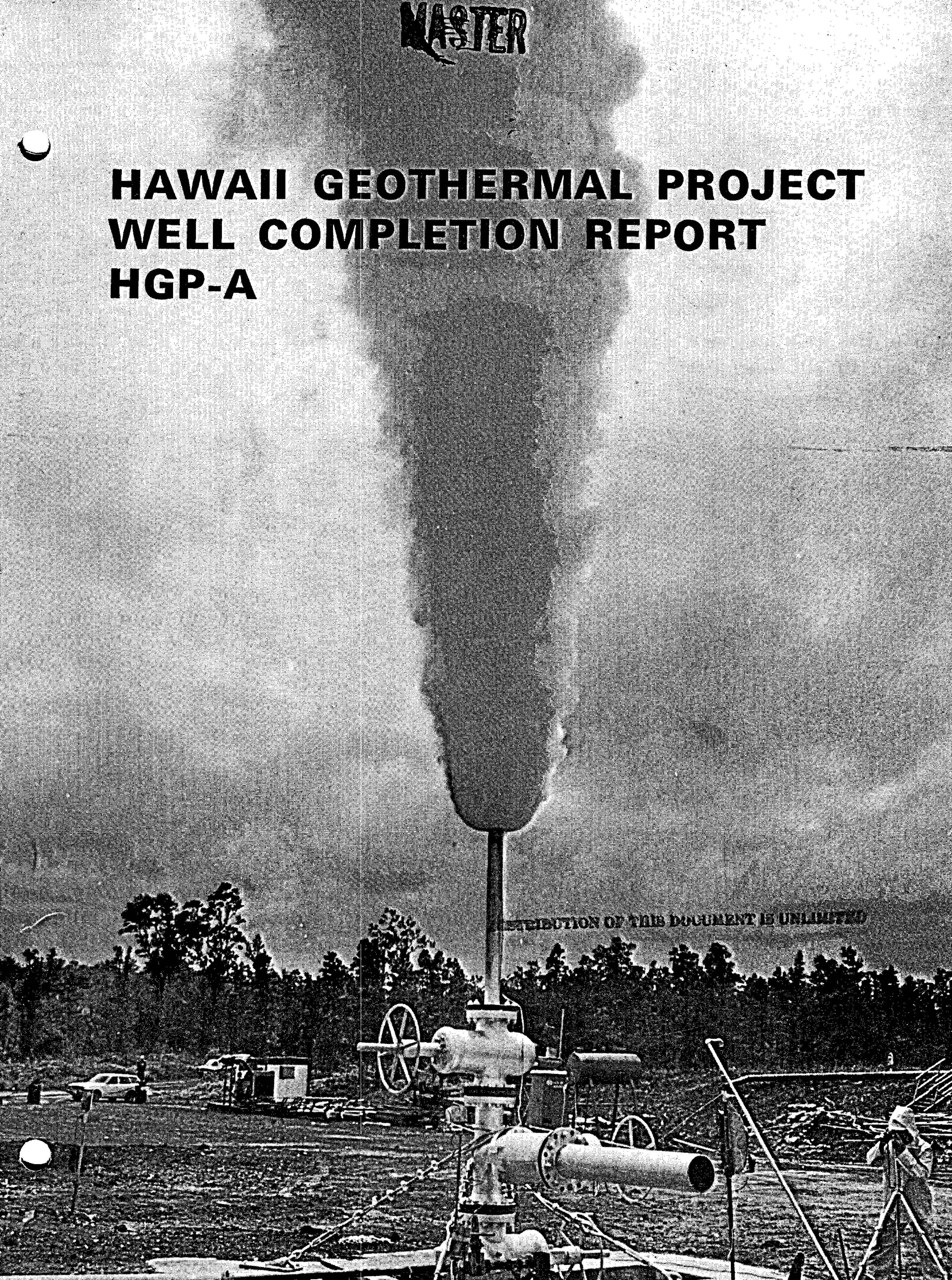
HAWAII GEOTHERMAL PROJECT WELL COMPLETION REPORT HGP-A



HAWAII GEOTHERMAL PROJECT WELL COMPLETION REPORT HGP-A

Report Prepared for
UNIVERSITY OF HAWAII RESEARCH CORPORATION, and
U.S. ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION

