig test | 160 - 360 | 300 | ~1,000 | 45 | 235 | | | 14.7 | |
| | | 21 Aug to 18 Sep 97 | flow test | 110 | 275 | 950 | 56 | 200 | 4.4 | 1,329 | 12.5 | Initially dry steam, then began making water. |
| KRH 4-2RD | full-sized | | | | | | | | | | | No significant drilling breaks. No flow test conducted. |
| KRH 5-1 | full-sized | 27-28 Aug 97 | rig test | 24 | 155 | 680 | 55 | 0 | | | 0.0 | |
| | | 23 Sep to 3 Oct 97 | flow test | 120 | 85 | 700 | 40 | 38 | 2.4 | 366 | 2.4 | |
| | | 4-11 Nov 97 | flow test | 90 | 105 | 740 | 45 | 0 | | | 0.0 | After injection test (22-24 Oct 97). |
| | | 3-17 Dec 97 | flow test | 110 | 202 | 600 | 115 | 67 | | | 4.2 | After acid stimulation (27 Nov 97). |
| K-33 | slim hole | 30 Nov to 5 Dec 97 | flow test | 130 | 19 | 875 | 5 | 12 | 13.4 | 2,786 | 0.8 | High NCG in steam. |
| **Telaga project area** | | | | | | | | | | | | |
| TLG 1-1ST2 | full-sized | 10-11 Nov 97 | rig test | 130 | 65 | 1,100 | 3 | 60 | 1.1 | 2,803 | 3.8 | |
| | | 29 Nov to 1 Dec 97 | flow test | 198 | 80 | 1,150 | 0 | 80 | | | 5.0 | Dry steam. Acidic condensate (pH < 3). Poss. casing leak. |
| TLG 2-1 | full-sized | 28-29 Dec 97 | rig test | 130 | 64 | 1,150 | 0 | 64 | 10.3 | 844 | 4.0 | Initally produced some water, then dried out. |
| | | 3-21 Feb 98 | flow test | 110 | 42 | 1,150 | 0 | 42 | apx 27 | apx 1,280 | 2.6 | Dry steam with high NCG. |
| TLG 3-1 | full-sized | 4 Feb 98 | rig test | 113 | 162 | 1,088 | 11 | 139 | | | 8.7 | Tested at 7,747 feet before running 10-3/4" liner. |
| | | 6-7 Feb 98 | rig test | | | | | | | | | Tested at 7,981 feet after running 10-3/4" liner. Data NA. |
| | | 16 Feb to 18 Mar 98 | flow test | 110 | 125 | 1,100 | 6 | 112 | 0.5 | 360 | 7.0 | One chemical sample, 18 Feb 98. |
| T-2 | slim hole | 8-11 Jun 97 | flow test | 47 | 12 | 1,110 | < 1 | 0 | 9.5 | 1,830 | 0.0 | With 2-3/8" tubing in hole. Acidic condensate (pH = 3.8). |
| | | 17-18 Oct 97 | flow test | 220 | 27 | 1,150 | 0 | 27 | 7.8 | 1,150 | 1.7 | With 2-3/8" tubing removed. P&A 12-Nov-97. |
| T-8 | slim hole | 10-13 Jul 97 | flow test | 75 | 16 | 1,140 | < 1 | 0 | 7.1 | 5,100 | 0.0 | Small amount of water with low pH (2-3) and high chlorides. |
| | | 20-26 Jul 97 | flow test | 104 | 22 | 1,140 | < 1 | 21 | | | 0.0 | Power capacity = 0 MW because WHP < 110 psig. |

Notes: [a] NCG and $H_2S$ concentrations in steam normalized to flash fraction at 116 psia, even if WHP < 116 psia during test.
[b] Steam conversion factor = 16 kph/MW.
[c] Sample with low reliability.

## Table 4.2. Summary of Productive Wells, Karaha - Telaga Bodas Geothermal Field

| Project area | Well | Well type | Total depth (feet) | Total mass rate (kph)[a] | Enthalpy (BTU/lbm) | Steam rate (kph)[b] | Non-condensible gas (NCG) (weight % in steam)[b] | Hydrogen sulfide ($H_2S$) (ppm-wt in steam)[b] | Power capacity (MW)[c] | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Karaha | KRH 4-1 | full-sized | 6,083 | 275 | 950 | 200 | 4.4 | 1,329 | 12.5 | |
| | KRH 5-1 | full-sized | 8,014 | 205 | 600 | 67 | 2.4 | 366 | 4.2 | After acid stimulation. |
| | K-33 | slim hole | 6,621 | 19 | 875 | 12 | 13.4 | 2,786 | 0.8 | |
| Telaga | TLG 1-1ST2 | full-sized | 5,844 | 80 | 1,150 | 80 | 1.1 | 2,803 | 5.0 | |
| | TLG 2-1 | full-sized | 8,490 | 42 | 1,150 | 42 | 27 | 1,280 | 2.6 | High NCG. |
| | TLG 3-1 | full-sized | 8,133 | 125 | 1,060 | 112 | NA | NA | 7.0 | |
| | T-2 | slim hole | 4,536 | 27 | 1,150 | 27 | 7.8 | 1,150 | 1.7 | Plugged and abandoned. |
| | T-8 | slim hole | 4,352 | 22[d] | 1,140 | 21[d] | 7.1 | 5,100 | 0.0[d] | Flowing WHP < 110 psig. |
| | | | | | | | | **Karaha sub-total:** | **17.5** | |
| | | | | | | | | **Telaga sub-total:** | **14.6**[e] | |
| | | | | | | | | **Field total:** | **32.1**[e] | |



Notes: [a] Total mass rate estimated at flowing wellhead pressure (WHP) of 110 psig (122 psia, 8 bars absolute).

[b] Estimated at design separator pressure of 116 psia (8.0 bars absolute).

[c] Steam conversion factor = 16 kph/MW.

[d] Total mass and steam rates at flowing WHP of 104 psig. Power capacity listed as 0 because WHP < 110 psig.

[e] Excluding abandoned slim hole T-2.

## Table 4.3. Pressure Build-Up Test Data, Karaha - Telaga Bodas Geothermal Field

*1998, GeothermEx, Inc.*

| Well | Dates of flow period prior to build-up | Duration of flow period (hours) | Duration of build-up (hours) | Depth of pressure sensor (feet) | Static pressure at sensor depth (psia) | Flowing pressure at sensor depth prior to shut-in (psia) | Pressure draw-down prior to shut-in (psi) | Total mass rate at end of flow period (kph) | Enthalpy of produced fluid (BTU/lbm) | Estimated reservoir temperature[a] (deg F) | Depth of main producing zone (feet) | Static pressure of main producing zone (psia) | Estimated dynamic viscosity at producing zone conditions (centipoise) | Estimated total compressibility at producing zone conditions (psi $^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KRH 4-1 | 10-13 May 97 | 75.75 | 2.12 | 5,300 | 797 | 557 | 240 | 303 | 1000 | 500 | 5,430 | 800 | 0.0189 | 0.061 |
| KRH 4-1 | 23 Aug to 18 Sep 97 | 669.63 | 2.05 | 5,370 | 798 | 546 | 252 | 200 | 1000 | 500 | 5,430 | 800 | 0.0189 | 0.061 |
| KRH 5-1 | 27-28 Aug 97 | 29.67 | 2.08 | 7,731 | 1,400 | 379 | 1,021 | 114 | 680 | 500 | 7,590 | 1,350 | 0.0245 | 0.025 |
| KRH 5-1 | 23 Sep to 3 Oct 97 | 247.75 | 2.46 | 7,901 | 1,450 | 633 | 817 | 92 | 740 | 500 | 7,590 | 1,350 | 0.0225 | 0.025 |
| K-33 | 30 Nov to 5 Dec 97 | 117.50 | 2.50 | 5,870 [b] | 950 [b] | 521 | 429 | 22 | 900 | 500 | 6,300 | 1,100 | 0.0198 | 0.036 |
| TLG 1-1ST2 | 10-11 Nov 97 | 16.53 | 10.15 | 5,200 | 1,109 [c] | 272 | 837 | 65 | 1100 | 545 | 5,844 | 1,120 [c] | 0.0196 | 0.035 |
| T-2 | 17-18 Oct 97 | 22.92 | 1.00 | 1,400 | 897 | 823 | 74 | 26 | 1187 | 560 | 3,950 | 956 | 0.0194 | 0.002 [d] |

Notes: [a] For wells with multiple producing zones, an intermediate value of reservoir temperature has been used to estimate reservoir fluid properties.
[b] Estimated sensor depth and static pressure.
[c] Pressure at sensor estimated from extrapolation to P* on Horner plot; pressure at TD (5,844 ft) estimated assuming vapor column at 545 deg F.
[d] Estimated total compressibility for dry steam zone.

## Table 4.4. Calculated Results of Pressure Build-Up Tests, Karaha Geothermal Field

*1998, GeothermEx, Inc.*

| Well | Dates of flow period prior to build-up | Slope (m) of semi-log straight line on Horner plot (psi per log cycle) | Extrapolated pressure (P*) (psia) | | Permeability-thickness product (kh) (millidarcy-feet) | | Skin (s) (dimensionless) | |
|---|---|---|---|---|---|---|---|---|
| | | | Straight-line | Automated match [a] | Straight-line | Automated match [a] | Straight-line | Automated match [a] |
| KRH 4-1 | 10-13 May 97 | 44 | 762 | 807 | 44,340 | 29,076 | - 0.7 | - 3.7 |
| KRH 4-1 | 23 Aug to 18 Sep 97 | 51 | 773 | 782 | 25,130 | 24,308 | - 1.8 | - 3.9 |
| KRH 5-1 [b] | 27-28 Aug 97 | 77 | 1,265 | NA | 4,929 | NA | + 8.3 | NA |
| KRH 5-1 [b] | 23 Sep to 3 Oct 97 | 359 | 2,078 [c] | 2,241 [c] | 1,012 | 776 | - 0.5 | - 1.0 |
| K-33 | 30 Nov to 5 Dec 97 | 130 | 950 | NA | 930 | NA | - 1.9 | NA |
| TLG 1-1ST2 [b] | 10-11 Nov 97 | 64 | 1,109 | NA | 5,325 | NA | + 10.2 | NA |
| T-2 [b] | 17-18 Oct 97 | 50,000 [c] | 891 | NA | 6,472 | NA | - 4.6 | NA |



Notes: [a] Automated match using storage and skin model. "NA" indicates automated modeling did not converge.
[b] Values of kh and s are considered rough estimates, because downhole pressure data were affected by wellbore storage throughout the build-up.
[c] Extrapolated pressure is unrealistically high in comparison with static pressure or about 1,450 psia at sensor depth.
[d] Slope in units of $psia^2$ per log cycle for pressure-squared analysis of dry steam well.

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# FIGURES

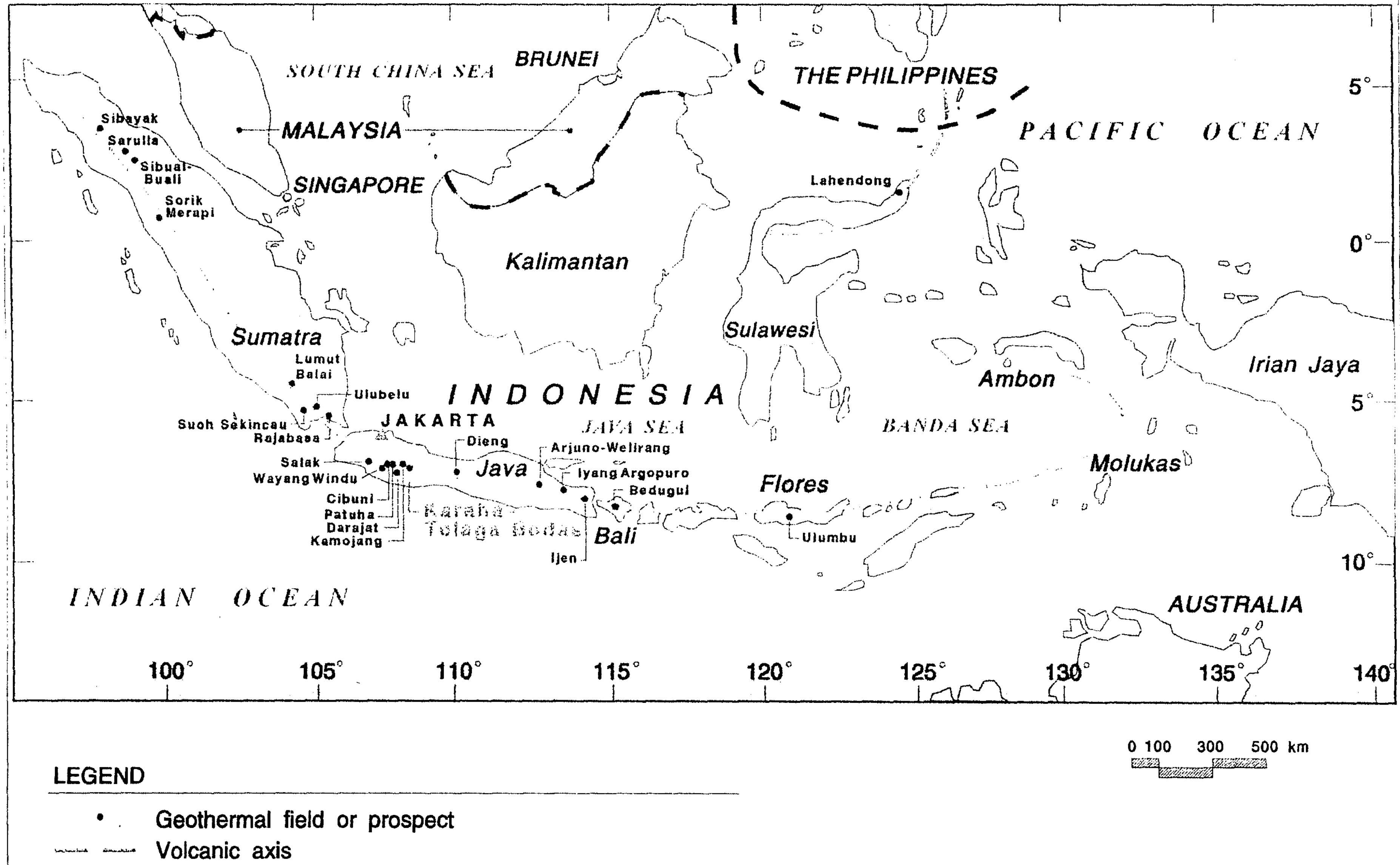


Figure 1.1: Location of Karaha - Telaga Bodas geothermal field

1998, GeothermEx, Inc. KARAHADJ/11FEB98/P1846/DJ92%

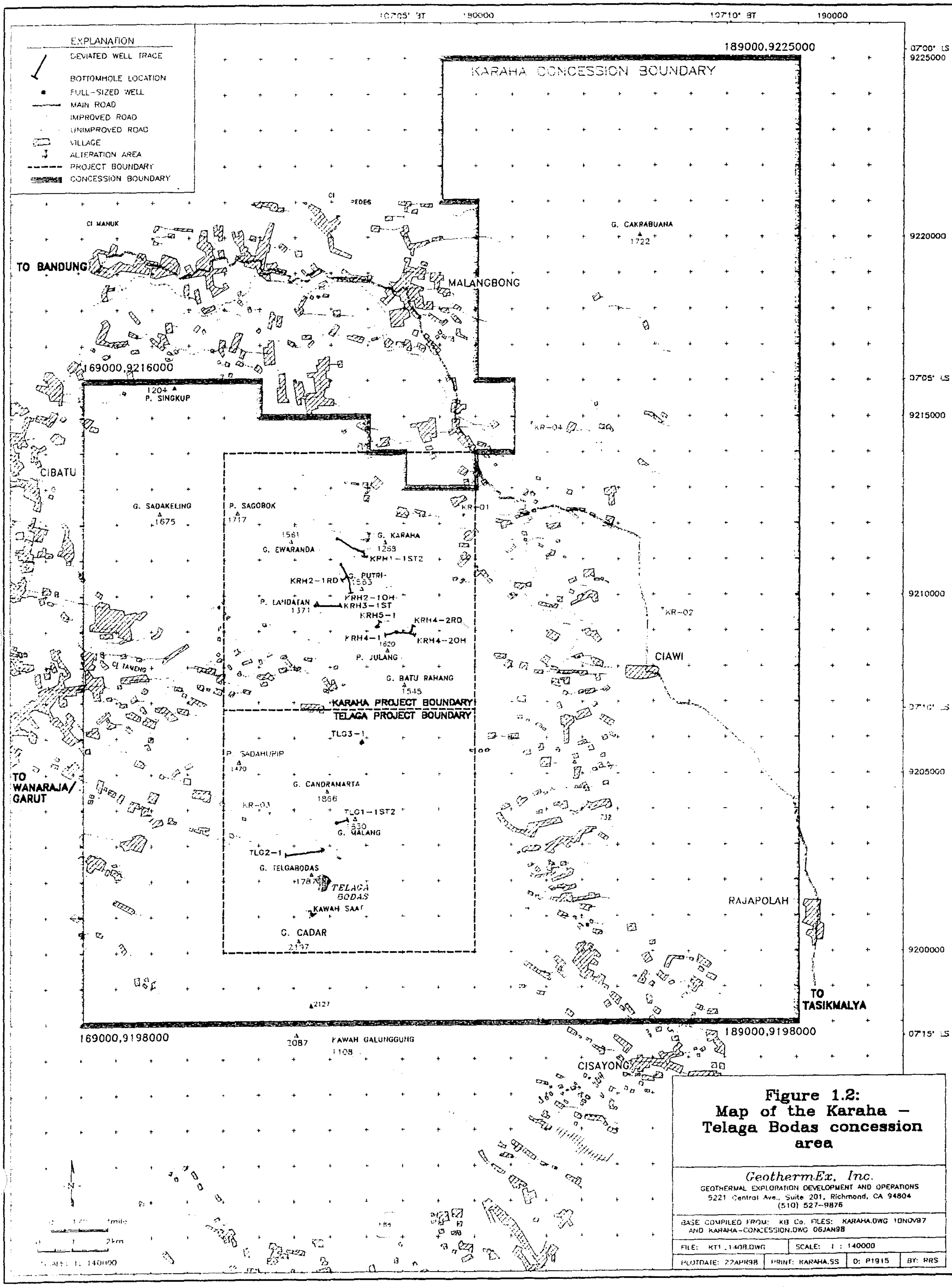


**Figure 1.2: Map of the Karaha – Telaga Bodas concession area**

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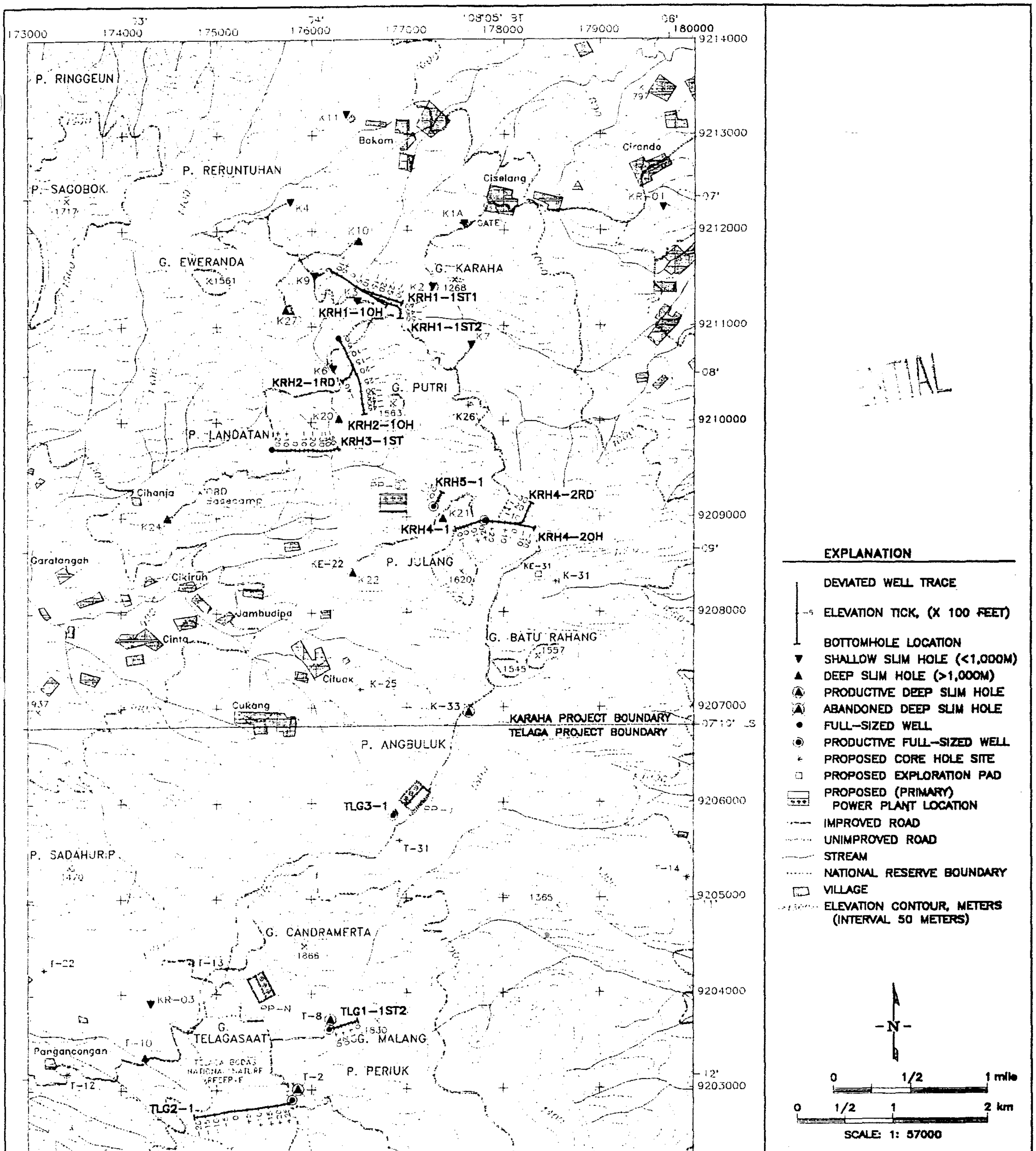


**Figure 2.1: Well location map, Karaha – Telaga Bodas geothermal field**

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| | | |
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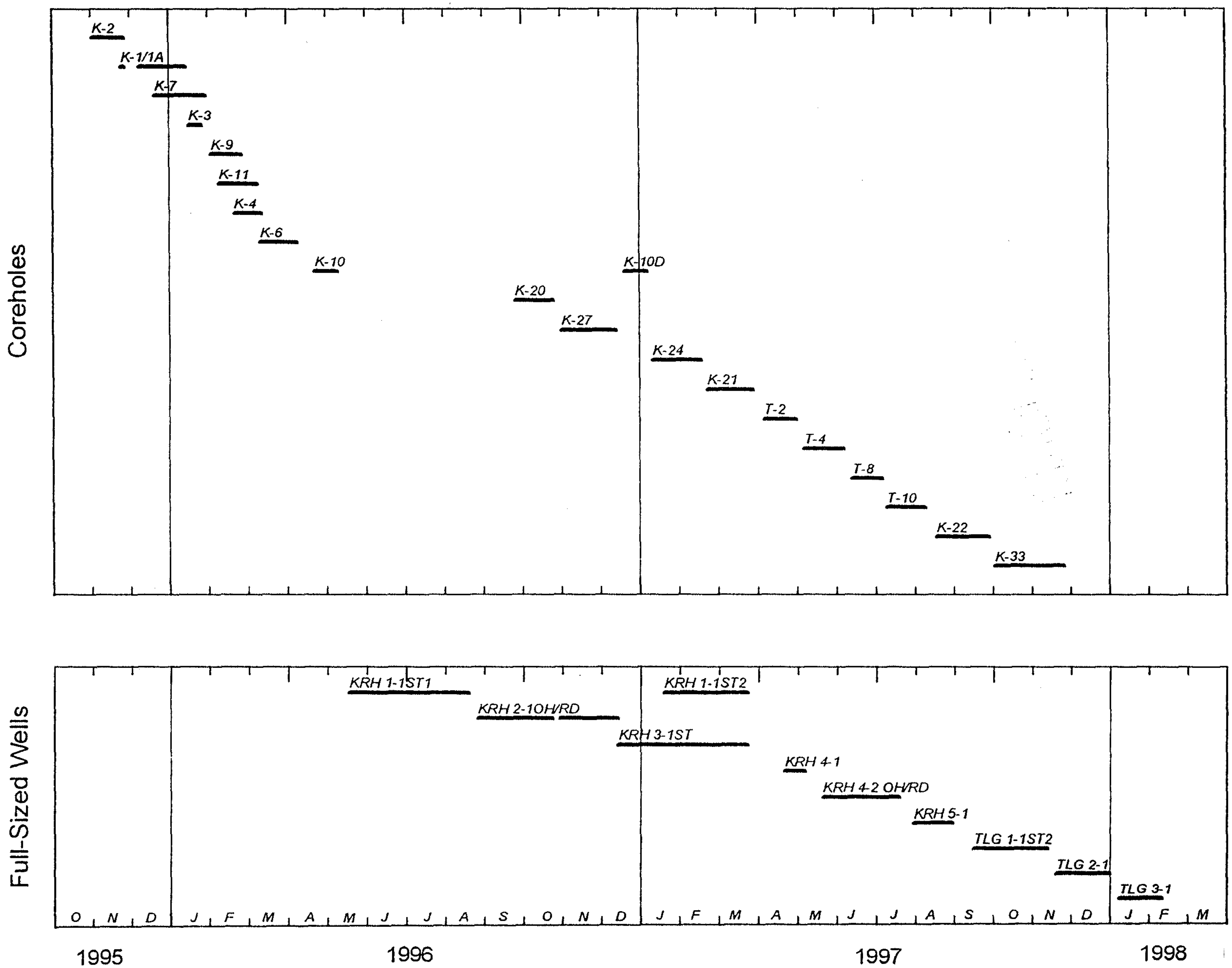
| FILE: ... | P1915 | SCALE: 1 : 57000 |
| PLOTDATE: 09FEB98 | PRINT: KARAHA.SS | BY: RRS |

**Figure 2.2: Drilling history, Karaha - Telaga Bodas geothermal field**




1998, GeothermEx, Inc.
P1702/HISTORY.GRF

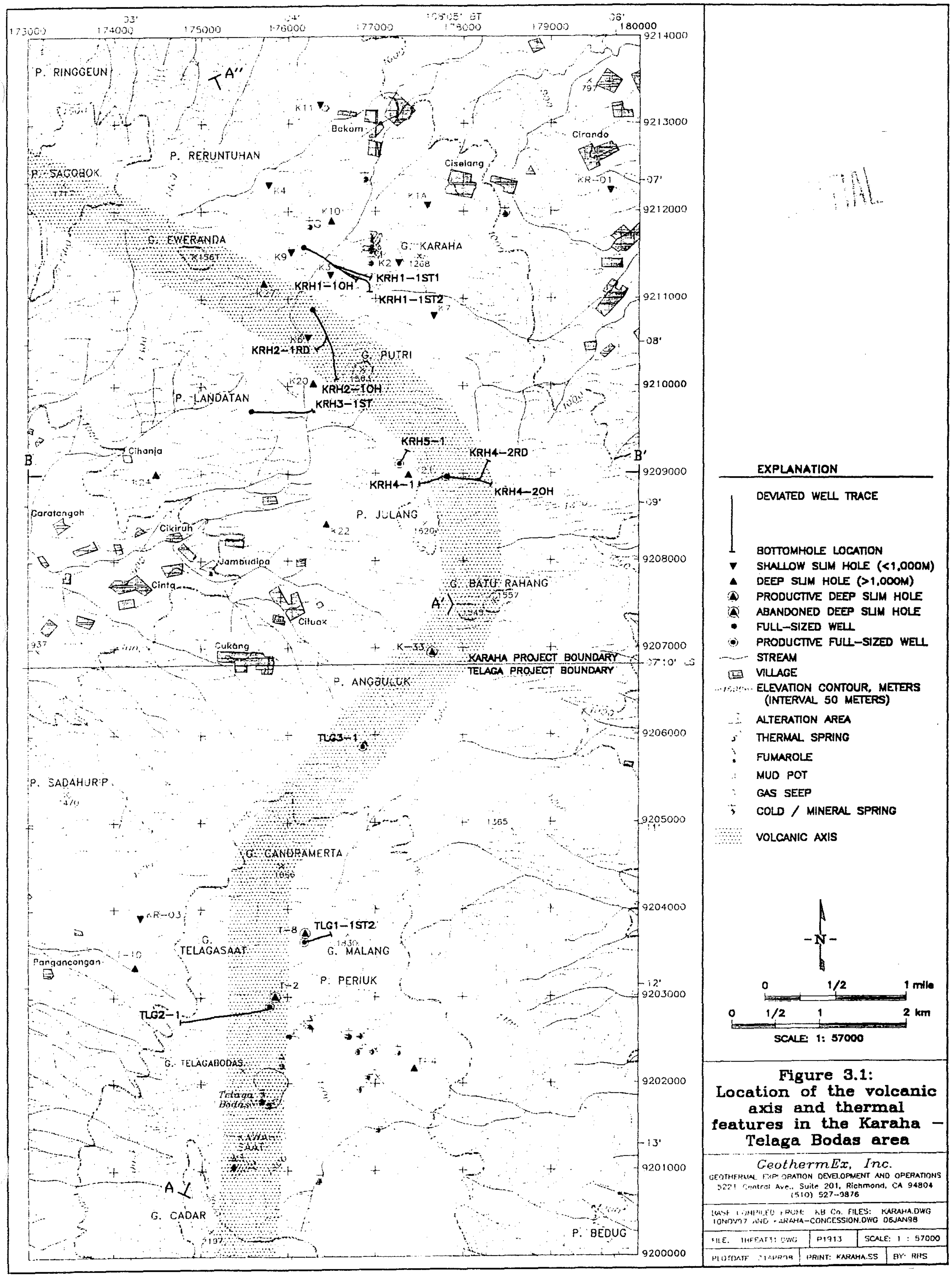



**Figure 3.1: Location of the volcanic axis and thermal features in the Karaha – Telaga Bodas area**

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BASE COMPILED FROM: KB Co. FILES: KARAHA.DWG 10NOV97 AND KARAHA-CONCESSION.DWG 06JAN98

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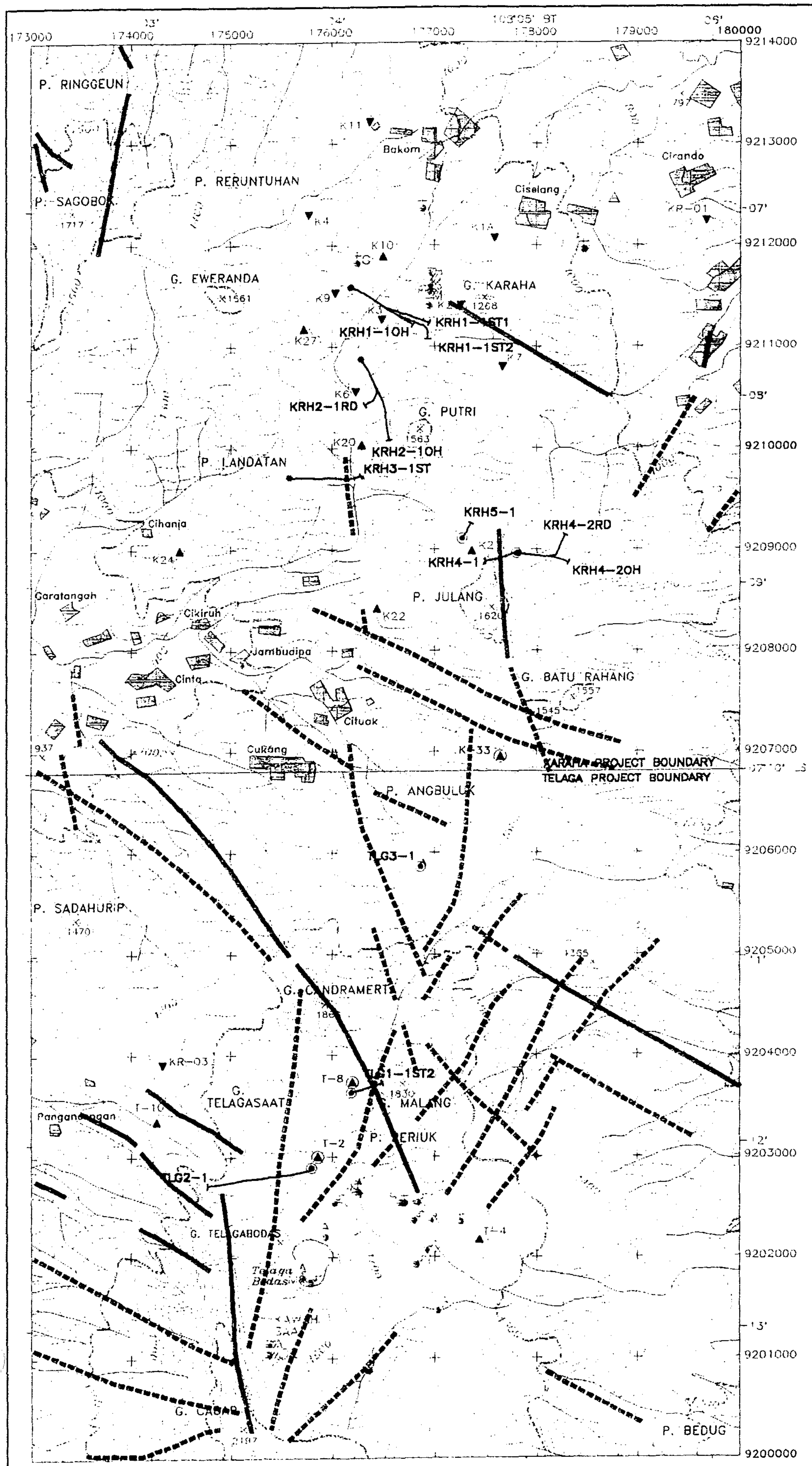


## EXPLANATION

- DEVIATED WELL TRACE
- BOTTOMHOLE LOCATION
- ▼ SHALLOW SLIM HOLE (<1,000M)
- ▲ DEEP SLIM HOLE (>1,000M)
- PRODUCTIVE DEEP SLIM HOLE
- ABANDONED DEEP SLIM HOLE
- • FULL-SIZED WELL
- PRODUCTIVE FULL-SIZED WELL
- STREAM
- VILLAGE
- ELEVATION CONTOUR, METERS (INTERVAL 50 METERS)
- ALTERATION AREA
- THERMAL SPRING
- FUMAROLE
- MUD POT
- GAS SEEP
- COLD / MINERAL SPRING
- FAULT WITH STRONG EXPRESSION
- FAULT WITH RELIABLE EXPRESSION

N

0 1/2 1 mile

0 1/2 1 2 km

SCALE: 1: 57000

**Figure 3.2: Recent faulting interpreted from aerial photographs, Karaha – Telaga Bodas area**

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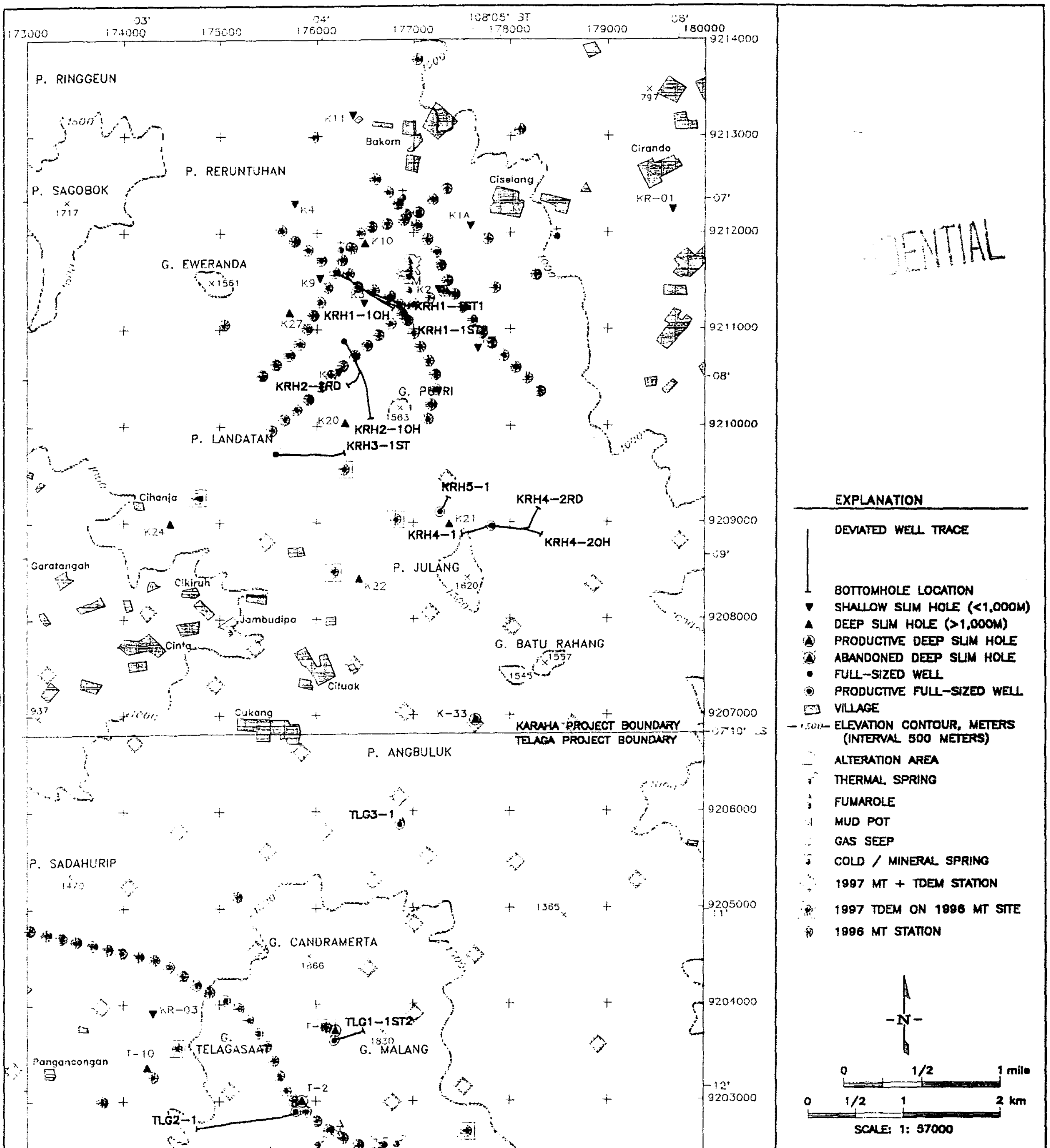


**Figure 3.3: MT station locations, Karaha – Telaga Bodas area, surveys of 1996–1997**
(Data adapted from GENZL, 1997)

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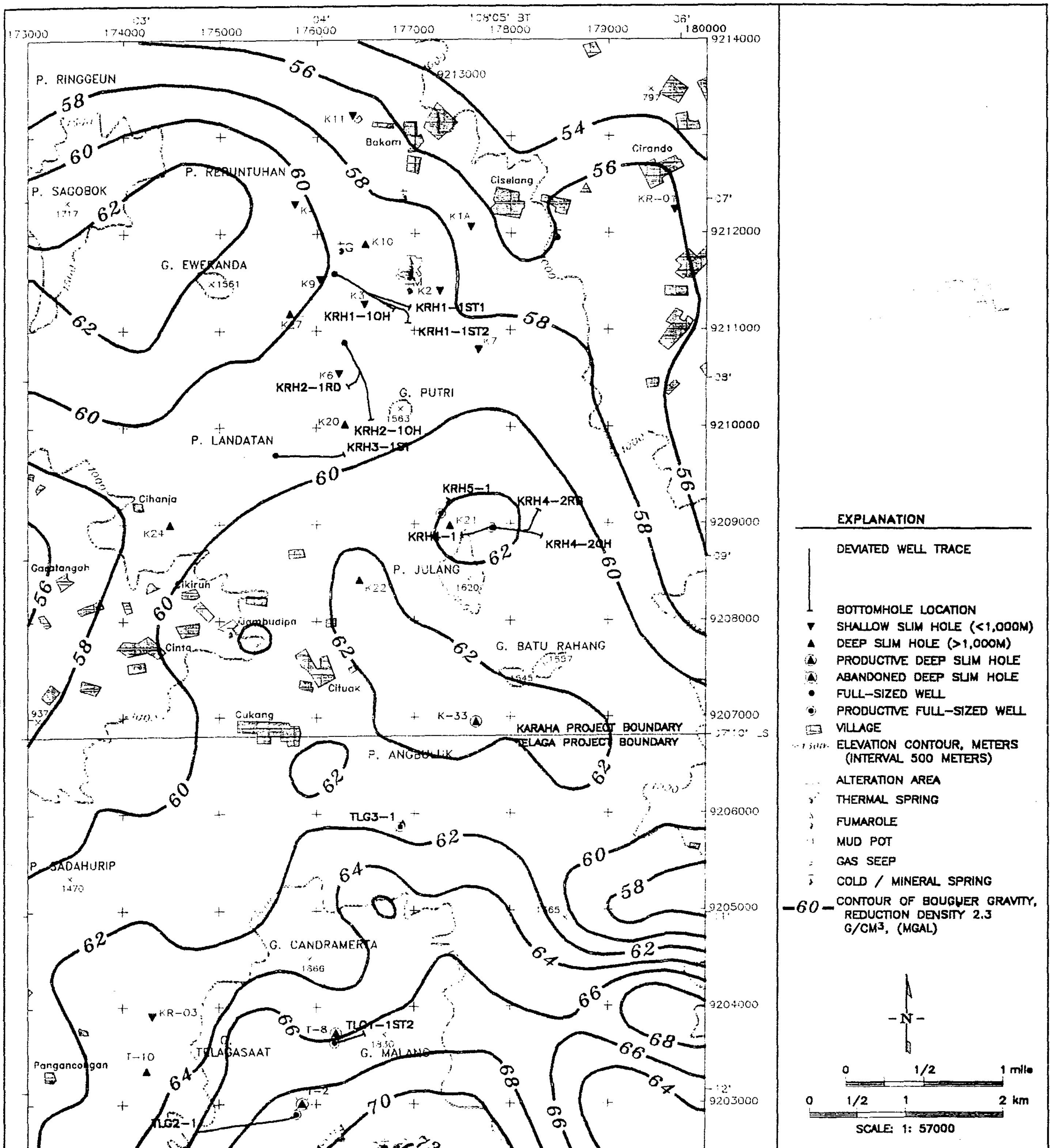


**Figure 3.4: Bouguer gravity anomaly, reduction density 2.3 g/cm3, Karaha – Telaga Bodas area**
(Data adapted from GENZL, 1997)

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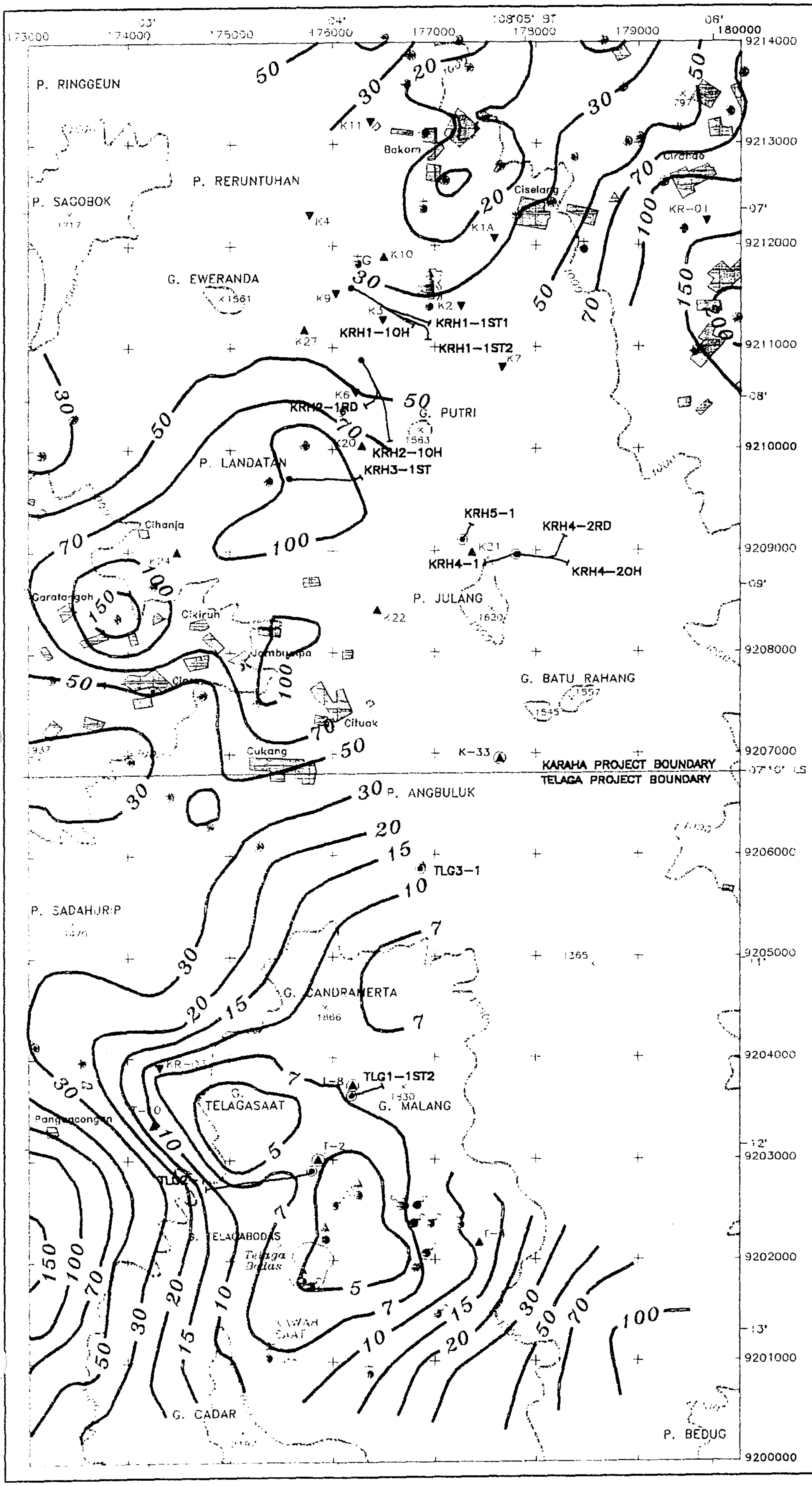


**EXPLANATION**

- DEVIATED WELL TRACE
- BOTTOMHOLE LOCATION
- ▼ SHALLOW SLIM HOLE (<1,000M)
- ▲ DEEP SLIM HOLE (>1,000M)
- PRODUCTIVE DEEP SLIM HOLE
- ABANDONED DEEP SLIM HOLE
- ● FULL-SIZED WELL
- PRODUCTIVE FULL-SIZED WELL
- VILLAGE
- 1500 ELEVATION CONTOUR, METERS (INTERVAL 500 METERS)
- ALTERATION AREA
- THERMAL SPRING
- FUMAROLE
- MUD POT
- GAS SEEP
- COLD / MINERAL SPRING
- —7— CONTOUR OF APPARENT RESISTIVITY, OHM-M, AB/2 = 1,000 M
- SCHLUMBERGER SPREAD CENTER

N

0 1/2 1 mile

0 1/2 1 2 km

SCALE: 1: 57000

**Figure 3.5: Schlumberger apparent resistivity, AB/2=1,000m, Karaha – Telaga Bodas area** (Data adapted from GENZL, 1996A, 1996B)

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BASE COMPILED FROM: KB Co. FILES: KARAHA.DWG 10NOV97 AND KARAHA-CONCESSION.DWG 06JAN98

| FILE: AR1000.DWG | P1913 | SCALE: 1 : 57000 |
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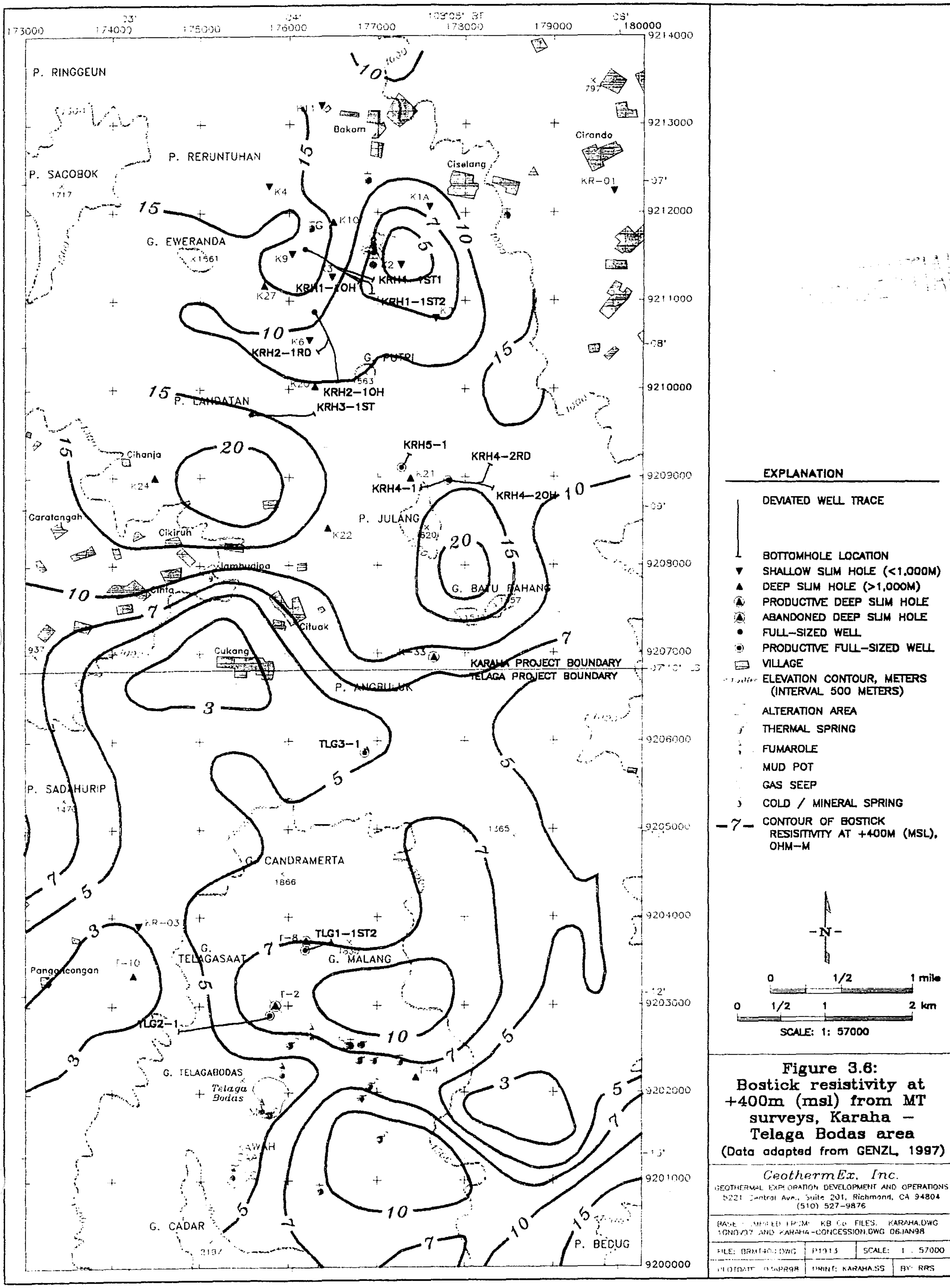