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HAWAII GEOTHERMAL PROJECT
COMPLETION REPORT

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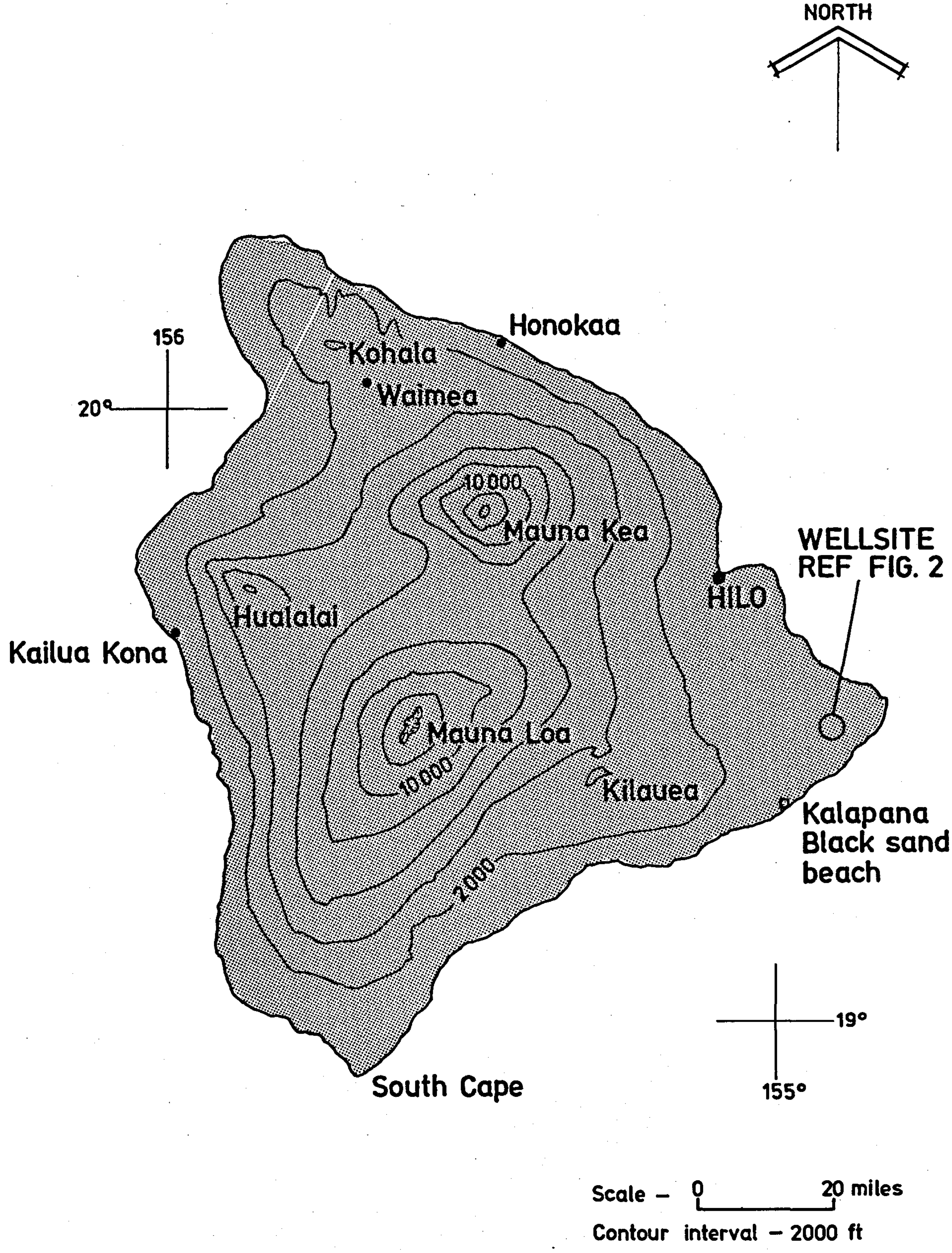