**Figure 3.6: Bostick resistivity at +400m (msl) from MT surveys, Karaha – Telaga Bodas area**
(Data adapted from GENZL, 1997)

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BASE: COMPILED FROM: KB Co. FILES, KARAHA.DWG 10NOV97 AND KARAHA-CONCESSION.DWG 06JAN98

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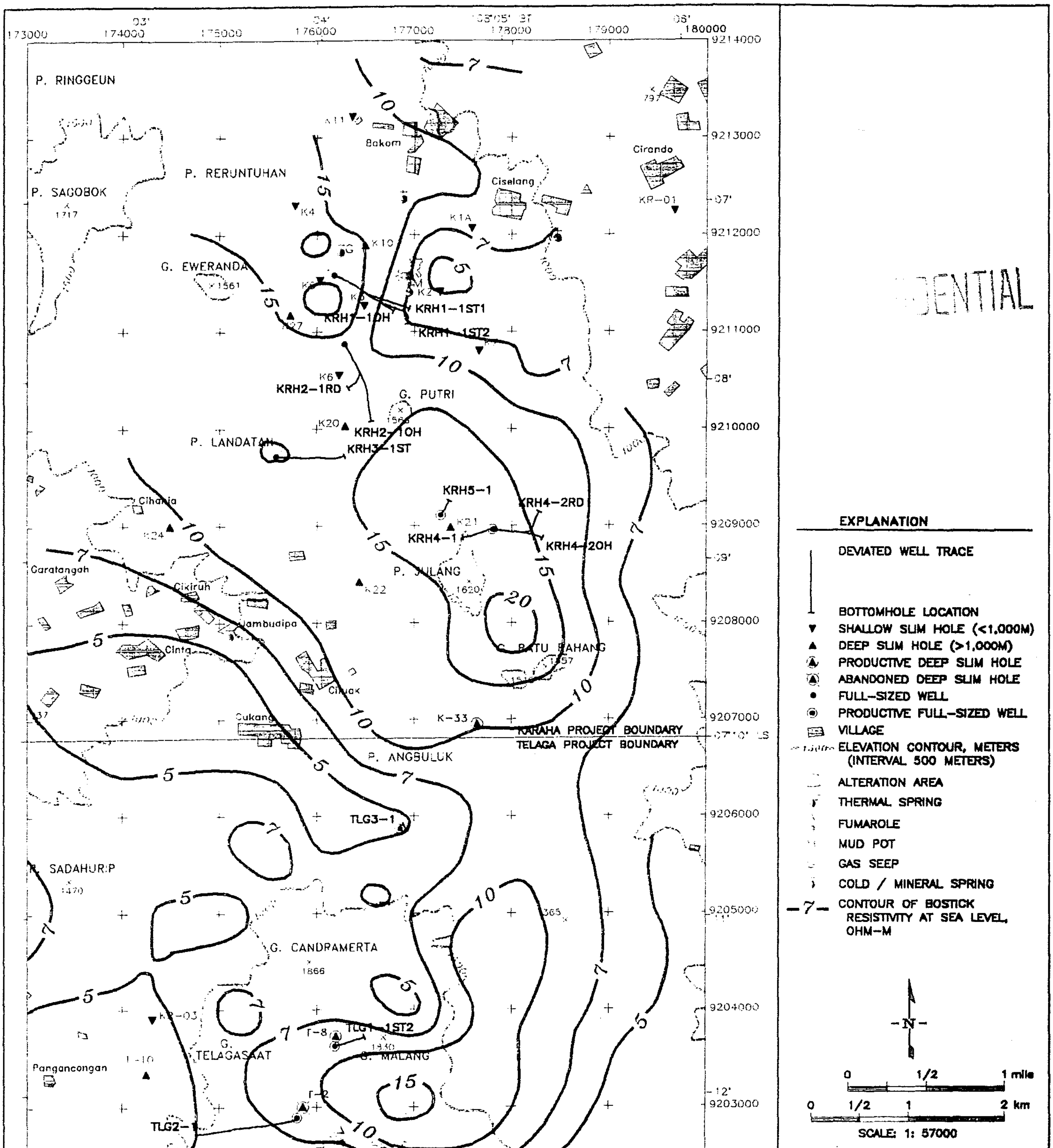


**Figure 3.7: Bostick resistivity at sea level from MT surveys, Karaha – Telaga Bodas area**
(Data adapted from GENZL, 1997)

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BASE COMPILED FROM: KB Co. FILES: KARAHA.DWG 13NOV97 AND KARAHA-CONCESSION.DWG 06JAN98

| | | |
|---|---|---|
| FILE: BRMTO.DWG | P1913 | SCALE: 1 : 57000 |
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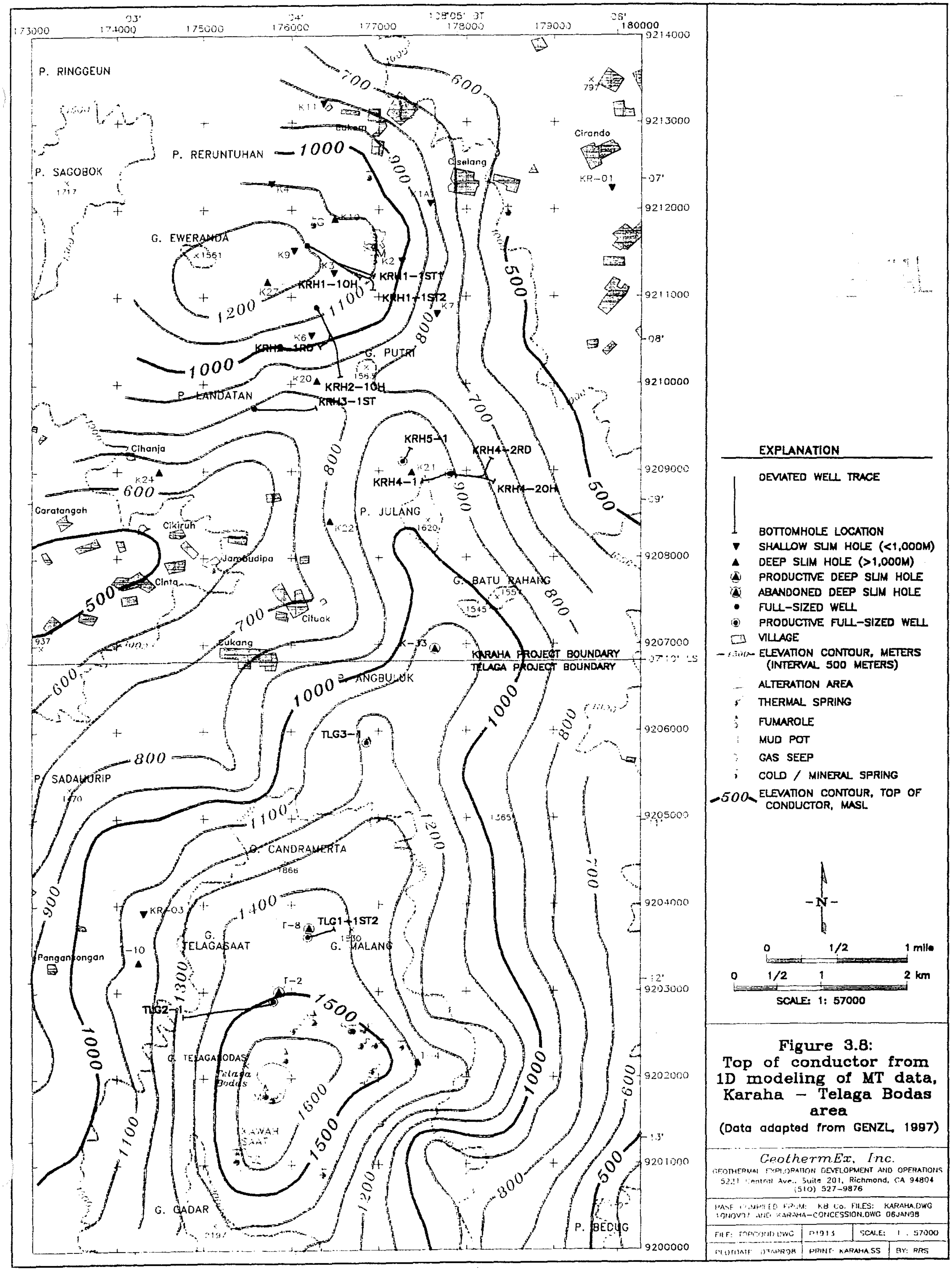



**Figure 3.8: Top of conductor from 1D modeling of MT data, Karaha – Telaga Bodas area**

(Data adapted from GENZL, 1997)

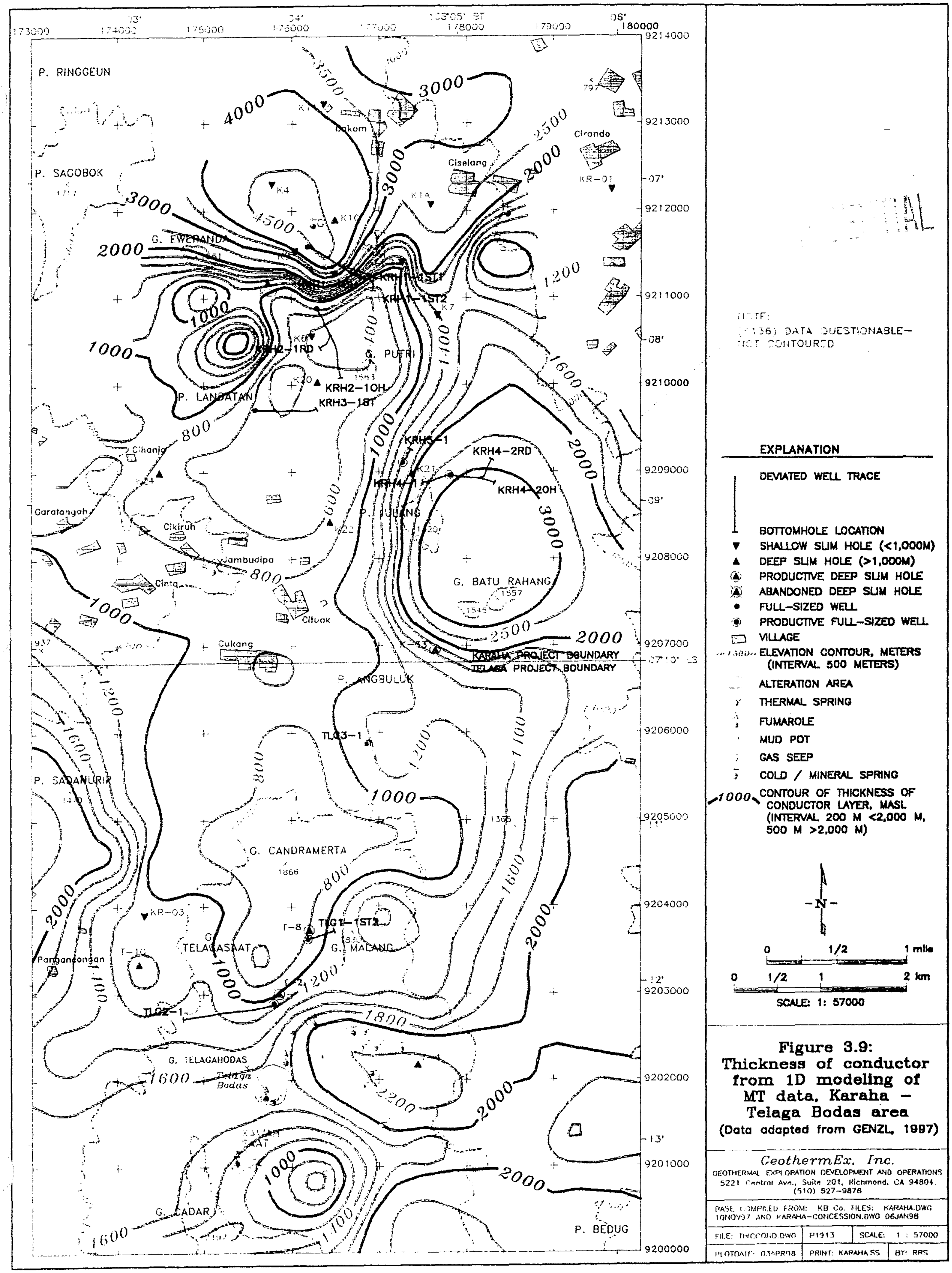
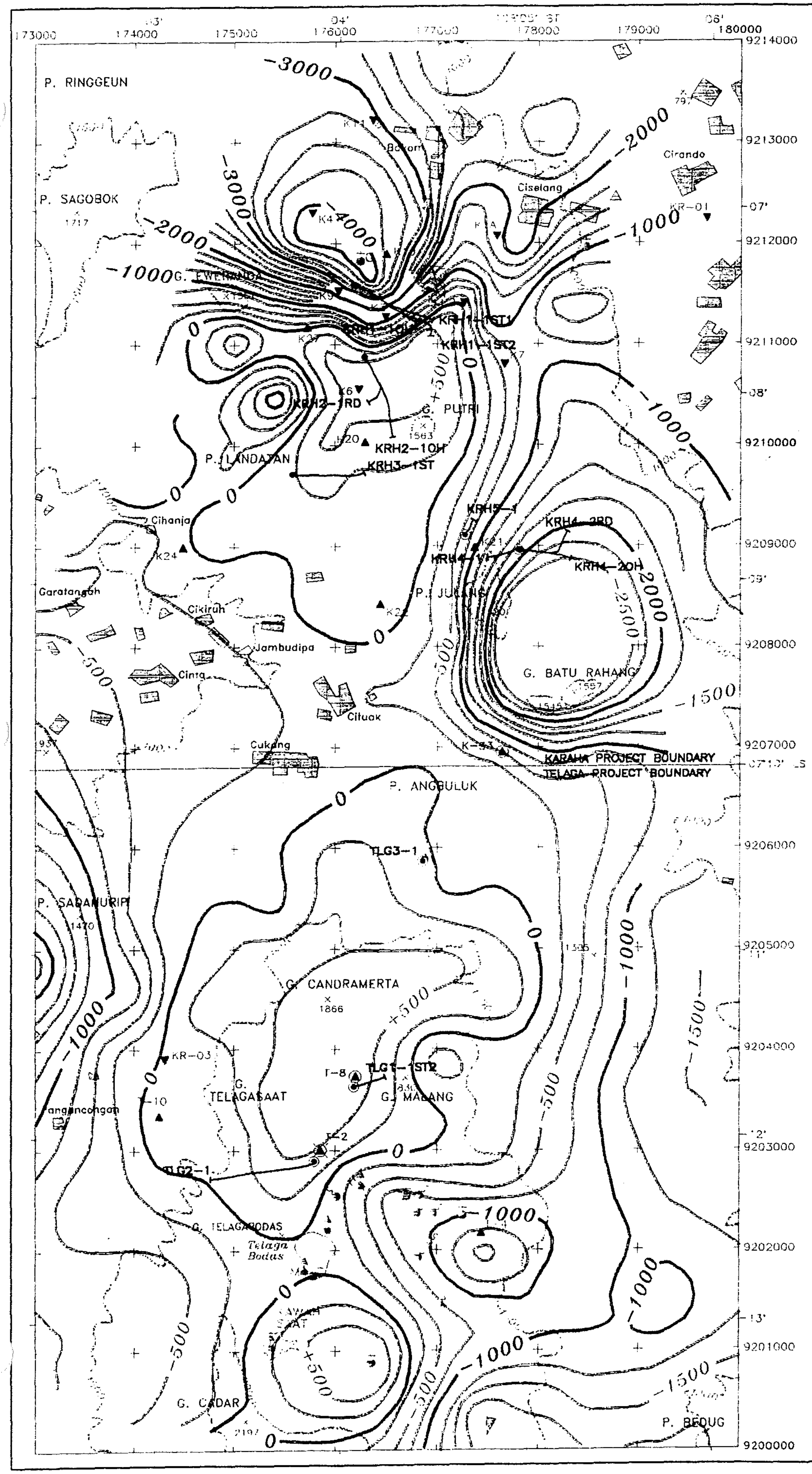



**Figure 3.9: Thickness of conductor from 1D modeling of MT data, Karaha – Telaga Bodas area**
(Data adapted from GENZL, 1997)




**EXPLANATION**

- DEVIATED WELL TRACE
- BOTTOMHOLE LOCATION
- ▼ SHALLOW SLIM HOLE (<1,000M)
- ▲ DEEP SLIM HOLE (>1,000M)
- PRODUCTIVE DEEP SLIM HOLE
- ABANDONED DEEP SLIM HOLE
- • FULL-SIZED WELL
- PRODUCTIVE FULL-SIZED WELL
- VILLAGE
- ELEVATION CONTOUR, METERS (INTERVAL 500 METERS)
- ALTERATION AREA
- THERMAL SPRING
- FUMAROLE
- MUD POT
- GAS SEEP
- COLD / MINERAL SPRING
- —0— ELEVATION CONTOUR, BASE OF CONDUCTOR, MASL (INTERVAL 250 M)

N

0 1/2 1 mile

0 1/2 1 2 km

SCALE: 1: 57000

**Figure 3.10: Base of conductor from 1D modeling of MT data, Karaha – Telaga Bodas area**
(Data adapted from GENZL, 1997)

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BASE COMPILED FROM: KB Co. FILES: KARAHA.DWG 10NOV97 AND KARAHA-CONCESSION.DWG 06JAN98

| FILE: BASECOND.DWG | P1913 | SCALE: 1 : 57000 |
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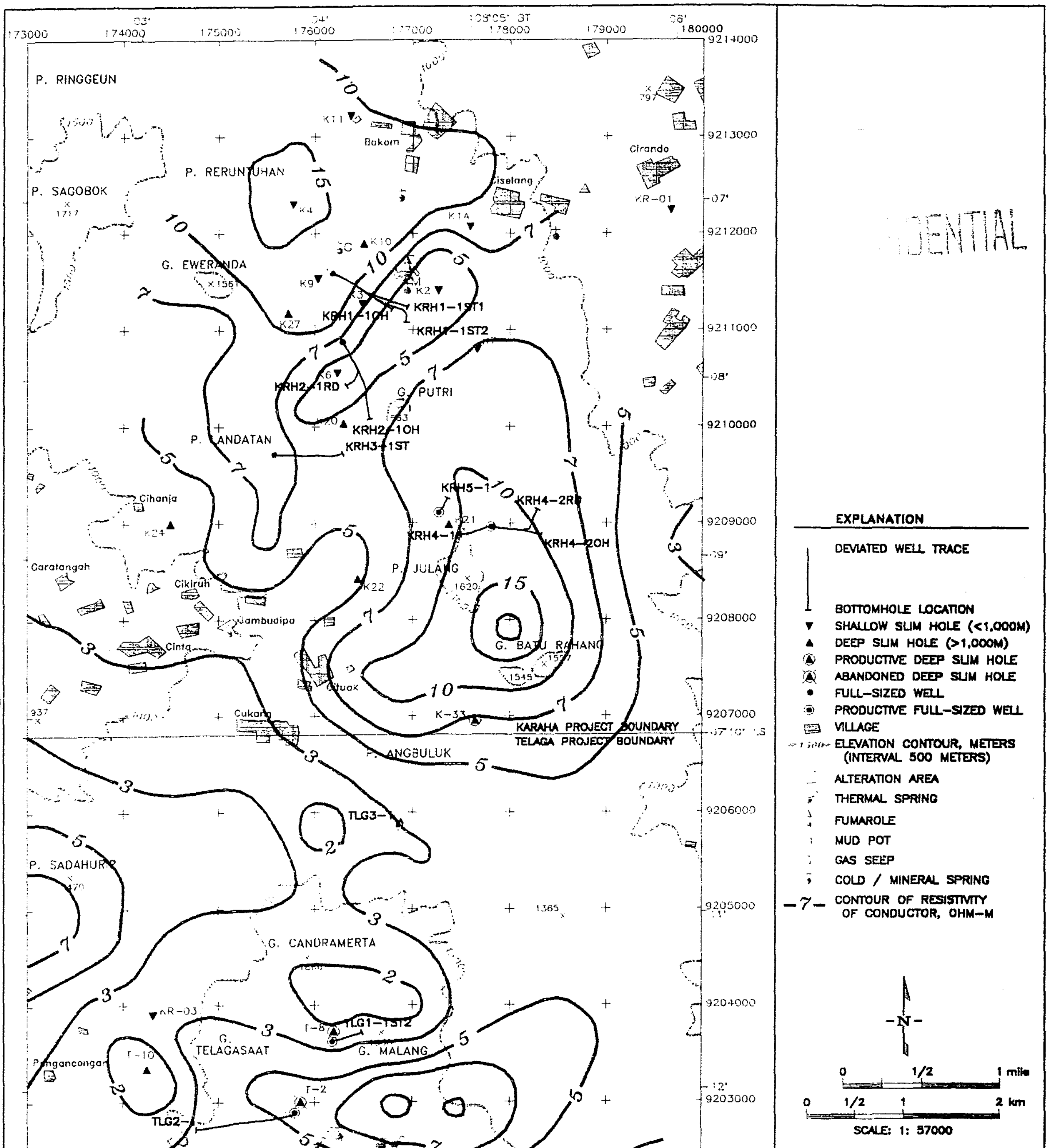


**Figure 3.11: Resistivity of conductor from 1D modeling of MT data, Karaha – Telaga Bodas area** (Data adapted from GENZL, 1996A, 1996B)

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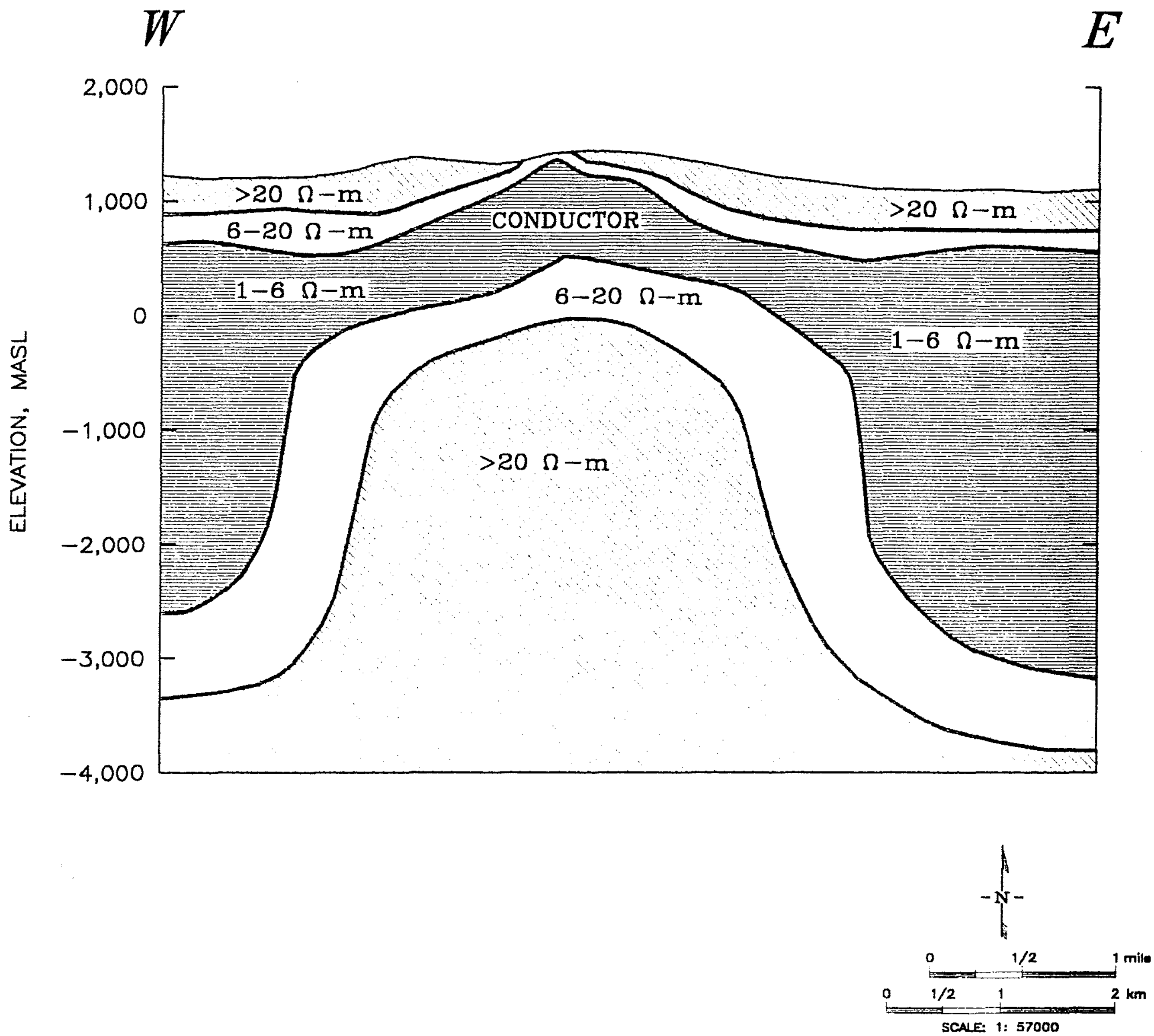


**Figure 3.12: Schematic 2D model of resistivity structure, Karaha – Telaga Bodas area**

(Based on GENZL, 1997)

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KARAHA.DWG
AND KARAHA–CONCESSION.DWG 06JAN98

SCALE: 1 : 57000

PRINT: KARAHA.SS | BY: RRS

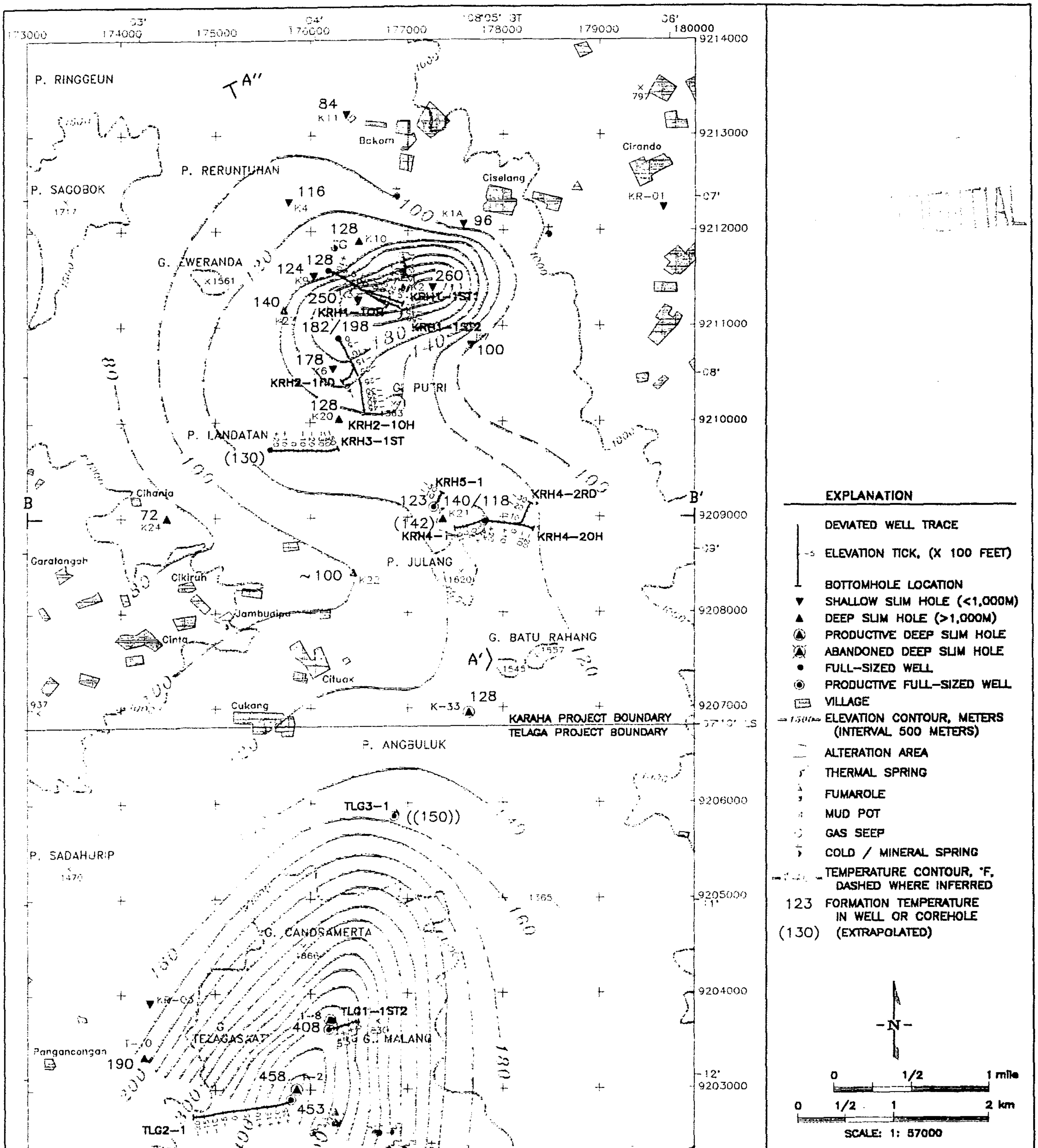


**Figure 3.13: Temperature distribution at +3,000 feet (msl), Karaha – Telaga Bodas geothermal field**

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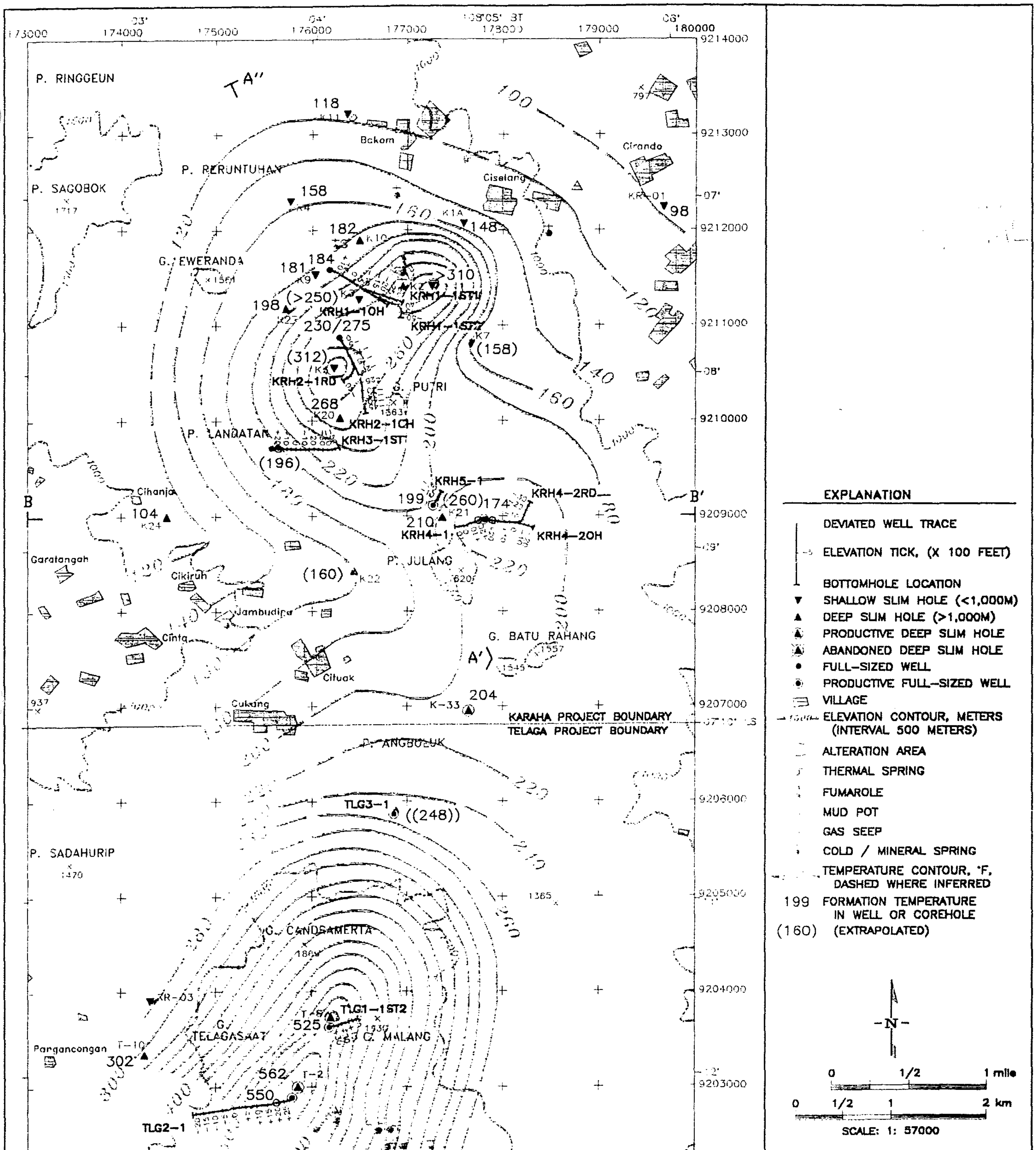


**Figure 3.14: Temperature distribution at +2,000 feet (msl), Karaha – Telaga Bodas geothermal field**

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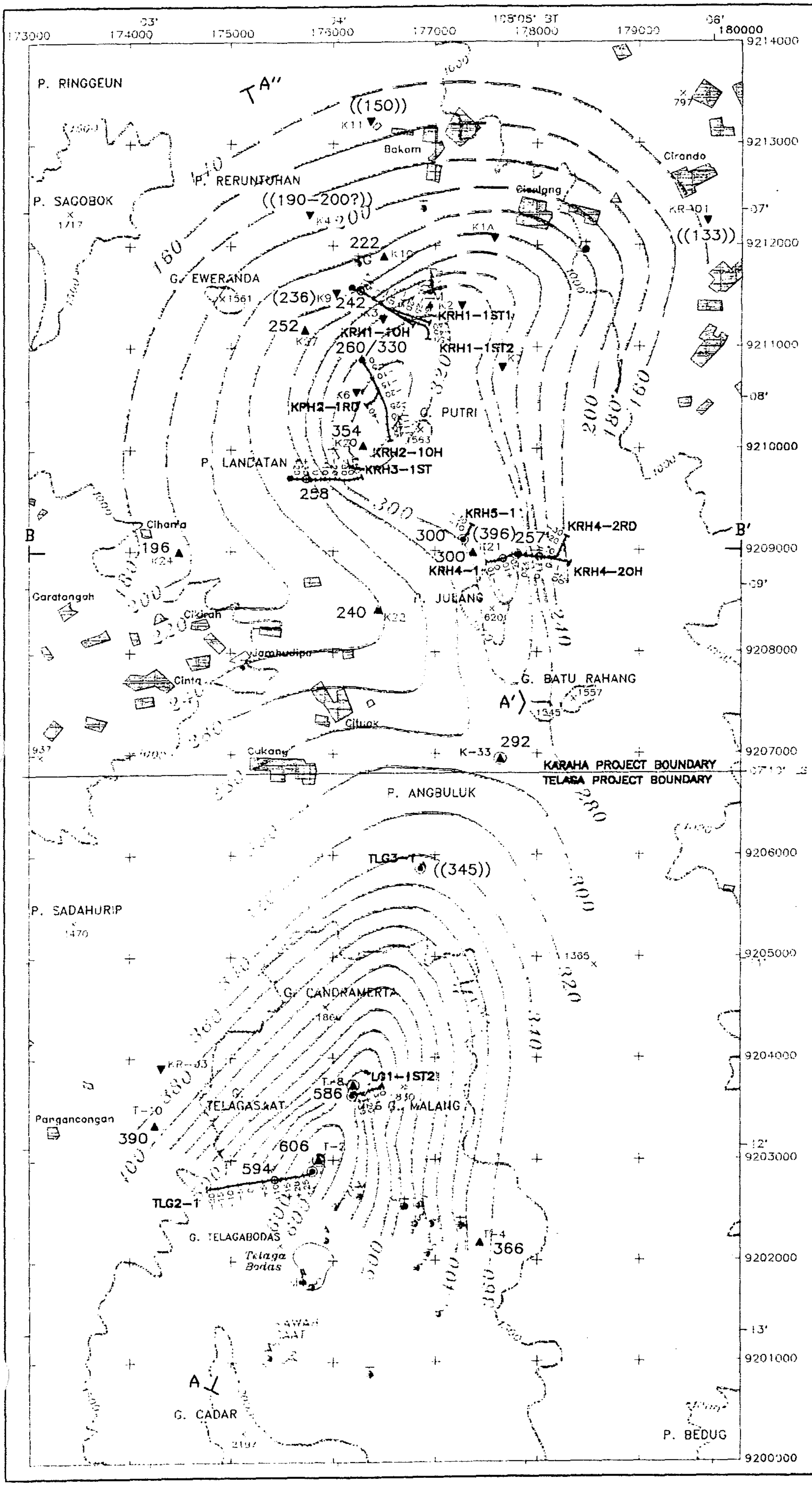


**EXPLANATION**

- DEVIATED WELL TRACE
- ELEVATION TICK, (X 100 FEET)
- BOTTOMHOLE LOCATION
- ▼ SHALLOW SLIM HOLE (<1,000M)
- ▲ DEEP SLIM HOLE (>1,000M)
- PRODUCTIVE DEEP SLIM HOLE
- ABANDONED DEEP SLIM HOLE
- ● FULL-SIZED WELL
- PRODUCTIVE FULL-SIZED WELL
- VILLAGE
- ELEVATION CONTOUR, METERS (INTERVAL 500 METERS)
- ALTERATION AREA
- THERMAL SPRING
- FUMAROLE
- MUD POT
- GAS SEEP
- COLD / MINERAL SPRING
- TEMPERATURE CONTOUR, °F, DASHED WHERE INFERRED
- 300 FORMATION TEMPERATURE IN WELL OR COREHOLE
- (396) (EXTRAPOLATED)

N

0 1/2 1 mile

0 1/2 1 2 km

SCALE: 1: 57000

**Figure 3.15: Temperature distribution at +1,000 feet (msl), Karaha – Telaga Bodas geothermal field**

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| | | | |
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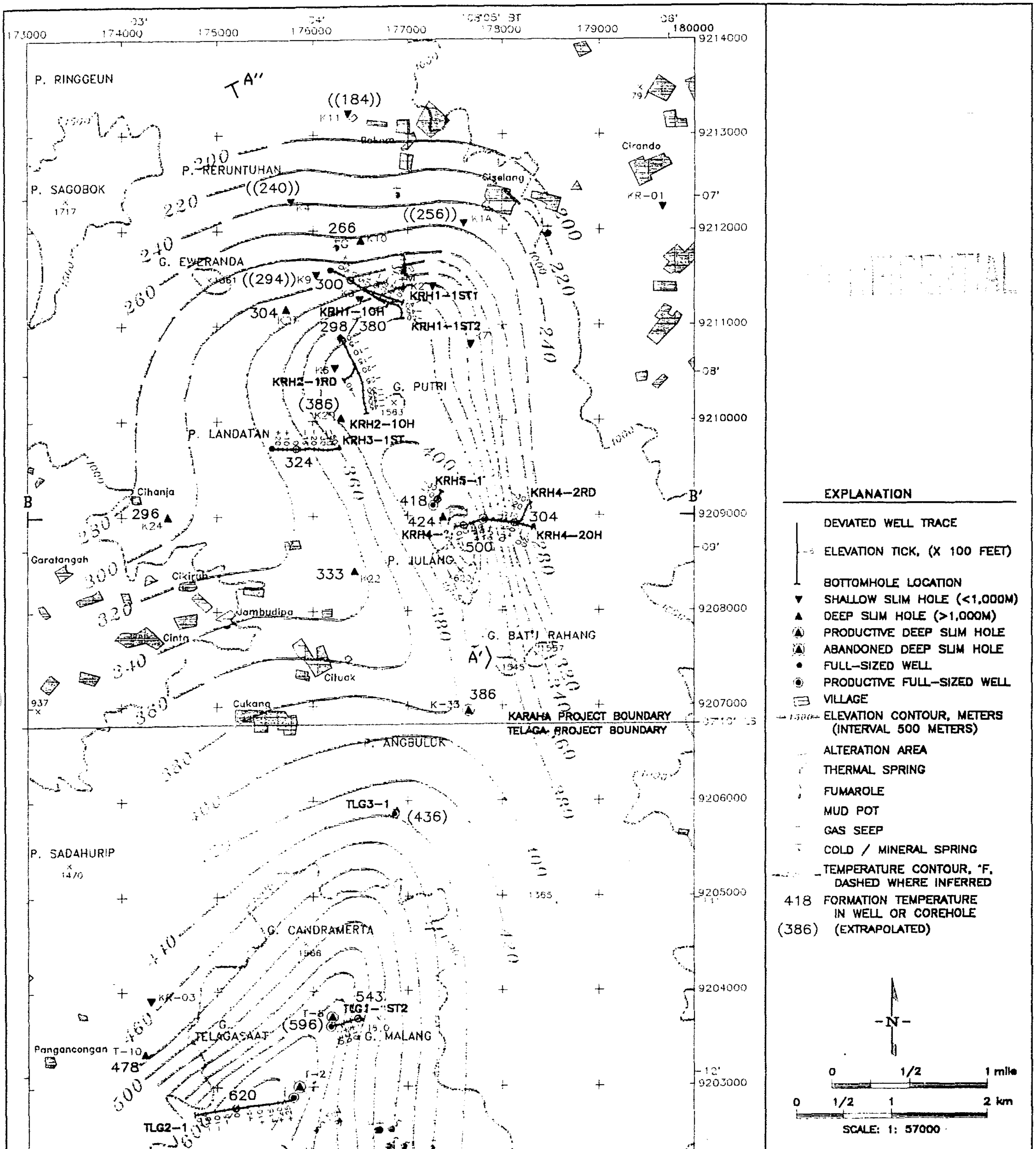


**Figure 3.18: Temperature distribution at mean sea level, Karaha – Telaga Bodas geothermal field**

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| | | |
|---|---|---|
| FILE: KITTS.DWG | P1316 | SCALE: 1 : 57000 |
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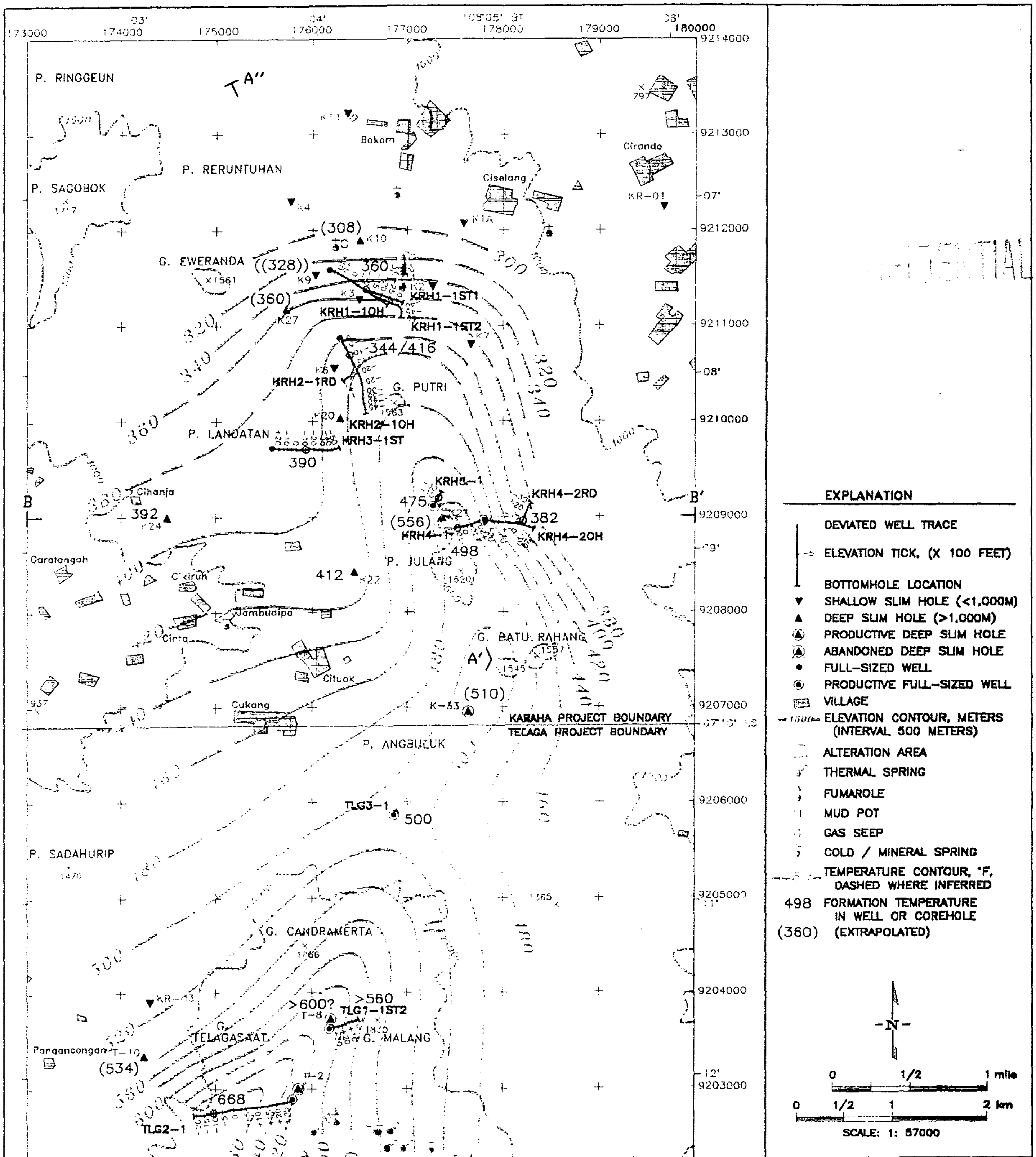


**Figure 3.17: Temperature distribution at −1,000 feet (msl), Karaha – Telaga Bodas geothermal field**

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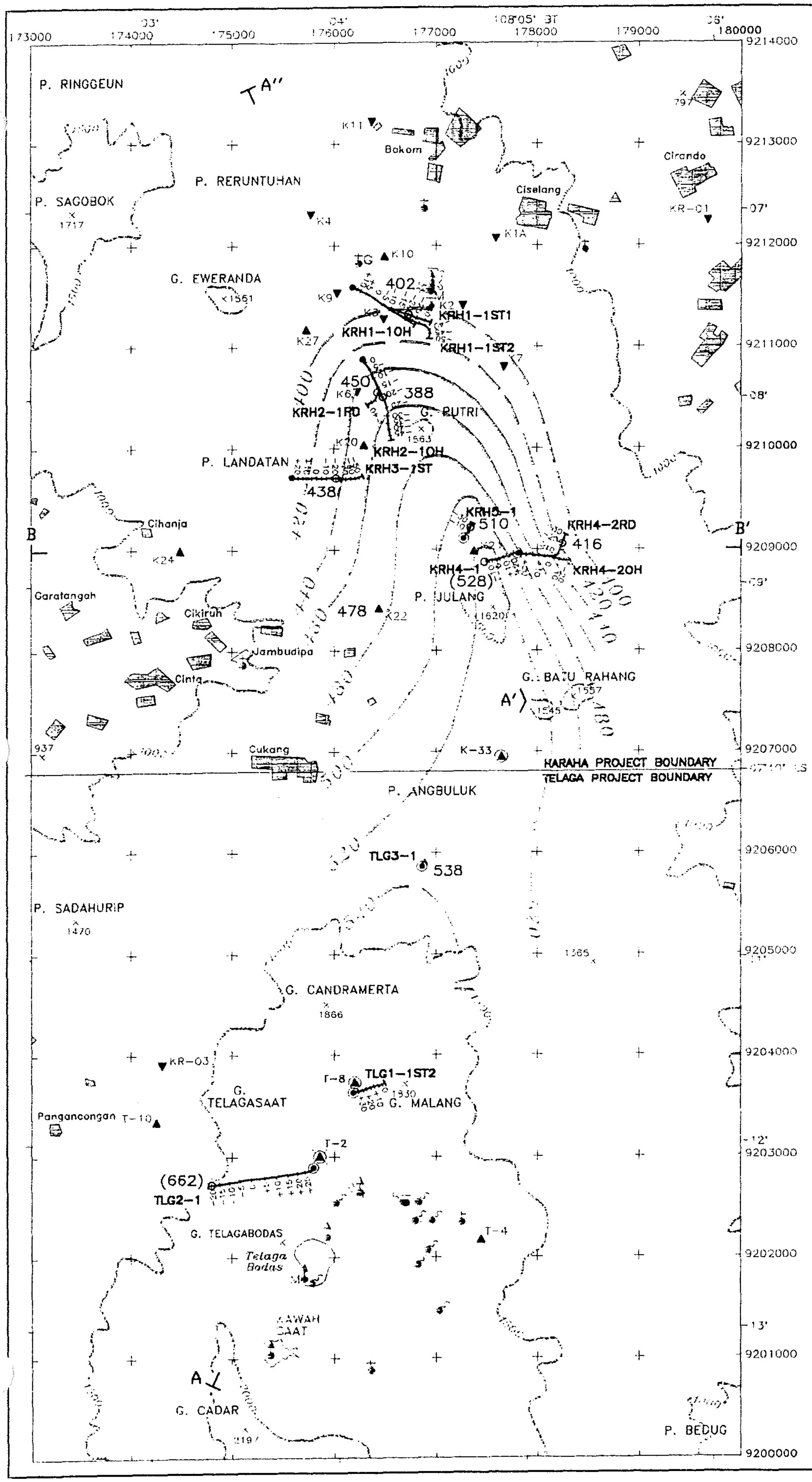


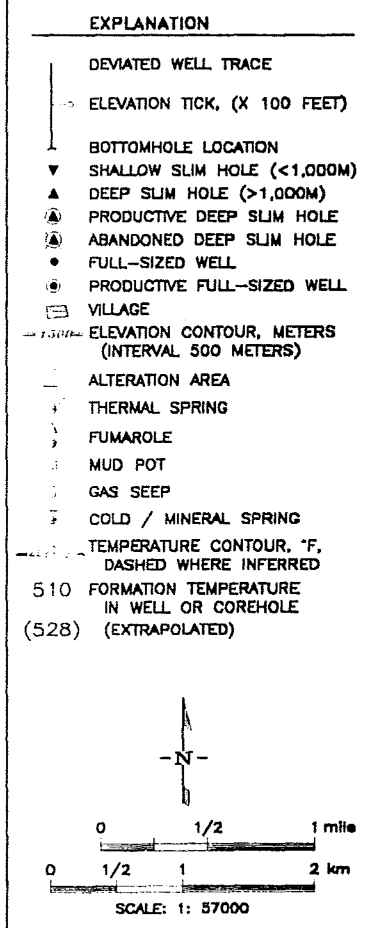


**Figure 3.18: Temperature distribution at −2,000 feet (msl), Karaha – Telaga Bodas geothermal field**

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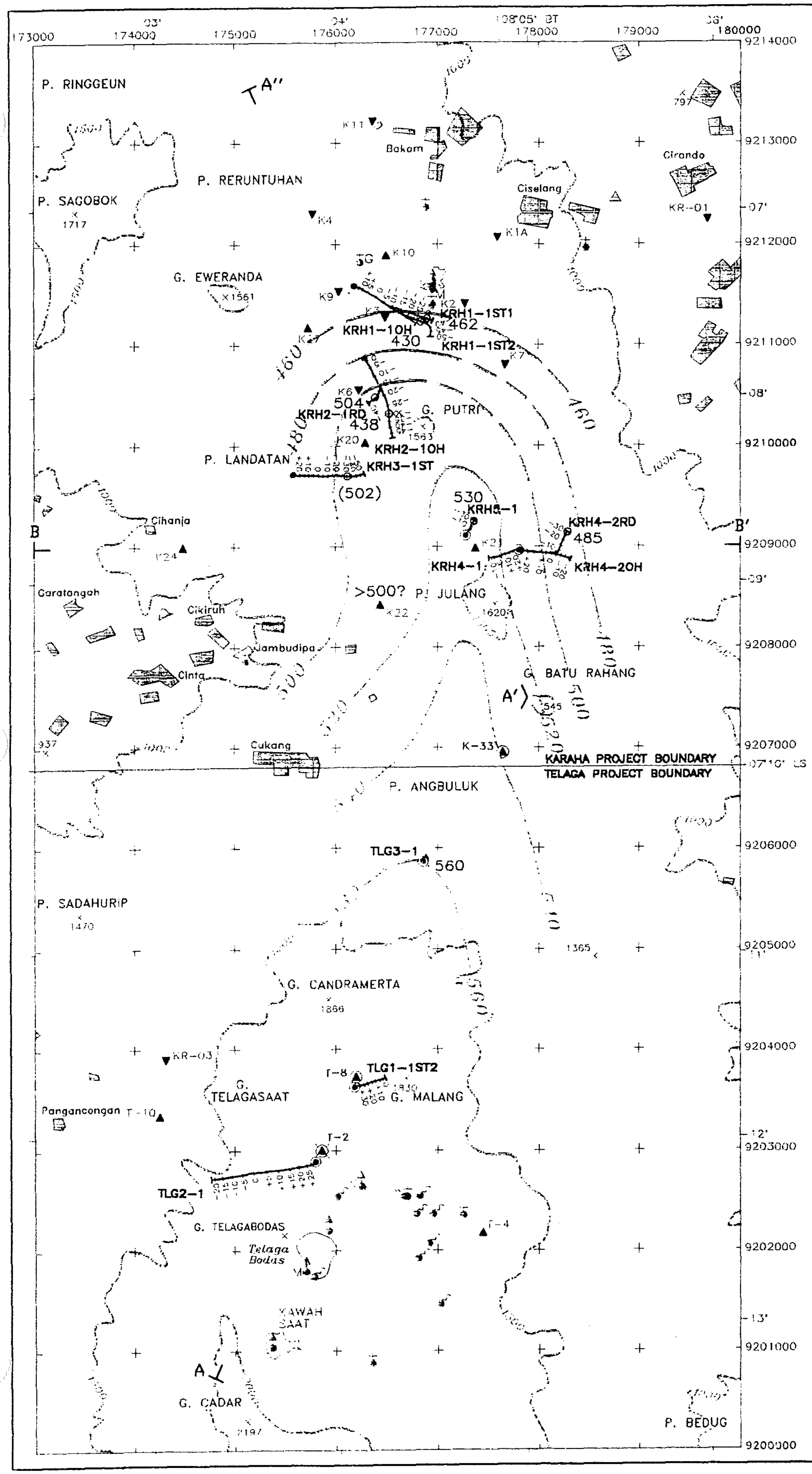


**EXPLANATION**

- DEVIATED WELL TRACE
- ELEVATION TICK, (X 100 FEET)
- BOTTOMHOLE LOCATION
- ▼ SHALLOW SLIM HOLE (<1,000M)
- ▲ DEEP SLIM HOLE (>1,000M)
- PRODUCTIVE DEEP SLIM HOLE
- ABANDONED DEEP SLIM HOLE
- • FULL-SIZED WELL
- PRODUCTIVE FULL-SIZED WELL
- VILLAGE
- ELEVATION CONTOUR, METERS (INTERVAL 500 METERS)
- ALTERATION AREA
- THERMAL SPRING
- FUMAROLE
- MUD POT
- GAS SEEP
- COLD / MINERAL SPRING
- TEMPERATURE CONTOUR, °F, DASHED WHERE INFERRED
- 530 FORMATION TEMPERATURE IN WELL OR COREHOLE
- (502) (EXTRAPOLATED)

-N-

0 1/2 1 mile

0 1/2 1 2 km

SCALE: 1: 57000

**Figure 3.19: Temperature distribution at −3,000 feet (msl), Karaha – Telaga Bodas geothermal field**

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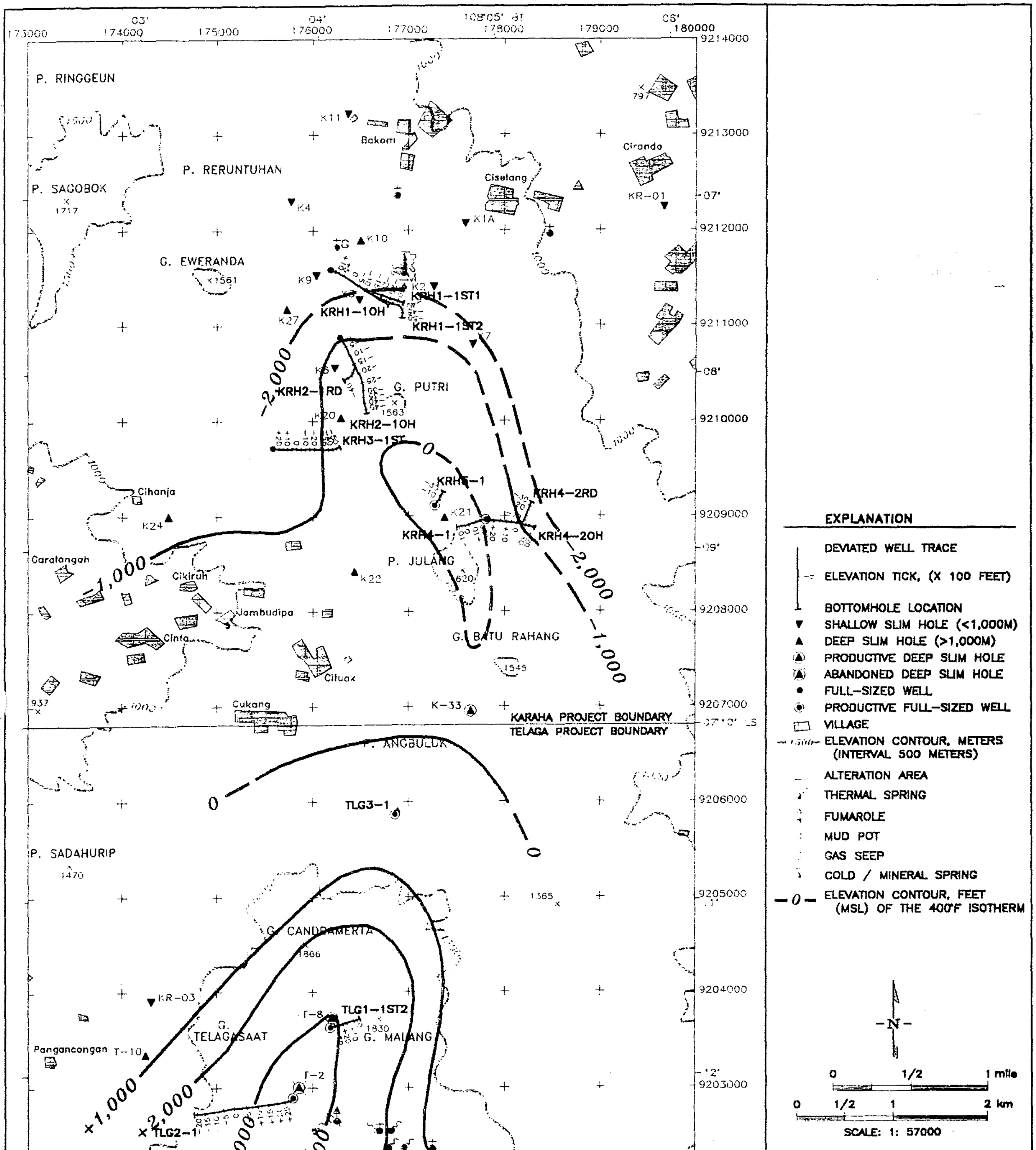


**Figure 3.20: Elevation of the 400°F isotherm, Karaha – Telaga Bodas geothermal field**

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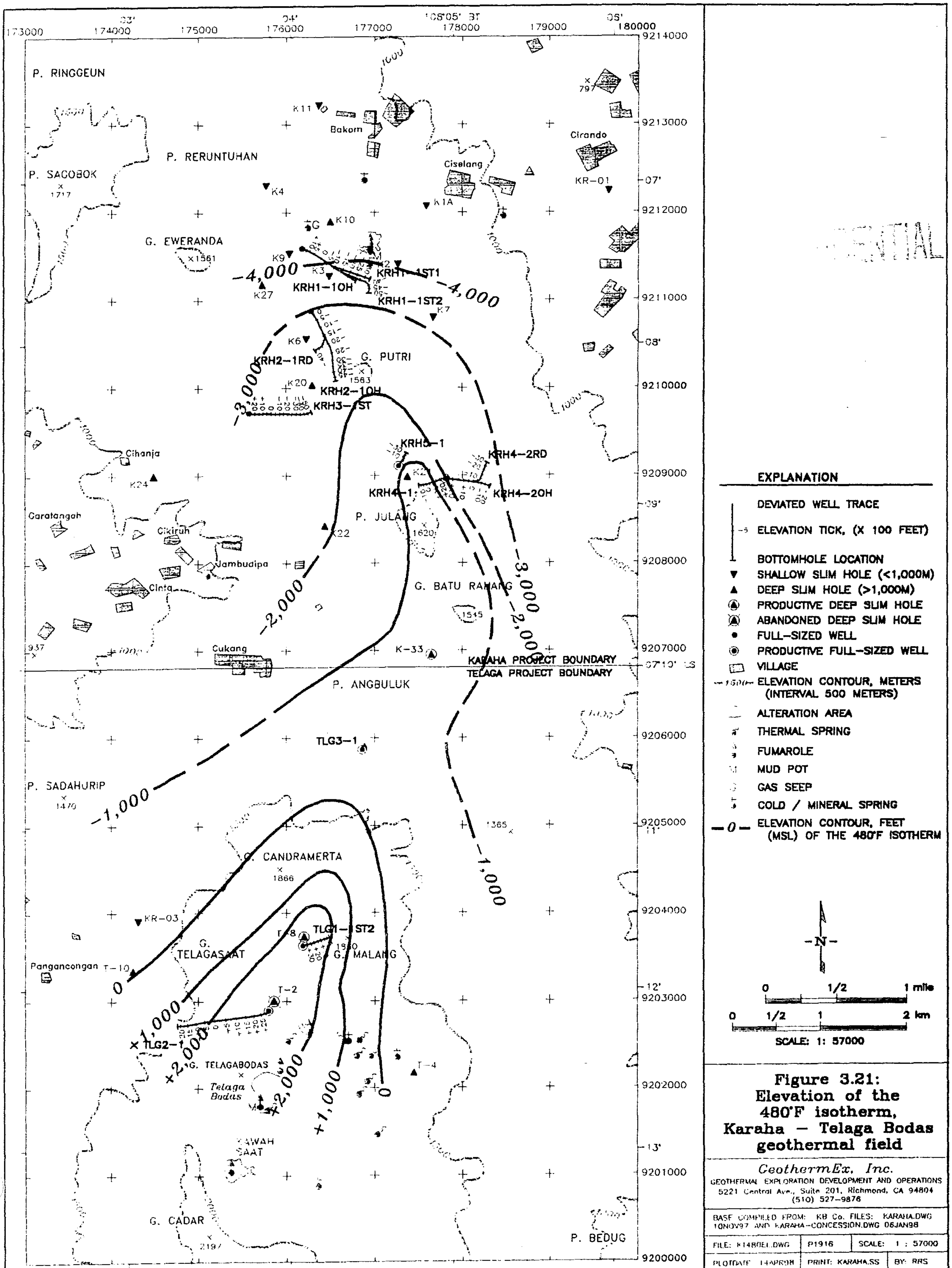
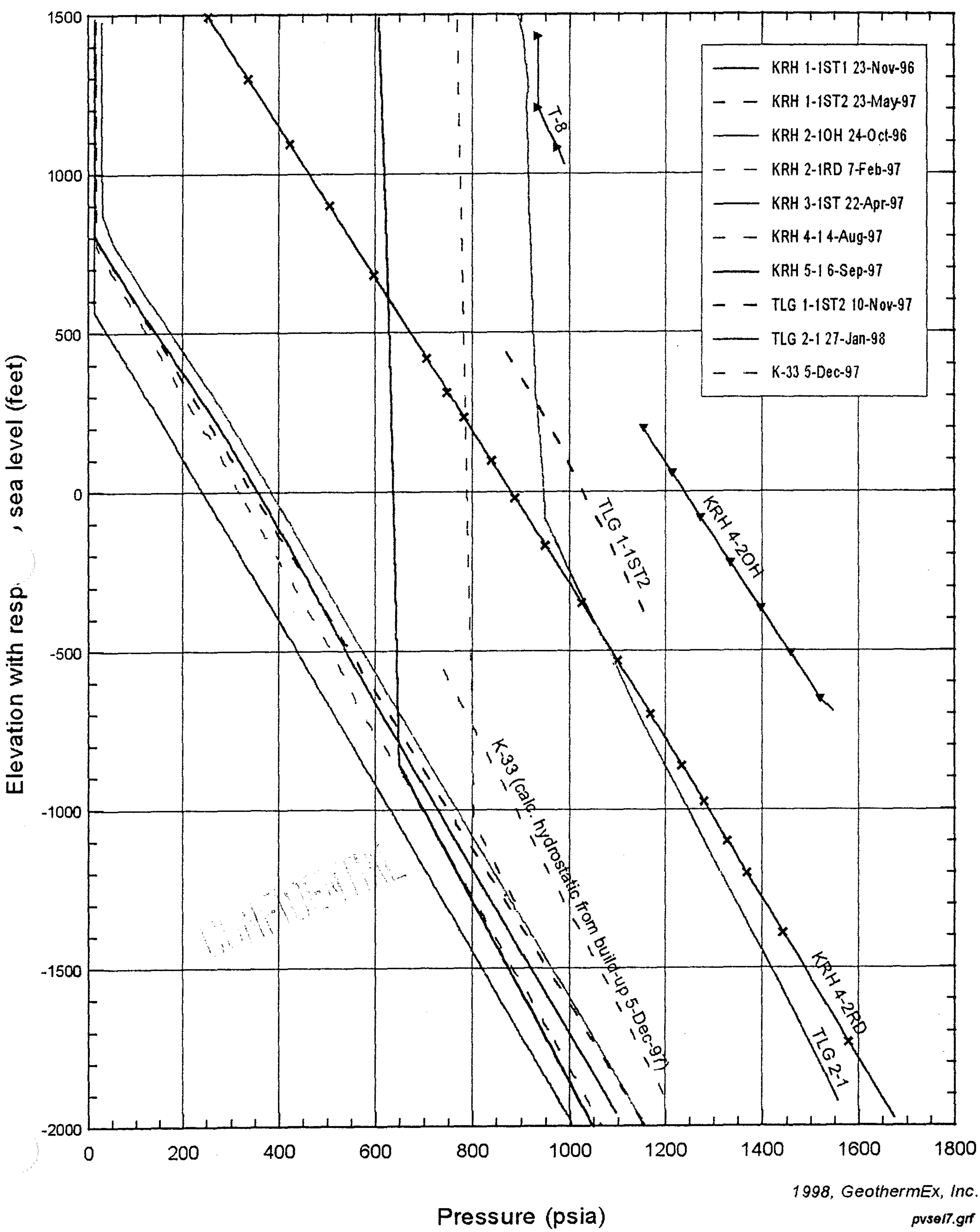



**Figure 3.21: Elevation of the 480°F isotherm, Karaha – Telaga Bodas geothermal field**

# Figure 3.23: Expanded plot of pressure surveys, Karaha geothermal field




1998, GeothermEx, Inc.

pvsel7.grf

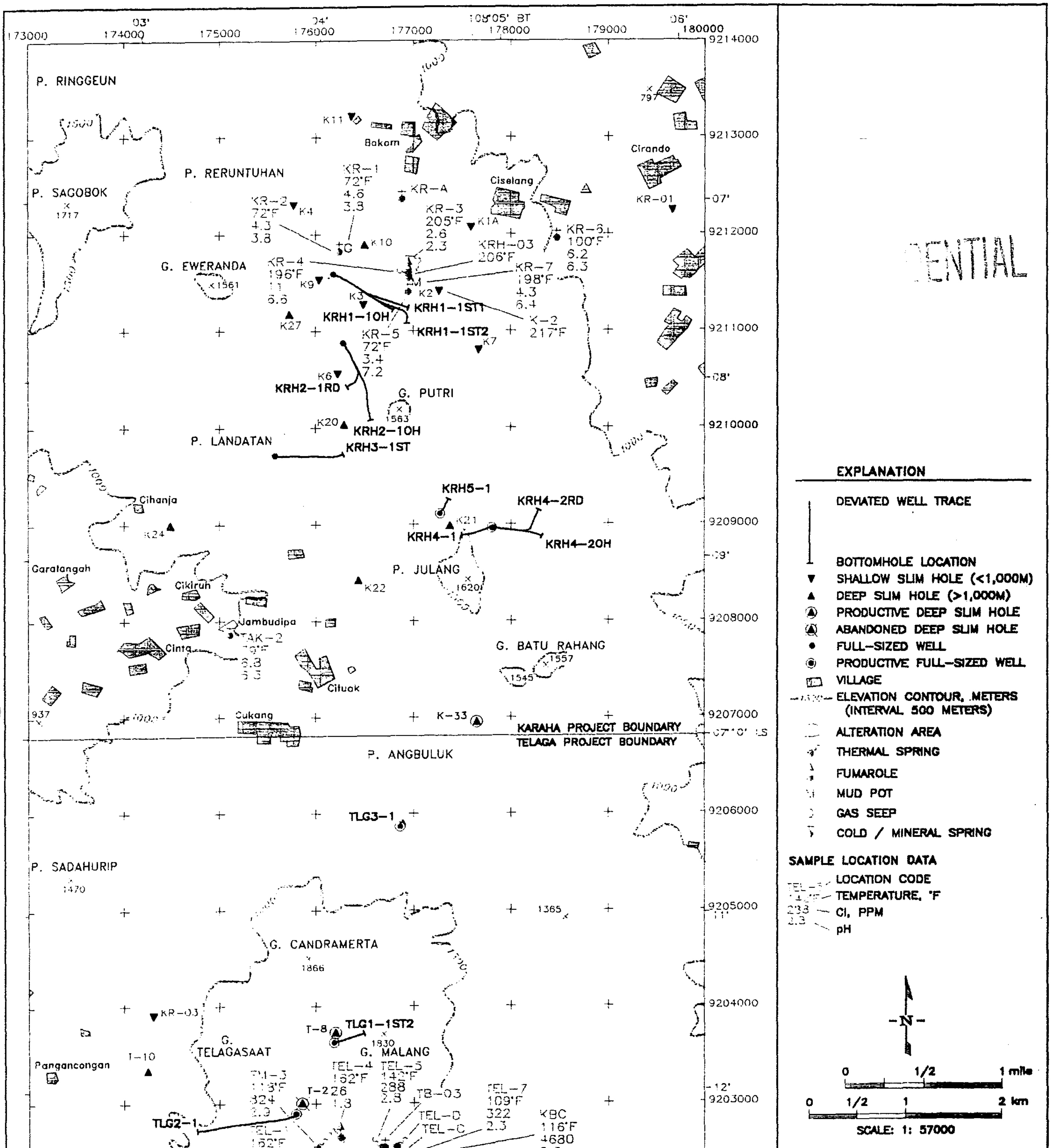



**Figure 3.24: Map of fluid sample locations, showing temperature, Cl and pH at surface features, Karaha–Telaga Bodas area**

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| | |
|---|---|
| FILE: KT1_57CH.DWG | SCALE: 1 : 57000 |

| | | |
|---|---|---|
| PLOTDATE: 22APR98 | PRINT: KARAHA.SS | BY: RRS |

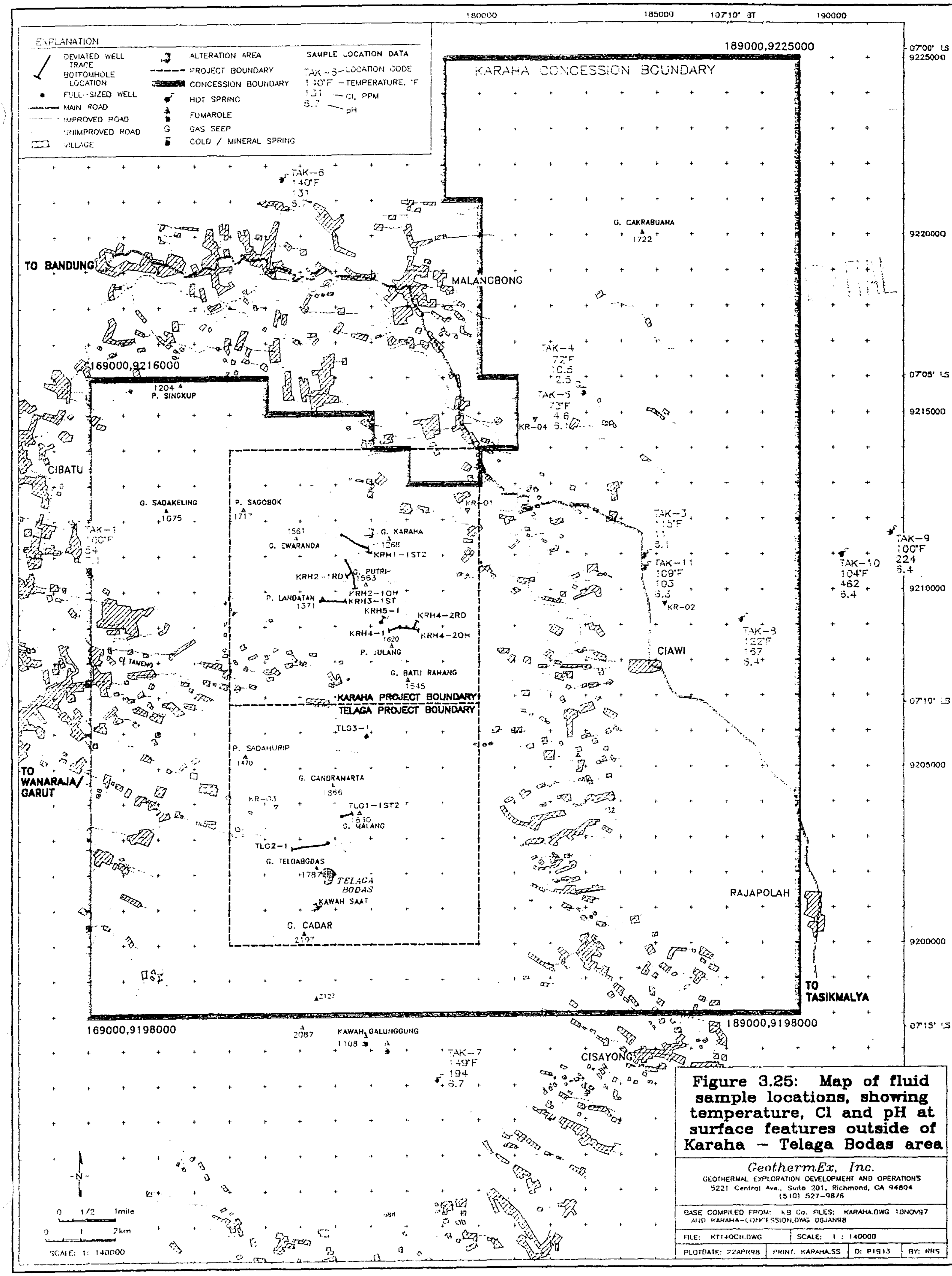
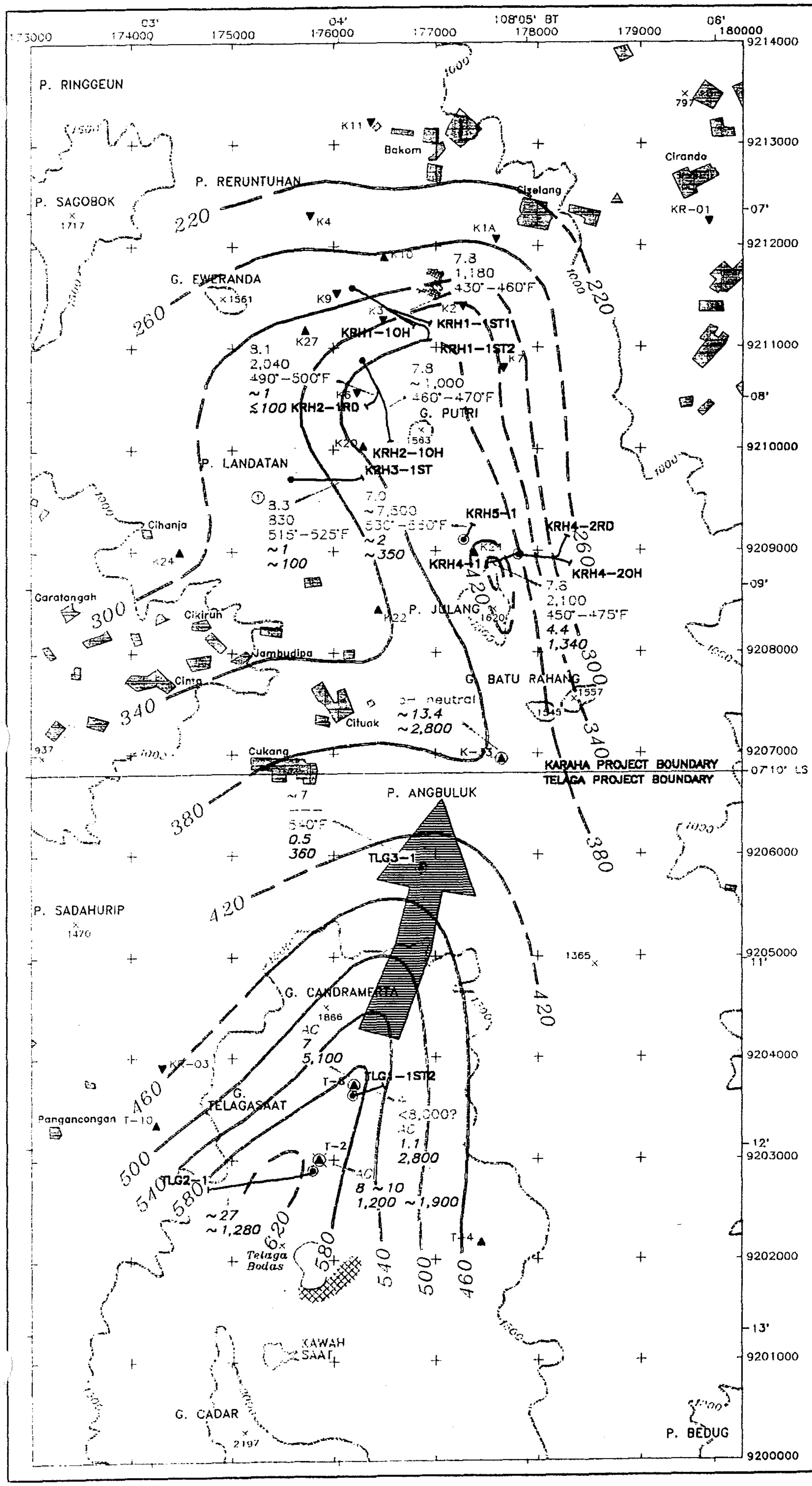



**Figure 3.25: Map of fluid sample locations, showing temperature, Cl and pH at surface features outside of Karaha – Telaga Bodas area**




CONFIDENTIAL

**EXPLANATION**

- DEVIATED WELL TRACE
- BOTTOMHOLE LOCATION
- ▼ SHALLOW SLIM HOLE (<1,000M)
- ▲ DEEP SLIM HOLE (>1,000M)
- PRODUCTIVE DEEP SLIM HOLE
- ABANDONED DEEP SLIM HOLE
- ● FULL-SIZED WELL
- PRODUCTIVE FULL-SIZED WELL
- VILLAGE
- ELEVATION CONTOUR, METERS (INTERVAL 500 METERS)
- ALTERATION AREA

**SAMPLE LOCATION DATA**

| | |
|---|---|
| 3.3 | pH SAMPLE |
| 2,040 | Cl RESERVOIR LIQUID |
| 500°F | CHEMICAL GEOTHERMOMETERS, °F |
| AC | AC = ACID-Cl CONDENSATE |
| ~2 | NCG/STEAM AT 116 PSIA, WT% |
| ~350 | $H_2S$/STEAM AT 116 PSIA, PPMW |

**NOTE:**

(1) DATA INCLUDE WATER FLOW AT pH 2.2, LOW $SO_4$; HIGH Cl BEFORE COMPLETION OF DRILLING

- GENERAL DIRECTION OF FLUID MOVEMENT SUGGESTED BY CHEMISTRY AND ISOTOPES
- ACID-Cl FUMAROLES AND STEAM-HEATED SPRINGS
- ACID-$SO_4$ FUMAROLE POOLS AND STEAM-HEATED HOT SPRINGS
- –460– TEMPERATURE CONTOUR, °F, AT MEAN SEA LEVEL, DASHED WHERE INFERRED

N

0 1/2 1 mile

0 1/2 1 2 km

SCALE: 1: 57000

**Figure 3.26: Schematic map summary of fluids chemistry, Karaha – Telaga Bodas area**

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BASE COMPILED FROM: KB Co. FILES: KARAHA.DWG 10NOV97 AND KARAHA-CONCESSION.DWG 06JAN98

| | |
|---|---|
| FILE: FLUCHEM.DWG | SCALE: 1 : 57000 |

| | | |
|---|---|---|
| PLOTDATE: 22APR98 | PRINT: KARAHA.SS | BY: RRS |

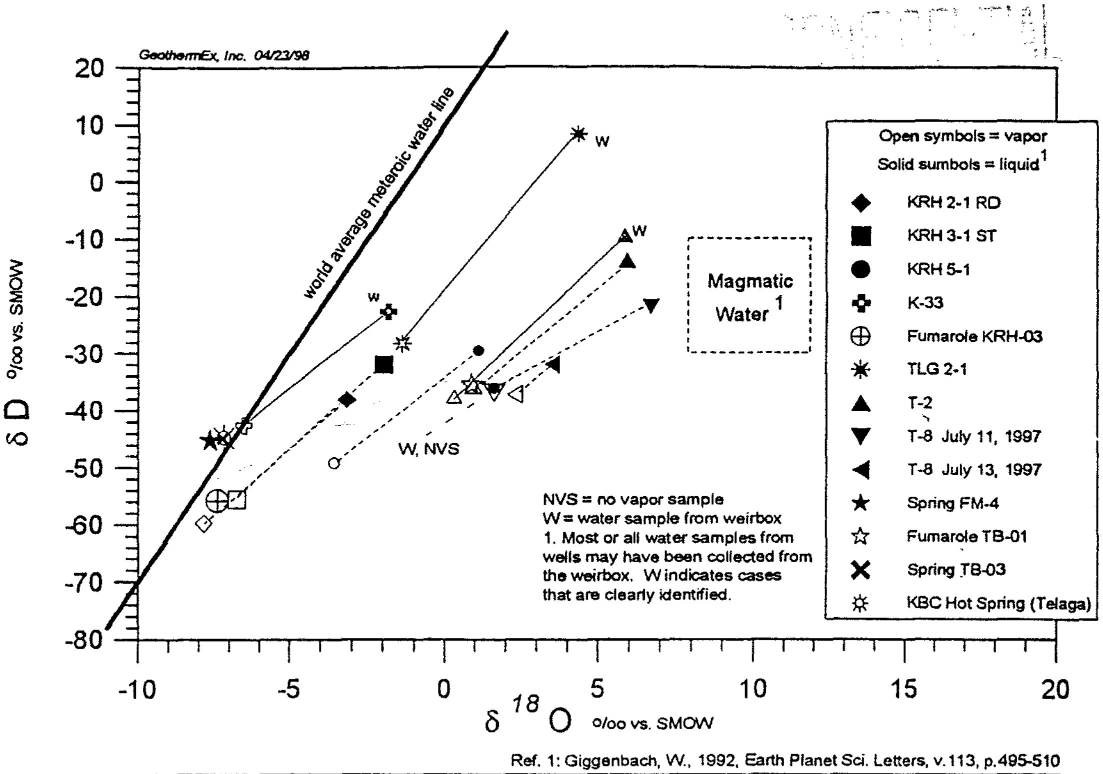



Figure 3.27 : Part A
Stable isotopes of oxygen and hydrogen in water and steam samples - showing samples of water and steam as analysed.

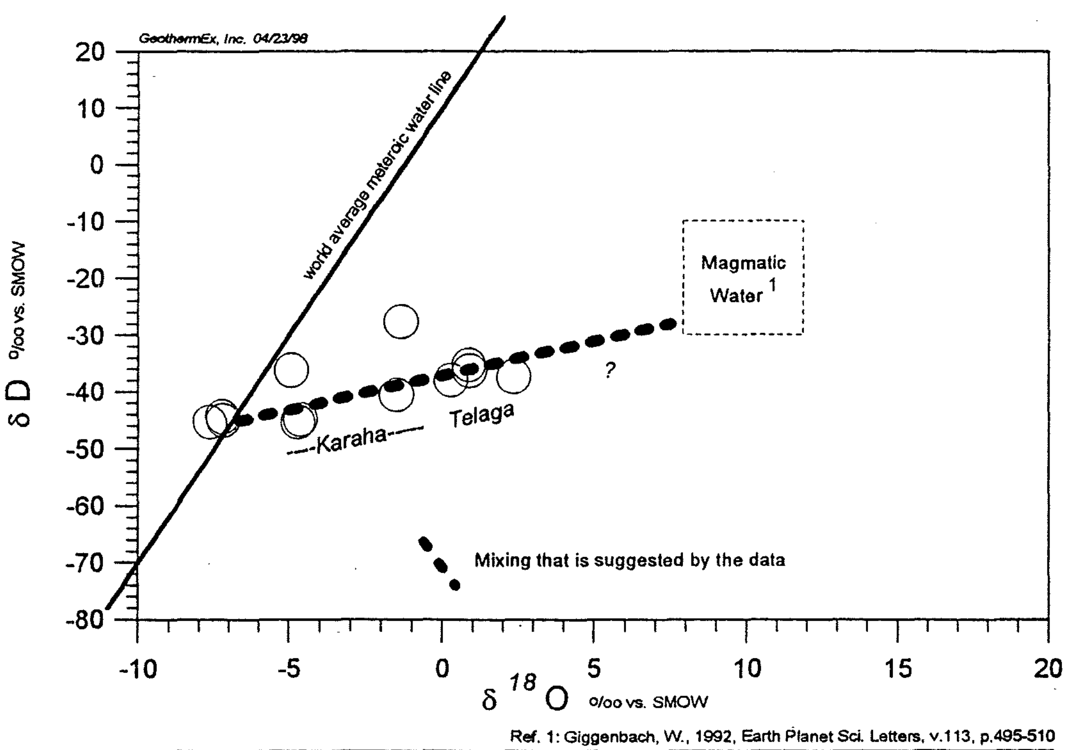
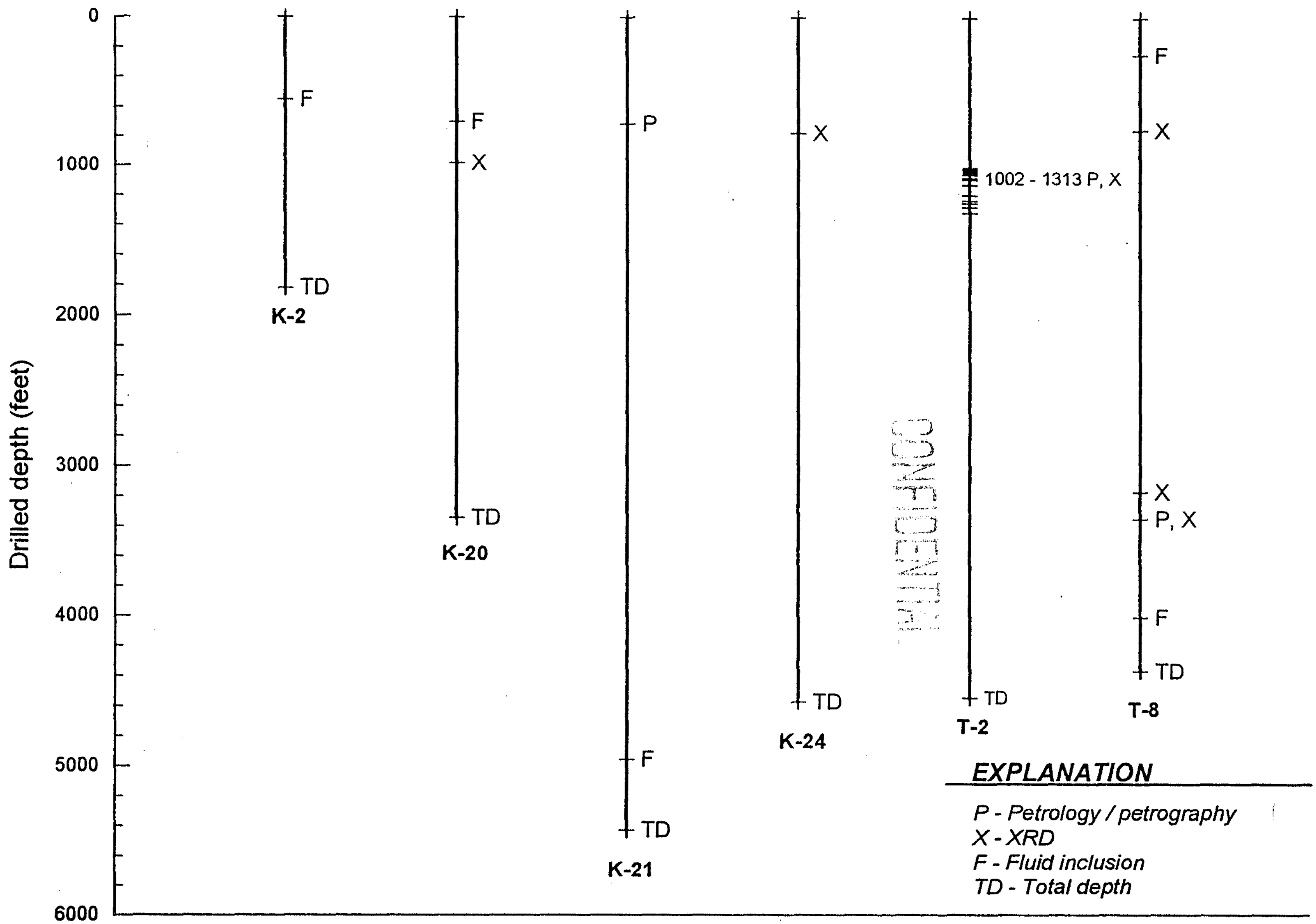



Figure 3.27 : Part B
Stable isotopes of oxygen and hydrogen in water and steam samples - showing approximate reconstructions to total flow.

## Figure 6.1: Petrologic analyses in core holes

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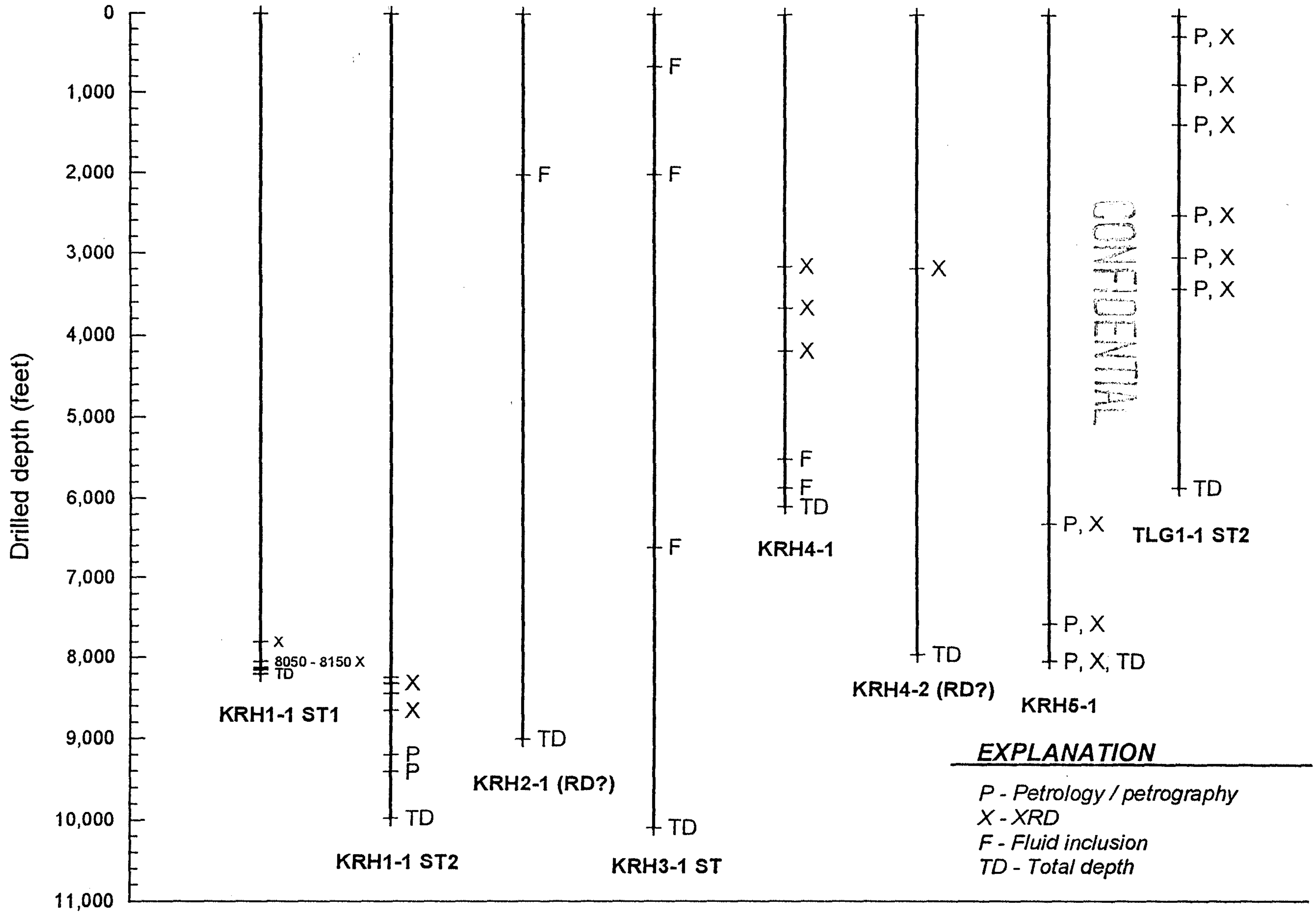
*CORE_SAM.GRF*

## Figure 6.2: Petrologic analyses in full-sized wells




1998, GeothermEx, Inc.
FULL_SAM.GRF

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# ASSESSMENT OF THE GEOTHERMAL RESOURCE IN THE KARAHA - TELAGA BODAS AREA, INDONESIA

## VOLUME II: Appendices

*for*

**FPL ENERGY**
**North Palm Beach, Florida**

*by*

**GeothermEx, Inc.**
**Richmond, California**

**JUNE 1998**

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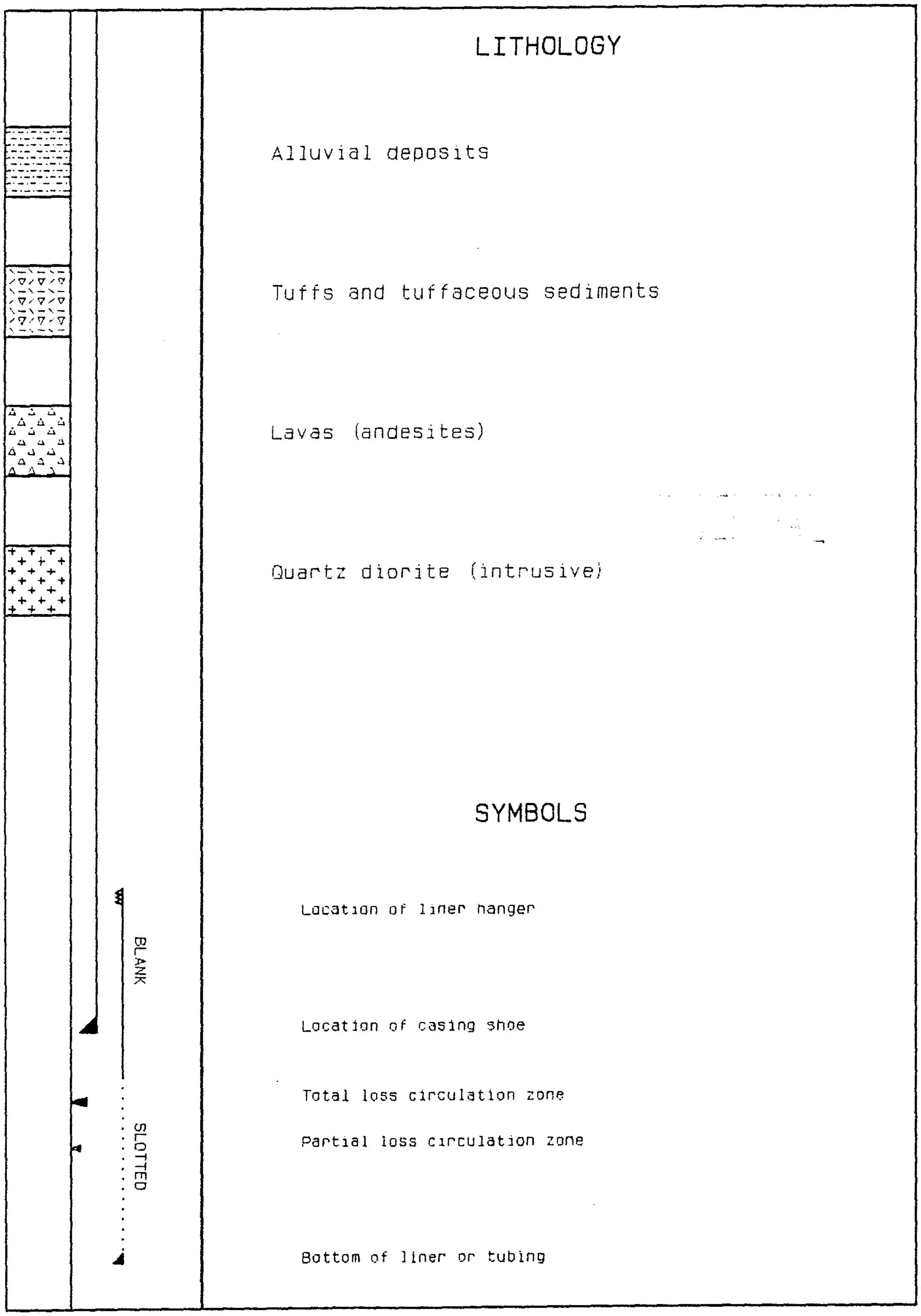
# APPENDIX A: Downhole Summary Plots, Core Holes

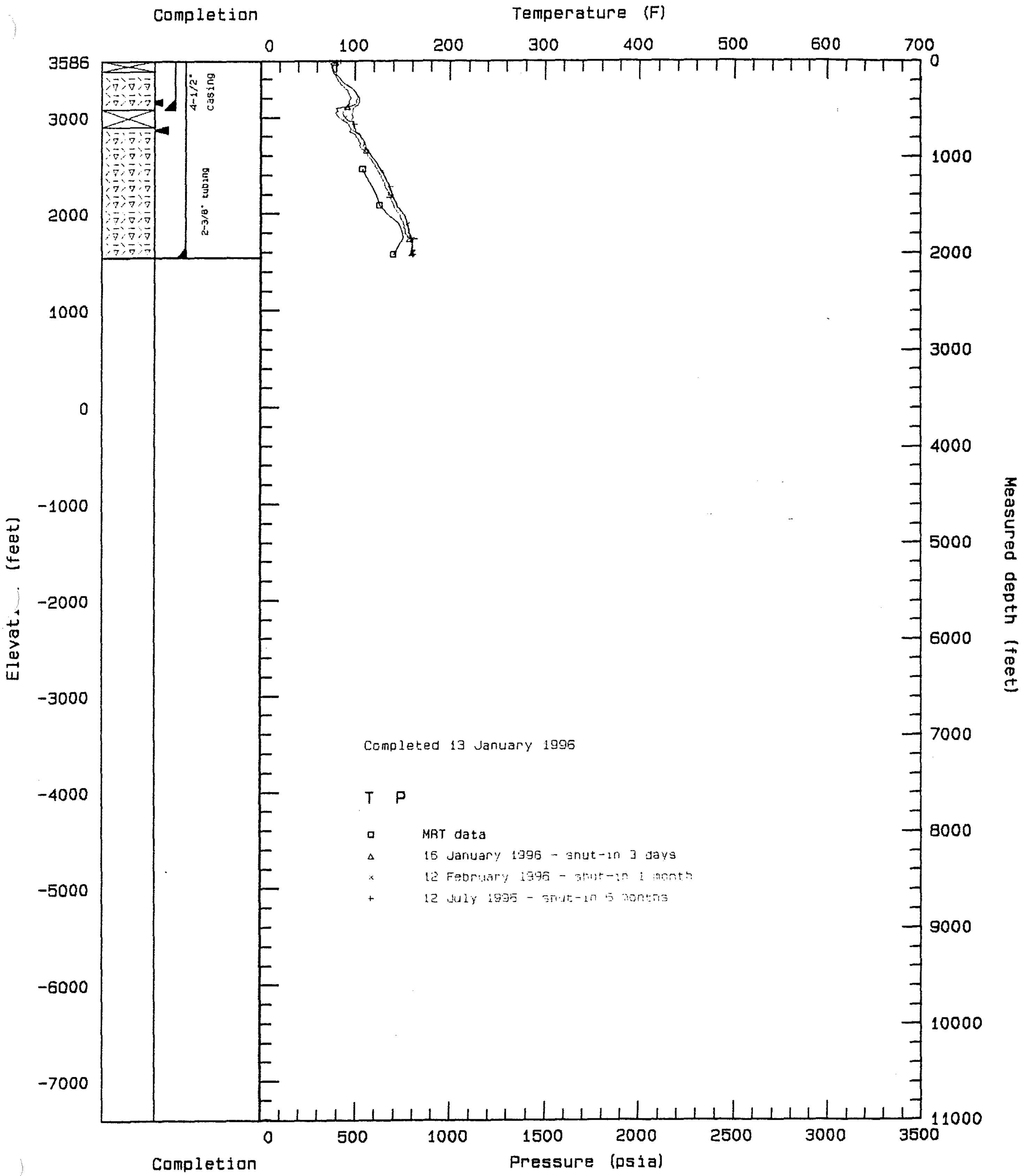
# EXPLANATION FOR KARAHA DOWNHOLE SUMMARY PLOTS




GeothermEx, Inc.