Figure 1 – Map of Hawaii

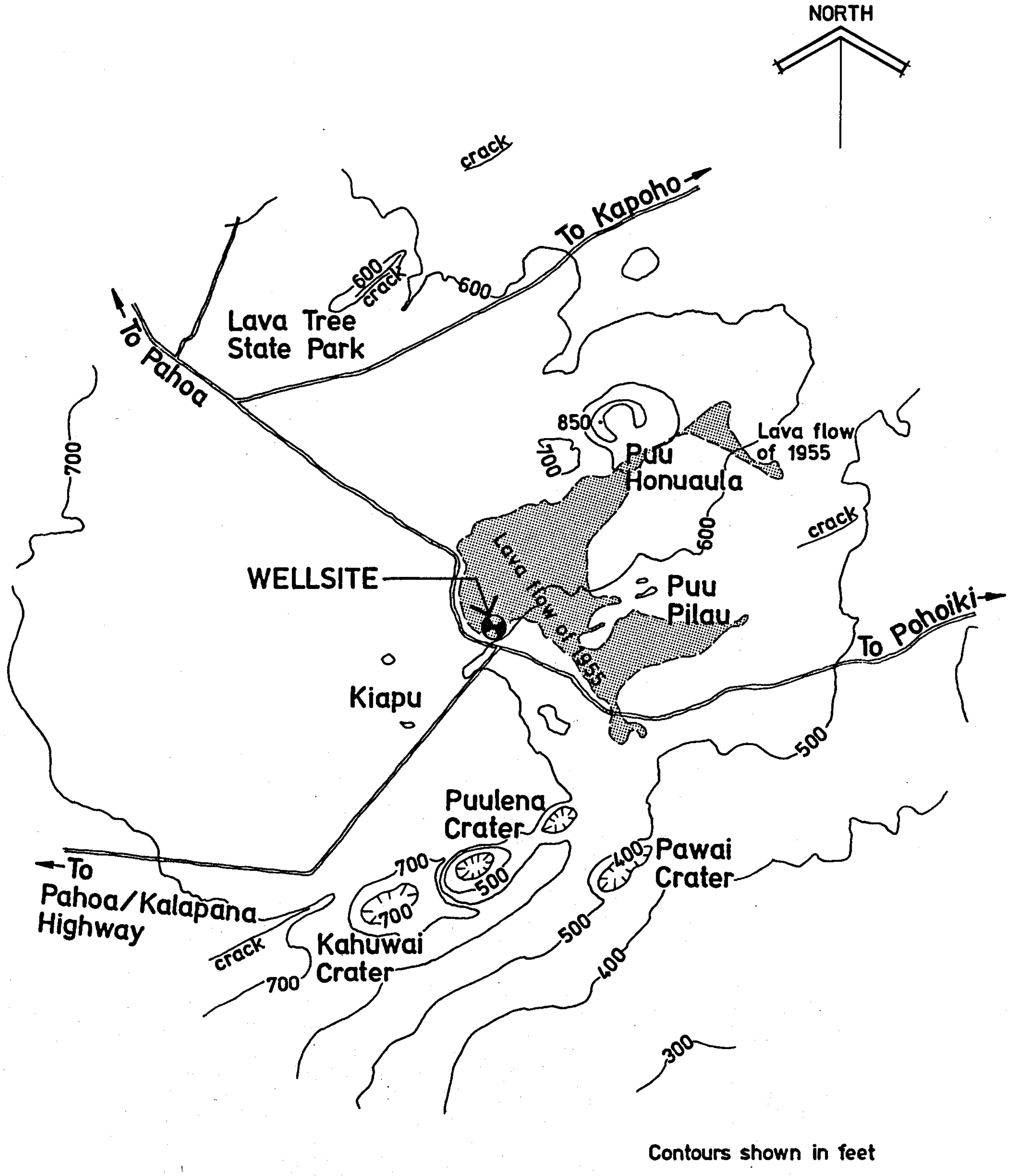


Figure 2 - Site Location

HAWAII GEOTHERMAL PROJECT
COMPLETION REPORT

1. INTRODUCTION

The Hawaii Geothermal Project was organised to focus the resources of the University, the State, the County of Hawaii and the Federal Government through the offices of the United States Energy Research & Development Administration (ERDA) on the identification, generation and utilisation of geothermal energy on the Big Island of Hawaii. This island is the largest and youngest of the islands in the Hawaiian chain, and is still growing from recent activity of the Mauna Loa and Kilauea volcanoes; therefore it is the island with the greatest amount of heat at or near the earth's surface. Consequently, the Big Island was selected as the site for initial geothermal exploration.

Phase I of the project was organised into geophysical, engineering, environmental, socio-economic and research drilling programmes. Research work started early in the summer of 1973, with the major emphasis on the geophysical aspects. In early 1974 it was apparent that an exploratory drilling programme was essential to investigate the subsurface conditions predicted by the surveys. Consequently a Site Selection Committee was established in April 1974, chaired by Dr A. T. Abbot, to develop recommendations for the drilling programme and site selection.

The committee considered all the geophysical, geological, thermal and geochemical evidence, and concluded that the most favourable site was on the Pahoa self-potential anomaly (ref. fig. 8 HGP – Phase II, Revision to Proposal AER7500285–000). However, as it was not possible to get permission to drill there, the site was shifted northeast to a slightly less favourable position, where permission to drill was obtained from the Kapoho Land and Development Company. The site is just under 600 feet altitude, approximately 200 feet north of the Pohoiki Bay Road, 0.6 miles southwest of the prehistoric cone of Puu Honuaula, and 0.23 miles south of the first vents of the 1955 eruption (ref. figs. 1 and 2). Dr Abbot placed a stake in the ground at the site early in May 1975. Shortly after the site was selected Dr Abbot was forced by ill health, resulting in his death on 31 July, to withdraw from active participation in the project, and Project Director, Dean John W. Shupe requested Dr G. A. Macdonald to take over Dr Abbott's duties.