02-10-1998 D:DUMMY.PLT

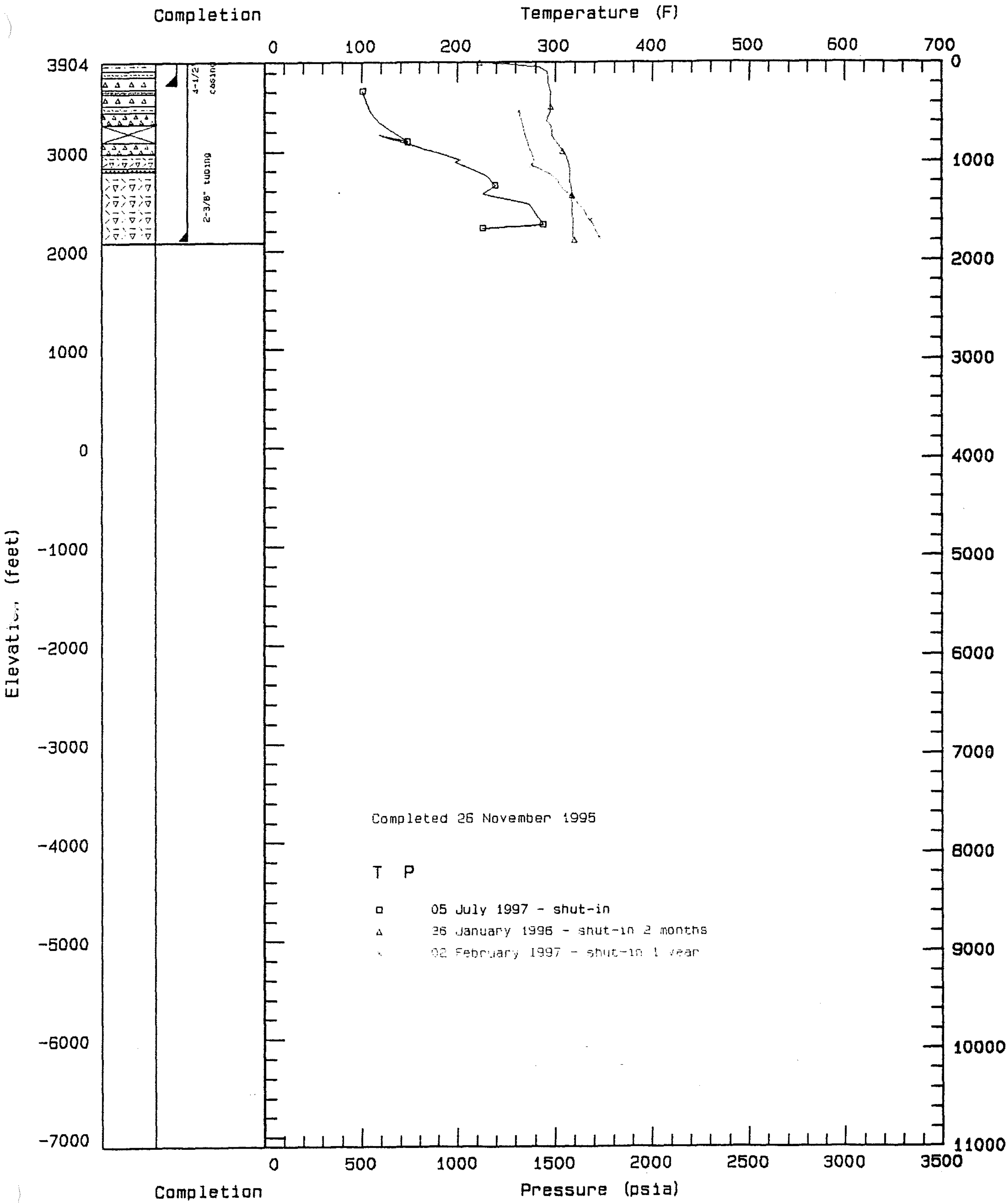
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-1A




GeothermEx, Inc.

03-09-1998 D: MRT.PLT

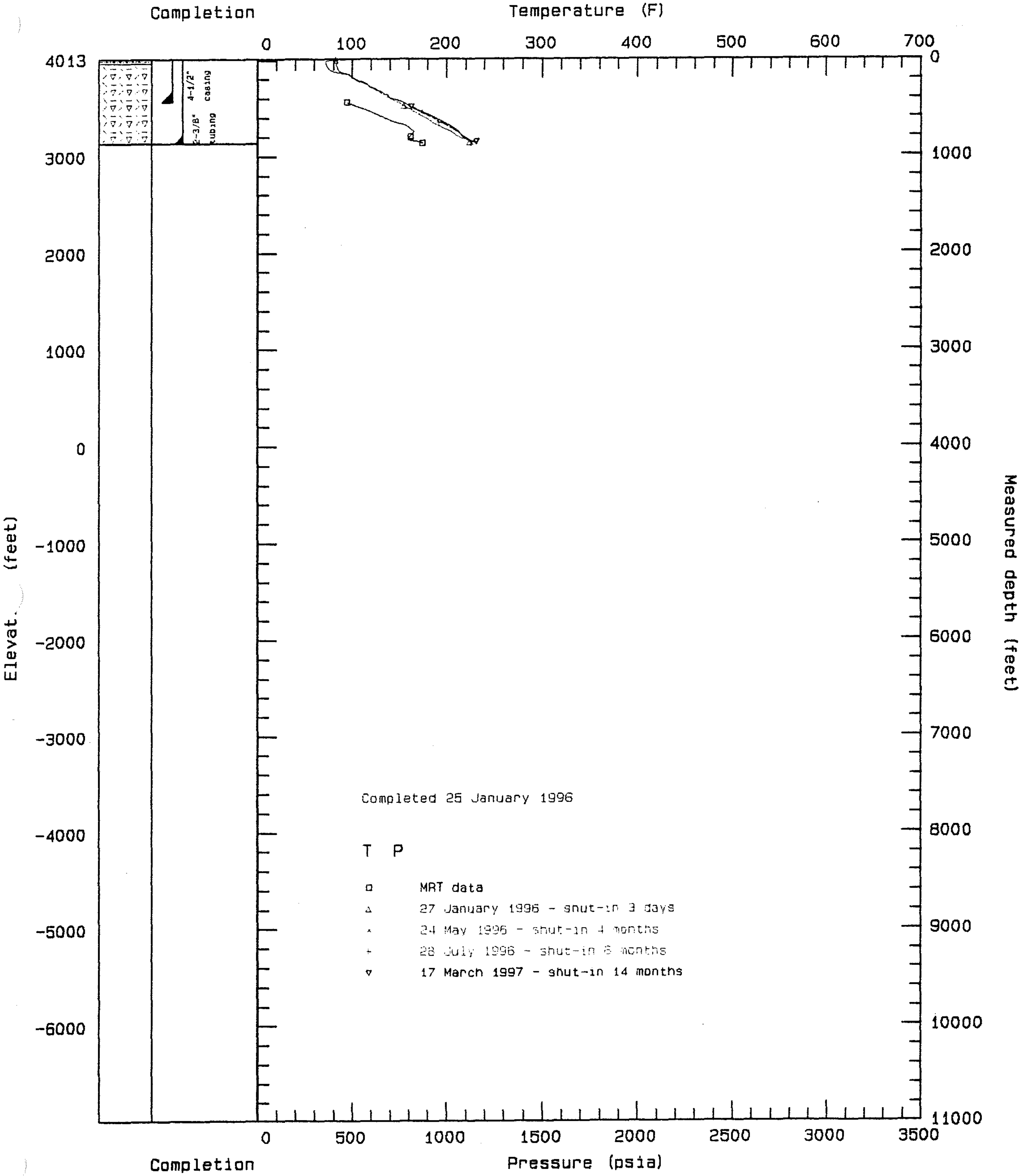
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-2




GeothermEx, Inc.

03-09-1998 D: MRT.PLT

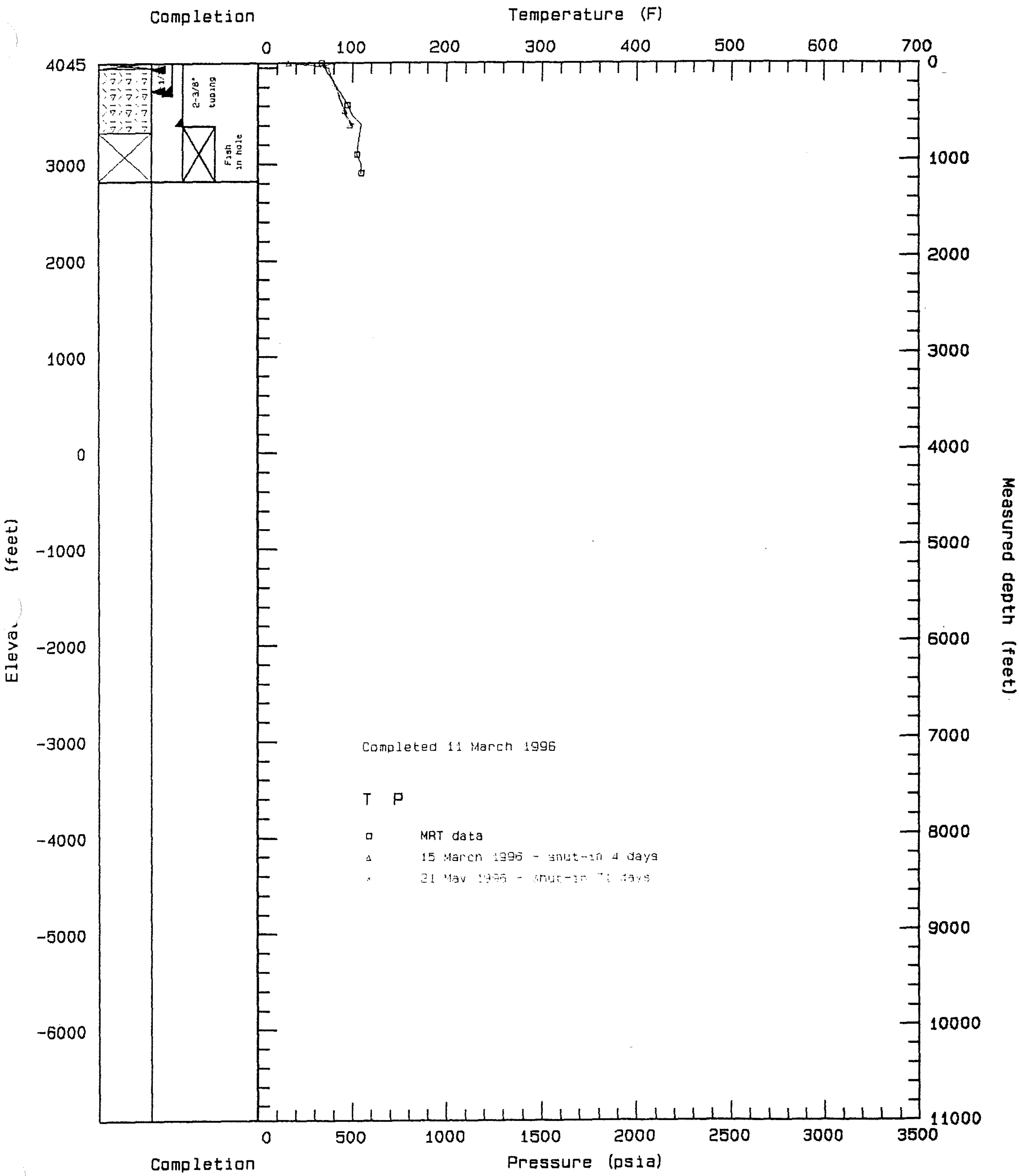
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-3




GeothermEx, Inc.

03-09-1998 D: MRT.PLT

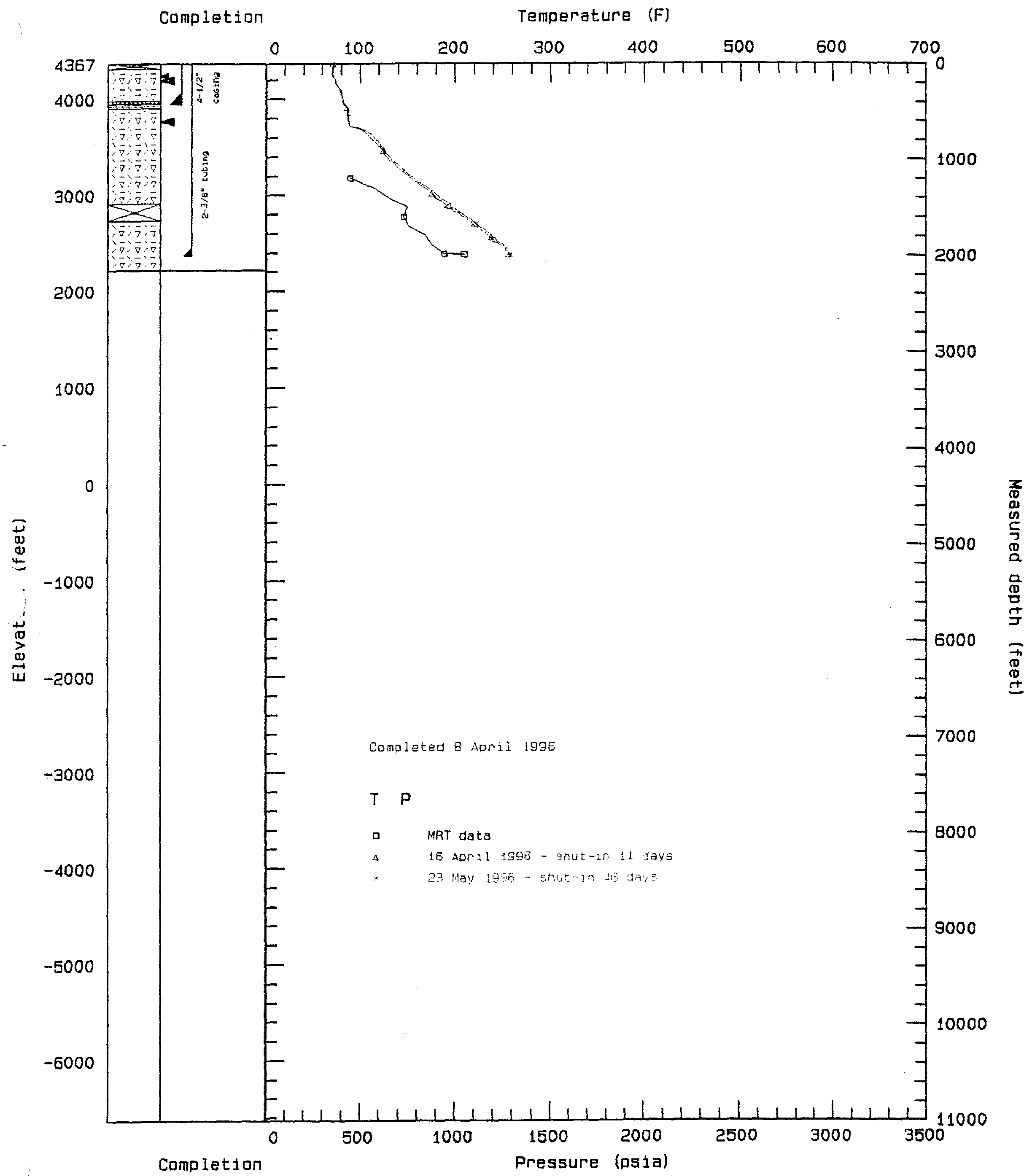
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-4




GeothermEx, Inc.

03-09-1998 D:MRT.PLT

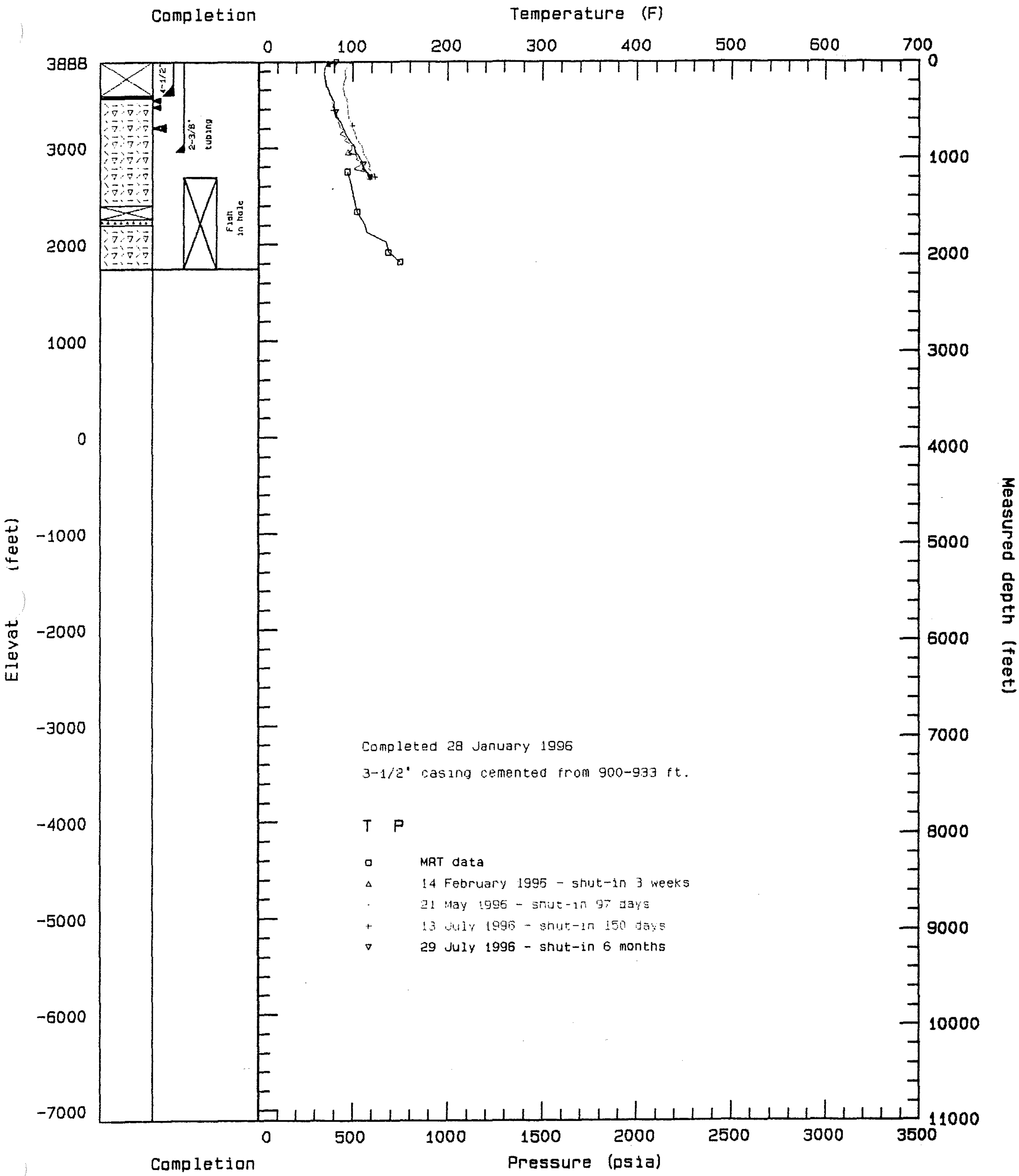
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-6




GeothermEx, Inc.

03-09-1998 D: MRT.PLT

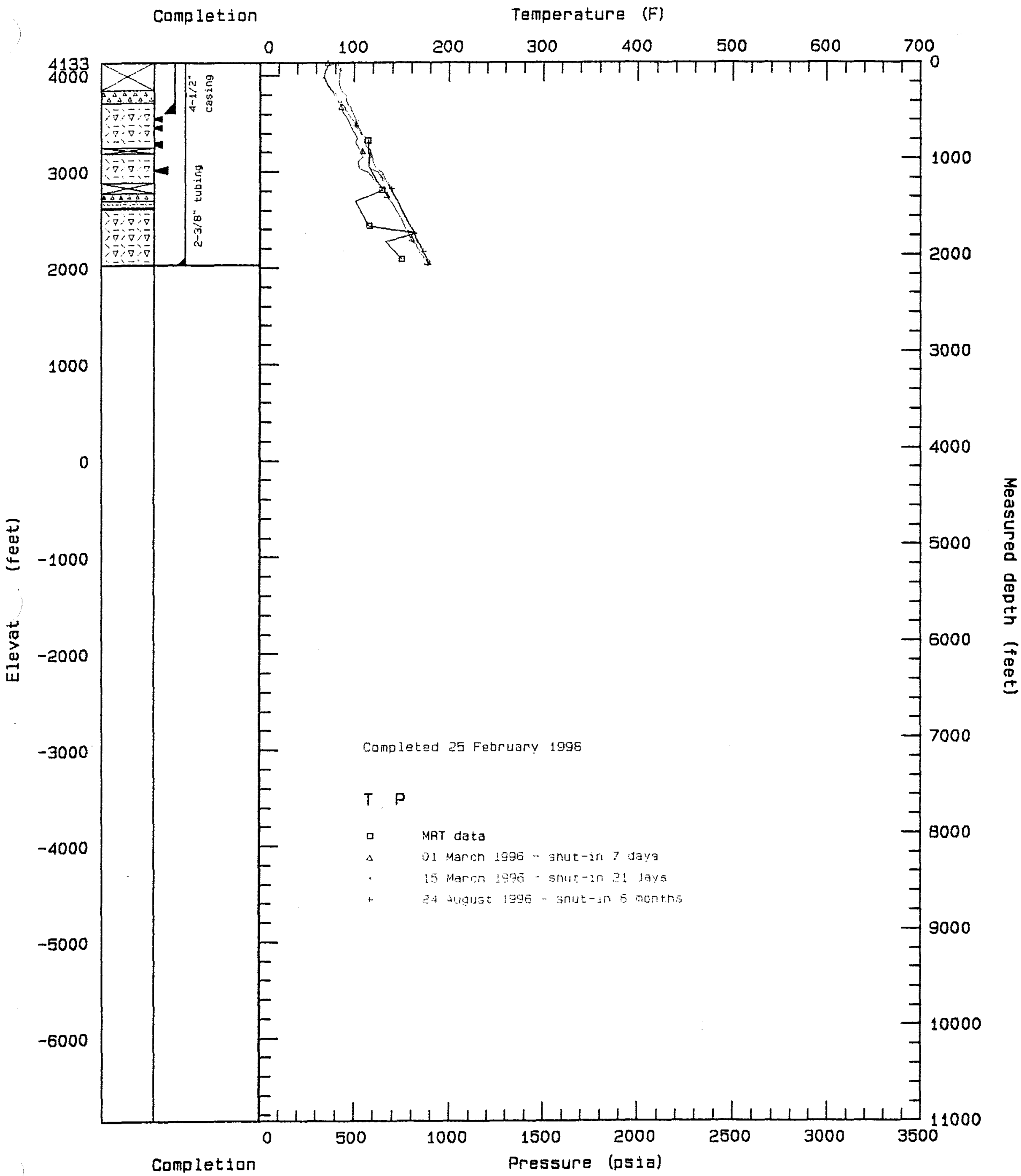
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-7




GeothermEx, Inc.

03-09-1998 D:MRT.PLT

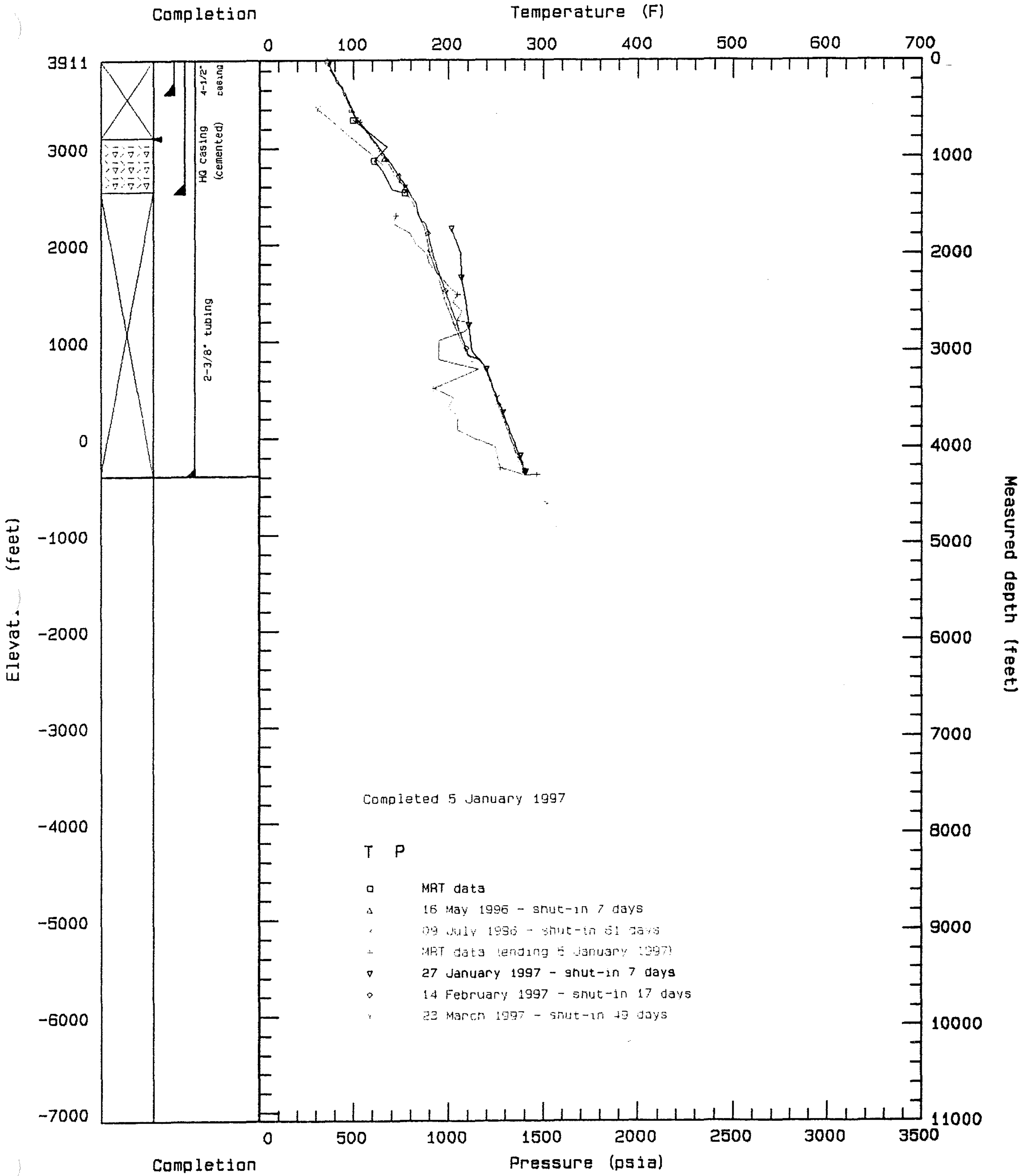
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-9




GeothermEx, Inc.

03-09-1998 D:MRT.PLT

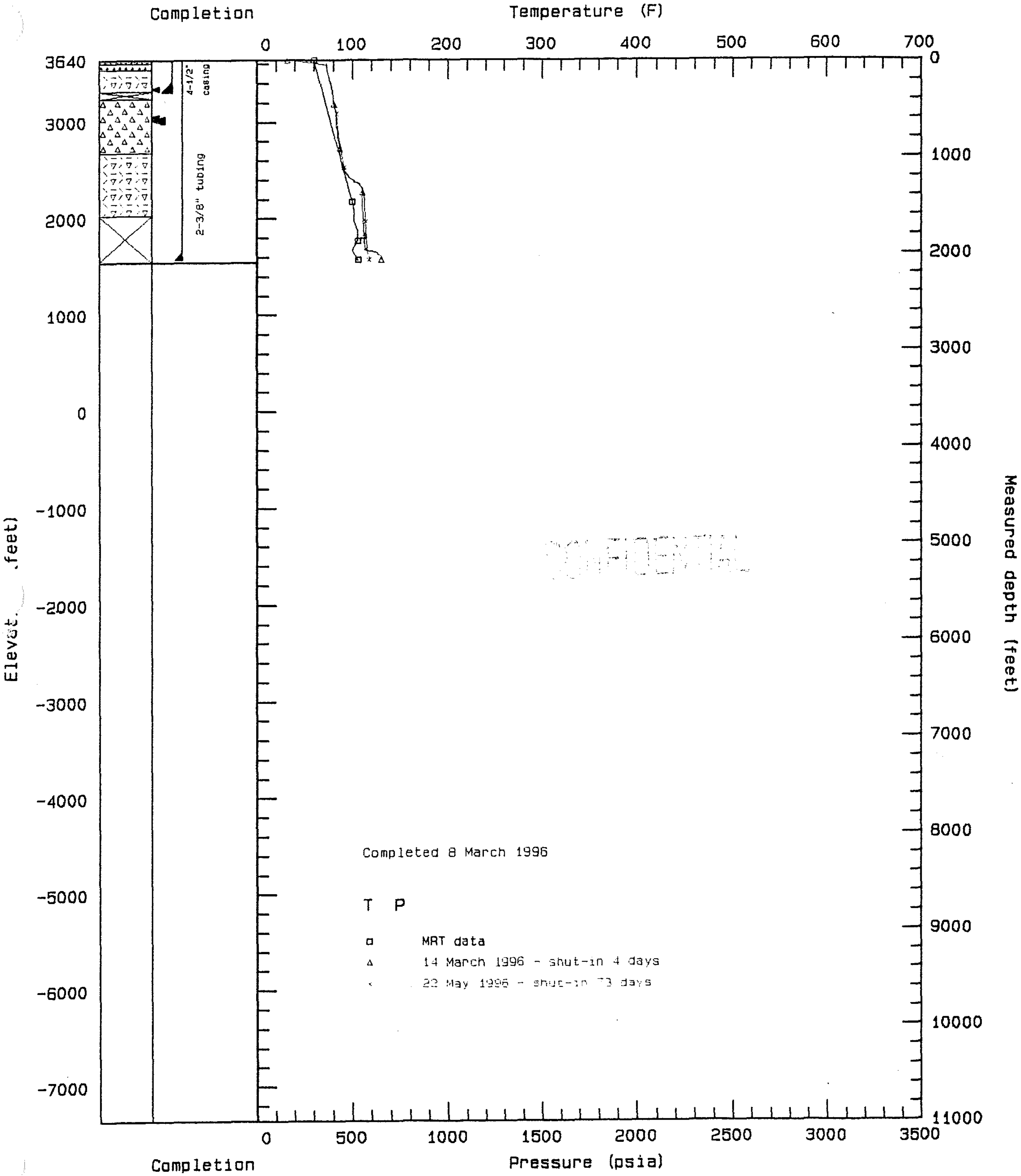
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-10




GeothermEx, Inc.

03-09-1998 D: MRT.PLT

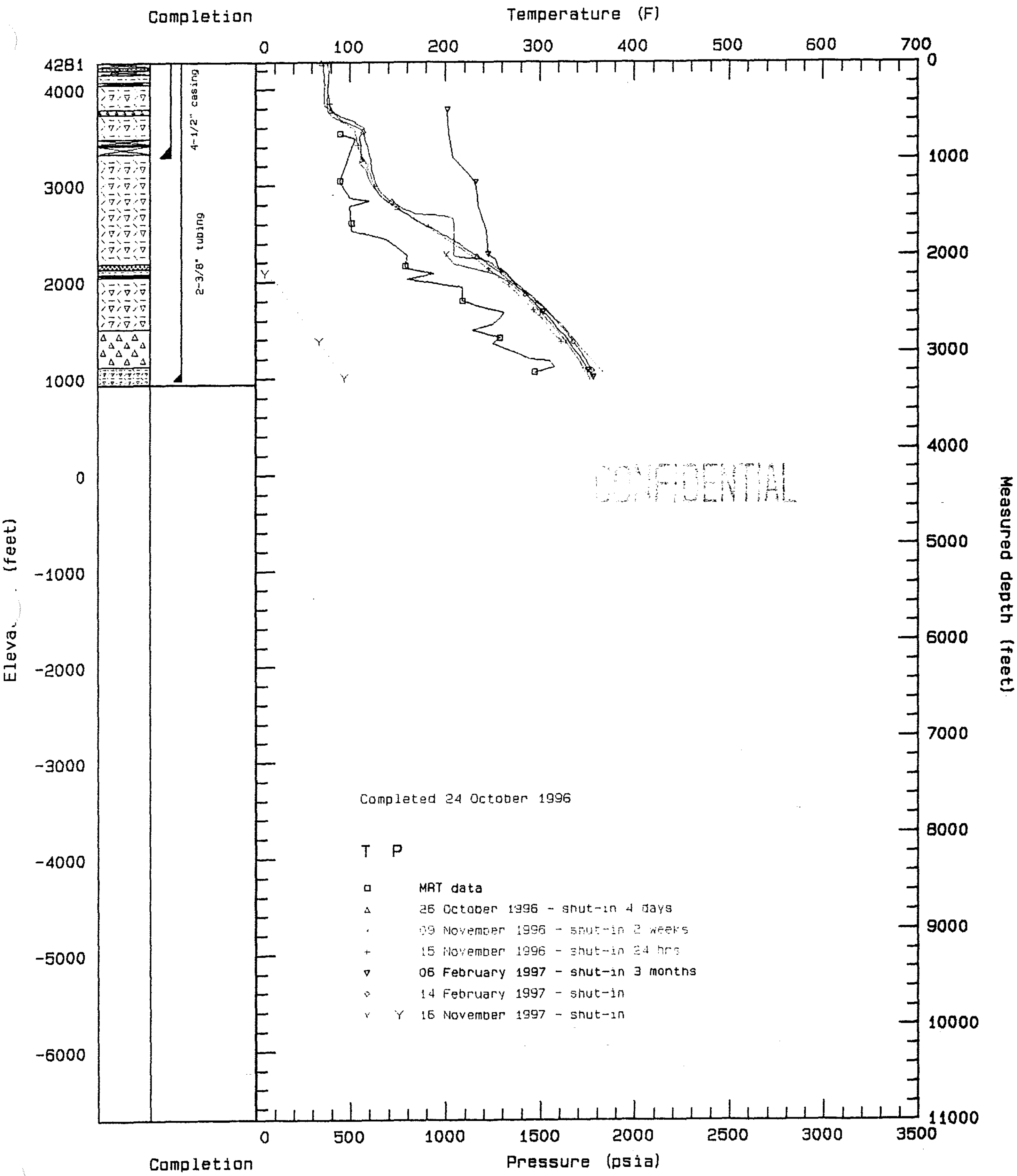
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-11




GeothermEx, Inc.

03-09-1998 D:MRT.PLT

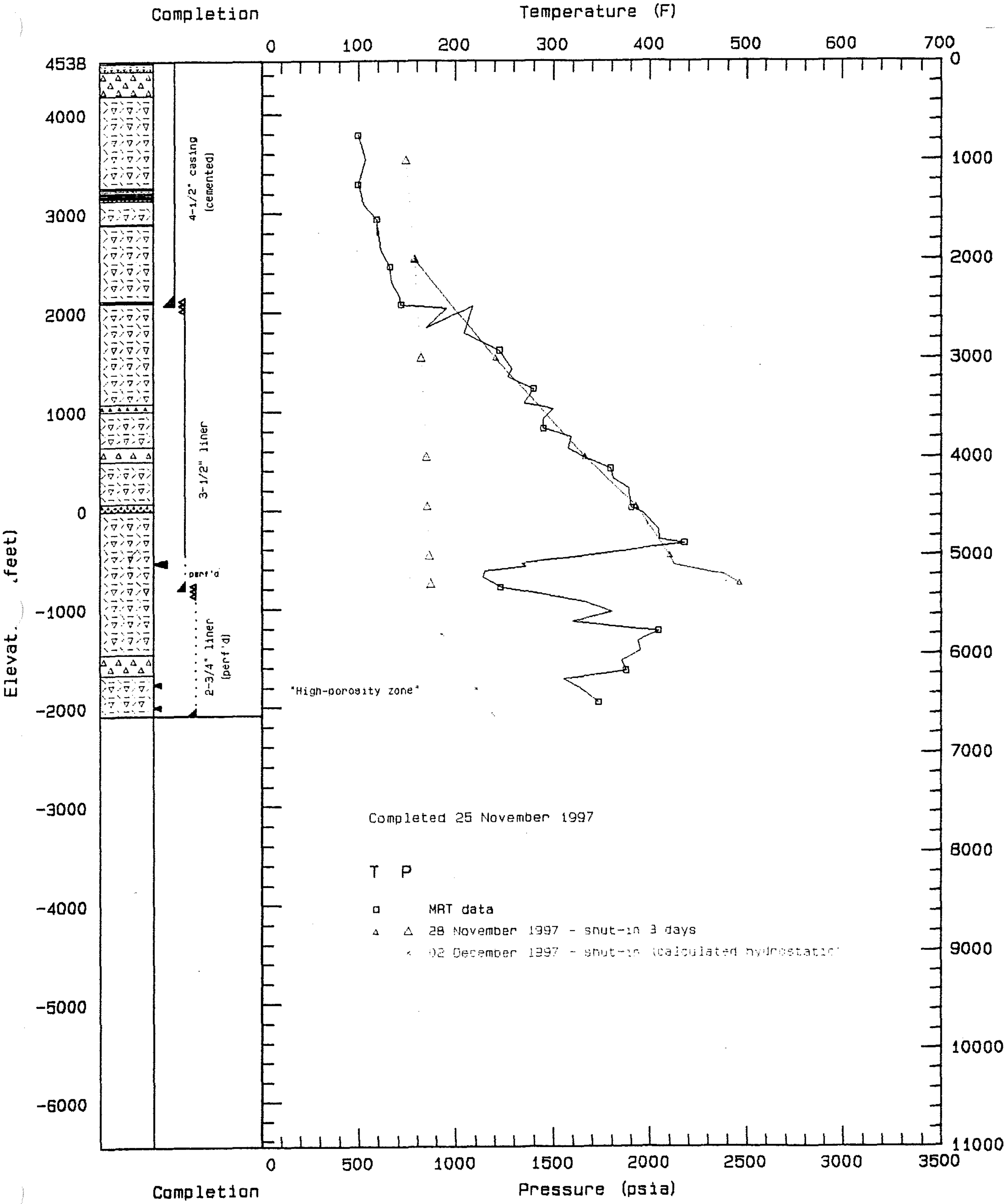
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-20




GeothermEx, Inc.

03-31-1998 D: MRT.PLT

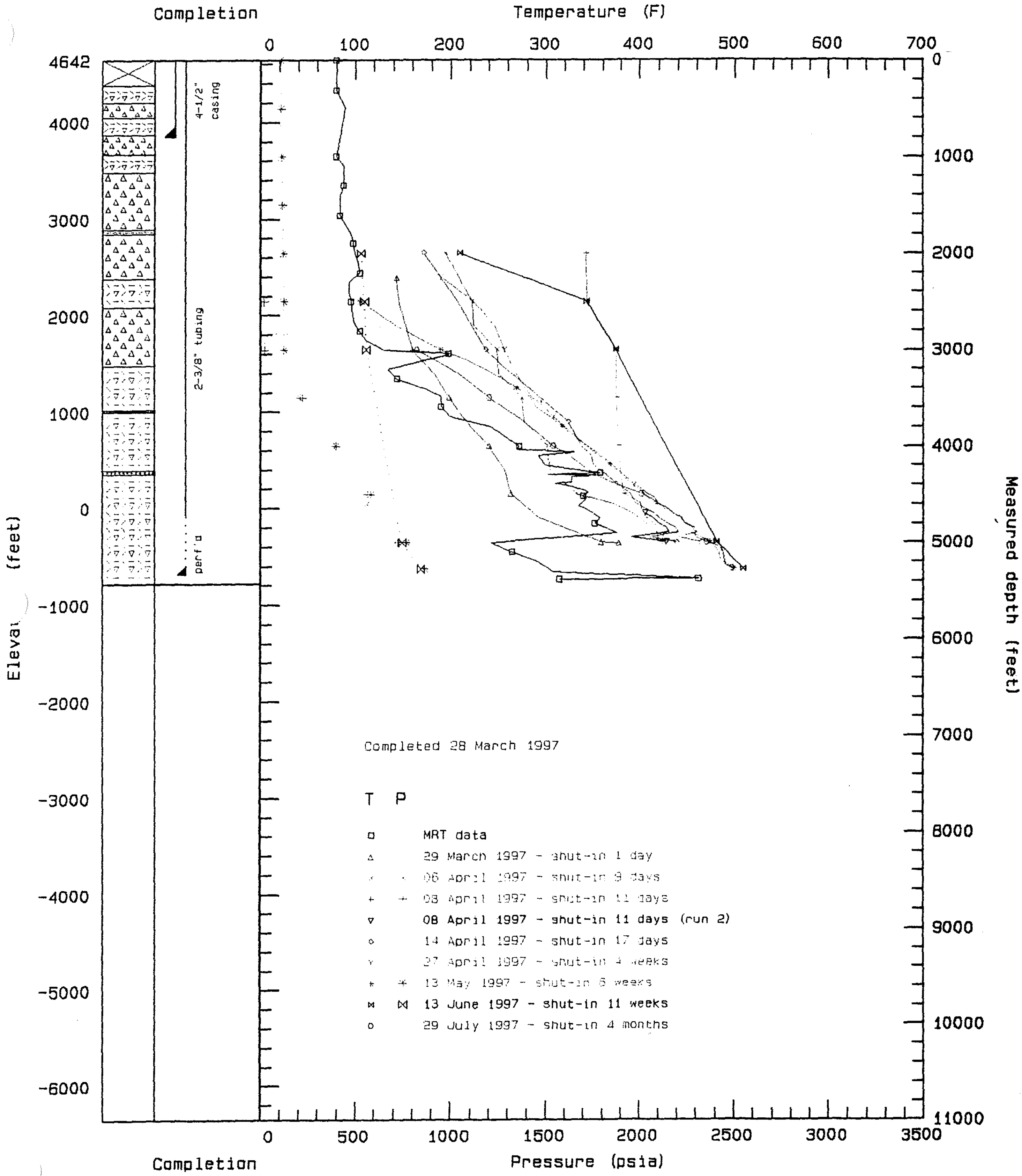
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-33




GeothermEx, Inc.

03-09-1998 D: MRT.PLT

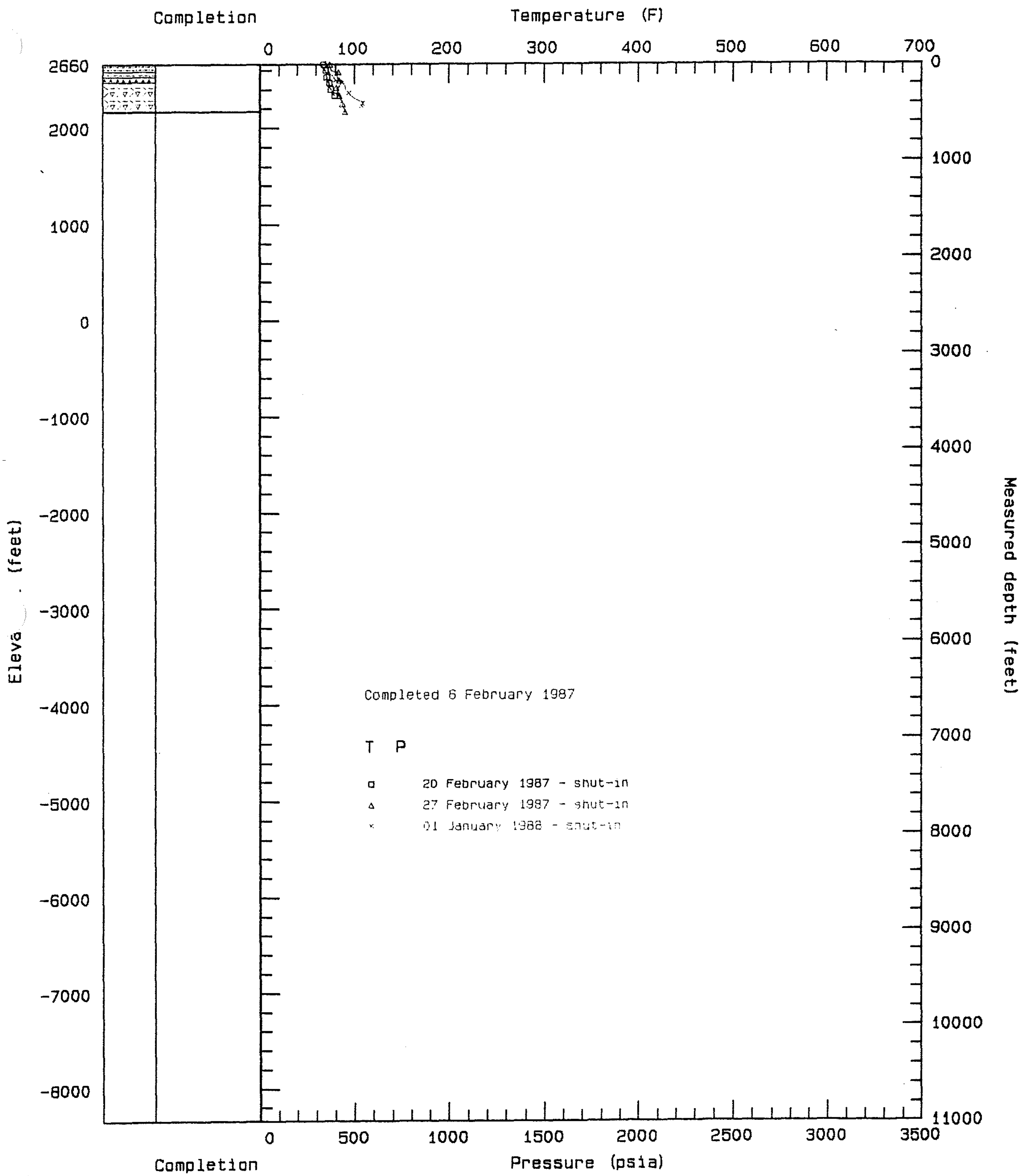
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE K-21




GeothermEx, Inc.

03-09-1998 D: MRT.PLT

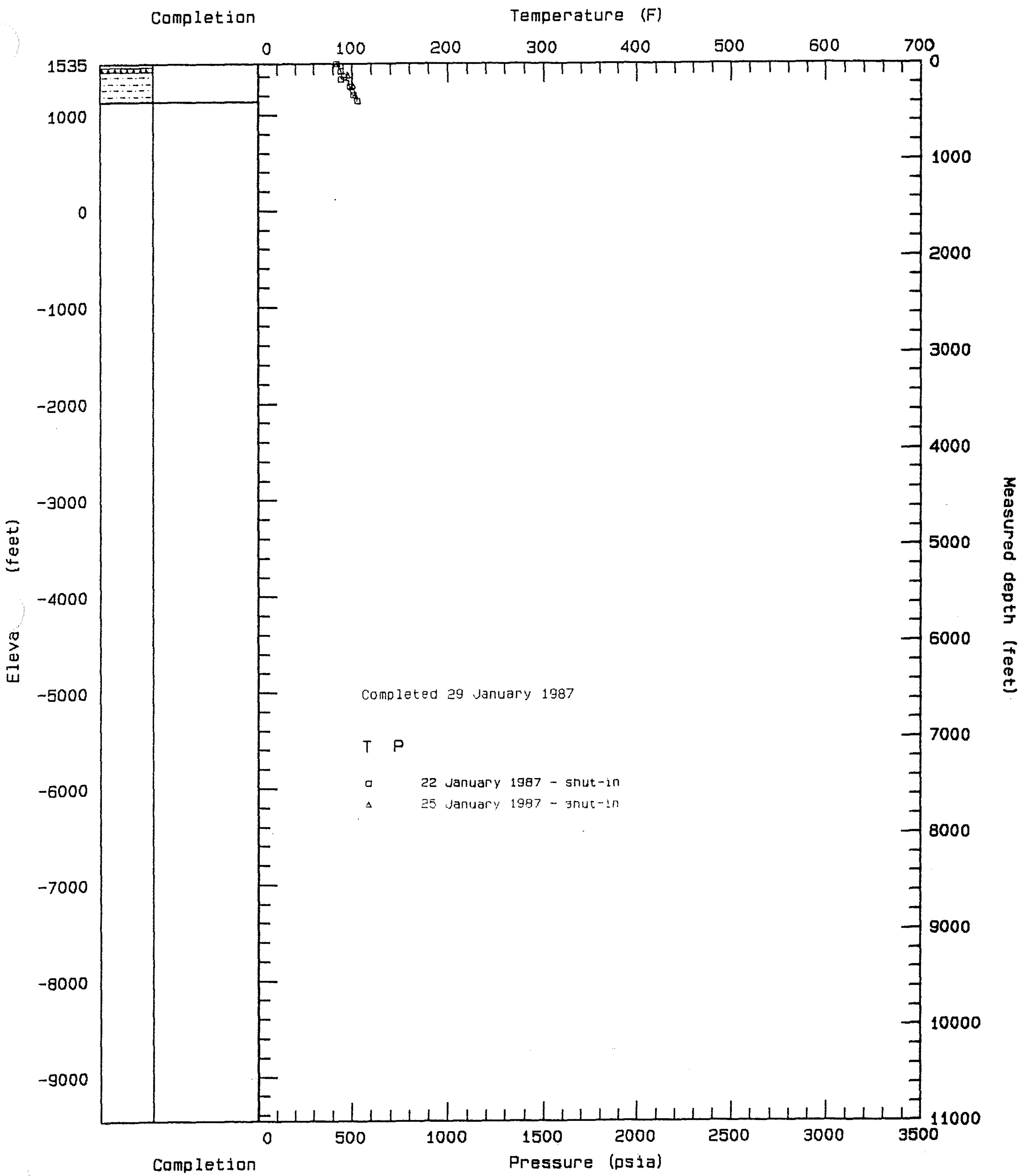
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE KR-1




GeothermEx, Inc.

03-31-1998 D: T870220.PLT

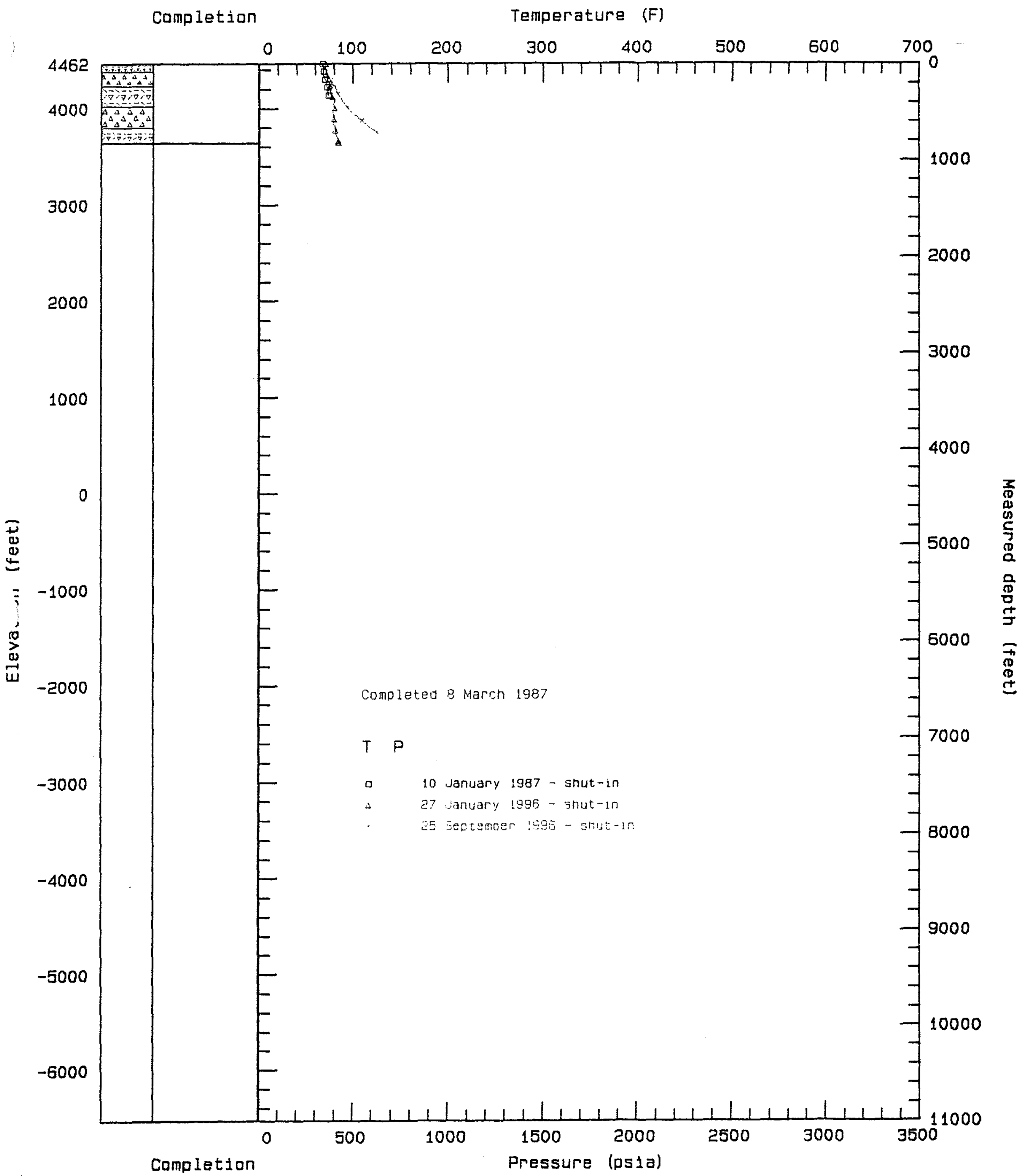
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE KR-2




GeothermEx, Inc.

01-28-1998 D: T870122.PLT

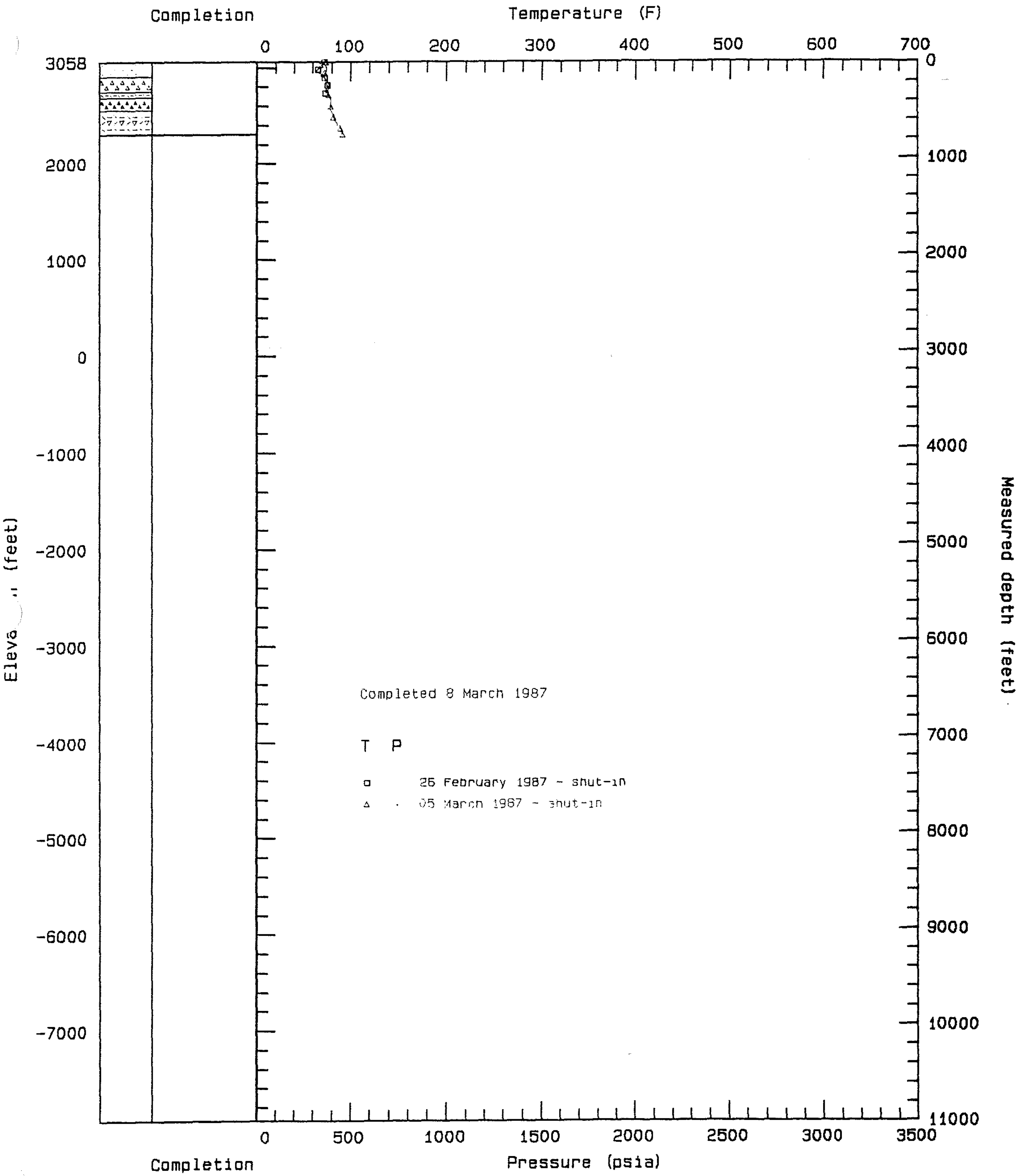
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE KR-3




GeothermEx, Inc.

01-28-1998 D:T870110.PLT

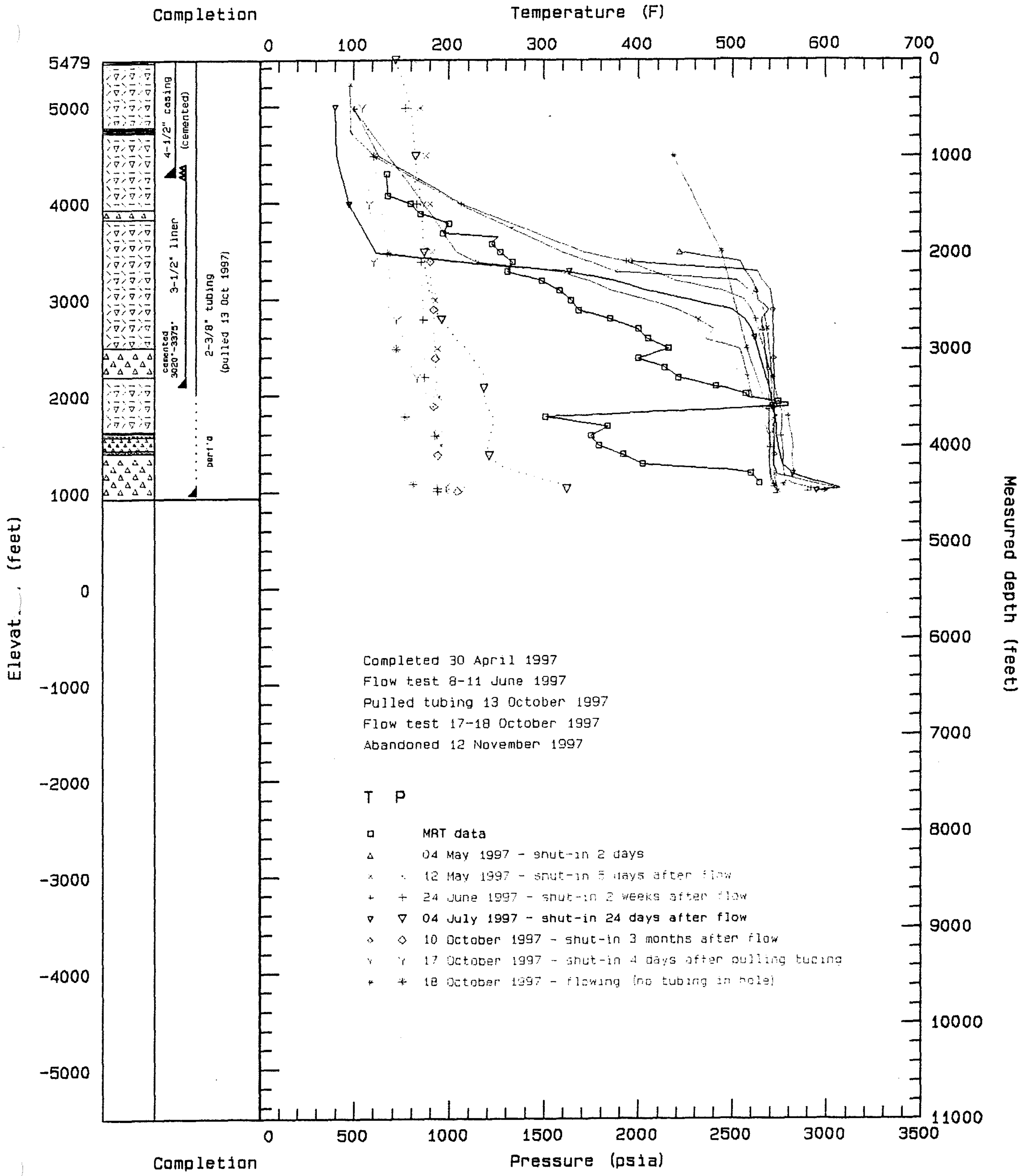
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE KR-4




GeothermEx, Inc.

01-28-1998 D: T870226.PLT

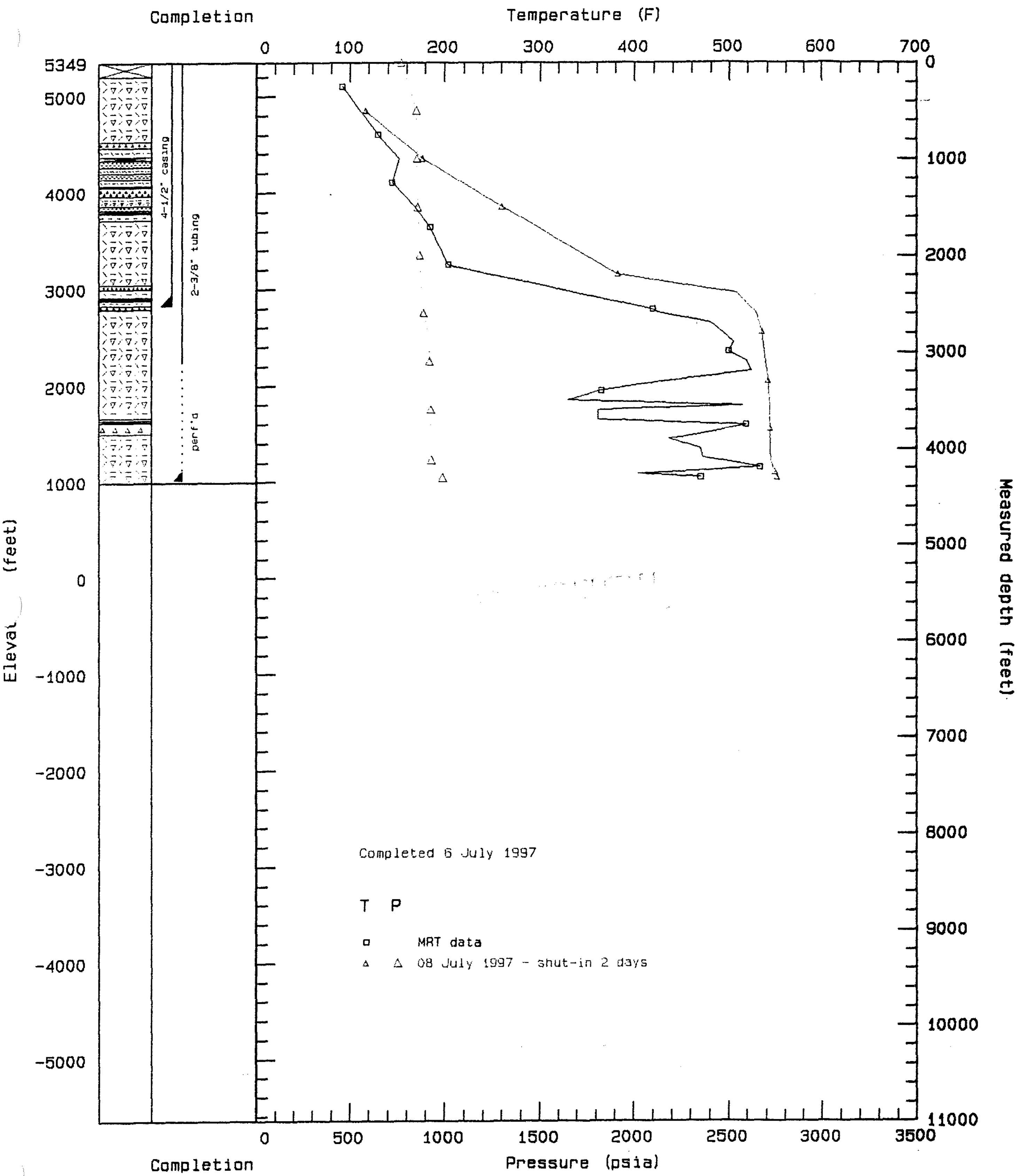
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE T-2




GeothermEx, Inc.

03-31-1998 0: MRT.PLT

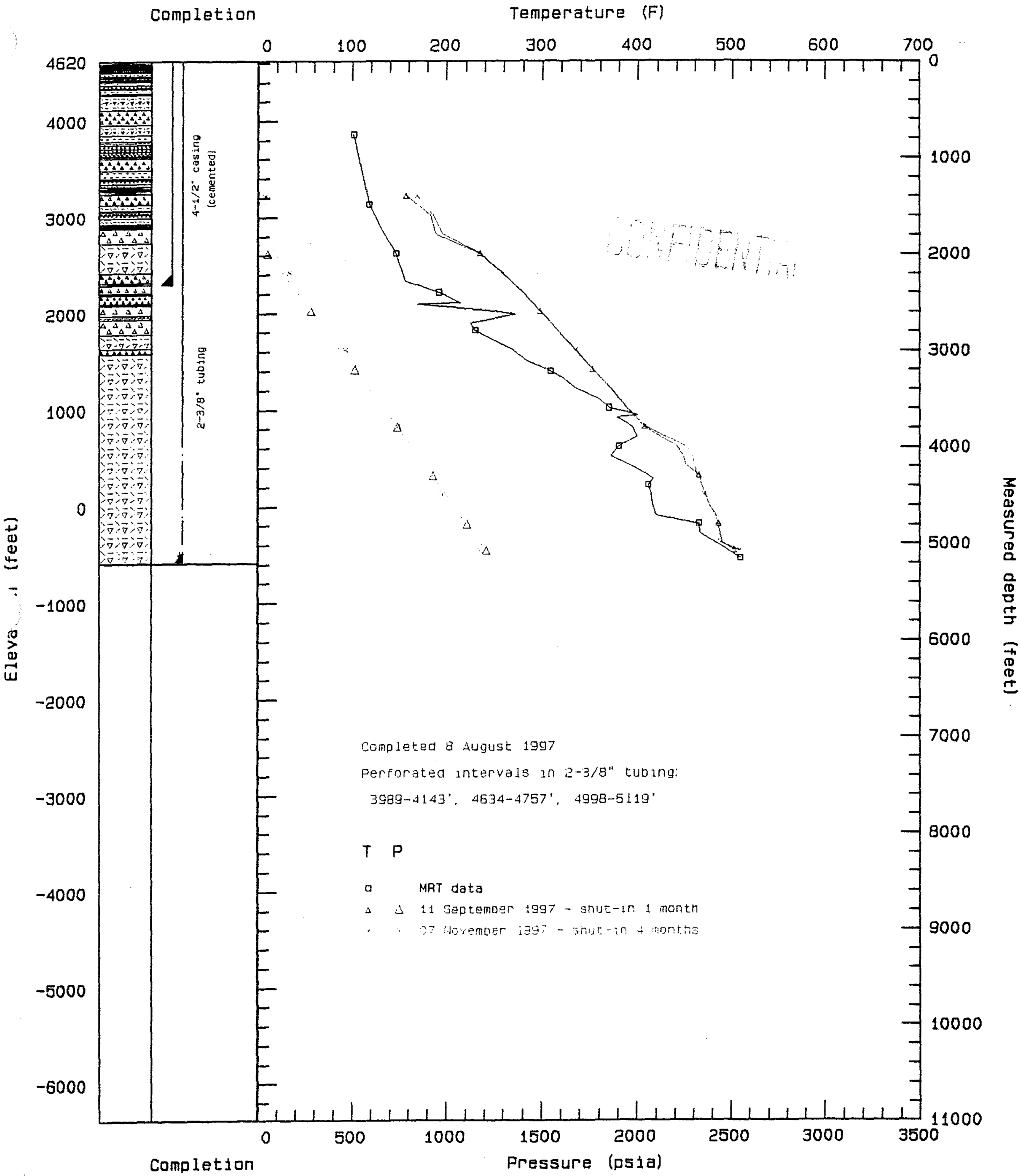
# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE T-8




GeothermEx, Inc.

03-09-1998 D:MRT.PLT

# DOWNHOLE SUMMARY PLOT, KARAHA COREHOLE T-10

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03-31-1998 D: MRT.PLT

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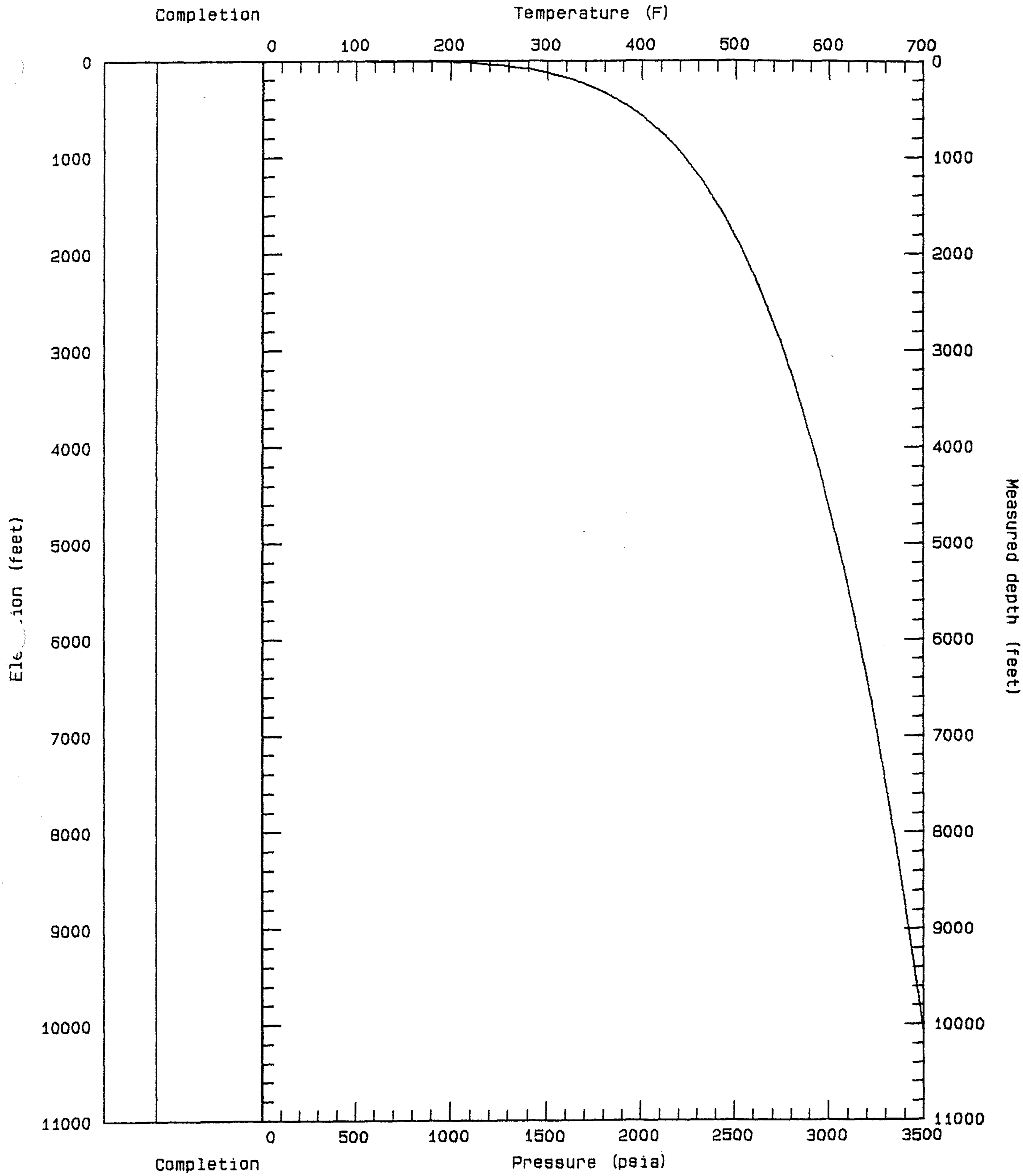
# APPENDIX B: Downhole Summary Plots, Full-Sized Wells

# KARAHA BOILING POINT CURVE




GeothermEx, Inc.

02-06-1998 B:BP.PLT

**Subject: Re: re**
**Date:** Thu, 2 Aug 2001 15:09:17 -0700
**From:** "Jess McCulloch" <jmcculloch@caithnessenergy.com>
**To:** Joseph Moore <jmoore@egi.utah.edu>

Howdy Joe,

Confirmation; KE-13 was renamed KRH 2-1, KE-13ST was renamed KRH 2-1RD.
GeothermEx refers to KRH 2-1 as KRH 2-1OH.

For consistency, Caithness Energy LLC refers to Karaha Bodas Co. as an affiliate.

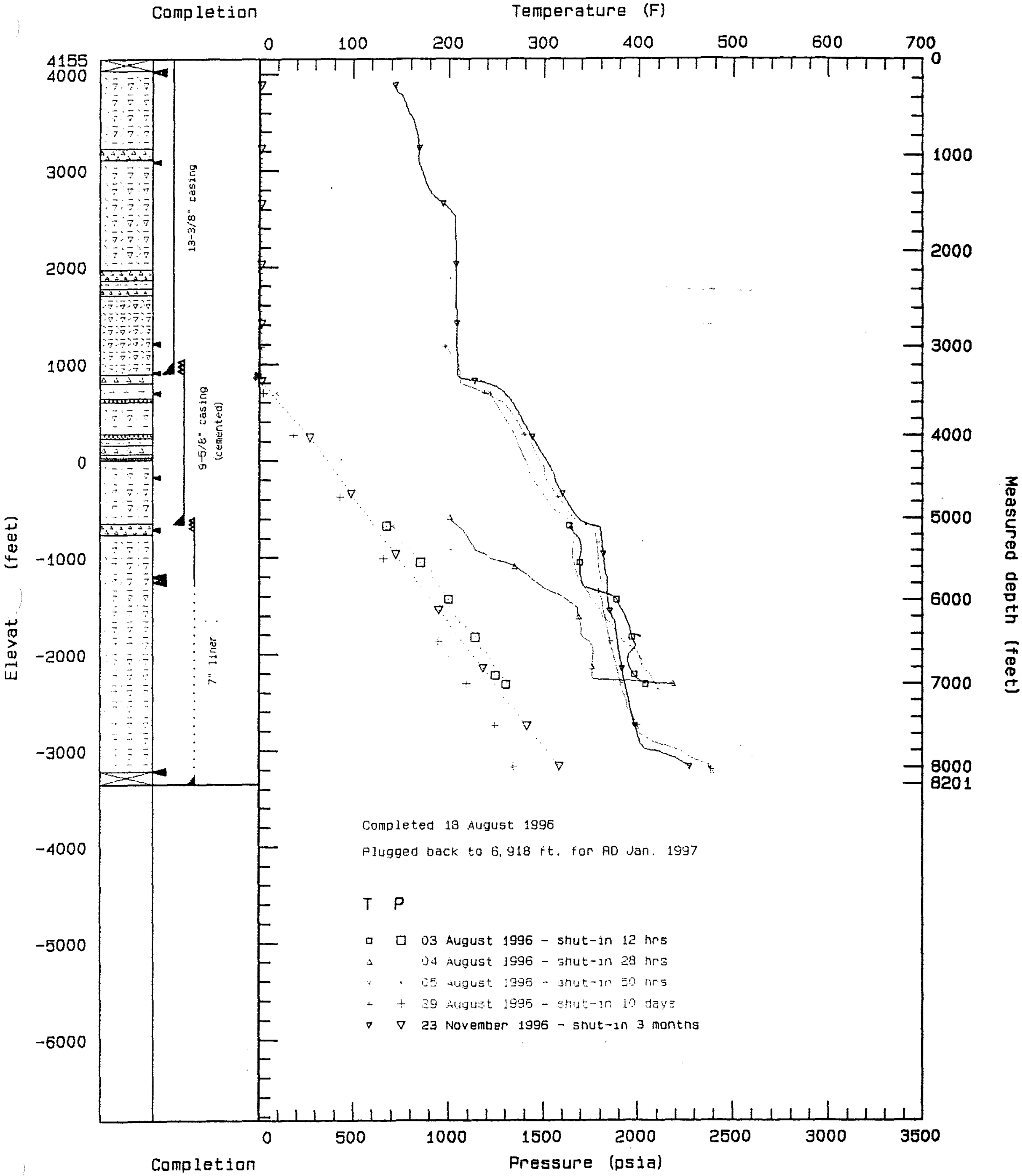
Been doing a little fishing on the upper Kern. As soon as we finish the well we are

Jess

---------- Original Message ----------------------------------
From: Joseph Moore <jmoore@egi.utah.edu>
Date: Wed, 25 Jul 2001 15:55:49 -0600

*>Hi Jess,*
*>I am writing a program review paper and I need to describe our*
*>collaborative efforts. Should I describe the work on Karaha as a joint*
*>effort between the Karaha Bodas Co. LLC (a subsidiary of Caithness*
*>Energy) and EGI or would you like me to say it differently.*
*>*
*>And to confirm again, KE-13ST and KE-13 was renamed KRH2-1RD and*
*>KE-2-1OH. Yes.*
*>*
*>Been fishing??*
*>Joe*
*>*
*>*

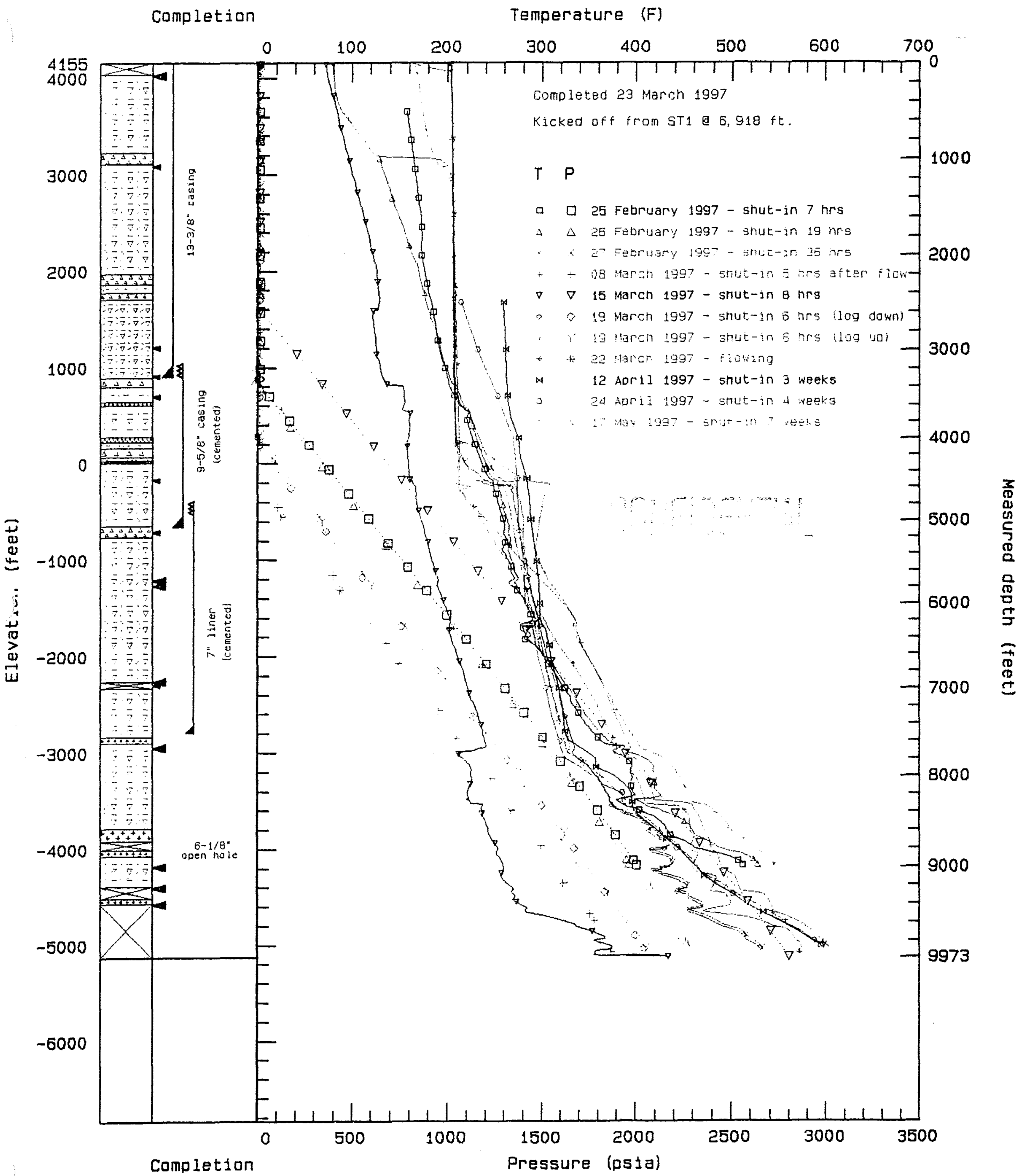
# DOWNHOLE SUMMARY PLOT, KARAHA WELL KRH 1-1ST1




GeothermEx, Inc.

02-03-1998 D:T960803.PLT

# DOWNHOLE SUMMARY PLOT, KARAHA WELL KRH 1-1ST2

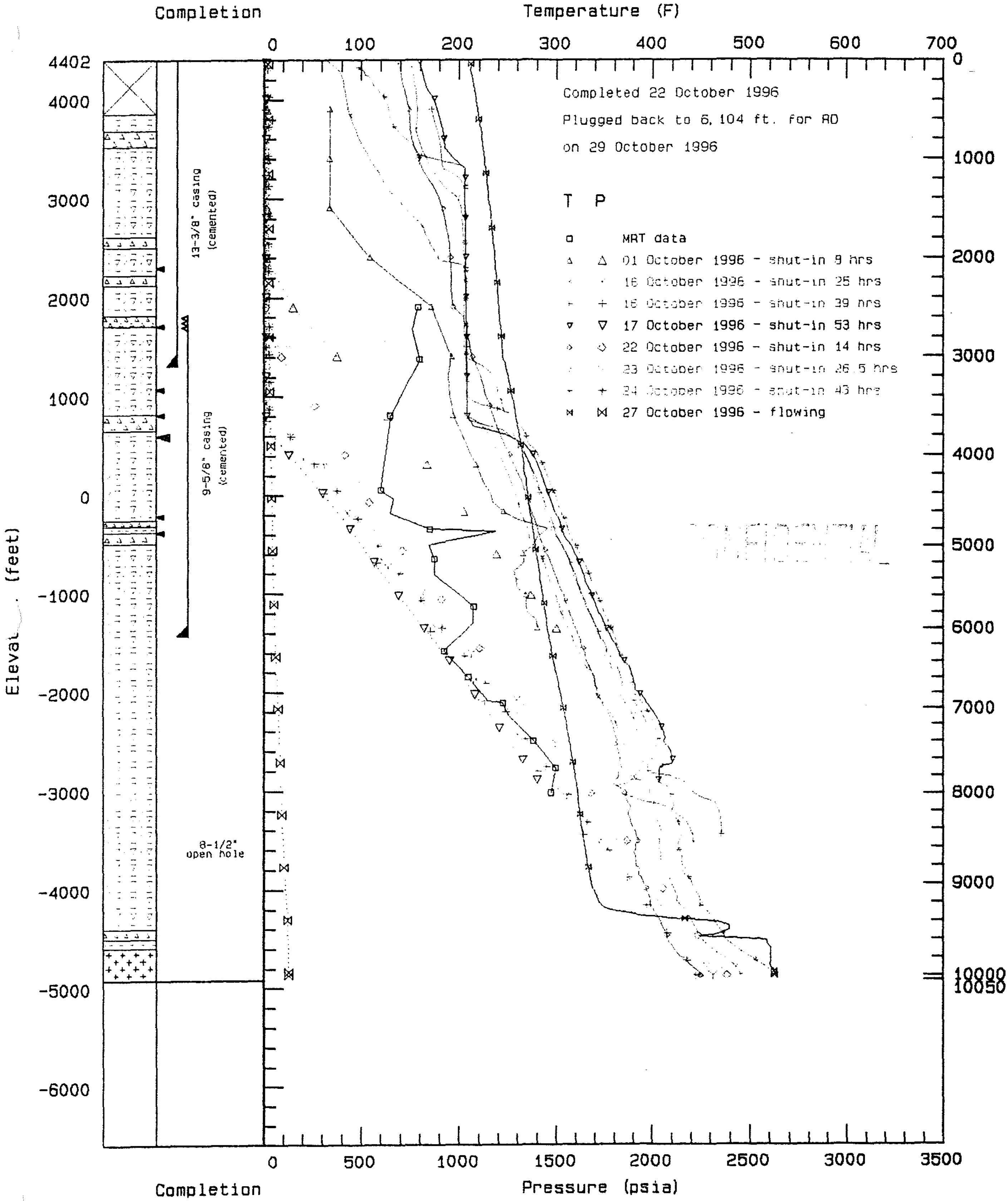



GeothermEx, Inc.

04-10-1998 D: T970225.PLT

KE-13

# DOWNHOLE SUMMARY PLOT, KARAHA WELL KRH 2-10H

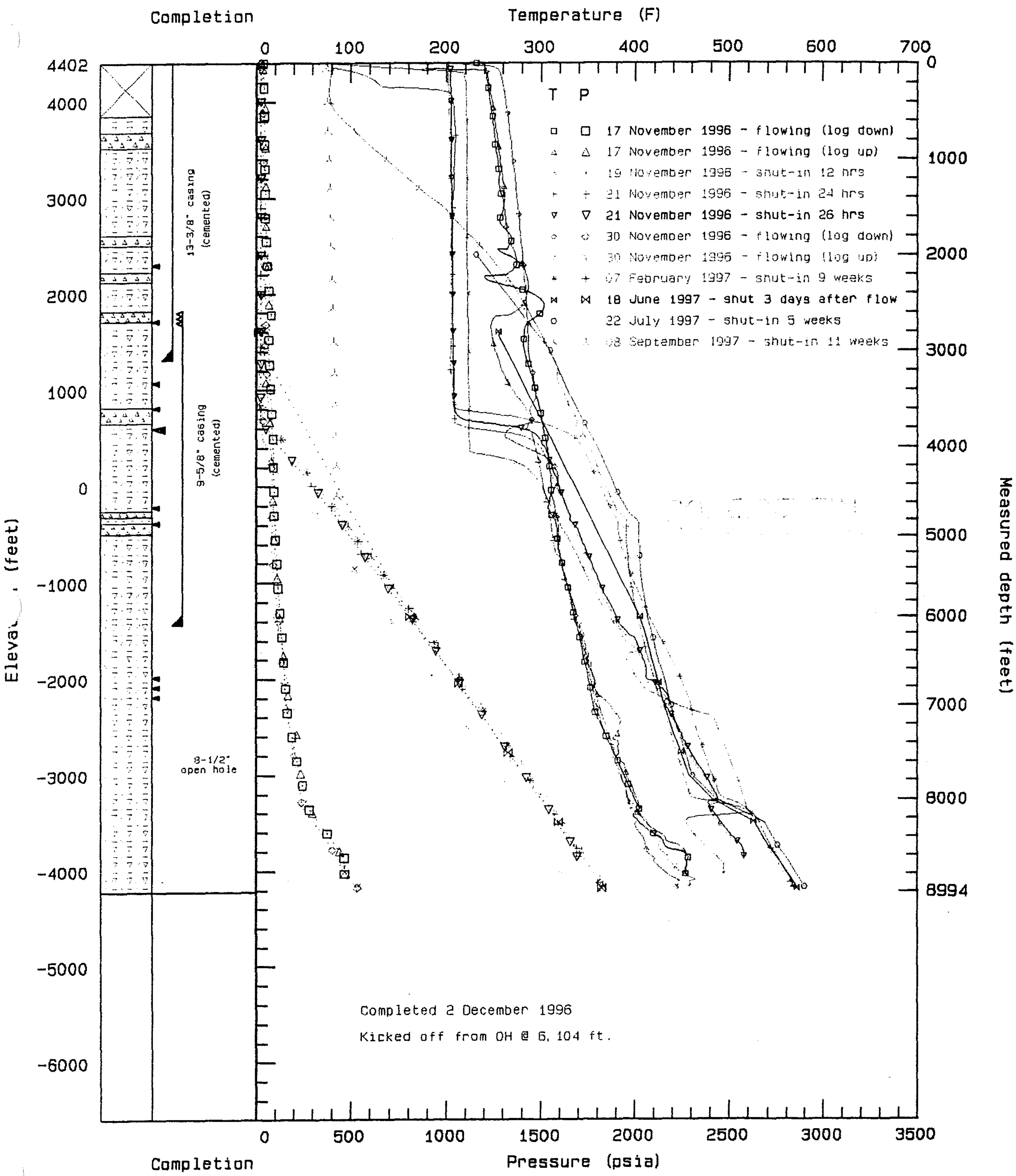



GeothermEx, Inc.

02-03-1998 D:MRT.PLT

KE-13 ST

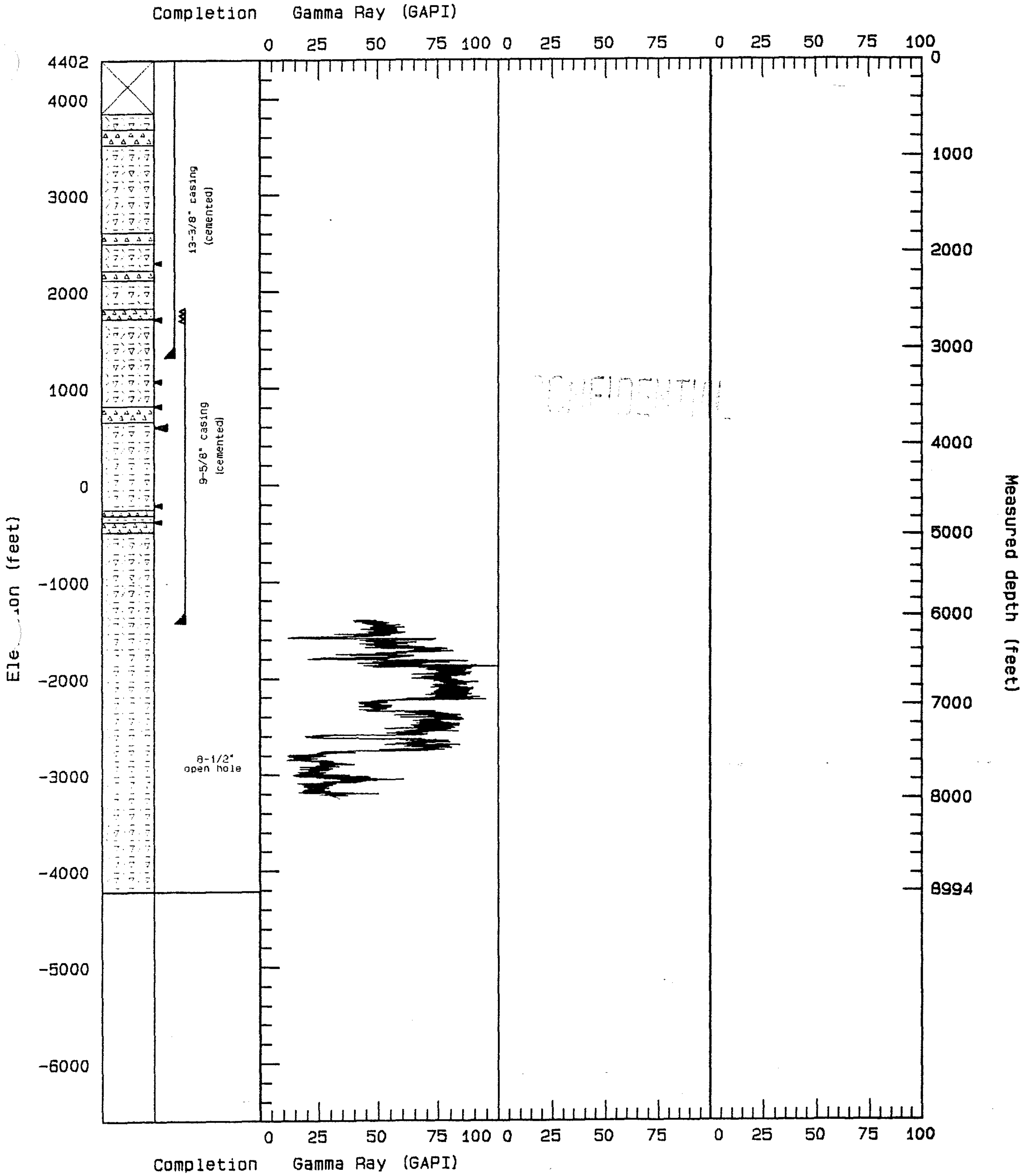
# DOWNHOLE SUMMARY PLOT, KARAHA WELL KRH 2-1RD




GeothermEx, Inc.

03-30-1998 D:T961117A.PLT

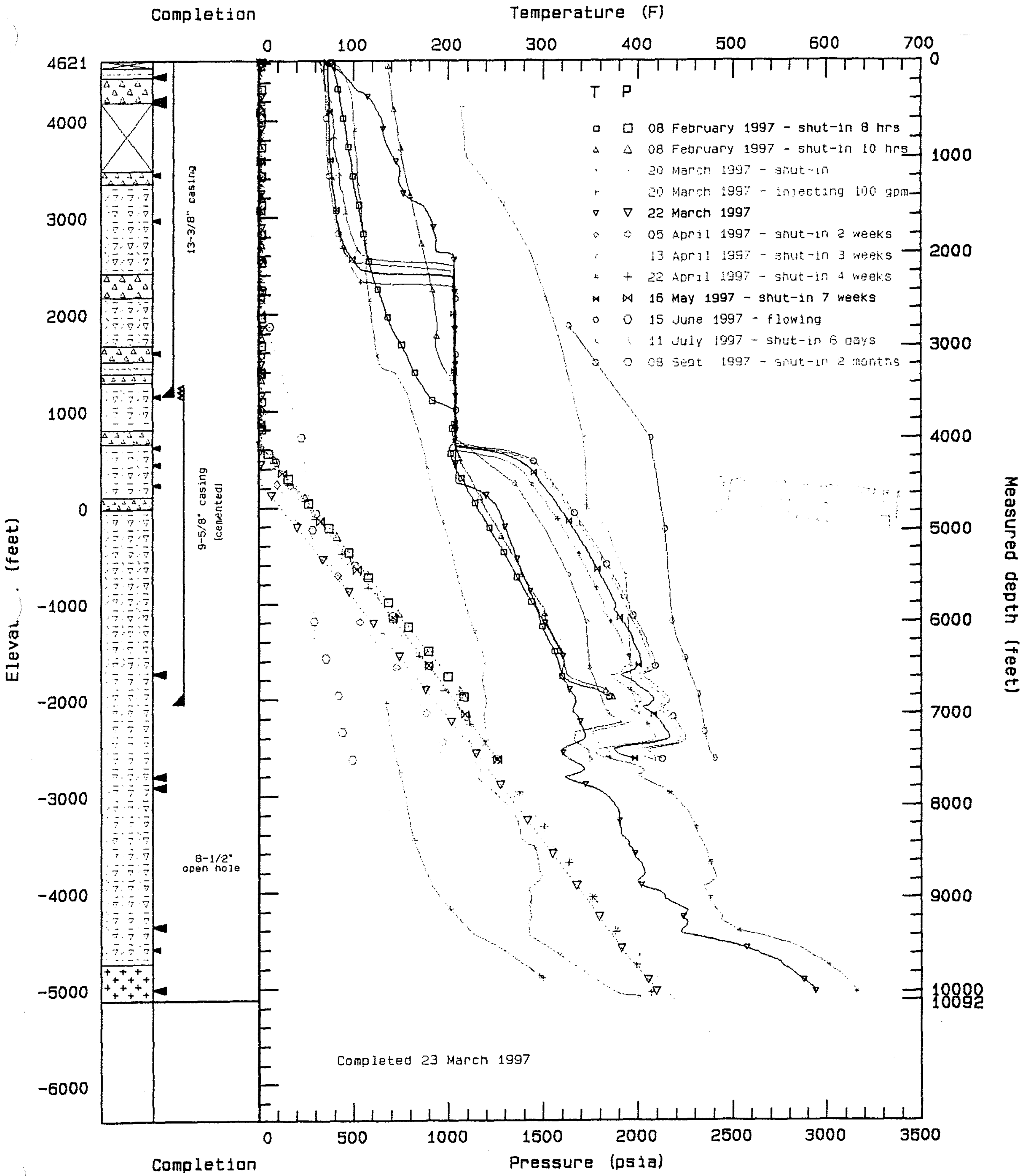
# GEOPHYSICAL LOG, KARAHA WELL KRH 2-1RD




GeothermEx, Inc.

02-09-1998 B: K2_1GR.PLT

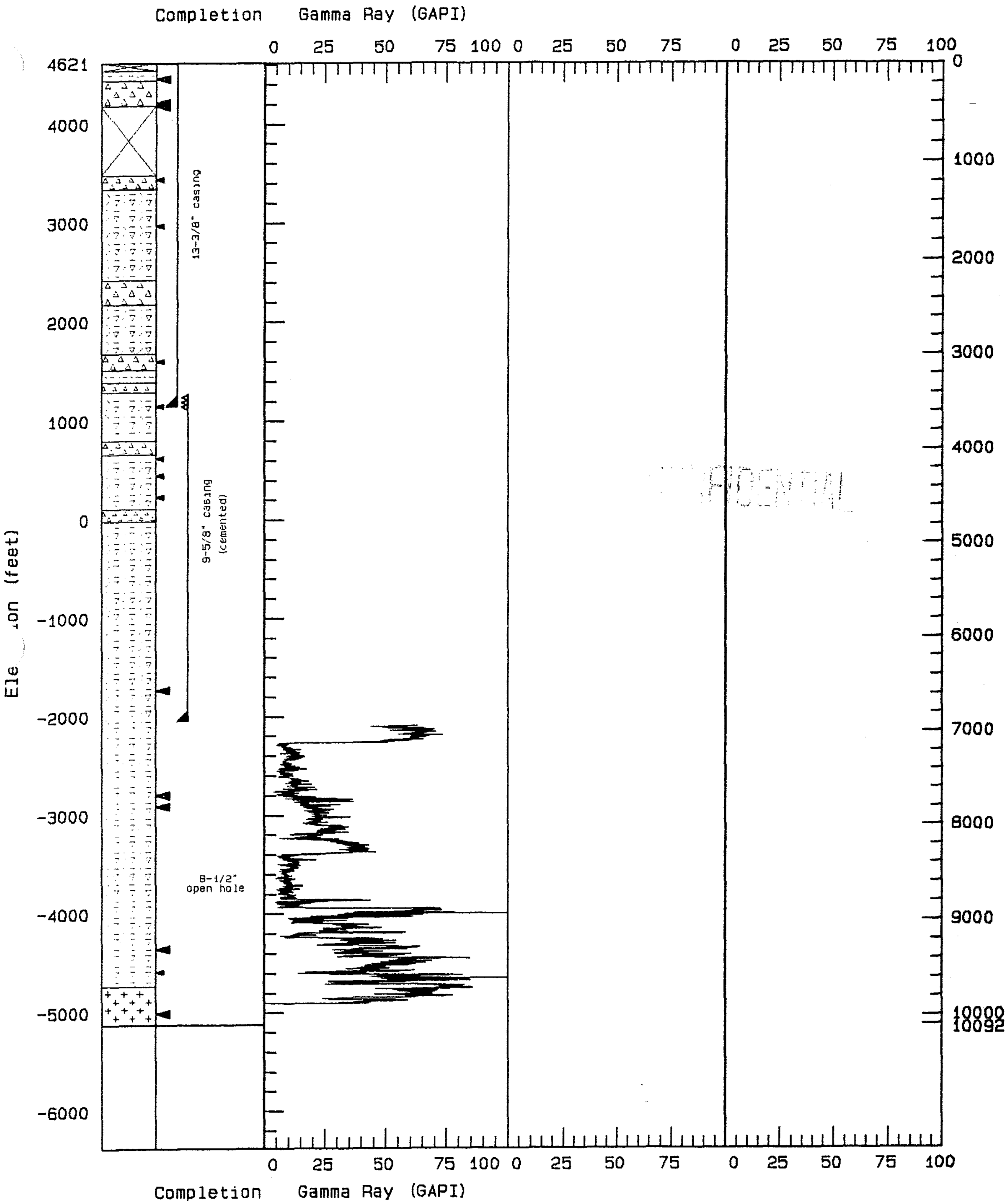
# DOWNHOLE SUMMARY PLOT, KARAHA WELL KRH 3-1ST




GeothermEx, Inc.

02-03-1998 D: T970208A.PLT

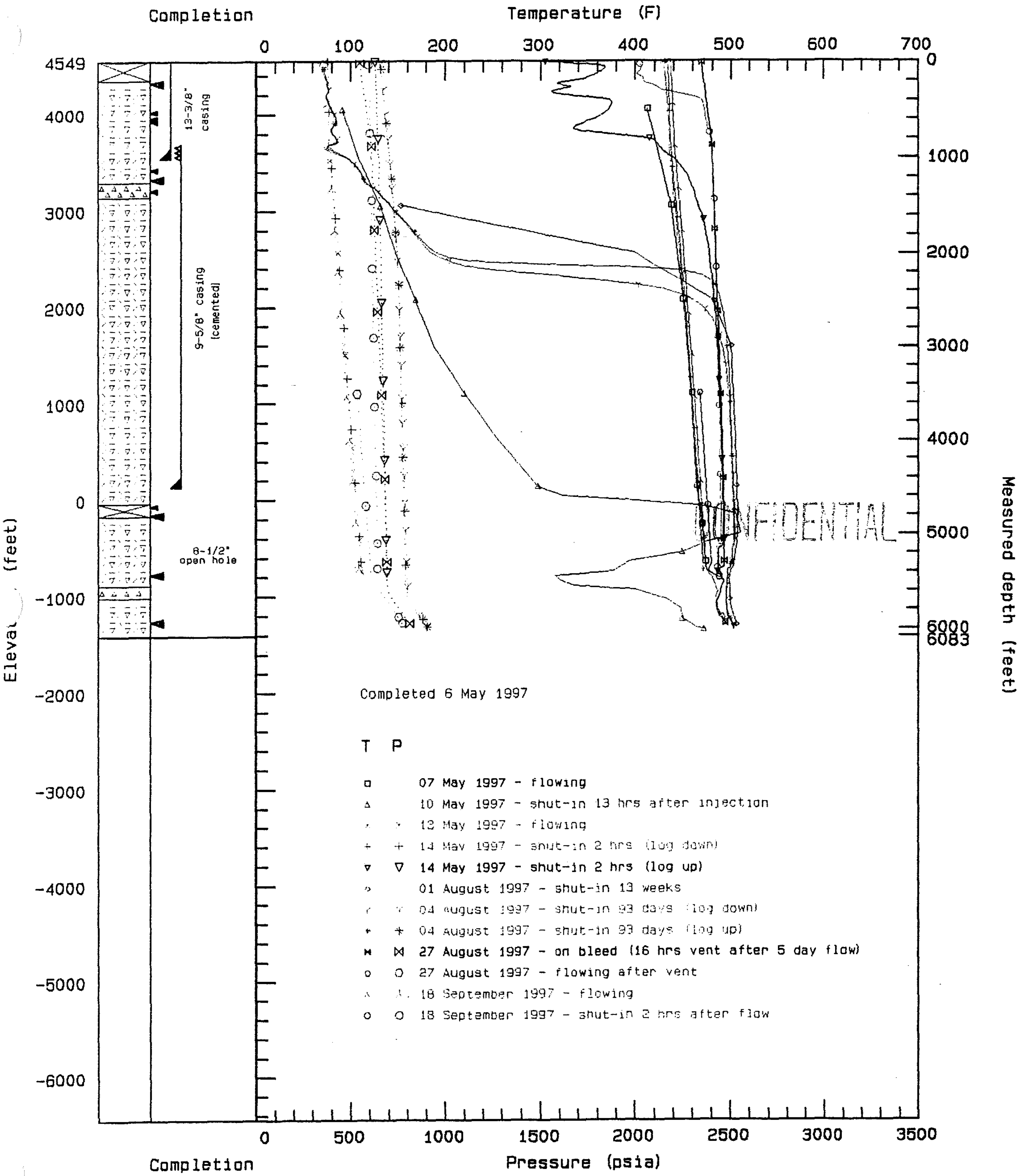
# GEOPHYSICAL LOG PLOT, KARAHA WELL KAH 3-1ST




GeothermEx, Inc.

02-09-1998 B: K3_1GR.PLT

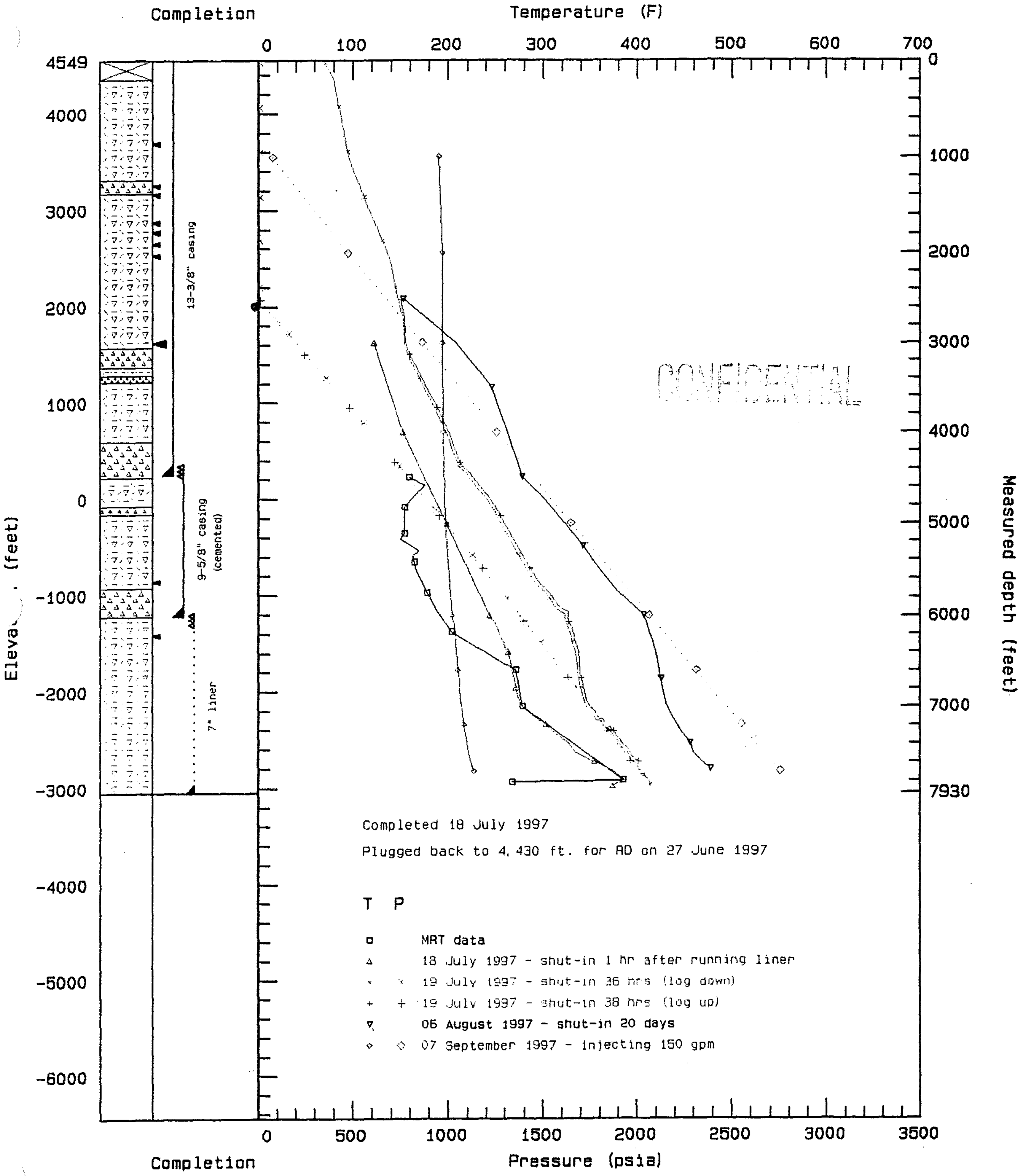
# DOWNHOLE SUMMARY PLOT, KARAHA WELL KRH 4-1




GeothermEx, Inc.

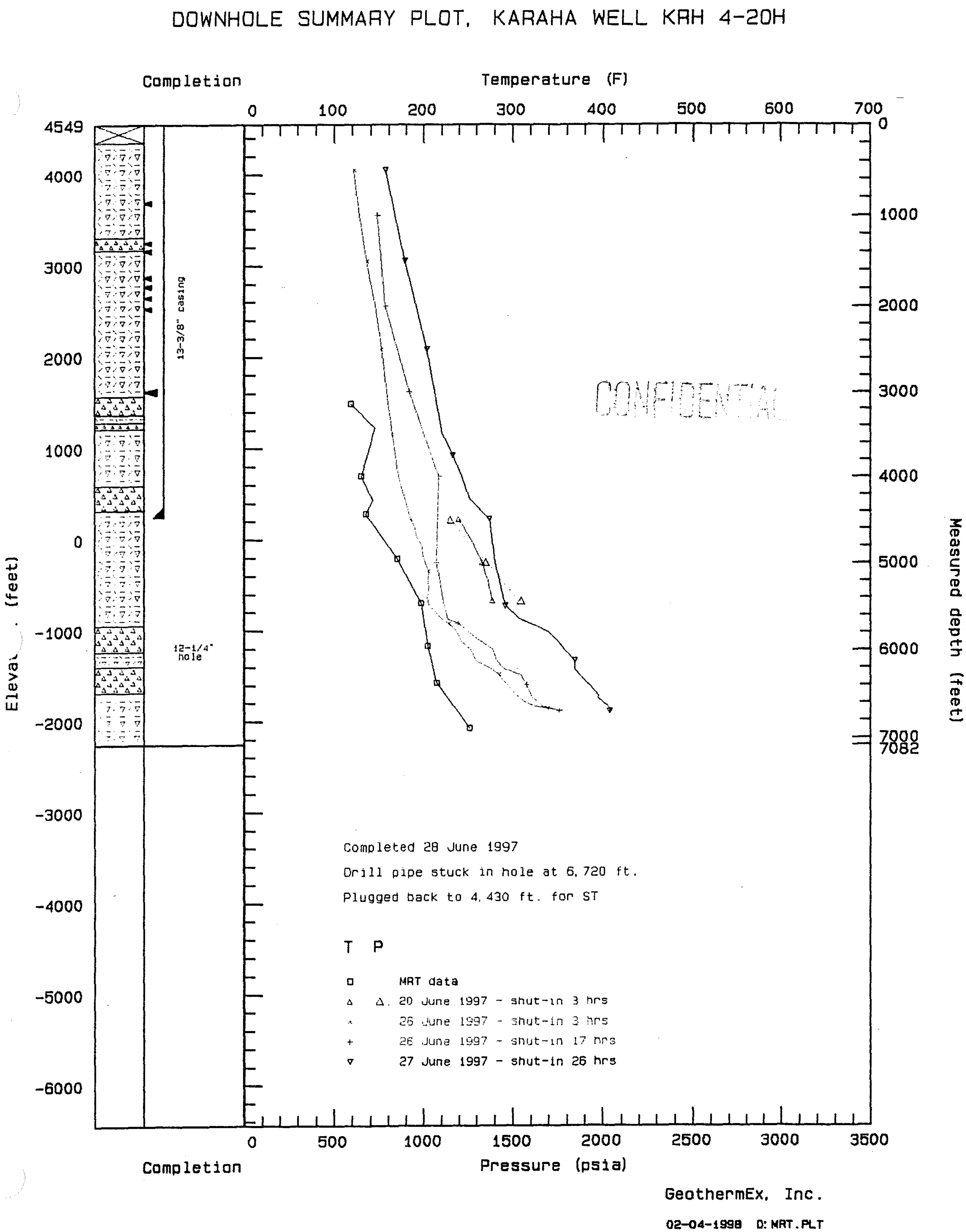
02-03-1998 D: T970507.PLT

# DOWNHOLE SUMMARY PLOT, KARAHA WELL KRH 4-2RD

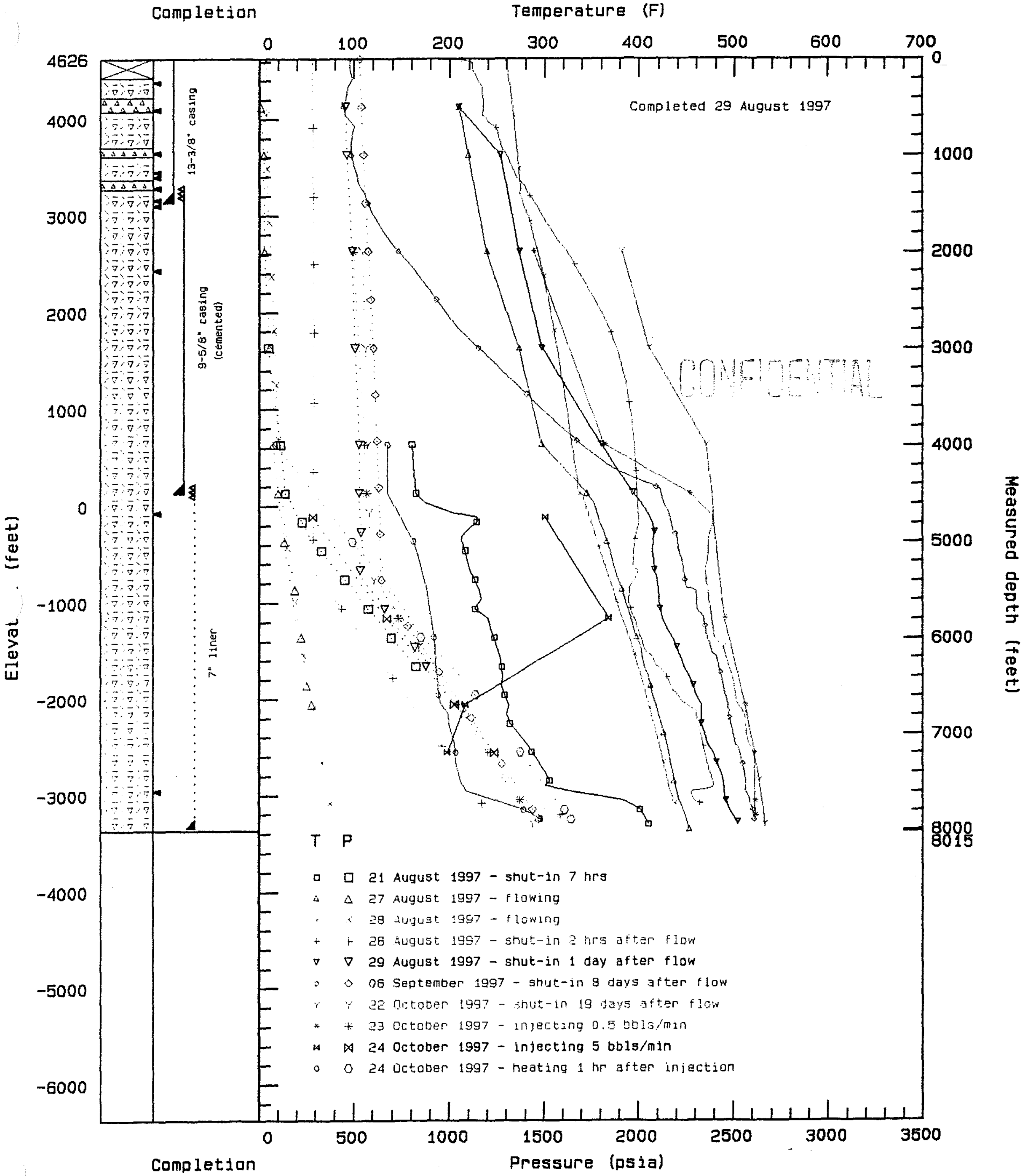



GeothermEx, Inc.

02-04-1998 D: MRT.PLT


DOWNHOLE SUMMARY PLOT, KARAHA WELL KRH 4-20H
Completion
Temperature (F)
0 100 200 300 400 500 600 700
4549
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
Elevation (feet)
13-3/8" casing
12-1/4" hole
0
1000
2000
3000
4000
5000
6000
7000
7082
Measured depth (feet)
CONFIDENTIAL
Completed 28 June 1997
Drill pipe stuck in hole at 6,720 ft.
Plugged back to 4,430 ft. for ST
T P
MRT data
20 June 1997 - shut-in 3 hrs
26 June 1997 - shut-in 3 hrs
26 June 1997 - shut-in 17 hrs
27 June 1997 - shut-in 26 hrs
0 500 1000 1500 2000 2500 3000 3500
Completion
Pressure (psia)
GeothermEx, Inc.
02-04-1998 D:MRT.PLT

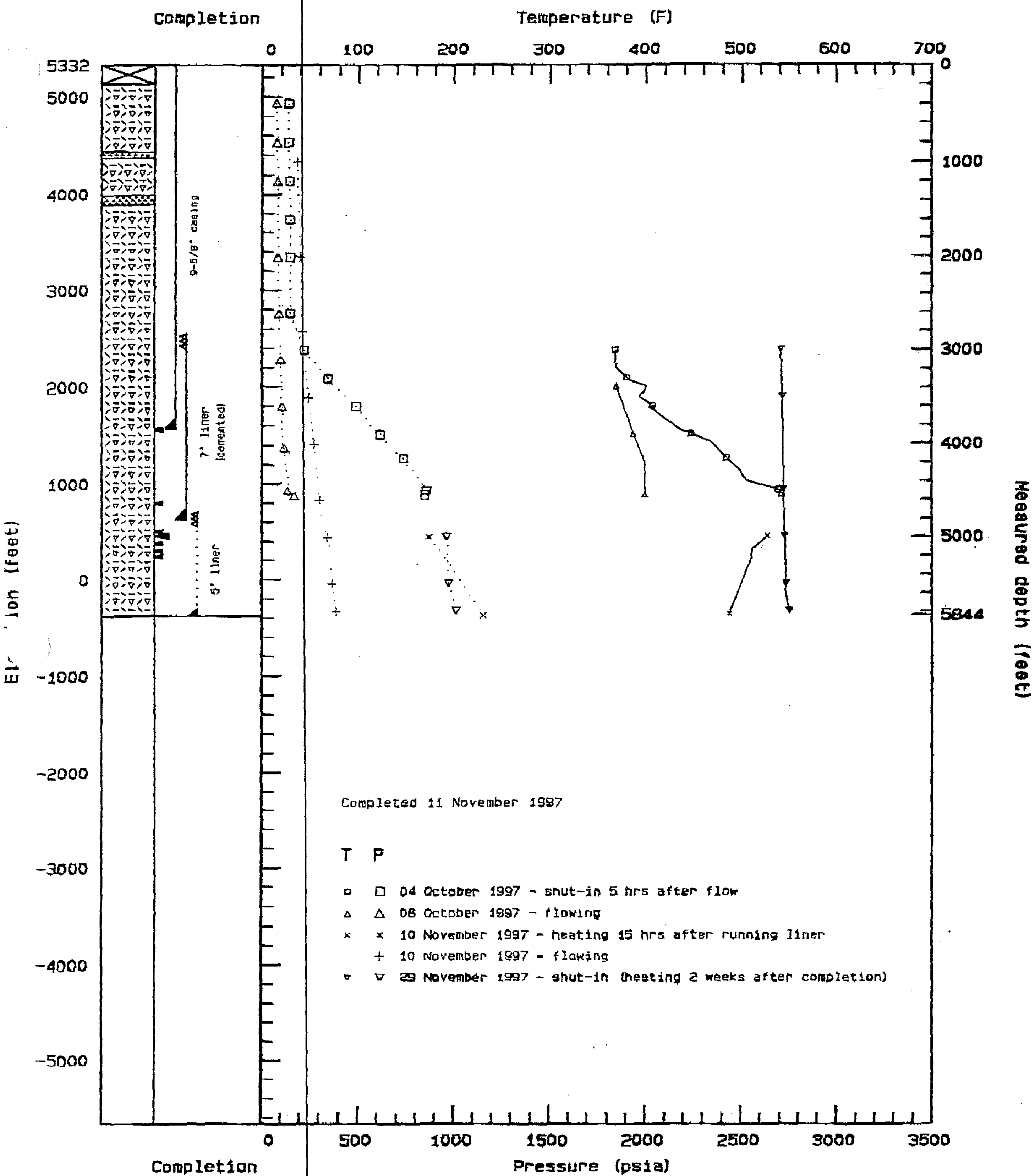
# DOWNHOLE SUMMARY PLOT, KARAHA WELL KRH 5-1




GeothermEx, Inc.

02-24-1998 D: T970821.PLT

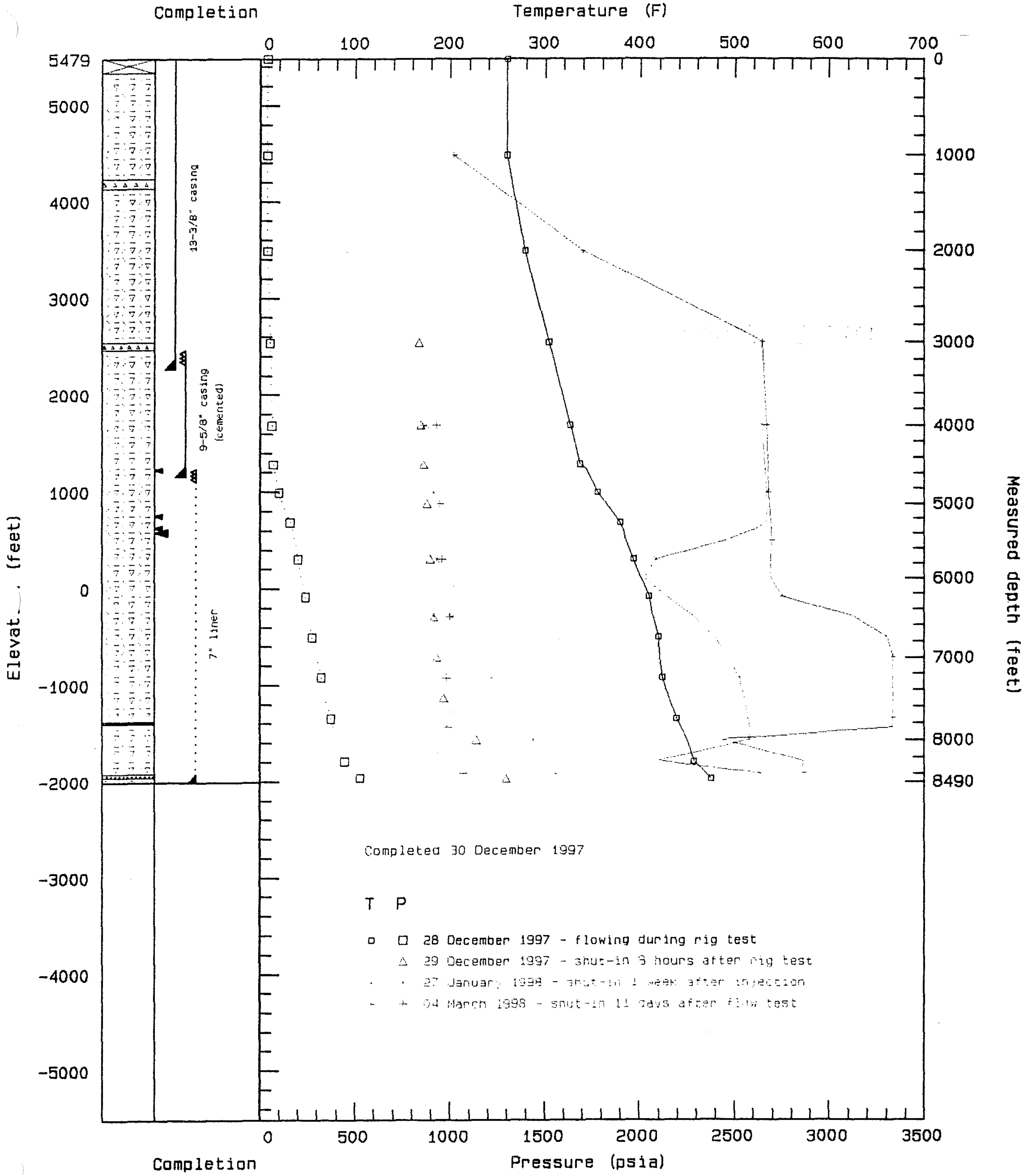
# DOWNHOLE SUMMARY PLOT, KARAHA WELL TLG 1-1ST2




GeothermEx, Inc.

02-12-1998 D:T971004.PLT

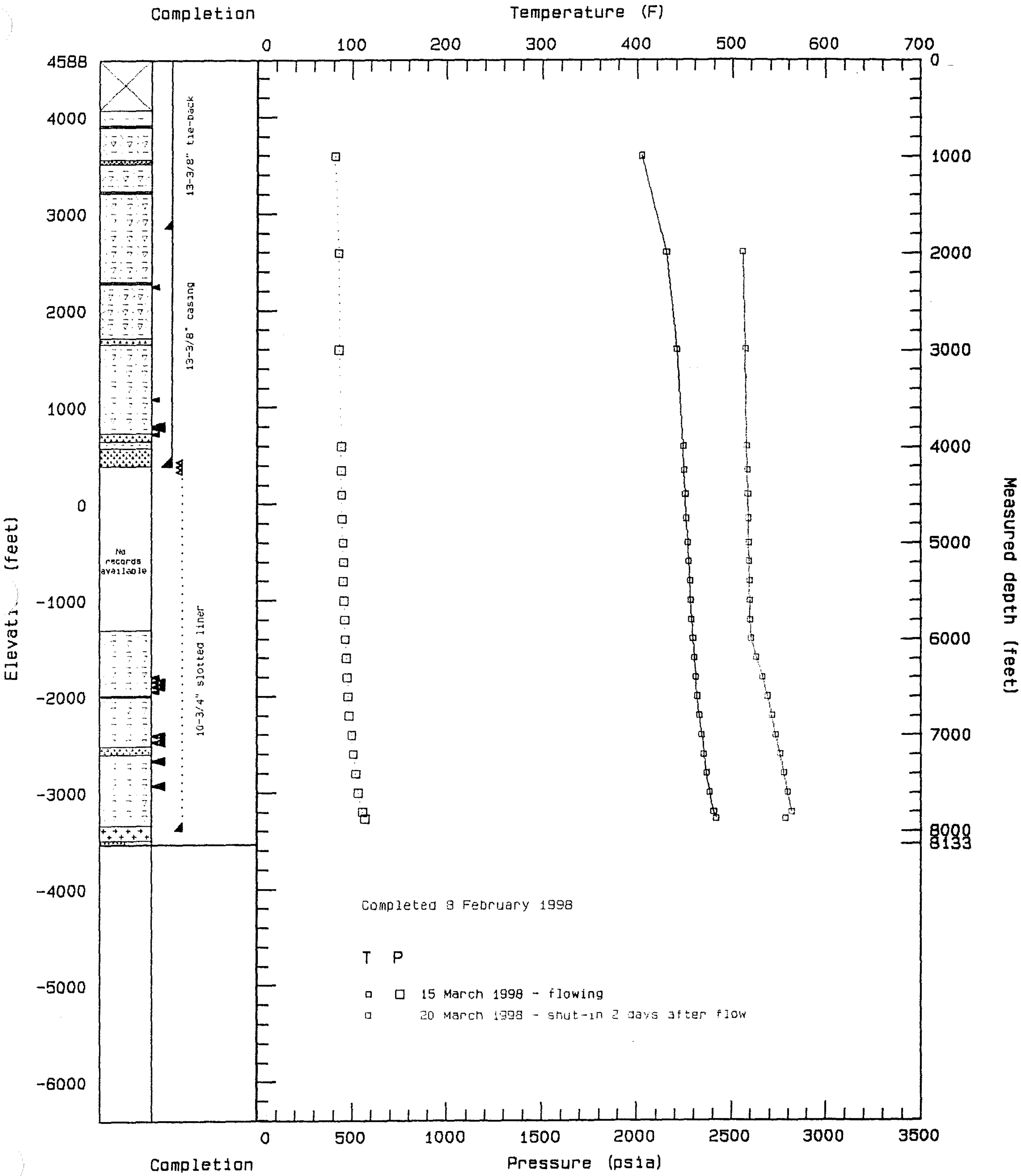
# DOWNHOLE SUMMARY PLOT, KARAHA WELL TLG 2-1




GeothermEx, Inc.

03-24-1998 D:TP971228.PLT

# DOWNHOLE SUMMARY PLOT, KARAHA WELL TLG 3-1




GeothermEx, Inc.

03-31-1998 D: TP980315.PLT

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# APPENDIX C: Fluids Chemistry Database

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 1

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | WHP -ga | PORT | Enth | Steam / Water T | Psat | Pabs | Stm. Fr. | Lab pH | Ca | Mg | Na | K | TAlk. HCO3 | SO4 | Cl | B | SiO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TLG 3-1*** | | | | ***Telaga Deep Hole*** | | | | | | | | | | | | | | |
| 98.02.18 | 1330 | 118 | portsp | 1120.00 | | | | | 5.60 | | | 0.01 | | | | | | |
| 98.02.20 | 1300 | 108 | wbx | 1130.00 | | | 110.40 | 0.933 | 6.70 | | | | | 112.0 | | | | |
| 98.02.23 | | 104 | wbx | 1130.00 | | | 115.40 | 0.932 | 6.90 | | | | | 103.0 | | | | |
| 98.02.23 | 1130 | 104 | wbx | 1130.00 | | | | | | | | | | | | | | |
| ***WELL: T-2*** | | | | ***Telaga Deep Slim Hole*** | | | | | | | | | | | | | | |
| 97.06.10 | | 49 | portsp | 1116.00 | 270.0 | 41.87 | 48.40 | 0.941 | 3.73 | 22.30 | 0.224 | 32.10 | 12.20 | | 8.7 | 2640.00 | 436.00 | 11.3 |
| 97.06.11 | | 47 | portsp | 1116.00 | 267.0 | 39.85 | 46.40 | 0.943 | 3.78 | 36.80 | 0.193 | 47.50 | 14.70 | | 2.6 | 2170.00 | 1310.00 | 14.1 |
| 97.10.18 | 1400 | | portsp | | | | | | | | | | | | | | | |
| ***WELL: T-8*** | | | | | | | | | | | | | | | | | | |
| 97.07.11 | 1730 | 64 | portsp | | | | | | 2.16 | 171.00 | 7.800 | 65.70 | 4.03 | | 36.7 | 57800.00 | 2060.00 | 182.0 |
| 97.07.13 | | 76 | portsp | | | | | | 2.87 | 1210.00 | 17.100 | 412.00 | 47.10 | | 154.0 | 125000.00 | 3290.00 | 254.0 |
| 97.07.13 | | 76 | portsp | | | | | | 2.09 | 1230.00 | 170.000 | 414.00 | 47.20 | | 165.0 | 127000.00 | 3360.00 | 280.0 |
| 97.07.22 | | 76 | portsp | | | | | | 3.14 | 1260.00 | 101.000 | 388.00 | 43.70 | | 881.0 | 178000.00 | 2680.00 | 144.0 |
| ***WELL: FM-3 spring*** | | | | ***Telaga Thermal Manifestation*** | | | | | | | | | | | | | | |
| 97.06.25 | 1415 | | spring | | 118.0 | | 12.40 | | 2.88 | 105.00 | 54.500 | 71.20 | 1.79 | | 346.0 | 824.00 | 4.32 | 188.0 |
| ***WELL: FM-4 spring*** | | | | | | | | | | | | | | | | | | |
| 97.06.10 | | | spring | | | | 12.40 | | | | | | | | | | | |
| ***WELL: KBC Hot Spring*** | | | | | | | | | | | | | | | | | | |
| 97.10.21 | 1530 | | spring | | 116.0 | | | | 2.28 | 203.00 | 633.000 | 69.30 | 10.60 | | 584.0 | 4680.00 | 1.49 | 247.0 |
| ***WELL: TB-01 TelagaBod*** | | | | | | | | | | | | | | | | | | |
| 96.05.03 | | | fum | | | | 12.40 | 1.000 | | | | | | | | | | |
| ***WELL: TB-03 TelagaBod*** | | | | | | | | | | | | | | | | | | |
| 96.05.03 | | | spring | | | | 12.40 | | | | | | | | | | | |
| ***WELL: TEL-01 Tel.Boda*** | | | | | | | | | | | | | | | | | | |
| 95.05.08 | | | lake | | 162.0 | | | | 3.80 | 36.90 | 32.000 | 12.30 | 3.30 | | 216.0 | 62.00 | 0.25 | 97.1 |
| ***WELL: TEL-02 Tel.Bod*** | | | | | | | | | | | | | | | | | | |
| 95.05.08 | | | fum | | 199.0 | | 12.40 | 1.000 | 2.83 | 207.40 | 92.000 | 42.30 | 1.70 | | 2050.0 | 16.00 | 0.19 | 336.0 |
| ***WELL: TEL-03 Tel.Boda*** | | | | | | | | | | | | | | | | | | |
| 95.05.08 | | | mudpot | | 194.0 | | 12.40 | | 0.82 | 322.70 | 140.400 | 68.90 | 27.10 | | 5016.0 | 3072.00 | 1.46 | 320.0 |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 1

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | WHP -ga | PORT | Enth | Steam / Water T | Psat | Pabs | Stm. Fr. | Lab pH | Ca | Mg | Na | K | TAlk. HCO3 | SO4 | Cl | B | SiO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: KR-6 SawahCipan*** | | | ***Karaha Thermal Manifestation*** | | | | | | | | | | | | | | | |
| 95.05.12 | | | hs | | 100.0 | | | | 6.28 | 36.10 | 20.000 | 25.40 | 8.10 | 167.0 | 38.0 | 6.20 | 0.07 | 134.0 |
| ***WELL: KR-7 Karaha*** | | | | | | | | | | | | | | | | | | |
| 95.05.18 | | | mudpot | | 198.0 | | | | 6.38 | 10.00 | 1.400 | 4.70 | 11.10 | 33.0 | 370.4 | 4.30 | -0.10 | 203.0 |
| ***WELL: KR-A Kp.Bakom*** | | | | | | | | | | | | | | | | | | |
| . . | | | spring | | | | | | | | | | | | | | | |
| ***WELL: KRH-03*** | | | | | | | | | | | | | | | | | | |
| 96.05.02 | | | fum | | 206.0 | | | 1.000 | | | | | | | | | | |
| ***WELL: KR-01*** | | | ***Pertamina Shallow Slim Hole*** | | | | | | | | | | | | | | | |
| 87.01.01 | | | dh | | | | | | 7.50 | 23.02 | 9.720 | 16.61 | 4.85 | 169.6 | 7.0 | 7.29 | -0.06 | 50.0 |
| ***WELL: KR-02*** | | | | | | | | | | | | | | | | | | |
| . . | | | dh | | | | | | 6.43 | 91.25 | 72.140 | 198.00 | 52.42 | 1097.8 | 3.0 | 128.59 | 6.28 | 116.0 |
| ***WELL: KR-03*** | | | | | | | | | | | | | | | | | | |
| . . | | | dh | | | | | | 6.21 | 108.25 | 74.240 | 201.00 | 52.42 | 112.9 | 3.0 | 131.62 | 6.84 | 119.0 |
| ***WELL: KR-04*** | | | | | | | | | | | | | | | | | | |
| . . | | | dh | | | | | | 6.18 | 98.35 | 72.140 | 298.40 | 53.30 | 1120.2 | 3.0 | 142.62 | 6.40 | 132.0 |
| ***WELL: TLG 1-1 ST2*** | | | ***Telaga Deep Hole*** | | | | | | | | | | | | | | | |
| 97.10.04 | 0900 | | portsp | | | | | | 5.05 | 7160.00 | 84.200 | 6590.00 | 2710.00 | 36.6 | 359.0 | 25780.00 | 0.78 | 176.0 |
| 97.10.04 | 2300 | | dh | | | | | | 4.22 | 7960.00 | 63.200 | 6230.00 | 2050.00 | | 156.0 | 26600.00 | 0.89 | 323.0 |
| 97.10.05 | 0200 | | dh | | | | | | 4.19 | 9430.00 | 72.500 | 7390.00 | 2410.00 | | 157.0 | 30420.00 | 1.17 | 333.0 |
| 97.10.06 | | | portsp | | | | | | 4.80 | 7021.00 | 83.900 | 7758.00 | 2707.00 | -5.0 | 265.0 | 28983.00 | 104.00 | 49.0 |
| 97.10.06 | 1300 | | portsp | | | | | | 3.94 | 17800.00 | 292.000 | 13100.00 | 4450.00 | | 280.0 | 56440.00 | 1.68 | 168.0 |
| 97.11.10 | | 130 | portsp | 1160.00 | | | | | 4.00 | 1498.00 | 57.800 | 2069.00 | 1089.00 | -5.0 | 11.0 | 8243.00 | 22.00 | 406.0 |
| ***WELL: TLG 2-1*** | | | | | | | | | | | | | | | | | | |
| 97.12.29 | 0930 | 130 | wbx | 1125.00 | | | 12.40 | 0.977 | 6.30 | 3440.00 | 57.300 | 5190.00 | 1996.00 | | 164.0 | 15688.00 | 29.00 | 217.0 |
| 97.12.29 | 1130 | 130 | portsp | | | | | 1.000 | | | | | | | | | | |
| 97.12.29 | 1130 | | portsp | | | | | 1.000 | 7.00 | | | 0.48 | | | | | | |
| 98.02.10 | 1100 | 158 | portsp | | | | | 1.000 | 7.30 | | | 0.08 | | | | | | |
| 98.02.18 | 1045 | 137 | portsp | | | | | 1.000 | 7.00 | | | 0.78 | | | | | | |
| ***WELL: TLG 3-1*** | | | | | | | | | | | | | | | | | | |
| 98.02.17 | 1300 | 119 | wbx | 1100.00 | | | 123.40 | 0.896 | 7.20 | | | | | 102.0 | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

# Table C-1 : CHEMICAL ANALYSES OF WATERS: part 1

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | WHP -ga | PORT | Steam / Water Enth | T | Psat | Pabs | Stm. Fr. | Lab pH | Ca | Mg | Na | K | TAlk. HCO3 | SO4 | Cl | B | SiO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: KRH 4-1*** | | | | ***Karaha Deep Hole*** | | | | | | | | | | | | | | |
| 97.09.02 | 1500 | | wbx | 1023.00 | | | 12.40 | 0.873 | 7.79 | 46.30 | 0.047 | 2420.00 | 382.00 | 163.0 | 52.4 | 4050.00 | 194.00 | 686.0 |
| 97.09.03 | 1630 | | wbx | 1003.00 | | | 12.40 | 0.852 | 7.79 | 47.80 | 0.042 | 2310.00 | 350.00 | 157.0 | 48.4 | 4100.00 | 193.00 | 703.0 |
| 97.09.04 | 1725 | | portsp | 1040.00 | 431.0 | 347.37 | 372.40 | 0.794 | | | | | | | | | | |
| 97.09.04 | 1725 | | portsp | 1040.00 | 431.0 | 347.37 | 372.40 | 0.794 | | | | | | | | | | |
| 97.09.04 | 1745 | | wbx | 1040.00 | | | 12.40 | 0.794 | 7.80 | 45.70 | -0.008 | 2380.00 | 359.00 | 160.0 | 50.5 | 4010.00 | 197.00 | 695.0 |
| 97.09.13 | 1620 | | portsp | 966.00 | 388.0 | 215.22 | 222.40 | 0.721 | | | | | | | | | | |
| 97.09.13 | 1620 | | portsp | 966.00 | 388.0 | 215.22 | 222.40 | 0.721 | | | | | | | | | | |
| 97.09.13 | 1720 | | wbx | 969.00 | | | 12.40 | 0.817 | 7.73 | 74.10 | 0.037 | 2480.00 | 400.00 | 127.0 | 38.0 | 4260.00 | 191.00 | 699.0 |
| ***WELL: KRH 5-1*** | | | | | | | | | | | | | | | | | | |
| 97.08.28 | 1235 | | wbx | 645.00 | | | 12.40 | 0.485 | 6.60 | 986.00 | 3.420 | 4396.00 | 1322.00 | | 50.0 | 9838.00 | 152.00 | 811.0 |
| 97.09.25 | | 94 | portsp | 692.00 | | | | | | | | | | | | | | |
| 97.09.25 | 2200 | 94 | portsp | 692.00 | | | | | 7.16 | 1100.00 | 1.490 | 4850.00 | 1350.00 | 41.8 | 32.3 | 11230.00 | 167.00 | 179.0 |
| 97.10.02 | 1515 | 63 | portsp | 766.00 | | | | | 7.01 | 1200.00 | 1.710 | 4930.00 | 1650.00 | 50.9 | 22.8 | 11590.00 | 1.73 | 873.0 |
| 97.12.17 | | | wbx | | | | | | | | | | | | | | | |
| ***WELL: K-33*** | | | | ***Karaha Deep Slim Hole*** | | | | | | | | | | | | | | |
| . . | | | wellhd | | | | 12.40 | | 7.50 | | | | | | | | | |
| 97.12.01 | 0510 | 130 | portsp | 875.00 | | | 130.00 | | | | | | | | | | | |
| ***WELL: K2*** | | | | ***Karaha Shallow Slim Hole*** | | | | | | | | | | | | | | |
| 96.05.02 | | | wellhd | | 217.0 | 16.22 | | 1.000 | | | | | | | | | | |
| 96.05.02 | | | wellhd | | 217.0 | 16.22 | | 1.000 | | | | | | | | | | |
| ***WELL: KR-1 Jenkin'sSe*** | | | | ***Karaha Thermal Manifestation*** | | | | | | | | | | | | | | |
| 95.05.08 | | | spring | | 72.0 | | | | 3.80 | 8.40 | 4.900 | 3.70 | 1.10 | | 27.4 | 4.60 | -0.10 | 39.2 |
| ***WELL: KR-2 Kp.Bakom*** | | | | | | | | | | | | | | | | | | |
| 95.05.08 | | | spring | | 72.0 | | | | 3.82 | 3.30 | 1.400 | 6.50 | 3.00 | | 184.0 | 4.30 | 0.18 | 43.2 |
| ***WELL: KR-3 Karaha*** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | | fum | | 205.0 | | | 1.000 | 2.29 | 28.90 | 19.400 | 12.80 | 6.60 | | 965.0 | 2.60 | 0.09 | 246.0 |
| ***WELL: KR-4 Karaha*** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | | hs | | 196.0 | | | | 6.61 | 7.00 | 1.000 | 3.00 | 10.70 | 33.0 | 208.0 | 11.20 | -0.10 | 60.7 |
| ***WELL: KR-5 Kp.Ciselan*** | | | | | | | | | | | | | | | | | | |
| 95.05.11 | | | spring | | 72.0 | | | | 7.24 | 10.80 | 4.500 | 9.80 | 3.60 | 41.0 | 6.1 | 3.40 | 0.24 | 48.8 |
| ***WELL: KR-6 SawahCipan*** | | | | | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 1

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | WHP -ga | PORT | Steam / Water Enth | T | Psat | Pabs | Stm. Fr. | Lab pH | Ca | Mg | Na | K | TAlk. HCO3 | SO4 | Cl | B | SiO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: KRH 1-1 RD*** | | | ***Karaha Deep Hole*** | | | | | | | | | | | | | | | |
| 96.06.06 | | | ? | | | | | | 7.78 | 12.10 | 0.030 | 258.00 | 27.00 | 154.0 | 162.0 | 190.00 | 13.80 | 290.0 |
| 97.06.19 | | | wbx | | | | | | 7.49 | 4.27 | 0.281 | 87.10 | 6.85 | 156.0 | 36.2 | 23.60 | 1.55 | 342.0 |
| 97.06.19 | | | wbx | | | | 12.40 | | 7.98 | 246.00 | 0.320 | 746.00 | 176.00 | 46.0 | 114.0 | 1606.00 | 34.30 | 430.0 |
| 97.06.19 | | | wbx | | | | 12.40 | | 7.50 | 165.00 | 0.660 | 761.00 | 151.00 | 99.0 | 134.0 | 1439.00 | 32.30 | 382.0 |
| ***WELL: KRH 2-1*** | | | | | | | | | | | | | | | | | | |
| 96.10.26 | | 1 | ? | | | | 12.40 | | 7.90 | 78.00 | 0.060 | 678.00 | 114.00 | | 276.0 | 821.00 | 490.00 | 590.0 |
| 96.10.27 | | | ? | | | | 12.40 | | 7.76 | 70.00 | 0.100 | 970.00 | 173.00 | 226.0 | 229.0 | 1423.00 | 440.00 | 625.0 |
| ***WELL: KRH 2-1 RD*** | | | | | | | | | | | | | | | | | | |
| 96.11.06 | | | ? | | | | | | 8.34 | 32.00 | 0.080 | 619.00 | 138.00 | 198.0 | 143.0 | 859.00 | 69.00 | 315.0 |
| 96.11.06 | | | ? | | | | | | 8.31 | 32.00 | 0.080 | 640.00 | 147.00 | 173.0 | 159.0 | 893.00 | 67.00 | 321.0 |
| 96.11.16 | 0500 | | wbx | | | | | | 7.50 | 48.00 | 0.050 | 368.00 | 74.00 | 247.0 | 233.0 | 355.00 | 35.00 | 164.0 |
| 96.11.17 | 1600 | | wbx | | | | | | 7.96 | 26.00 | 0.120 | 824.00 | 130.00 | 131.0 | 128.0 | 1224.00 | 79.00 | 664.0 |
| 96.11.17 | 1900 | | wbx | | | | | | 7.47 | 35.00 | 0.060 | 861.00 | 135.00 | 127.0 | 128.0 | 1313.00 | 92.00 | 529.0 |
| 96.11.29 | 2200 | | ? | | | | | | 8.06 | 50.00 | 0.140 | 1775.00 | 335.00 | 101.0 | 101.0 | 2969.00 | 129.00 | 730.0 |
| 96.11.30 | 0100 | | ? | | | | | | 8.17 | 52.00 | 0.110 | 1176.00 | 198.00 | 96.0 | 117.0 | 1945.00 | 118.00 | 436.0 |
| 96.11.30 | 0200 | | ? | | | | | | 8.16 | 64.00 | 1.200 | 1760.00 | 330.00 | 101.0 | 91.0 | 2958.00 | 117.00 | 676.0 |
| 97.06.12 | | | portsp | | 235.0 | 22.80 | 37.40 | | 8.15 | 5.02 | 0.421 | 573.00 | 70.00 | 265.0 | 173.0 | 722.00 | 44.60 | 471.0 |
| ***WELL: KRH 3-1 ST*** | | | | | | | | | | | | | | | | | | |
| . . | | | ? | | | | | | 2.77 | 2010.00 | 21.900 | 3880.00 | 2630.00 | | 137.0 | 16200.00 | 118.00 | 385.0 |
| 97.06.09 | | | portsp | | | | | | 2.16 | 5040.00 | 0.165 | 10120.00 | 7380.00 | | 13.6 | 40870.00 | 178.00 | 122.0 |
| 97.06.14 | | | portsp | | 285.0 | 53.26 | 62.40 | | 8.33 | 4.04 | 0.028 | 759.00 | 146.00 | 99.0 | 89.3 | 1260.00 | 66.30 | 826.0 |
| ***WELL: KRH 4-1*** | | | | | | | | | | | | | | | | | | |
| 97.08.24 | | | portsp | | | | | 1.000 | | | | | | | | | | |
| 97.08.25 | 1703 | | portsp | 1147.00 | 380.0 | 195.73 | 207.40 | 0.940 | | | | | | | | | | |
| 97.08.27 | 0630 | | wbx | 1010.00 | | | 12.40 | 0.859 | 7.79 | 47.20 | 0.130 | 2300.00 | 264.00 | 226.0 | 66.1 | 3940.00 | 191.00 | 770.0 |
| 97.08.27 | 2210 | | portsp | 1060.00 | 440.0 | 381.54 | 422.40 | 0.816 | | | | | | | | | | |
| 97.08.28 | 1435 | | portsp | 1146.00 | 381.5 | 199.32 | 230.40 | 0.938 | | | | | | | | | | |
| 97.08.29 | 2130 | | wbx | 1042.00 | | | 12.40 | 0.892 | 7.77 | 38.80 | 0.110 | 2190.00 | 308.00 | 186.0 | 61.4 | 3760.00 | 176.00 | 726.0 |
| 97.08.30 | 2030 | | wbx | 985.00 | | | 12.40 | 0.834 | 7.70 | 38.80 | 0.056 | 2190.00 | 344.00 | 177.0 | 54.9 | 3850.00 | 181.00 | 707.0 |
| 97.08.31 | 1138 | | portsp | 924.00 | 382.0 | 200.51 | 212.40 | 0.674 | | | | | | | | | | |
| 97.08.31 | 1750 | | wbx | 983.00 | | | 12.40 | 0.832 | 7.70 | 49.00 | 0.050 | 2358.00 | 358.00 | 94.0 | 49.0 | 3988.00 | 190.00 | 763.0 |
| 97.08.31 | 2000 | | wbx | 986.50 | | | 12.40 | 0.835 | 7.73 | 44.20 | 0.070 | 2340.00 | 359.00 | 165.0 | 51.4 | 4010.00 | 189.00 | 699.0 |
| 97.09.01 | 1341 | | wbx | 1026.00 | | | 12.40 | 0.876 | 7.60 | 51.00 | 0.030 | 2393.00 | 375.00 | 88.0 | 47.0 | 3988.00 | 196.00 | 793.0 |
| 97.09.01 | 2100 | | wbx | 1016.00 | | | 12.40 | 0.865 | 7.75 | 45.90 | 0.023 | 2320.00 | 352.00 | 169.0 | 50.1 | 4000.00 | 191.00 | 686.0 |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 1

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | WHP -ga | PORT | Enth | Steam / Water T | Psat | Pabs | Stm. Fr. | Lab pH | Ca | Mg | Na | K | TAlk. HCO3 | SO4 | Cl | B | SiO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WELL: TEL-04 ResurFum Telaga Thermal Manifestation** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | | fum | | 162.0 | | 12.40 | 1.000 | 1.78 | 61.50 | 20.100 | 26.30 | 10.30 | | 1560.0 | 26.00 | 0.35 | 189.0 |
| **WELL: TEL-05 Cipanas** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | | hs | | 142.0 | | 12.40 | | 2.78 | 131.10 | 58.700 | 75.80 | 14.50 | | 622.0 | 288.00 | 1.97 | 293.0 |
| **WELL: TEL-06 Cikahuri** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | | hs | | 118.0 | | 12.40 | | 2.72 | 157.30 | 72.100 | 51.10 | 24.40 | | 438.0 | 2129.00 | 10.30 | 189.0 |
| **WELL: TEL-07 Ciateul** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | | hs | | 109.0 | | 12.40 | | 2.29 | 67.10 | 32.800 | 38.20 | 9.90 | | 298.0 | 322.00 | 1.91 | 183.0 |
| **WELL: TEL-08 Cikajaya** | | | | | | | | | | | | | | | | | | |
| 95.05.19 | | | hs | | 118.0 | | 12.40 | | 1.81 | 174.70 | 97.400 | 98.60 | 27.60 | | 614.0 | 2204.00 | 13.35 | 210.0 |
| **WELL: TEL-09 FireMtn** | | | | | | | | | | | | | | | | | | |
| 96.07.08 | | | hs | | 115.0 | | 12.40 | | 3.89 | 41.00 | 17.000 | 12.50 | 3.50 | 58.0 | 221.0 | 5.20 | 0.86 | 153.0 |
| **WELL: TEL-10 Mixed-Fe** | | | | | | | | | | | | | | | | | | |
| 96.07.08 | | | spring | | 91.0 | 0.09 | 12.40 | | 5.45 | 118.00 | 47.000 | 61.00 | 11.00 | 99.0 | 360.0 | 172.00 | 1.30 | 112.0 |
| **WELL: TEL-A KawahSaat** | | | | | | | | | | | | | | | | | | |
| . . | | | fum | | | | 12.40 | 1.000 | | | | | | | | | | |
| **WELL: TEL-B Tel.Bodas** | | | | | | | | | | | | | | | | | | |
| . . | | | hs | | | | 12.40 | | | | | | | | | | | |
| **WELL: TEL-C Panyipuha** | | | | | | | | | | | | | | | | | | |
| . . | | | hs | | | | 12.40 | | | | | | | | | | | |
| **WELL: TEL-D Cienagang** | | | | | | | | | | | | | | | | | | |
| . . | | | hs | | | | 12.40 | | | | | | | | | | | |
| **WELL: TelagaBodas** | | | | | | | | | | | | | | | | | | |
| 97.06.11 | | | spring | | | | 12.40 | | 2.46 | 33.80 | 46.600 | 28.00 | 1.69 | | 95.6 | 1.81 | 0.35 | 233.0 |
| 97.10.22 | 1000 | | lake | | | | 12.40 | | -1.00 | 394.00 | 206.000 | 122.00 | 30.10 | | 30500.0 | 8850.00 | 1.31 | 348.0 |
| 97.10.22 | 1130 | | lake | | | | 12.40 | | | | | | | | | | | |
| 97.10.22 | 1130 | | lake | | | | 12.40 | | | | | | | | | | | |
| **WELL: Ciawi Artesian X: Concession Area** | | | | | | | | | | | | | | | | | | |
| 97.08.30 | | | well | | 105.0 | 1.10 | 12.40 | | 6.60 | 88.00 | 62.900 | 189.00 | 45.00 | 916.0 | 8.0 | 115.00 | 5.00 | 137.0 |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 1

## Karaha - Telaga Geothermal Prospects
### Water Samples, as collected

| Date | Time (24hr) | WHP -ga | PORT | Enth | Steam / Water T | Psat | Pabs | Stm. Fr. | Lab pH | Ca | Mg | Na | K | TAlk. HCO3 | SO4 | Cl | B | SiO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TAK-01 Kp.Sumur X: Concession Area*** | | | | | | | | | | | | | | | | | | |
| 95.05.20 | | | hs | | 100.4 | | | | 7.10 | 19.30 | 17.500 | 72.40 | 14.80 | 166.0 | 11.0 | 54.00 | 0.75 | 93.5 |
| ***WELL: TAK-02 Kp.Cinta*** | | | | | | | | | | | | | | | | | | |
| 95.05.20 | | | spring | | 78.8 | | | | 6.28 | 14.70 | 7.500 | 8.40 | 1.40 | 55.0 | 8.0 | 6.80 | | 75.1 |
| ***WELL: TAK-03 Panoyana*** | | | | | | | | | | | | | | | | | | |
| 95.05.21 | | | hs | | 114.8 | | | | 6.08 | 79.80 | 65.300 | 187.70 | 45.20 | 656.0 | 1.6 | 11.00 | 6.05 | 191.0 |
| ***WELL: TAK-04 Kp.Salaa*** | | | | | | | | | | | | | | | | | | |
| 95.05.21 | | | spring | | 71.6 | | | | 2.49 | 3.70 | 2.000 | 3.60 | 1.00 | | 191.0 | 10.50 | 1.36 | 36.4 |
| ***WELL: TAK-05 Kp.Salaa*** | | | | | | | | | | | | | | | | | | |
| 95.05.21 | | | spring | | 73.4 | | | | 6.10 | 8.50 | 3.000 | 6.70 | 3.40 | 44.2 | 2.6 | 4.60 | | 53.4 |
| ***WELL: TAK-06 Ci Peles*** | | | | | | | | | | | | | | | | | | |
| 95.06.13 | | | hs | | 104.0 | | | | 6.65 | 132.50 | 88.200 | 165.10 | 36.50 | 980.0 | | 131.00 | 4.53 | 158.4 |
| ***WELL: TAK-07 Galunggu*** | | | | | | | | | | | | | | | | | | |
| 95.06.19 | | | hs | | 149.0 | | | | 6.70 | 150.70 | 127.400 | 367.90 | 62.20 | 545.0 | 1110.0 | 194.00 | 3.30 | 209.2 |
| ***WELL: TAK-08 Kp.Cipac*** | | | | | | | | | | | | | | | | | | |
| 95.06.22 | | | hs | | 122.0 | | | | 6.40 | 67.90 | 86.300 | 253.90 | 60.50 | 1080.0 | | 167.00 | 5.50 | 180.2 |
| ***WELL: TAK-09 Tanjungk*** | | | | | | | | | | | | | | | | | | |
| 95.06.22 | | | hs | | 100.4 | | | | 6.40 | 72.60 | 61.500 | 205.70 | 33.30 | 703.0 | | 224.00 | 8.74 | 150.5 |
| ***WELL: TAK-10 Cicilap*** | | | | | | | | | | | | | | | | | | |
| 95.06.22 | | | hs | | 104.0 | | | | 6.42 | 122.20 | 99.000 | 376.60 | 35.00 | 1070.0 | | 462.00 | 22.22 | 152.5 |
| ***WELL: TAK-11 Panoyana*** | | | | | | | | | | | | | | | | | | |
| 95.06.22 | | | hs | | 109.4 | | | | 6.29 | 74.70 | 61.800 | 188.90 | 43.00 | 881.0 | 2.0 | 103.00 | 5.99 | 189.6 |
| ***WELL: TelagaCipanas*** | | | | | | | | | | | | | | | | | | |
| 97.10.22 | 1500 | | hs | | | | 12.40 | | | | | | | | | | | |
| ***WELL: TelegaCipanas*** | | | | | | | | | | | | | | | | | | |
| 97.10.22 | 1400 | | hs | | | | 12.40 | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

Port C (Additional detail may be found in Comments section of t ):

flowln = flowline (no separator, usually single phase steam or artesian water)
portsp = portable separator
prodsp = output of a production scale or full flow separator
injln = injection line
dh = downhole sampler
atm = after boiling to the atmosphere (but not at weirbox)
wbx = weirbox
wellhd = wellhead (e.g.wingvalve or not specified)
dhpump = single phase pumped flow sampled at surface
spring = spring
hs = hot spring
rain = rainwater
fum = fumarole

# Table C-1 : CHEMICAL ANALYSES OF WATERS: part 2

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | As | Fe | Li | Sr | F | Br | NH4 | Tot. H2S | TDS Meas. | TDS Sum | TDS M/S | meq Sum+ | meq Sum- | meq Tot. | Dif. (%Tot) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: KRH 1-1 RD*** | | | | | | | | | | | | | | | | | | |
| 96.06.06 | | ? | | 2.100 | | 0.310 | | | | | | | 1031 | | 12.5 | 11.2 | 23.8 | 5.49 |
| 97.06.19 | | wbx | | 0.006 | -0.500 | 0.344 | 0.182 | 0.35 | | 1.74 | | | 584 | | 4.3 | 3.9 | 8.3 | 4.52 |
| 97.06.19 | | wbx | | 0.390 | | 1.200 | | | | | | | 3379 | | 49.4 | 48.4 | 97.8 | 1.04 |
| 97.06.19 | | wbx | | 0.180 | | 2.200 | | | | | | | 3118 | | 45.5 | 45.0 | 90.5 | 0.64 |
| ***WELL: KRH 2-1*** | | | | | | | | | | | | | | | | | | |
| 96.10.26 | | ? | | 3.400 | | 0.310 | | | | | | | 3078 | | 36.3 | 29.8 | 66.1 | 9.89 |
| 96.10.27 | | ? | | 3.800 | | 0.660 | | | | | | | 4008 | | 50.2 | 48.6 | 98.8 | 1.63 |
| ***WELL: KRH 2-1 RD*** | | | | | | | | | | | | | | | | | | |
| 96.11.06 | | ? | | 0.640 | | 0.280 | | | | | | | 2252 | | 32.1 | 30.4 | 62.5 | 2.64 |
| 96.11.06 | | ? | | 0.820 | | 0.290 | | | | | | | 2319 | | 33.2 | 31.3 | 64.5 | 2.96 |
| 96.11.16 | 0500 | wbx | | 0.220 | | 0.120 | | | | | | | 1436 | | 20.3 | 18.9 | 39.2 | 3.58 |
| 96.11.17 | 1600 | wbx | | 2.000 | | 0.420 | | | | | | | 3133 | | 40.5 | 39.3 | 79.8 | 1.51 |
| 96.11.17 | 1900 | wbx | | 1.600 | | 0.360 | | | | | | | 3168 | | 42.7 | 41.7 | 84.5 | 1.11 |
| 96.11.29 | 2200 | ? | | 4.400 | | 4.800 | | | | | | | 6152 | | 89.0 | 87.5 | 176.5 | 0.85 |
| 96.11.30 | 0100 | ? | | 1.600 | | 1.300 | | | | | | | 4094 | | 59.0 | 58.8 | 117.9 | 0.13 |
| 96.11.30 | 0200 | ? | | 4.600 | | 5.300 | | | | | | | 6061 | | 89.0 | 86.9 | 176.0 | 1.19 |
| 97.06.12 | | portsp | | 1.520 | 2.470 | 0.975 | 0.056 | 1.45 | | 6.76 | | | 2211 | | 27.7 | 28.3 | 56.0 | -1.22 |
| ***WELL: KRH 3-1 ST*** | | | | | | | | | | | | | | | | | | |
| . . | | ? | | -0.040 | | 32.000 | | | | | | | 25443 | | 344.7 | 459.8 | 804.6 | -14.30 |
| 97.06.09 | | portsp | | -0.510 | 6100.000 | 84.500 | 52.300 | 2.26 | | | | | 70490 | | 1121.5 | 1153.3 | 2274.9 | -1.40 |
| 97.06.14 | | portsp | | 2.490 | -0.500 | 2.560 | 0.027 | 0.84 | | 3.49 | | | 3214 | | 37.5 | 39.0 | 76.6 | -1.94 |
| ***WELL: KRH 4-1*** | | | | | | | | | | | | | | | | | | |
| 97.08.24 | | portsp | 1.000 | | | | | | | | | | | | | | | |
| 97.08.25 | 1703 | portsp | 0.940 | | | | | | | | | | | | | | | |
| 97.08.27 | 0630 | wbx | 0.859 | | 0.302 | 6.080 | 0.514 | 2.75 | | 28.10 | | | 7756 | | 111.6 | 116.3 | 228.0 | -2.08 |
| 97.08.27 | 2210 | portsp | 0.816 | | | | | | | | | | | | | | | |
| 97.08.28 | 1435 | portsp | 0.938 | | | | | | | | | | | | | | | |
| 97.08.29 | 2130 | wbx | 0.892 | | 0.386 | 6.480 | 0.356 | 2.42 | | 23.70 | | | 7409 | | 107.3 | 110.5 | 217.8 | -1.45 |
| 97.08.30 | 2030 | wbx | 0.834 | | 0.259 | 6.720 | 0.369 | 2.05 | | 20.80 | | | 7504 | | 108.1 | 112.7 | 220.9 | -2.09 |
| 97.08.31 | 1138 | portsp | 0.674 | | | | | | | | | | | | | | | |
| 97.08.31 | 1750 | wbx | 0.832 | 10.000 | -0.100 | 5.800 | | 1.00 | | 6.50 | | | 7834 | | 115.4 | 115.1 | 230.5 | 0.12 |
| 97.08.31 | 2000 | wbx | 0.835 | | 0.191 | 6.820 | 0.452 | -2.10 | | 19.60 | | | 7821 | | 115.2 | 116.8 | 232.1 | -0.70 |
| 97.09.01 | 1341 | wbx | 0.876 | 11.000 | -0.100 | 6.900 | | 1.00 | | 6.30 | | | 7920 | | 117.6 | 114.9 | 232.5 | 1.13 |
| 97.09.01 | 2100 | wbx | 0.865 | | -0.200 | 6.850 | 0.525 | -2.00 | | 26.20 | | | 7788 | | 114.6 | 116.6 | 231.3 | -0.86 |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

# Table C-1 : CHEMICAL ANALYSES OF WATERS: part 2

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | As | Fe | Li | Sr | F | Br | NH4 | Tot. H2S | TDS Meas. | TDS Sum | TDS M/S | meq Sum+ | meq Sum- | meq Tot. | Dif. (%Tot) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WELL: KRH 4-1** | | | | | | | | | | | | | | | | | | |
| 97.09.02 | 1500 | wbx | 0.873 | 12.200 | -0.200 | 6.820 | 0.564 | -2.00 | | 22.20 | | | 7976 | | 119.6 | 118.0 | 237.6 | 0.69 |
| 97.09.03 | 1630 | wbx | 0.852 | | -0.200 | 6.700 | 0.587 | -2.10 | | 18.20 | | | 7873 | | 113.8 | 119.2 | 233.0 | -2.33 |
| 97.09.04 | 1725 | portsp | 0.794 | | | | | | | | | | | | | | | |
| 97.09.04 | 1725 | portsp | 0.794 | | | | | | | | | | | | | | | |
| 97.09.04 | 1745 | wbx | 0.794 | | -0.200 | 6.690 | 0.595 | -2.00 | | 24.20 | | | 7872 | | 117.3 | 116.7 | 234.1 | 0.22 |
| 97.09.13 | 1620 | portsp | 0.721 | | | | | | | | | | | | | | | |
| 97.09.13 | 1620 | portsp | 0.721 | | | | | | | | | | | | | | | |
| 97.09.13 | 1720 | wbx | 0.817 | 13.400 | -0.200 | 7.070 | 1.290 | -2.00 | | 22.60 | | | 8272 | | 124.1 | 123.0 | 247.2 | 0.46 |
| **WELL: KRH 5-1** | | | | | | | | | | | | | | | | | | |
| 97.08.28 | 1235 | wbx | 0.485 | 9.000 | -0.100 | 24.300 | | 0.90 | | 6.30 | | | 17618 | | 278.5 | 278.6 | 557.1 | -0.02 |
| 97.09.25 | | portsp | | | | | | | | | | | | | | | | |
| 97.09.25 | 2200 | portsp | | 16.200 | 0.408 | 39.400 | 16.300 | 5.88 | | 18.90 | | | 19061 | | 308.0 | 318.4 | 626.5 | -1.66 |
| 97.10.02 | 1515 | portsp | | 13.400 | -0.210 | 29.700 | 17.500 | 3.65 | | 19.70 | | | 20420 | | 323.1 | 328.4 | 651.5 | -0.82 |
| 97.12.17 | | wbx | | | | | | | | | | | | | | | | |
| **WELL: K-33** | | | | | | | | | | | | | | | | | | |
| . . | | wellhd | | | | | | | | | | | | | | | | -81.82 |
| 97.12.01 | 0510 | portsp | | | | | | | | | | | | | | | | |
| **WELL: K2** | | | | | | | | | | | | | | | | | | |
| 96.05.02 | | wellhd | 1.000 | | | | | | | | | | | | | | | |
| 96.05.02 | | wellhd | 1.000 | | | | | | | | | | | | | | | |
| **WELL: KR-1 Jenkin'sSe** | | | | | | | | | | | | | | | | | | |
| 95.05.08 | | spring | | -0.040 | 1.000 | -0.010 | 0.050 | 0.06 | | | | | 90 | | 1.2 | 0.7 | 1.9 | 26.34 |
| **WELL: KR-2 Kp.Bakom** | | | | | | | | | | | | | | | | | | |
| 95.05.08 | | spring | | 0.010 | 30.700 | 0.100 | 0.040 | 0.04 | | | | | 282 | | 2.4 | 3.9 | 6.4 | -23.29 |
| **WELL: KR-3 Karaha** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | fum | 1.000 | 0.010 | 14.400 | -0.100 | 0.100 | 0.18 | | 49.40 | 9.80 | | 1432 | | 16.1 | 20.1 | 36.3 | -11.02 |
| **WELL: KR-4 Karaha** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | -0.040 | 1.200 | -0.100 | 0.030 | 0.11 | | 94.20 | 32.00 | | 508 | | 6.1 | 5.1 | 11.3 | 8.48 |
| **WELL: KR-5 Kp.Ciselan** | | | | | | | | | | | | | | | | | | |
| 95.05.11 | | spring | | -0.040 | -1.000 | 0.080 | -0.030 | 0.06 | | | | | 108 | | 1.4 | 0.8 | 2.3 | 23.14 |
| **WELL: KR-6 SawahCipan** | | | | | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 2

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | As | Fe | Li | Sr | F | Br | NH4 | Tot. H2S | TDS Meas. | TDS Sum | TDS M/S | meq Sum+ | meq Sum- | meq Tot. | Dif. (%Tot) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: KR-6 SawahCipan*** | | | | | | | | | | | | | | | | | | |
| 95.05.12 | | hs | | -0.040 | 2.400 | -0.100 | 0.140 | 0.07 | | | | | 353 | | 4.8 | 3.7 | 8.5 | 13.34 |
| ***WELL: KR-7 Karaha*** | | | | | | | | | | | | | | | | | | |
| 95.05.18 | | mudpot | | 0.010 | 0.400 | -0.100 | 0.030 | 0.06 | | | 20.00 | | 622 | | 1.1 | 8.3 | 9.4 | -76.46 |
| ***WELL: KR-A Kp.Bakom*** | | | | | | | | | | | | | | | | | | |
| . . | | spring | | | | | | | | | | | | | | | | |
| ***WELL: KRH-03*** | | | | | | | | | | | | | | | | | | |
| 96.05.02 | | fum | 1.000 | | | | | | | | | | | | | | | |
| ***WELL: KR-01*** | | | | | | | | | | | | | | | | | | |
| 87.01.01 | | dh | | 0.040 | 1.000 | | | | | 0.60 | | | 204 | | 2.8 | 3.1 | 5.9 | -4.48 |
| ***WELL: KR-02*** | | | | | | | | | | | | | | | | | | |
| . . | | dh | | 0.030 | 6.000 | 1.630 | | | | 1.00 | | | 1217 | | 20.9 | 21.6 | 42.6 | -1.72 |
| ***WELL: KR-03*** | | | | | | | | | | | | | | | | | | |
| . . | | dh | | 0.040 | 6.070 | 1.630 | | | | 1.04 | | | 762 | | 22.1 | 5.6 | 27.7 | 59.42 |
| ***WELL: KR-04*** | | | | | | | | | | | | | | | | | | |
| . . | | dh | | 0.050 | 6.050 | 1.630 | | | | 1.02 | | | 1367 | | 25.6 | 22.4 | 48.1 | 6.75 |
| ***WELL: TLG 1-1 ST2*** | | | | | | | | | | | | | | | | | | |
| 97.10.04 | 0900 | portsp | | 2.050 | 24.100 | 1.560 | 28.600 | 51.50 | | 43.90 | | | 43185 | | 728.0 | 738.0 | 1466.0 | -0.68 |
| 97.10.04 | 2300 | dh | | 1.150 | 86.900 | 1.870 | 32.200 | 29.20 | | 47.20 | | | 43737 | | 736.0 | 755.1 | 1491.2 | -1.28 |
| 97.10.05 | 0200 | dh | | 0.606 | 137.000 | 2.040 | 37.800 | 26.10 | | 31.10 | | | 50576 | | 870.5 | 862.7 | 1733.3 | 0.45 |
| 97.10.06 | | portsp | | 1.000 | 96.800 | 1.700 | | 0.50 | | 56.80 | | | 47193 | | 770.9 | 823.1 | 1594.0 | -3.28 |
| 97.10.06 | 1300 | portsp | | 0.110 | 536.000 | 3.050 | 71.100 | 31.20 | | 130.00 | | | 93816 | | 1637.4 | 1599.6 | 3237.1 | 1.17 |
| 97.11.10 | | portsp | | | 302.200 | 1.600 | | 0.30 | | 6.10 | | | 13712 | | 208.8 | 232.7 | 441.6 | -5.42 |
| ***WELL: TLG 2-1*** | | | | | | | | | | | | | | | | | | |
| 97.12.29 | 0930 | wbx | 0.977 | -0.500 | 0.160 | 1.590 | | 0.40 | | 298.00 | | | 27385 | | 470.0 | 445.9 | 916.0 | 2.63 |
| 97.12.29 | 1130 | portsp | 1.000 | | | | | | | | | | | | | | | |
| 97.12.29 | 1130 | portsp | 1.000 | | | | | | | 75.90 | | | 152 | | 4.2 | | | |
| 98.02.10 | 1100 | portsp | 1.000 | | | | | | | 387.00 | | | 774 | | 21.4 | | | |
| 98.02.18 | 1045 | portsp | 1.000 | | | | | | | 475.00 | | | 951 | | 26.3 | | | |
| ***WELL: TLG 3-1*** | | | | | | | | | | | | | | | | | | |
| 98.02.17 | 1300 | wbx | 0.896 | | | | | | | | | 5760 | 50 | **.** | | 1.6 | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

# Table C-1 : CHEMICAL ANALYSES OF WATERS: part 2

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | As | Fe | Li | Sr | F | Br | NH4 | Tot. H2S | TDS Meas. | TDS Sum | TDS M/S | meq Sum+ | meq Sum- | meq Tot. | Dif. (%Tot) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TLG 3-1*** | | | | | | | | | | | | | | | | | | |
| 98.02.18 | 1330 | portsp | | | | | | | | 39.20 | | | 78 | | 2.1 | | | |
| 98.02.20 | 1300 | wbx | 0.933 | | | | | | | | | 7240 | 55 | **.** | | 1.8 | | |
| 98.02.23 | | wbx | 0.932 | | | | | | | | | 7680 | 51 | **.** | | 1.6 | | |
| 98.02.23 | 1130 | wbx | | | | | | | | | | | | | | | | |
| ***WELL: T-2*** | | | | | | | | | | | | | | | | | | |
| 97.06.10 | | portsp | 0.941 | -0.052 | 51.100 | 0.042 | 0.360 | 22.40 | | 697.00 | | | 4661 | | 44.6 | 75.8 | 120.4 | -25.88 |
| 97.06.11 | | portsp | 0.943 | -0.056 | 175.000 | 0.038 | 0.454 | 15.70 | | 115.00 | | | 4058 | | 18.6 | 62.0 | 80.7 | -53.80 |
| 97.10.18 | 1400 | portsp | | | | | | | | | | | | | | | | |
| ***WELL: T-8*** | | | | | | | | | | | | | | | | | | |
| 97.07.11 | 1730 | portsp | | -0.050 | 9999.999 | 0.143 | 0.612 | 34.60 | | 999.99 | | | 73070 | | 464.7 | 1633.1 | 2097.8 | -55.70 |
| 97.07.13 | | portsp | | | 9999.999 | 0.291 | 3.420 | 45.10 | | 999.99 | | | 142433 | | 495.9 | 3531.8 | 4027.7 | -75.37 |
| 97.07.13 | | portsp | | -0.052 | 9999.999 | 0.276 | 3.380 | 39.90 | | 999.99 | | | 146349 | | 591.4 | 3588.2 | 4179.6 | -71.70 |
| 97.07.22 | | portsp | | -0.050 | 9999.999 | 0.168 | 3.710 | 30.70 | | 999.99 | | | 197543 | | 595.6 | 5041.3 | 5637.0 | -78.87 |
| ***WELL: FM-3 spring*** | | | | | | | | | | | | | | | | | | |
| 97.06.25 | 1415 | spring | | -0.050 | 19.200 | 0.035 | 0.112 | 0.95 | | 3.54 | | | 1682 | | 21.5 | 30.5 | 52.0 | -17.21 |
| ***WELL: FM-4 spring*** | | | | | | | | | | | | | | | | | | |
| 97.06.10 | | spring | | | | | | | | | | | | | | | | |
| ***WELL: KBC Hot Spring*** | | | | | | | | | | | | | | | | | | |
| 97.10.21 | 1530 | spring | | 0.040 | 555.000 | -0.050 | 0.333 | -0.99 | | 2.08 | | | 7011 | | 91.6 | 144.1 | 235.7 | -22.30 |
| ***WELL: TB-01 TelagaBod*** | | | | | | | | | | | | | | | | | | |
| 96.05.03 | | fum | 1.000 | | | | | | | | | | | | | | | |
| ***WELL: TB-03 TelagaBod*** | | | | | | | | | | | | | | | | | | |
| 96.05.03 | | spring | | | | | | | | | | | | | | | | |
| ***WELL: TEL-01 Tel.Boda*** | | | | | | | | | | | | | | | | | | |
| 95.05.08 | | lake | | -0.040 | 3.300 | 0.080 | 0.080 | 0.21 | | | | | 472 | | 6.2 | 6.2 | 12.5 | 0.11 |
| ***WELL: TEL-02 Tel.Bod*** | | | | | | | | | | | | | | | | | | |
| 95.05.08 | | fum | 1.000 | -0.040 | 30.800 | 0.040 | 0.090 | 0.54 | | | | | 2874 | | 32.9 | 43.1 | 76.1 | -13.44 |
| ***WELL: TEL-03 Tel.Boda*** | | | | | | | | | | | | | | | | | | |
| 95.05.08 | | mudpot | | -0.040 | 168.400 | 0.480 | 1.010 | 0.08 | | | | | 9471 | | 225.4 | 191.1 | 416.5 | 8.23 |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

# Table C-1 : CHEMICAL ANALYSES OF WATERS: part 2

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | As | Fe | Li | Sr | F | Br | NH4 | Tot. H2S | TDS Meas. | TDS Sum | TDS M/S | meq Sum+ | meq Sum- | meq Tot. | Dif. (%Tot) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TEL-04 ResurFum*** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | fum | 1.000 | -0.040 | 24.800 | 0.170 | 0.250 | 0.29 | | | | | 1978 | | 30.1 | 33.2 | 63.3 | -4.89 |
| ***WELL: TEL-05 Cipanas*** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | -0.040 | 17.600 | 0.160 | 0.250 | 1.04 | | | | | 1539 | | 21.0 | 21.1 | 42.1 | -0.28 |
| ***WELL: TEL-06 Cikahuri*** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | 0.650 | 94.400 | 0.060 | 0.580 | 1.59 | | | | | 3633 | | 73.3 | 69.2 | 142.5 | 2.84 |
| ***WELL: TEL-07 Ciateul*** | | | | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | 0.040 | 15.200 | | 0.180 | 0.80 | | | | | 1006 | | 17.6 | 15.3 | 32.9 | 6.97 |
| ***WELL: TEL-08 Cikajaya*** | | | | | | | | | | | | | | | | | | |
| 95.05.19 | | hs | | 0.080 | 48.000 | -0.010 | 0.660 | 0.77 | | | | | 3841 | | 77.9 | 75.0 | 152.9 | 1.90 |
| ***WELL: TEL-09 FireMtn*** | | | | | | | | | | | | | | | | | | |
| 96.07.08 | | hs | | | -1.000 | -0.010 | | | | | | | 483 | | 4.2 | 5.7 | 9.9 | -15.08 |
| ***WELL: TEL-10 Mixed-Fe*** | | | | | | | | | | | | | | | | | | |
| 96.07.08 | | spring | | | -1.000 | -0.010 | | | | | | | 931 | | 12.6 | 13.9 | 26.6 | -4.80 |
| ***WELL: TEL-A KawahSaat*** | | | | | | | | | | | | | | | | | | |
| . . | | fum | 1.000 | | | | | | | | | | | | | | | |
| ***WELL: TEL-B Tel.Bodas*** | | | | | | | | | | | | | | | | | | |
| . . | | hs | | | | | | | | | | | | | | | | |
| ***WELL: TEL-C Panyipuha*** | | | | | | | | | | | | | | | | | | |
| . . | | hs | | | | | | | | | | | | | | | | |
| ***WELL: TEL-D Cienagang*** | | | | | | | | | | | | | | | | | | |
| . . | | hs | | | | | | | | | | | | | | | | |
| ***WELL: TelagaBodas*** | | | | | | | | | | | | | | | | | | |
| 97.06.11 | | spring | | -0.050 | 13.700 | -0.020 | 0.055 | 0.52 | | 1.09 | | | 492 | | 14.4 | 2.0 | 16.5 | 74.95 |
| 97.10.22 | 1000 | lake | | 0.098 | 2320.000 | -0.050 | 1.380 | -2.80 | | 13.90 | | | 43522 | | 201.8 | 884.9 | 1086.8 | -62.86 |
| 97.10.22 | 1130 | lake | | | | | | | | | | | | | | | | |
| 97.10.22 | 1130 | lake | | | | | | | | | | | | | | | | |
| ***WELL: Ciawi Artesian*** | | | | | | | | | | | | | | | | | | |
| 97.08.30 | | well | | -0.500 | -0.100 | 0.500 | | 0.10 | | 0.30 | | | 1102 | | 19.0 | 18.4 | 37.4 | 1.60 |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

GeothermEx, Inc. KBANA 98.04.23

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 2

**Karaha - Telaga Geothermal Prospects**
**Water Samples, as collected**

| Date | Time (24hr) | PORT | Stm. Fr. | As | Fe | Li | Sr | F | Br | NH4 | Tot. H2S | TDS Meas. | TDS Sum | TDS M/S | meq Sum+ | meq Sum- | meq Tot. | Dif. (%Tot) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TAK-01 Kp.Sumur*** | | | | | | | | | | | | | | | | | | |
| 95.05.20 | | hs | | | 0.200 | | 0.090 | 0.06 | | | | | 366 | | 5.9 | 4.4 | 10.4 | 14.52 |
| ***WELL: TAK-02 Kp.Cinta*** | | | | | | | | | | | | | | | | | | |
| 95.05.20 | | spring | | 0.010 | | | 0.050 | 0.05 | | | | | 149 | | 1.7 | 1.2 | 3.0 | 16.33 |
| ***WELL: TAK-03 Panoyana*** | | | | | | | | | | | | | | | | | | |
| 95.05.21 | | hs | | 0.010 | 0.400 | 0.390 | 0.690 | 0.07 | | | 0.30 | | 912 | | 18.7 | 11.0 | 29.8 | 25.67 |
| ***WELL: TAK-04 Kp.Salaa*** | | | | | | | | | | | | | | | | | | |
| 95.05.21 | | spring | | | 6.800 | | 0.020 | 0.04 | | | | | 256 | | 4.0 | 4.2 | 8.2 | -3.20 |
| ***WELL: TAK-05 Kp.Salaa*** | | | | | | | | | | | | | | | | | | |
| 95.05.21 | | spring | | | 0.100 | | 0.070 | 0.05 | | | | | 104 | | 1.0 | 0.9 | 1.9 | 7.34 |
| ***WELL: TAK-06 Ci Peles*** | | | | | | | | | | | | | | | | | | |
| 95.06.13 | | hs | | | 3.900 | 0.230 | 1.330 | 0.10 | | | | | 1204 | | 22.1 | 19.7 | 41.9 | 5.79 |
| ***WELL: TAK-07 Galunggu*** | | | | | | | | | | | | | | | | | | |
| 95.06.19 | | hs | | 0.020 | | 0.210 | 0.660 | 0.12 | | | | | 2494 | | 35.6 | 37.5 | 73.1 | -2.58 |
| ***WELL: TAK-08 Kp.Cipac*** | | | | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | | 0.800 | 0.460 | 0.520 | 0.12 | | | | | 1355 | | 23.1 | 22.4 | 45.6 | 1.70 |
| ***WELL: TAK-09 Tanjungk*** | | | | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | | 1.600 | 0.280 | 0.550 | 0.13 | | | | | 1105 | | 18.5 | 17.8 | 36.4 | 2.05 |
| ***WELL: TAK-10 Cicilap*** | | | | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | 0.010 | 0.400 | 0.490 | 1.270 | 0.07 | | | | | 1798 | | 31.6 | 30.5 | 62.2 | 1.71 |
| ***WELL: TAK-11 Panoyana*** | | | | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | | | 0.360 | 0.660 | 0.10 | | | | | 1104 | | 18.2 | 17.3 | 35.5 | 2.27 |
| ***WELL: TelagaCipanas*** | | | | | | | | | | | | | | | | | | |
| 97.10.22 | 1500 | hs | | | | | | | | | | | | | | | | |
| ***WELL: TelegaCipanas*** | | | | | | | | | | | | | | | | | | |
| 97.10.22 | 1400 | hs | | | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 3

**Karaha - Telaga Geothermal Prospects**

**Water Samples, as collected**

| Date | Time (24hr) | PORT | Stm. Fr. | Ag | Al | Ba | Cd | Cu | Cr | Cs | Hg | Mn | Ni | Pb | Rb | Sb | Se |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: KRH 1-1 RD*** | | | | | | | | | | | | | | | | | |
| 96.06.06 | | ? | | | | | | | | 0.020 | | | | | 0.110 | | |
| 97.06.19 | | wbx | | | 0.160 | -0.970 | | | | 0.109 | | -0.050 | | | 0.387 | | |
| 97.06.19 | | wbx | | | | | | | | 0.880 | | | | | 1.210 | | |
| 97.06.19 | | wbx | | | | | | | | 0.670 | | | | | 1.020 | | |
| ***WELL: KRH 2-1*** | | | | | | | | | | | | | | | | | |
| 96.10.26 | | ? | | | | | | | | 0.180 | | | | | 0.460 | | |
| 96.10.27 | | ? | | | | | | | | 0.420 | | | | | 0.940 | | |
| ***WELL: KRH 2-1 RD*** | | | | | | | | | | | | | | | | | |
| 96.11.06 | | ? | | | | | | | | 0.190 | | | | | 0.480 | | |
| 96.11.06 | | ? | | | | | | | | 0.210 | | | | | 0.500 | | |
| 96.11.16 | 0500 | wbx | | | | | | | | 0.050 | | | | | 0.200 | | |
| 96.11.17 | 1600 | wbx | | | | | | | | 0.390 | | | | | 0.800 | | |
| 96.11.17 | 1900 | wbx | | | | | | | | 0.400 | | | | | 0.830 | | |
| 96.11.29 | 2200 | ? | | | | | | | | 1.500 | | | | | 2.700 | | |
| 96.11.30 | 0100 | ? | | | | | | | | 0.710 | | | | | 1.400 | | |
| 96.11.30 | 0200 | ? | | | | | | | | 1.400 | | | | | 2.600 | | |
| 97.06.12 | | portsp | | | 0.592 | -1.000 | | | | 0.309 | | -0.050 | | | 0.733 | | |
| ***WELL: KRH 3-1 ST*** | | | | | | | | | | | | | | | | | |
| . . | | ? | | | | | | | | 10.500 | | | | | 18.400 | | |
| 97.06.09 | | portsp | | | 10.600 | 14.200 | | | | 2.520 | | 21.200 | | | 4.030 | | |
| 97.06.14 | | portsp | | | 0.448 | -1.000 | | | | 0.592 | | -0.050 | | | 1.020 | | |
| ***WELL: KRH 4-1*** | | | | | | | | | | | | | | | | | |
| 97.08.24 | | portsp | 1.000 | | | | | | | | | | | | | | |
| 97.08.25 | 1703 | portsp | 0.940 | | | | | | | | | | | | | | |
| 97.08.27 | 0630 | wbx | 0.859 | | | 0.261 | | | | | | | | | | | |
| 97.08.27 | 2210 | portsp | 0.816 | | | | | | | | | | | | | | |
| 97.08.28 | 1435 | portsp | 0.938 | | | | | | | | | | | | | | |
| 97.08.29 | 2130 | wbx | 0.892 | | | 0.132 | | | | | | | | | | | |
| 97.08.30 | 2030 | wbx | 0.834 | | | 0.111 | | | | | | | | | | | |
| 97.08.31 | 1138 | portsp | 0.674 | | | | | | | | | | | | | | |
| 97.08.31 | 1750 | wbx | 0.832 | | | | | | | 0.700 | | | | | 1.830 | | |
| 97.08.31 | 2000 | wbx | 0.835 | | | 0.107 | | | | | | | | | | | |
| 97.09.01 | 1341 | wbx | 0.876 | | | | | | | 0.700 | | | | | 1.930 | | |
| 97.09.01 | 2100 | wbx | 0.865 | | | 0.117 | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi deg F btu/lb mg/l

Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 3

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | Ag | Al | Ba | Cd | Cu | Cr | Cs | Hg | Mn | Ni | Pb | Rb | Sb | Se |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: KRH 4-1*** | | | | | | | | | | | | | | | | | |
| 97.09.02 | 1500 | wbx | 0.873 | | 0.691 | 0.135 | | -0.005 | | | | 0.034 | | -0.007 | | | |
| 97.09.03 | 1630 | wbx | 0.852 | | | 0.205 | | | | | | | | | | | |
| 97.09.04 | 1725 | portsp | 0.794 | | | | | | | | | | | | | | |
| 97.09.04 | 1725 | portsp | 0.794 | | | | | | | | | | | | | | |
| 97.09.04 | 1745 | wbx | 0.794 | | | 0.121 | | | | | | | | | | | |
| 97.09.13 | 1620 | portsp | 0.721 | | | | | | | | | | | | | | |
| 97.09.13 | 1620 | portsp | 0.721 | | | | | | | | | | | | | | |
| 97.09.13 | 1720 | wbx | 0.817 | | 0.533 | 0.117 | | -0.005 | | -0.005 | | 0.027 | | -0.007 | 0.027 | | |
| ***WELL: KRH 5-1*** | | | | | | | | | | | | | | | | | |
| 97.08.28 | 1235 | wbx | 0.485 | | | | | | | 4.300 | | | | | 8.460 | | |
| 97.09.25 | | portsp | | | | | | | | | | | | | | | |
| 97.09.25 | 2200 | portsp | | | 0.158 | 5.310 | | -0.005 | | | | 8.940 | | -0.007 | | | |
| 97.10.02 | 1515 | portsp | | | -0.021 | 5.770 | | -0.008 | | | | 16.200 | | -0.007 | | | |
| 97.12.17 | | wbx | | | | | | | | | | | | | | | |
| ***WELL: K-33*** | | | | | | | | | | | | | | | | | |
| . . | | wellhd | | | | | | | | | | | | | | | |
| 97.12.01 | 0510 | portsp | | | | | | | | | | | | | | | |
| ***WELL: K2*** | | | | | | | | | | | | | | | | | |
| 96.05.02 | | wellhd | 1.000 | | | | | | | | | | | | | | |
| 96.05.02 | | wellhd | 1.000 | | | | | | | | | | | | | | |
| ***WELL: KR-1 Jenkin'sSe*** | | | | | | | | | | | | | | | | | |
| 95.05.08 | | spring | | | -0.100 | | | | | -0.040 | | -0.100 | | | -0.050 | | |
| ***WELL: KR-2 Kp.Bakom*** | | | | | | | | | | | | | | | | | |
| 95.05.08 | | spring | | | 5.000 | | | | | -0.040 | | -0.100 | | | -0.050 | | |
| ***WELL: KR-3 Karaha*** | | | | | | | | | | | | | | | | | |
| 95.05.09 | | fum | 1.000 | | 35.800 | | | | | -0.040 | | 1.250 | | | -0.050 | | |
| ***WELL: KR-4 Karaha*** | | | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | | 0.500 | | | | | -0.040 | | -0.100 | | | -0.050 | | |
| ***WELL: KR-5 Kp.Ciselan*** | | | | | | | | | | | | | | | | | |
| 95.05.11 | | spring | | | -0.100 | | | | | -0.040 | | -0.100 | | | -0.050 | | |
| ***WELL: KR-6 SawahCipan*** | | | | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

# Table C-1 : CHEMICAL ANALYSES OF WATERS: part 3

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | Ag | Al | Ba | Cd | Cu | Cr | Cs | Hg | Mn | Ni | Pb | Rb | Sb | Se |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: KR-6 SawahCipan*** | | | | | | | | | | | | | | | | | |
| 95.05.12 | | hs | | | -0.100 | | | | | -0.040 | | -0.100 | | | -0.050 | | |
| ***WELL: KR-7 Karaha*** | | | | | | | | | | | | | | | | | |
| 95.05.18 | | mudpot | | | -0.100 | | | | | -0.040 | | -0.100 | | | -0.050 | | |
| ***WELL: KR-A Kp.Bakom*** | | | | | | | | | | | | | | | | | |
| . . | | spring | | | | | | | | | | | | | | | |
| ***WELL: KRH-03*** | | | | | | | | | | | | | | | | | |
| 96.05.02 | | fum | 1.000 | | | | | | | | | | | | | | |
| ***WELL: KR-01*** | | | | | | | | | | | | | | | | | |
| 87.01.01 | | dh | | | | | | | | | | | | | | | |
| ***WELL: KR-02*** | | | | | | | | | | | | | | | | | |
| . . | | dh | | | | | | | | | | | | | | | |
| ***WELL: KR-03*** | | | | | | | | | | | | | | | | | |
| . . | | dh | | | | | | | | | | | | | | | |
| ***WELL: KR-04*** | | | | | | | | | | | | | | | | | |
| . . | | dh | | | | | | | | | | | | | | | |
| ***WELL: TLG 1-1 ST2*** | | | | | | | | | | | | | | | | | |
| 97.10.04 | 0900 | portsp | | | 0.047 | 18.800 | | -0.008 | | | | 92.900 | | -0.007 | | | |
| 97.10.04 | 2300 | dh | | | 0.140 | 15.800 | | 0.029 | | | | 86.900 | | -0.008 | | | |
| 97.10.05 | 0200 | dh | | | 0.108 | 15.600 | | 0.958 | | | | 77.400 | | -0.008 | | | |
| 97.10.06 | | portsp | | | | | | | | 1.700 | | | | | 7.100 | | |
| 97.10.06 | 1300 | portsp | | | 0.103 | 41.300 | | -0.008 | | | | 340.000 | | -0.007 | | | |
| 97.11.10 | | portsp | | | | | | | | | | | | | | | |
| ***WELL: TLG 2-1*** | | | | | | | | | | | | | | | | | |
| 97.12.29 | 0930 | wbx | 0.977 | | 0.500 | | | | | 0.390 | | | | | 4.380 | | |
| 97.12.29 | 1130 | portsp | 1.000 | | | | | | | | | | | | | | |
| 97.12.29 | 1130 | portsp | 1.000 | | | | | | | | | | | | | | |
| 98.02.10 | 1100 | portsp | 1.000 | | | | | | | | | | | | | | |
| 98.02.18 | 1045 | portsp | 1.000 | | | | | | | | | | | | | | |
| ***WELL: TLG 3-1*** | | | | | | | | | | | | | | | | | |
| 98.02.17 | 1300 | wbx | 0.896 | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

# Table C-1 : CHEMICAL ANALYSES OF WATERS: part 3

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | Ag | Al | Ba | Cd | Cu | Cr | Cs | Hg | Mn | Ni | Pb | Rb | Sb | Se |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TLG 3-1*** | | | | | | | | | | | | | | | | | |
| 98.02.18 | 1330 | portsp | | | | | | | | | | | | | | | |
| 98.02.20 | 1300 | wbx | 0.933 | | | | | | | | | | | | | | |
| 98.02.23 | | wbx | 0.932 | | | | | | | | | | | | | | |
| 98.02.23 | 1130 | wbx | | | | | | | | | | | | | | | |
| ***WELL: T-2*** | | | | | | | | | | | | | | | | | |
| 97.06.10 | | portsp | 0.941 | | 0.752 | -1.000 | | | -0.100 | | | 28.700 | | | 0.257 | | |
| 97.06.11 | | portsp | 0.943 | | 0.672 | -1.000 | | | | -0.100 | | 39.800 | | | 0.255 | | |
| 97.10.18 | 1400 | portsp | | | | | | | | | | | | | | | |
| ***WELL: T-8*** | | | | | | | | | | | | | | | | | |
| 97.07.11 | 1730 | portsp | | | -0.030 | -25.400 | | -0.050 | | | | 697.000 | | 2.540 | | | |
| 97.07.13 | | portsp | | | | -25.300 | | | | | | | | | | | |
| 97.07.13 | | portsp | | | -0.030 | -26.400 | | -0.050 | | | | 1630.000 | | 3.970 | | | |
| 97.07.22 | | portsp | | | -0.030 | -24.900 | | -0.050 | | | | 2000.000 | | 4.640 | | | |
| ***WELL: FM-3 spring*** | | | | | | | | | | | | | | | | | |
| 97.06.25 | 1415 | spring | | | 57.200 | -1.000 | | | | -0.100 | | 2.510 | | | 0.339 | | |
| ***WELL: FM-4 spring*** | | | | | | | | | | | | | | | | | |
| 97.06.10 | | spring | | | | | | | | | | | | | | | |
| ***WELL: KBC Hot Spring*** | | | | | | | | | | | | | | | | | |
| 97.10.21 | 1530 | spring | | | 6.900 | 0.052 | | -0.200 | | | | 2.490 | | -0.050 | | | |
| ***WELL: TB-01 TelagaBod*** | | | | | | | | | | | | | | | | | |
| 96.05.03 | | fum | 1.000 | | | | | | | | | | | | | | |
| ***WELL: TB-03 TelagaBod*** | | | | | | | | | | | | | | | | | |
| 96.05.03 | | spring | | | | | | | | | | | | | | | |
| ***WELL: TEL-01 Tel.Boda*** | | | | | | | | | | | | | | | | | |
| 95.05.08 | | lake | | | 8.000 | | | | | -0.040 | | -0.100 | | | -0.050 | | |
| ***WELL: TEL-02 Tel.Bod*** | | | | | | | | | | | | | | | | | |
| 95.05.08 | | fum | 1.000 | | 94.100 | | | | | 0.050 | | 2.610 | | | -0.050 | | |
| ***WELL: TEL-03 Tel.Boda*** | | | | | | | | | | | | | | | | | |
| 95.05.08 | | mudpot | | | 328.000 | | | | | -0.040 | | 4.020 | | | 0.100 | | |
| ***WELL: TEL-04 ResurFum*** | | | | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

GeothermEx, Inc. KBANA 98.04.23

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 3

**Karaha - Telaga Geothermal Prospects**
**Water Samples, as collected**

| Date | Time (24hr) | PORT | Stm. Fr. | Ag | Al | Ba | Cd | Cu | Cr | Cs | Hg | Mn | Ni | Pb | Rb | Sb | Se |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TEL-04 ResurFum*** | | | | | | | | | | | | | | | | | |
| 95.05.09 | | fum | 1.000 | | 58.200 | | | | | 0.040 | | 0.820 | | | -0.050 | | |
| ***WELL: TEL-05 Cipanas*** | | | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | | 32.000 | | | | | 0.050 | | 2.790 | | | -0.050 | | |
| ***WELL: TEL-06 Cikahuri*** | | | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | | 460.800 | | | | | -0.040 | | 3.670 | | | 0.050 | | |
| ***WELL: TEL-07 Ciateul*** | | | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | | 35.600 | | | | | -0.040 | | 0.930 | | | -0.050 | | |
| ***WELL: TEL-08 Cikajaya*** | | | | | | | | | | | | | | | | | |
| 95.05.19 | | hs | | | 349.600 | | | | | 0.040 | | 2.460 | | | 0.150 | | |
| ***WELL: TEL-09 FireMtn*** | | | | | | | | | | | | | | | | | |
| 96.07.08 | | hs | | | -0.100 | | | | | -0.040 | | | | | -0.050 | | |
| ***WELL: TEL-10 Mixed-Fe*** | | | | | | | | | | | | | | | | | |
| 96.07.08 | | spring | | | -0.100 | | | | | -0.040 | | | | | -0.050 | | |
| ***WELL: TEL-A KawahSaat*** | | | | | | | | | | | | | | | | | |
| . . | | fum | 1.000 | | | | | | | | | | | | | | |
| ***WELL: TEL-B Tel.Bodas*** | | | | | | | | | | | | | | | | | |
| . . | | hs | | | | | | | | | | | | | | | |
| ***WELL: TEL-C Panyipuha*** | | | | | | | | | | | | | | | | | |
| . . | | hs | | | | | | | | | | | | | | | |
| ***WELL: TEL-D Cienagang*** | | | | | | | | | | | | | | | | | |
| . . | | hs | | | | | | | | | | | | | | | |
| ***WELL: TelagaBodas*** | | | | | | | | | | | | | | | | | |
| 97.06.11 | | spring | | | 32.100 | -0.960 | | | | -0.100 | | 2.000 | | | 0.283 | | |
| 97.10.22 | 1000 | lake | | | 675.000 | 0.136 | | -0.200 | | | | 5.600 | | -0.050 | | | |
| 97.10.22 | 1130 | lake | | | | | | | | | | | | | | | |
| 97.10.22 | 1130 | lake | | | | | | | | | | | | | | | |
| ***WELL: Ciawi Artesian*** | | | | | | | | | | | | | | | | | |
| 97.08.30 | | well | | | | | | | | -0.010 | | | | | 0.120 | | |
| ***WELL: TAK-01 Kp.Sumur*** | | | | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

# Table C-1 : CHEMICAL ANALYSES OF WATERS: part 3

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | Ag | Al | Ba | Cd | Cu | Cr | Cs | Hg | Mn | Ni | Pb | Rb | Sb | Se |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TAK-01 Kp.Sumur*** | | | | | | | | | | | | | | | | | |
| 95.05.20 | | hs | | | 0.500 | | | | | 0.040 | | | | | 0.050 | | |
| ***WELL: TAK-02 Kp.Cinta*** | | | | | | | | | | | | | | | | | |
| 95.05.20 | | spring | | | | | | | | | | | | | 0.170 | | |
| ***WELL: TAK-03 Panoyana*** | | | | | | | | | | | | | | | | | |
| 95.05.21 | | hs | | | | | | | | 0.080 | | | | | 0.170 | | |
| ***WELL: TAK-04 Kp.Salaa*** | | | | | | | | | | | | | | | | | |
| 95.05.21 | | spring | | | | | | | | | | | | | | | |
| ***WELL: TAK-05 Kp.Salaa*** | | | | | | | | | | | | | | | | | |
| 95.05.21 | | spring | | | | | | | | | | | | | | | |
| ***WELL: TAK-06 Ci Peles*** | | | | | | | | | | | | | | | | | |
| 95.06.13 | | hs | | | | | | | | 0.110 | | | | | 0.130 | | |
| ***WELL: TAK-07 Galunggu*** | | | | | | | | | | | | | | | | | |
| 95.06.19 | | hs | | | | | | | | 0.130 | | | | | 0.220 | | |
| ***WELL: TAK-08 Kp.Cipac*** | | | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | | | | | | | 0.140 | | | | | 0.210 | | |
| ***WELL: TAK-09 Tanjungk*** | | | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | | | | | | | 0.110 | | | | | 0.110 | | |
| ***WELL: TAK-10 Cicilap*** | | | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | | | | | | | 0.130 | | | | | 0.120 | | |
| ***WELL: TAK-11 Panoyana*** | | | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | | | | | | | 0.150 | | | | | 0.110 | | |
| ***WELL: TelagaCipanas*** | | | | | | | | | | | | | | | | | |
| 97.10.22 | 1500 | hs | | | | | | | | | | | | | | | |
| ***WELL: TelegaCipanas*** | | | | | | | | | | | | | | | | | |
| 97.10.22 | 1400 | hs | | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)
File Units: klb/hr psi degF btu/lb mg/l
Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 4

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | Sn | Zn | I | NO3 | True HCO3 | True CO3 | T.I.C. as CO2 (TCO2) | Alk. HCO3 | Alk. CO3 | T.Alk HCO3 | Density 25degC | Ec micromho 25degC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WELL: KRH 1-1 RD** | | | | | | | | | | | | | | | |
| 96.06.06 | | ? | | | | | | | | | 154.00 | | 154.00 | | |
| 97.06.19 | | wbx | | | -0.010 | | | | | | 156.00 | -2.00 | 156.00 | | |
| 97.06.19 | | wbx | | | | | | | | | 46.00 | | 46.00 | | |
| 97.06.19 | | wbx | | | | | | | | | 99.00 | | 99.00 | | |
| **WELL: KRH 2-1** | | | | | | | | | | | | | | | |
| 96.10.26 | | ? | | | | | | 55.000 | | | | | | | |
| 96.10.27 | | ? | | | | | | 146.000 | | | 226.00 | | 226.00 | | |
| **WELL: KRH 2-1 RD** | | | | | | | | | | | | | | | |
| 96.11.06 | | ? | | | | | | 153.000 | | | 198.00 | | 198.00 | | |
| 96.11.06 | | ? | | | | | | 119.000 | | | 173.00 | | 173.00 | | |
| 96.11.16 | 0500 | wbx | | | | | | 323.000 | | | 247.00 | | 247.00 | | |
| 96.11.17 | 1600 | wbx | | | | | | 111.000 | | | 131.00 | | 131.00 | | |
| 96.11.17 | 1900 | wbx | | | | | | 145.000 | | | 127.00 | | 127.00 | | |
| 96.11.29 | 2200 | ? | | | | | | | | | 101.00 | | 101.00 | | |
| 96.11.30 | 0100 | ? | | | | | | | | | 96.00 | | 96.00 | | |
| 96.11.30 | 0200 | ? | | | | | | | | | 101.00 | | 101.00 | | |
| 97.06.12 | | portsp | | | 0.028 | | | | | | 265.00 | -2.00 | 265.00 | | 2900 |
| **WELL: KRH 3-1 ST** | | | | | | | | | | | | | | | |
| . . | | ? | | | | | | | | | | | | | |
| 97.06.09 | | portsp | | | 475.000 | | | | | | -2.00 | -2.00 | | | 79860 |
| 97.06.14 | | portsp | | | -0.010 | | | | | | 99.00 | -2.00 | 99.00 | | 4060 |
| **WELL: KRH 4-1** | | | | | | | | | | | | | | | |
| 97.08.24 | | portsp | 1.000 | | | | | | | | | | | | |
| 97.08.25 | 1703 | portsp | 0.940 | | | | | | | | | | | | |
| 97.08.27 | 0630 | wbx | 0.859 | | | | | | | | 226.00 | -2.00 | 226.00 | | 13000 |
| 97.08.27 | 2210 | portsp | 0.816 | | | | | | | | | | | | |
| 97.08.28 | 1435 | portsp | 0.938 | | | | | | | | | | | | |
| 97.08.29 | 2130 | wbx | 0.892 | | | | | | | | 186.00 | -2.00 | 186.00 | | 12700 |
| 97.08.30 | 2030 | wbx | 0.834 | | | | | | | | 177.00 | -2.00 | 177.00 | | 12700 |
| 97.08.31 | 1138 | portsp | 0.674 | | | | | | | | | | | | |
| 97.08.31 | 1750 | wbx | 0.832 | | | | | | | | 94.00 | | 94.00 | | |
| 97.08.31 | 2000 | wbx | 0.835 | | | | | | | | 165.00 | -2.00 | 165.00 | | 13100 |
| 97.09.01 | 1341 | wbx | 0.876 | | | | | | | | 88.00 | | 88.00 | | |
| 97.09.01 | 2100 | wbx | 0.865 | | | | | | | | 169.00 | -2.00 | 169.00 | | 13300 |



Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l
Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 4

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | Sn | Zn | I | NO3 | True HCO3 | True CO3 | T.I.C. as CO2 (TCO2) | Alk. HCO3 | Alk. CO3 | T.Alk HCO3 | Density 25degC | Ec micromho 25degC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WELL: KRH 4-1** | | | | | | | | | | | | | | | |
| 97.09.02 | 1500 | wbx | 0.873 | | -0.100 | | | | | | 163.00 | -2.00 | 163.00 | | 13100 |
| 97.09.03 | 1630 | wbx | 0.852 | | | | | | | | 157.00 | -2.00 | 157.00 | | 13100 |
| 97.09.04 | 1725 | portsp | 0.794 | | | | | | | | | | | | |
| 97.09.04 | 1725 | portsp | 0.794 | | | | | | | | | | | | |
| 97.09.04 | 1745 | wbx | 0.794 | | | | | | | | 160.00 | -2.00 | 160.00 | | 13100 |
| 97.09.13 | 1620 | portsp | 0.721 | | | | | | | | | | | | |
| 97.09.13 | 1620 | portsp | 0.721 | | | | | | | | | | | | |
| 97.09.13 | 1720 | wbx | 0.817 | | -0.100 | | | | | | 127.00 | -2.00 | 127.00 | | 13900 |
| **WELL: KRH 5-1** | | | | | | | | | | | | | | | |
| 97.08.28 | 1235 | wbx | 0.485 | | | | | | | | -5.00 | | | | |
| 97.09.25 | | portsp | | | | | | | | | | | | | |
| 97.09.25 | 2200 | portsp | | | -0.100 | | | | | | 41.80 | -2.00 | 41.80 | | 31600 |
| 97.10.02 | 1515 | portsp | | | -0.010 | | | | | | 50.90 | -2.00 | 50.90 | | 34900 |
| 97.12.17 | | wbx | | | | | | | | | | | | | |
| **WELL: K-33** | | | | | | | | | | | | | | | |
| . . | | wellhd | | | | | | | | | | | | | |
| 97.12.01 | 0510 | portsp | | | | | | | | | | | | | |
| **WELL: K2** | | | | | | | | | | | | | | | |
| 96.05.02 | | wellhd | 1.000 | | | | | | | | | | | | |
| 96.05.02 | | wellhd | 1.000 | | | | | | | | | | | | |
| **WELL: KR-1 Jenkin'sSe** | | | | | | | | | | | | | | | |
| 95.05.08 | | spring | | | | | | | | | -1.00 | | | | |
| **WELL: KR-2 Kp.Bakom** | | | | | | | | | | | | | | | |
| 95.05.08 | | spring | | | | | | | | | -1.00 | | | | |
| **WELL: KR-3 Karaha** | | | | | | | | | | | | | | | |
| 95.05.09 | | fum | 1.000 | | | | | | | | -1.00 | | | | |
| **WELL: KR-4 Karaha** | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | | | | | | | | 33.00 | | 33.00 | | |
| **WELL: KR-5 Kp.Ciselan** | | | | | | | | | | | | | | | |
| 95.05.11 | | spring | | | | | | | | | 41.00 | | 41.00 | | |
| **WELL: KR-6 SawahCipan** | | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 4

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | Sn | Zn | I | NO3 | True HCO3 | True CO3 | T.I.C. as CO2 (TCO2) | Alk. HCO3 | Alk. CO3 | T.Alk HCO3 | Density 25degC | Ec micromho 25degC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WELL: KR-6 SawahCipan** | | | | | | | | | | | | | | | |
| 95.05.12 | | hs | | | | | | | | | 167.00 | | 167.00 | | |
| **WELL: KR-7 Karaha** | | | | | | | | | | | | | | | |
| 95.05.18 | | mudpot | | | | | | | | | 33.00 | | 33.00 | | |
| **WELL: KR-A Kp.Bakom** | | | | | | | | | | | | | | | |
| . . | | spring | | | | | | | | | | | | | |
| **WELL: KRH-03** | | | | | | | | | | | | | | | |
| 96.05.02 | | fum | 1.000 | | | | | | | | | | | | |
| **WELL: KR-01** | | | | | | | | | | | | | | | |
| 87.01.01 | | dh | | | | | | | | | 169.69 | | 169.69 | | |
| **WELL: KR-02** | | | | | | | | | | | | | | | |
| . . | | dh | | | | | | | | | 1097.84 | | 1097.84 | | |
| **WELL: KR-03** | | | | | | | | | | | | | | | |
| . . | | dh | | | | | | | | | 112.94 | | 112.94 | | |
| **WELL: KR-04** | | | | | | | | | | | | | | | |
| . . | | dh | | | | | | | | | 1120.24 | | 1120.24 | | |
| **WELL: TLG 1-1 ST2** | | | | | | | | | | | | | | | |
| 97.10.04 | 0900 | portsp | | | 0.071 | | | | | | 36.60 | -2.00 | 36.60 | | 70570 |
| 97.10.04 | 2300 | dh | | | 5.420 | | | | | | -2.00 | -2.00 | | | 81420 |
| 97.10.05 | 0200 | dh | | | 2.400 | | | | | | -2.00 | -2.00 | | | 83700 |
| 97.10.06 | | portsp | | | | | | | | | -5.00 | | -5.00 | | |
| 97.10.06 | 1300 | portsp | | | 1.450 | | | | | | -2.00 | -2.00 | | | 119600 |
| 97.11.10 | | portsp | | | | | | | | | -5.00 | | -5.00 | | |
| **WELL: TLG 2-1** | | | | | | | | | | | | | | | |
| 97.12.29 | 0930 | wbx | 0.977 | | | | | | | | -5.00 | | | | |
| 97.12.29 | 1130 | portsp | 1.000 | | | | | | | | | | | | |
| 97.12.29 | 1130 | portsp | 1.000 | | | | | | | | | | | | |
| 98.02.10 | 1100 | portsp | 1.000 | | | | | | | | | | | | |
| 98.02.18 | 1045 | portsp | 1.000 | | | | | | | | | | | | |
| **WELL: TLG 3-1** | | | | | | | | | | | | | | | |
| 98.02.17 | 1300 | wbx | 0.896 | | | | | | | | 102.00 | | 102.00 | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

# Table C-1 : CHEMICAL ANALYSES OF WATERS: part 4

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | Sn | Zn | I | NO3 | True HCO3 | True CO3 | T.I.C. as CO2 (TCO2) | Alk. HCO3 | Alk. CO3 | T.Alk HCO3 | Density 25degC | Ec micromho 25degC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TLG 3-1*** | | | | | | | | | | | | | | | |
| 98.02.18 | 1330 | portsp | | | | | | | | | | | | | |
| 98.02.20 | 1300 | wbx | 0.933 | | | | | | | | 112.00 | | 112.00 | | |
| 98.02.23 | | wbx | 0.932 | | | | | | | | 103.00 | | 103.00 | | |
| 98.02.23 | 1130 | wbx | | | | | | | | | | | | | |
| ***WELL: T-2*** | | | | | | | | | | | | | | | |
| 97.06.10 | | portsp | 0.941 | | 0.185 | | | | | | -2.00 | -2.00 | | | 6730 |
| 97.06.11 | | portsp | 0.943 | | 0.042 | | | | | | -2.00 | -2.00 | | | 7590 |
| 97.10.18 | 1400 | portsp | | | | | | | | | | | | | |
| ***WELL: T-8*** | | | | | | | | | | | | | | | |
| 97.07.11 | 1730 | portsp | | | 7.490 | | | | | | -2.00 | -2.00 | | | 75600 |
| 97.07.13 | | portsp | | | | | | | | | -2.00 | -2.00 | | | 100000 |
| 97.07.13 | | portsp | | | 5.150 | | | | | | -2.00 | -2.00 | | | 152000 |
| 97.07.22 | | portsp | | | 5.650 | | | | | | -2.00 | -2.00 | | | 133000 |
| ***WELL: FM-3 spring*** | | | | | | | | | | | | | | | |
| 97.06.25 | 1415 | spring | | | 0.172 | | | | | | -2.00 | -2.00 | | | 2850 |
| ***WELL: FM-4 spring*** | | | | | | | | | | | | | | | |
| 97.06.10 | | spring | | | | | | | | | | | | | |
| ***WELL: KBC Hot Spring*** | | | | | | | | | | | | | | | |
| 97.10.21 | 1530 | spring | | | 13.700 | | | | | | -2.00 | -2.00 | | | 1990 |
| ***WELL: TB-01 TelagaBod*** | | | | | | | | | | | | | | | |
| 96.05.03 | | fum | 1.000 | | | | | | | | | | | | |
| ***WELL: TB-03 TelagaBod*** | | | | | | | | | | | | | | | |
| 96.05.03 | | spring | | | | | | | | | | | | | |
| ***WELL: TEL-01 Tel.Boda*** | | | | | | | | | | | | | | | |
| 95.05.08 | | lake | | | | | | | | | -1.00 | | | | |
| ***WELL: TEL-02 Tel.Bod*** | | | | | | | | | | | | | | | |
| 95.05.08 | | fum | 1.000 | | | | | | | | -1.00 | | | | |
| ***WELL: TEL-03 Tel.Boda*** | | | | | | | | | | | | | | | |
| 95.05.08 | | mudpot | | | | | | | | | -1.00 | | | | |
| ***WELL: TEL-04 ResurFum*** | | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l
Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 4

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | Sn | Zn | I | NO3 | True HCO3 | True CO3 | T.I.C. as CO2 (TCO2) | Alk. HCO3 | Alk. CO3 | T.Alk HCO3 | Density 25degC | Ec micromho 25degC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TEL-04 ResurFum*** | | | | | | | | | | | | | | | |
| 95.05.09 | | fum | 1.000 | | | | | | | | -1.00 | | | | |
| ***WELL: TEL-05 Cipanas*** | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | | | | | | | | -1.00 | | | | |
| ***WELL: TEL-06 Cikahuri*** | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | | | | | | | | -1.00 | | | | |
| ***WELL: TEL-07 Ciateul*** | | | | | | | | | | | | | | | |
| 95.05.09 | | hs | | | | | | | | | -1.00 | | | | |
| ***WELL: TEL-08 Cikajaya*** | | | | | | | | | | | | | | | |
| 95.05.19 | | hs | | | | | | | | | -1.00 | | | | |
| ***WELL: TEL-09 FireMtn*** | | | | | | | | | | | | | | | |
| 96.07.08 | | hs | | | | | | | | | 58.00 | | 58.00 | | |
| ***WELL: TEL-10 Mixed-Fe*** | | | | | | | | | | | | | | | |
| 96.07.08 | | spring | | | | | | | | | 99.00 | | 99.00 | | |
| ***WELL: TEL-A KawahSaat*** | | | | | | | | | | | | | | | |
| . . | | fum | 1.000 | | | | | | | | | | | | |
| ***WELL: TEL-B Tel.Bodas*** | | | | | | | | | | | | | | | |
| . . | | hs | | | | | | | | | | | | | |
| ***WELL: TEL-C Panyipuha*** | | | | | | | | | | | | | | | |
| . . | | hs | | | | | | | | | | | | | |
| ***WELL: TEL-D Cienagang*** | | | | | | | | | | | | | | | |
| . . | | hs | | | | | | | | | | | | | |
| ***WELL: TelagaBodas*** | | | | | | | | | | | | | | | |
| 97.06.11 | | spring | | | 0.073 | | | | | | -2.00 | -2.00 | | | 2720 |
| 97.10.22 | 1000 | lake | | | 40.600 | | | | | | -2.00 | -2.00 | | | 107700 |
| 97.10.22 | 1130 | lake | | | | | | | | | | | | | |
| 97.10.22 | 1130 | lake | | | | | | | | | | | | | |
| ***WELL: Ciawi Artesian*** | | | | | | | | | | | | | | | |
| 97.08.30 | | well | | | | | | | | | 916.00 | | 916.00 | | |
| ***WELL: TAK-01 Kp.Sumur*** | | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l
Atmos.Press: 12.40

## Table C-1 : CHEMICAL ANALYSES OF WATERS: part 4

## Karaha - Telaga Geothermal Prospects
## Water Samples, as collected

| Date | Time (24hr) | PORT | Stm. Fr. | Sn | Zn | I | NO3 | True HCO3 | True CO3 | T.I.C. as CO2 (TCO2) | Alk. HCO3 | Alk. CO3 | T.Alk HCO3 | Density 25degC | Ec micromho 25degC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TAK-01 Kp.Sumur*** | | | | | | | | | | | | | | | |
| 95.05.20 | | hs | | | | | | | | | | | 166.00 | | |
| ***WELL: TAK-02 Kp.Cinta*** | | | | | | | | | | | | | | | |
| 95.05.20 | | spring | | | | | | | | | | | 55.00 | | |
| ***WELL: TAK-03 Panoyana*** | | | | | | | | | | | | | | | |
| 95.05.21 | | hs | | | | | | | | | | | 656.00 | | |
| ***WELL: TAK-04 Kp.Salaa*** | | | | | | | | | | | | | | | |
| 95.05.21 | | spring | | | | | | | | | | | | | |
| ***WELL: TAK-05 Kp.Salaa*** | | | | | | | | | | | | | | | |
| 95.05.21 | | spring | | | | | | | | | | | 44.20 | | |
| ***WELL: TAK-06 Ci Peles*** | | | | | | | | | | | | | | | |
| 95.06.13 | | hs | | | | | | | | | | | 980.00 | | |
| ***WELL: TAK-07 Galunggu*** | | | | | | | | | | | | | | | |
| 95.06.19 | | hs | | | | | | | | | | | 545.00 | | |
| ***WELL: TAK-08 Kp.Cipac*** | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | | | | | | | | | | 1080.00 | | |
| ***WELL: TAK-09 Tanjungk*** | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | | | | | | | | | | 703.00 | | |
| ***WELL: TAK-10 Cicilap*** | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | | | | | | | | | | 1070.00 | | |
| ***WELL: TAK-11 Panoyana*** | | | | | | | | | | | | | | | |
| 95.06.22 | | hs | | | | | | | | | | | 881.00 | | |
| ***WELL: TelagaCipanas*** | | | | | | | | | | | | | | | |
| 97.10.22 | 1500 | hs | | | | | | | | | | | | | |
| ***WELL: TelegaCipanas*** | | | | | | | | | | | | | | | |
| 97.10.22 | 1400 | hs | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

# Table C-2 : CHEMICAL ANALYSES OF GASES IN STEAM: part 1

## Karaha - Telaga Geothermal Prospects
## Gas in Steam Samples, as collected

| Date | Time (24hr) | WHP -ga | PORT | Steam / Water Enth | T | Psat | Pabs | Stm. Fr. | Gas/steam Total wt.% | ppm-wt CO2 | H2S | NH3 | Ar | N2 | CH4 | H2 | He |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WELL: KRH 2-1 RD** | | | **Karaha Deep Hole** | | | | | | | | | | | | | | |
| 97.06.12 | | | portsp | | 235.0 | 22.80 | 37.40 | | 0.7810 | 6680.0 | 25.0 | 21.20 | 15.1000 | 962.00 | 105.00 | 0.73 | |
| **WELL: KRH 3-1 ST** | | | **Karaha Deep Hole** | | | | | | | | | | | | | | |
| 97.06.14 | | | portsp | | 285.0 | 53.26 | 62.40 | | 0.8610 | 5420.0 | 70.1 | 51.10 | 53.4000 | 2990.00 | 36.20 | 1.14 | |
| **WELL: KRH 4-1** | | | **Karaha Deep Hole** | | | | | | | | | | | | | | |
| 97.08.24 | | | portsp | | | | | 1.000 | 9.6200 | 92900.0 | 2510.0 | 85.60 | 1.3900 | 289.00 | 372.00 | 25.70 | |
| 97.08.25 | 1703 | | portsp | 1147.00 | 380.0 | 195.73 | 207.40 | 0.940 | 9.0000 | 87000.0 | 2290.0 | 63.80 | 1.4300 | 268.00 | 343.00 | 24.20 | |
| 97.08.27 | 2210 | | portsp | 1060.00 | 440.0 | 381.54 | 422.40 | 0.816 | 3.5300 | 27600.0 | 47.2 | 26.20 | 127.0000 | 7430.00 | 62.00 | 8.72 | |
| 97.08.28 | 1435 | | portsp | 1146.00 | 381.5 | 199.32 | 230.40 | 0.938 | 8.0400 | 77700.0 | 2070.0 | 80.30 | 1.2300 | 292.00 | 302.00 | 21.80 | |
| 97.08.31 | 1138 | | portsp | 924.00 | 382.0 | 200.51 | 212.40 | 0.674 | 6.2500 | 60100.0 | 1820.0 | 89.50 | 0.5190 | 255.00 | 246.00 | 18.60 | |
| 97.09.04 | 1725 | | portsp | 1040.00 | 431.0 | 347.37 | 372.40 | 0.794 | 6.2800 | 59600.0 | 1722.0 | 195.00 | 25.3000 | 1964.00 | 196.00 | 18.00 | -0.0400 |
| 97.09.04 | 1725 | | portsp | 1040.00 | 431.0 | 347.37 | 372.40 | 0.794 | 5.7300 | 55300.0 | 1510.0 | 101.00 | 0.2310 | 191.00 | 210.00 | 19.60 | |
| 97.09.13 | 1620 | | portsp | 966.00 | 388.0 | 215.22 | 222.40 | 0.721 | 4.5500 | 43800.0 | 1300.0 | 110.00 | 0.3180 | 147.00 | 141.00 | 14.80 | |
| 97.09.13 | 1620 | | portsp | 966.00 | 388.0 | 215.22 | 222.40 | 0.721 | 4.5400 | 43500.0 | 1452.0 | 162.00 | 1.8000 | 128.00 | 136.00 | 15.00 | -0.0100 |
| **WELL: KRH 5-1** | | | **Karaha Deep Hole** | | | | | | | | | | | | | | |
| 97.09.25 | | 94 | portsp | 692.00 | | | | | 2.7200 | 24600.0 | 314.0 | 68.00 | 58.0000 | 2186.00 | 60.00 | 9.00 | -0.0300 |
| 97.09.25 | 2200 | 94 | portsp | 692.00 | | | | | 2.9100 | 26400.0 | 276.0 | 56.40 | 38.0000 | 2250.00 | 65.80 | 10.20 | |
| 97.10.02 | 1515 | 63 | portsp | 766.00 | | | | | 1.9800 | 18700.0 | 430.0 | 54.90 | 8.6600 | 552.00 | 57.50 | 8.41 | |
| **WELL: K-33** | | | **Karaha Deep Slim Hole** | | | | | | | | | | | | | | |
| 97.12.01 | 0510 | 130 | portsp | 875.00 | | | 130.00 | | 20.0000 | 194000.0 | 4150.0 | 149.00 | 13.8000 | 620.00 | 411.00 | 30.40 | |
| **WELL: K2** | | | **Karaha Shallow Slim Hole** | | | | | | | | | | | | | | |
| 96.05.02 | | | wellhd | | 217.0 | 16.22 | | 1.000 | 0.0774 | 671.3 | 41.9 | 0.37 | 1.6591 | 50.53 | 0.97 | 7.15 | |
| 96.05.02 | | | wellhd | | 217.0 | 16.22 | | 1.000 | 0.1971 | 480.3 | 251.1 | 0.94 | 22.2107 | 1214.12 | | 1.89 | |
| **WELL: KR-3 Karaha** | | | **Karaha Thermal Manifestation** | | | | | | | | | | | | | | |
| 95.05.09 | | | fum | | 205.0 | | | 1.000 | | | | | | | | | |
| **WELL: KR-7 Karaha** | | | **Karaha Thermal Manifestation** | | | | | | | | | | | | | | |
| 95.05.18 | | | mudpot | | 198.0 | | | | | | | | | | | | |
| **WELL: KRH-03** | | | **Karaha Thermal Manifestation** | | | | | | | | | | | | | | |
| 96.05.02 | | | fum | | 206.0 | | | 1.000 | 14.8162 | 142132.9 | 4721.6 | 67.64 | 4.9112 | 642.42 | 472.60 | 120.11 | |
| **WELL: TLG 1-1 ST2** | | | **Telaga Deep Hole** | | | | | | | | | | | | | | |
| 97.10.06 | | | portsp | | | | | | 2.5300 | 20400.0 | 617.0 | 14.10 | 86.2000 | 4182.00 | -5.00 | 8.61 | -0.1000 |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi deg F btu/lb mg/l

Atmos.Press: 12.40

GeothermEx, Inc. KBANA 98.04.23

# Table C-2 : CHEMICAL ANALYSES OF GASES IN STEAM: part 1

## Karaha - Telaga Geothermal Prospects
## Gas in Steam Samples, as collected

| Date | Time (24hr) | WHP -ga | PORT | Steam / Water Enth | T | Psat | Pabs | Stm. Fr. | Gas/steam Total wt.% | ppm-wt CO2 | H2S | NH3 | Ar | N2 | CH4 | H2 | He |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WELL: TLG 1-1 ST2** | | | **Telaga Deep Hole** | | | | | | | | | | | | | | |
| 97.10.06 | 1300 | | portsp | | | | | | 2.4400 | 18800.0 | 586.0 | 17.50 | 83.3000 | 4960.00 | 9.85 | 9.95 | |
| 97.11.10 | | 130 | portsp | 1160.00 | | | | | 1.0900 | 10900.0 | 2818.0 | 6.60 | 109.4000 | 5768.00 | 13.00 | 7.39 | -0.1000 |
| **WELL: TLG 2-1** | | | **Telaga Deep Hole** | | | | | | | | | | | | | | |
| 97.12.29 | 1130 | 130 | portsp | | | | | 1.000 | 10.3000 | 97100.0 | 844.0 | 143.00 | 78.0000 | 4520.00 | 180.00 | 87.60 | |
| 97.12.29 | 1130 | | portsp | | | | | 1.000 | 12.7200 | 121100.0 | 1129.0 | 75.90 | 88.2000 | 4626.00 | 131.00 | 71.20 | -0.1000 |
| 98.02.10 | 1100 | 158 | portsp | | | | | 1.000 | 24.0600 | 237500.0 | 1378.0 | 387.60 | 2.0000 | 1164.00 | 106.00 | 39.80 | -0.1000 |
| 98.02.18 | 1045 | 137 | portsp | | | | | 1.000 | 29.6400 | 293000.0 | 1183.0 | 476.60 | | 1753.00 | -2.00 | 1.07 | -0.1000 |
| **WELL: TLG 3-1** | | | **Telaga Deep Hole** | | | | | | | | | | | | | | |
| 98.02.18 | 1330 | 118 | portsp | 1120.00 | | | | | 0.5400 | 4800.0 | 359.0 | 39.20 | 4.0000 | 188.00 | -2.00 | 1.10 | -0.1000 |
| **WELL: T-2** | | | **Telaga Deep Slim Hole** | | | | | | | | | | | | | | |
| 97.06.11 | | 47 | portsp | 1116.00 | 267.0 | 39.85 | 46.40 | 0.943 | 9.4500 | 92400.0 | 1830.0 | 72.50 | 0.3130 | 93.90 | 124.00 | 24.90 | |
| 97.10.18 | 1400 | | portsp | | | | | | 7.8400 | 76900.0 | 1150.0 | 49.40 | 1.5500 | 125.00 | 92.70 | 14.70 | |
| **WELL: T-8** | | | **Telaga Deep Slim Hole** | | | | | | | | | | | | | | |
| 97.07.11 | 1730 | 64 | portsp | | | | | | 6.5700 | 60600.0 | 4950.0 | -4.83 | 0.3310 | 84.40 | 4.63 | 86.80 | |
| 97.07.13 | | 76 | portsp | | | | | | 8.2800 | 77400.0 | 5340.0 | -8.96 | 0.1770 | 64.80 | 2.70 | 53.20 | |
| 97.07.13 | | 76 | portsp | | | | | | 6.4200 | 58900.0 | 5040.0 | -8.04 | 1.5000 | 169.00 | 7.18 | 98.10 | |
| **WELL: TB-01 TelagaBod** | | | **Telaga Thermal Manifestation** | | | | | | | | | | | | | | |
| 96.05.03 | | | fum | | | | 12.40 | 1.000 | 10.0412 | 92301.8 | 7351.7 | 0.25 | 6.2983 | 750.16 | 0.72 | 0.49 | 0.0799 |
| **WELL: TEL-02 Tel.Bod** | | | **Telaga Thermal Manifestation** | | | | | | | | | | | | | | |
| 95.05.08 | | | fum | | 199.0 | | 12.40 | 1.000 | | | | | | | | | |
| **WELL: TEL-05 Cipanas** | | | **Telaga Thermal Manifestation** | | | | | | | | | | | | | | |
| 95.05.09 | | | hs | | 142.0 | | 12.40 | | | | | | | | | | |
| **WELL: TEL-A KawahSaat** | | | **Telaga Thermal Manifestation** | | | | | | | | | | | | | | |
| . . | | | fum | | | | 12.40 | 1.000 | | | | | | | | | |
| **WELL: TAK-03 Panoyana** | | | **X: Concession Area** | | | | | | | | | | | | | | |
| 95.05.21 | | | hs | | 114.8 | | | | | | | | | | | | |
| **WELL: TAK-04 Kp.Salaa** | | | **X: Concession Area** | | | | | | | | | | | | | | |
| 95.05.21 | | | spring | | 71.6 | | | | | | | | | | | | |
| **WELL: TAK-07 Galunggu** | | | **X: Concession Area** | | | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi deg F btu/lb mg/l

Atmos.Press: 12.40

## Table C-2 : CHEMICAL ANALYSES OF GASIS IN STEAM: part 2

## Karaha - Telaga Geothermal Prospects
## Gas in Steam Samples, as collected

| Date | Time (24hr) | WHP -ga | Steam / Water: PORT | Enth | Stm. Fr. | Total Gas in steam: wt.% | m/1000mH2O | Dry gas, vol.%: CO2 | H2S | NH3 | Ar | N2 | CH4 | H2 | He |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: KRH 2-1 RD*** | | | | | | | | | | | | | | | |
| 97.06.12 | | | portsp | | | 0.7810 | 3.550 | 77.70 | 0.375 | 0.6360 | 0.19300 | 17.6000 | 3.3500 | 0.1870 | |
| ***WELL: KRH 3-1 ST*** | | | | | | | | | | | | | | | |
| 97.06.14 | | | portsp | | | 0.8610 | 4.340 | 51.50 | 0.861 | 1.2600 | 0.56000 | 44.6000 | 0.9440 | 0.2350 | |
| ***WELL: KRH 4-1*** | | | | | | | | | | | | | | | |
| 97.08.24 | | | portsp | | 1.000 | 9.6200 | 44.600 | 94.40 | 3.290 | 0.2250 | 0.00156 | 0.4610 | 1.0400 | 0.5700 | |
| 97.08.25 | 1703 | | portsp | 1147.00 | 0.940 | 9.0000 | 41.400 | 94.60 | 3.210 | 0.1790 | 0.00171 | 0.4580 | 1.0200 | 0.5740 | |
| 97.08.27 | 2210 | | portsp | 1060.00 | 0.816 | 3.5300 | 16.900 | 69.20 | 0.153 | 0.1700 | 0.35100 | 29.3000 | 0.4260 | 0.4770 | |
| 97.08.28 | 1435 | | portsp | 1146.00 | 0.938 | 8.0400 | 36.600 | 94.40 | 3.240 | 0.2520 | 0.00164 | 0.5580 | 1.0100 | 0.5780 | |
| 97.08.31 | 1138 | | portsp | 924.00 | 0.674 | 6.2500 | 28.000 | 93.70 | 3.670 | 0.3610 | 0.00089 | 0.6250 | 1.0500 | 0.6310 | |
| 97.09.04 | 1725 | | portsp | 1040.00 | 0.794 | 6.2800 | 28.350 | 89.80 | 3.350 | 0.7592 | 0.04199 | 4.6493 | 0.8102 | 0.5920 | |
| 97.09.04 | 1725 | | portsp | 1040.00 | 0.794 | 5.7300 | 25.500 | 94.00 | 3.310 | 0.4420 | 0.00043 | 0.5110 | 0.9800 | 0.7250 | |
| 97.09.13 | 1620 | | portsp | 966.00 | 0.721 | 4.5500 | 20.000 | 93.80 | 3.600 | 0.6070 | 0.00075 | 0.4950 | 0.8310 | 0.6920 | |
| 97.09.13 | 1620 | | portsp | 966.00 | 0.721 | 4.5400 | 20.024 | 93.15 | 4.015 | 0.8965 | 0.00424 | 0.4306 | 0.7990 | 0.7012 | |
| ***WELL: KRH 5-1*** | | | | | | | | | | | | | | | |
| 97.09.25 | | 94 | portsp | 692.00 | | 2.7200 | 12.190 | 84.71 | 1.396 | 0.6051 | 0.22001 | 11.8272 | 0.5668 | 0.6765 | |
| 97.09.25 | 2200 | 94 | portsp | 692.00 | | 2.9100 | 13.000 | 85.50 | 1.150 | 0.4710 | 0.13500 | 11.4000 | 0.5840 | 0.7150 | |
| 97.10.02 | 1515 | 63 | portsp | 766.00 | | 1.9800 | 8.610 | 90.70 | 2.700 | 0.6890 | 0.04630 | 4.2100 | 0.7660 | 0.8890 | |
| ***WELL: K-33*** | | | | | | | | | | | | | | | |
| 97.12.01 | 0510 | 130 | portsp | 875.00 | | 20.0000 | 104.000 | 95.80 | 2.640 | 0.1900 | 0.00752 | 0.4810 | 0.5560 | 0.3260 | |
| ***WELL: K2*** | | | | | | | | | | | | | | | |
| 96.05.02 | | | wellhd | | 1.000 | 0.0774 | 0.396 | 69.45 | 5.606 | 0.1010 | 0.18910 | 8.2142 | 0.2777 | 16.1626 | |
| 96.05.02 | | | wellhd | | 1.000 | 0.1971 | 1.140 | 17.28 | 11.663 | 0.0876 | 0.88005 | 68.6036 | | 1.4907 | |
| ***WELL: KR-3 Karaha*** | | | | | | | | | | | | | | | |
| 95.05.09 | | | fum | | 1.000 | | | 96.46 | 0.042 | | 0.02020 | 1.1900 | 0.9850 | 0.8200 | 0.0001 |
| ***WELL: KR-7 Karaha*** | | | | | | | | | | | | | | | |
| 95.05.18 | | | mudpot | | | | | 95.26 | 0.025 | | 0.03900 | 2.4100 | 1.4500 | 0.7400 | 0.0000 |
| ***WELL: KRH-03*** | | | | | | | | | | | | | | | |
| 96.05.02 | | | fum | | 1.000 | 14.8162 | 73.685 | 92.69 | 3.976 | 0.1140 | 0.00352 | 0.6582 | 0.8454 | 1.7099 | |
| ***WELL: TLG 1-1 ST2*** | | | | | | | | | | | | | | | |
| 97.10.06 | | | portsp | | | 2.5300 | 11.810 | 72.63 | 2.837 | 0.1297 | 0.33811 | 23.3959 | | 0.6692 | |
| 97.10.06 | 1300 | | portsp | | | 2.4400 | 11.600 | 67.80 | 2.730 | 0.1630 | 0.33100 | 28.1000 | 0.0976 | 0.7830 | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

GeothermEx, Inc. KBANA 98.04.23

## Table C-2 : CHEMICAL ANALYSES OF GASIS IN STEAM: part 2

## Karaha - Telaga Geothermal Prospects
## Gas in Steam Samples, as collected

| Date | Time (24hr) | WHP -ga | Steam / Water: PORT | Enth | Stm. Fr. | Total Gas in steam: wt.% | m/1000mH2O | Dry gas, vol.%: CO2 | H2S | NH3 | Ar | N2 | CH4 | H2 | He |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 97.11.10 | | 130 | portsp | 1160.00 | | 1.0900 | 9.994 | 45.54 | 15.203 | 0.0712 | 0.50350 | 37.8628 | 0.1490 | 0.6739 | |
| ***WELL: TLG 2-1*** | | | | | | | | | | | | | | | |
| 97.12.29 | 1130 | 130 | portsp | | 1.000 | 10.3000 | 49.400 | 89.80 | 1.010 | 0.3420 | 0.07940 | 6.5800 | 0.4570 | 1.7600 | |
| 97.12.29 | 1130 | | portsp | | 1.000 | 12.7200 | 61.880 | 91.72 | 1.104 | 0.1485 | 0.07359 | 5.5049 | 0.2722 | 1.1772 | |
| 98.02.10 | 1100 | 158 | portsp | | 1.000 | 24.0600 | 131.360 | 97.63 | 0.732 | 0.4117 | 0.00090 | 0.7517 | 0.1195 | 0.3571 | |
| 98.02.18 | 1045 | 137 | portsp | | 1.000 | 29.6400 | 174.230 | 98.15 | 0.512 | 0.4125 | | 0.9226 | | 0.0078 | |
| ***WELL: TLG 3-1*** | | | | | | | | | | | | | | | |
| 98.02.18 | 1330 | 118 | portsp | 1120.00 | | 0.5400 | 2.360 | 84.37 | 8.150 | 1.7809 | 0.07746 | 5.1930 | | 0.4221 | |
| ***WELL: T-2*** | | | | | | | | | | | | | | | |
| 97.06.11 | | 47 | portsp | 1116.00 | 0.943 | 9.4500 | 43.400 | 96.30 | 2.460 | 0.1950 | 0.00035 | 0.1540 | 0.3560 | 0.5660 | |
| 97.10.18 | 1400 | | portsp | | | 7.8400 | 35.200 | 97.00 | 1.870 | 0.1610 | 0.00215 | 0.2470 | 0.3210 | 0.4030 | |
| ***WELL: T-8*** | | | | | | | | | | | | | | | |
| 97.07.11 | 1730 | 64 | portsp | | | 6.5700 | 30.300 | 87.80 | 9.270 | -0.0181 | 0.00052 | 0.1920 | 0.0184 | 2.7400 | |
| 97.07.13 | | 76 | portsp | | | 8.2800 | 38.200 | 90.40 | 8.070 | -0.0271 | 0.00022 | 0.1190 | 0.0086 | 1.3500 | |
| 97.07.13 | | 76 | portsp | | | 6.4200 | 29.700 | 86.80 | 9.600 | -0.0306 | 0.00244 | 0.3910 | 0.0291 | 3.1500 | |
| ***WELL: TB-01 TelagaBod*** | | | | | | | | | | | | | | | |
| 96.05.03 | | | fum | | 1.000 | 10.0412 | 46.866 | 89.62 | 9.218 | 0.0006 | 0.00673 | 1.1442 | 0.0019 | 0.0104 | 0.0008 |
| ***WELL: TEL-02 Tel.Bod*** | | | | | | | | | | | | | | | |
| 95.05.08 | | | fum | | 1.000 | | | 98.93 | 0.450 | | 0.00230 | 0.6000 | 0.0008 | 0.0036 | 0.0005 |
| ***WELL: TEL-05 Cipanas*** | | | | | | | | | | | | | | | |
| 95.05.09 | | | hs | | | | | 97.35 | | | 0.06600 | 2.5300 | 0.0740 | 0.0039 | 0.0001 |
| ***WELL: TEL-A KawahSaat*** | | | | | | | | | | | | | | | |
| . . | | | fum | | 1.000 | | | 99.03 | 0.054 | | 0.00130 | 0.7700 | 0.0558 | 0.0906 | 0.0009 |
| ***WELL: TAK-03 Panoyana*** | | | | | | | | | | | | | | | |
| 95.05.21 | | | hs | | | | | 86.87 | | | 0.19750 | 6.1900 | 6.6505 | 0.0594 | 0.0001 |
| ***WELL: TAK-04 Kp.Salaa*** | | | | | | | | | | | | | | | |
| 95.05.21 | | | spring | | | | | 97.08 | | | 0.00790 | 1.8600 | 0.9994 | 0.0433 | 0.0000 |
| ***WELL: TAK-07 Galunggu*** | | | | | | | | | | | | | | | |
| 95.06.19 | | | hs | | | | | | | | | | | | |

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

## Table C-2 : CHEMICAL ANALYSES OF GASES IN STEAM: part 1

## Karaha - Telaga Geothermal Prospects
## Gas in Steam Samples, as collected

| Date | Time (24hr) | WHP -ga | PORT | Steam / Water Enth | T | Psat | Pabs | Stm. Fr. | Gas/steam Total wt.% | ppm-wt CO2 | H2S | NH3 | Ar | N2 | CH4 | H2 | He |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***WELL: TAK-07 Galunggu X: Concession Area*** | | | | | | | | | | | | | | | | | |
| 95.06.19 | | | hs | | 149.0 | | | | | | | | | | | | |

Port Codes (Additional detail may be found in Comments section of table):
- flowln = flowline (no separator, e.g.single phase steam or artesian water)
- portsp = portable separator
- prodsp = output of a production scale or full flow separator
- injln = injection line
- dh = downhole sampler
- atm = after boiling to the atmosphere (but not at weirbox)
- wbx = weirbox
- wellhd = wellhead (e.g.wingvalve or not specified)
- dhpump = single phase pumped flow sampled at surface
- hs = hot spring
- spring = spring
- rain = rainwater
- fum = fumarole
- surfac = surface water sample (e.g. pond, lake, stream)

Negative values indicate < detection limit (e.g. -0.1 is <0.1)

File Units: klb/hr psi degF btu/lb mg/l

Atmos.Press: 12.40

# Table C-3 : CHEMICAL ANALYSES OF STABLE ISOTOPES

## Karaha - Telaga Geothermal Prospects
## Stable Isotopes, as collected

| Date | Time (24hr) | WHP-ga | Enth | Port | Smpl T | Smpl P (abs) | Stm Fract | Cl | Stable isotopes (o/oo SMOW) delD liq. | delD vap. | del-18o liq. | del-18o vap. | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Well: KRH 1-1 RD*** | | | | | | | | | | | | | |
| 97.06.19 | | | | wbx | | | | 23.60 | -41.3 | | -6.38 | | lies on meteoric water line |
| ***Well: KRH 2-1 RD*** | | | | | | | | | | | | | |
| 97.06.12 | | | | portsp | 235.0 | 37.4 | | 722.00 | -38.1 | -59.7 | -3.18 | -7.84 | Tchem condensate isotope sample date is 970611 |
| ***Well: KRH 3-1 ST*** | | | | | | | | | | | | | |
| 97.06.14 | | | | portsp | 285.0 | 62.4 | | 1260.00 | -31.9 | -55.5 | -1.98 | -6.75 | Date of condensate sample uncertain; Tchem lists 6/11 but also lists condensate analysis with same lab number as 6/14 |
| ***Well: KRH 5-1*** | | | | | | | | | | | | | |
| 97.10.02 | 1515 | 63 | 766 | portsp | | | | 11590.00 | -29.5 | -49.2 | 1.10 | -3.57 | |
| 97.12.17 | | | | wbx | | | | | -36.1 | | 1.59 | | |
| ***Well: K-33*** | | | | | | | | | | | | | |
| 97.12.01 | 0510 | 130 | 875 | portsp | | 130.0 | | | -22.6 | -42.5 | -1.85 | -6.52 | liquid sample from wbx |
| ***Well: K2*** | | | | | | | | | | | | | |
| 96.05.02 | | | | wellhd | 217.0 | | 1.000 | | | -188.3 | | -40.78 | |
| ***Well: KR-1 Jenkin'sSe*** | | | | | | | | | | | | | |
| 95.05.08 | | | | spring | 72.0 | | | 4.60 | | | | | 3He/4He = 7.26 (as sample K3 Jenkins Leak) |
| ***Well: KR-3 Karaha*** | | | | | | | | | | | | | |
| 95.05.09 | | | | fum | 205.0 | | 1.000 | 2.60 | | | | | 3He/4He = 7.12 (as sample K2 - North Scab) |
| ***Well: KR-7 Karaha*** | | | | | | | | | | | | | |
| 95.05.18 | | | | mudpot | 198.0 | | | 4.30 | | | | | 3He/4He = 7.24 (as sample K1 - South Scab) |
| ***Well: KRH-03*** | | | | | | | | | | | | | |
| 96.05.02 | | | | fum | 206.0 | | 1.000 | | | -55.8 | | -7.4 | |
| ***Well: TLG 2-1*** | | | | | | | | | | | | | |
| 97.12.29 | 0930 | 130 | 1125 | wbx | | 12.4 | 0.977 | 15688.00 | 8.4 | -28.2 | 4.34 | -1.39 | liquid isotope from wbx, steam from portable |

**File Units: klb/hr psi degF btu/lb mg/l**
**Atmos.Press: 12.40**

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# Table C-3 : CHEMICAL ANALYSES OF STABLE ISOTOPES

## Karaha - Telaga Geothermal Prospects
## Stable Isotopes, as collected

| Date | Time (24hr) | WHP-ga | Enth | Port | Smpl T | Smpl P (abs) | Stm Fract | Cl | Stable isotopes (o/oo SMOW) delD liq. | delD vap. | del-18o liq. | del-18o vap. | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Well: TLG 2-1*** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | separator |
| 97.06.11 | | 47 | 1116 | portsp | 267.0 | 46.4 | 0.943 | 2170.00 | -13.7 | -35.7 | 5.92 | .92 | |
| 97.10.18 | 1400 | | | portsp | | | | | -9.7 | -37.9 | 5.84 | 0.29 | liquid sample is from wbx. |
| ***Well: T-8*** | | | | | | | | | | | | | |
| 97.07.11 | 1730 | 64 | | portsp | | | | 57800.00 | -21.7 | -36.8 | 6.67 | 1.60 | |
| 97.07.13 | | 76 | | portsp | | | | 125000.00 | -31.9 | -37.2 | 3.50 | 2.27 | |
| ***Well: FM-4 spring*** | | | | | | | | | | | | | |
| 97.06.10 | | | | spring | | 12.4 | | | -45.2 | | -7.64 | | |
| ***Well: KBC Hot Spring*** | | | | | | | | | | | | | |
| 97.10.21 | 1530 | | | spring | 116.0 | | | 4680.00 | -44.7 | | -7.18 | | |
| ***Well: TB-01 TelagaBod*** | | | | | | | | | | | | | |
| 96.05.03 | | | | fum | | 12.4 | 1.000 | | | -35.50 | | 0.85 | |
| ***Well: TB-03 TelagaBod*** | | | | | | | | | | | | | |
| 96.05.03 | | | | spring | | 12.4 | | | -44.8 | | -7.22 | | |
| ***Well: TEL-02 Tel.Bod*** | | | | | | | | | | | | | |
| 95.05.08 | | | | fum | 199.0 | 12.4 | 1.000 | 16.00 | | | | | 3He/4He = 7.69 (as sample TB2-North Shore) |
| ***Well: TEL-05 Cipanas*** | | | | | | | | | | | | | |
| 95.05.09 | | | | hs | 142.0 | 12.4 | | 288.00 | | | | | 3He/4He = 7.09 (as sample TB-3 Cipanas) |
| ***Well: TEL-A KawahSaat*** | | | | | | | | | | | | | |
| . . | | | | fum | | 12.4 | 1.000 | | | | | | 3He/4He = 7.74 (as sample TB 1 - Backside Fumarole) |
| ***Well: TelagaBodas*** | | | | | | | | | | | | | |
| 97.10.22 | 1000 | | | lake | | 12.4 | | 8850.00 | 7.3 | | 14.94 | | |
| 97.10.22 | 1130 | | | lake | | 12.4 | | | -33.4 | | -3.55 | | |

**File Units: klb/hr psi degF btu/lb mg/l**
**Atmos.Press: 12.40**

# Table C-3 : CHEMICAL ANALYSES OF STABLE ISOTOPES

## Karaha - Telaga Geothermal Prospects
## Stable Isotopes, as collected

| Date | Time (24hr) | WHP-ga | Enth | Port | Smpl T | Smpl P (abs) | Stm Fract | Cl | Stable isotopes (o/oo SMOW) delD liq. | delD vap. | del-18o liq. | del-18o vap. | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Well: TelagaBodas*** | | | | | | | | | | | | | |
| 97.10.22 | 1130 | | | lake | | 12.4 | | | -46.7 | | -4.87 | | |
| ***Well: TAK-03 Panoyana*** | | | | | | | | | | | | | |
| 95.05.21 | | | | hs | 114.8 | | | 11.00 | | | | | 3He/4He = 5.70 (as sample East Side Cipanas) |
| ***Well: TAK-04 Kp.Salaa*** | | | | | | | | | | | | | |
| 95.05.21 | | | | spring | 71.6 | | | 10.50 | | | | | 3He/4He = 5.92 (as sample South Crater) |
| ***Well: TAK-07 Galunggu*** | | | | | | | | | | | | | |
| 95.06.19 | | | | hs | 149.0 | | | 194.00 | | | | | 3He/4He = 5.07 (as sample Gunung Galunggung) |
| ***Well: TelagaCipanas*** | | | | | | | | | | | | | |
| 97.10.22 | 1500 | | | hs | | 12.4 | | | -42.1 | | -5.24 | | |
| ***Well: TelegaCipanas*** | | | | | | | | | | | | | |
| 97.10.22 | 1400 | | | hs | | 12.4 | | | -47.5 | | -7.37 | | |

**File Units:** klb/hr psi degF btu/lb mg/l
**Atmos.Press:** 12.40