Specifications for the drilling had been drawn up by Dr Abbott and invitations to bid on the job were sent out to twenty-eight drilling companies, in addition to general advertising, in early June. Only one bid was received, from Water Resources International Inc. of Honolulu, and after assessment this bid was accepted.

As no one in the University of Hawaii had experience in deep hole geothermal drilling, Kingston Reynolds Thom & Allardice Ltd of Auckland, New Zealand was appointed to handle the technical contract management and advise on testing procedures and equipment. Warwick J. Tracey was the company's representative on the site during the drilling and completion testing of the well.

The drilling site was dedicated on 22 November, and mobilisation had proceeded far enough to enable the contractor to start drilling on 10 December 1975, using a Spencer Harris model 7000 drilling rig. This report describes the procedures followed and equipment used in the completion of the well.

2. DRILLING SUMMARY

A site for the drilling rig and supporting equipment including consumable materials, with approximate dimensions of 300 feet by 150 feet, was prepared in late Sepember 1975, and mobilisation of drilling equipment started in early October. By early December a reservoir containing approximately 200,000 US gallons had been formed adjacent to the rig (ref. fig. 3), and after lining with Butyl rubber it was filled with water trucked from the nearest supply, approximately one mile away.

The well was spudded in on 10 December and 2 feet of 9⅞ inch hole was made in nine and a half hours. Drilling was slow due to the lack of weight on the bit, and to the hardness of the fresh basalt lava flow. After resolving a few minor problems drilling continued on a twenty-four hour basis from 11 December.

Maintenance of circulation in the upper 200–300 feet of the well was initially a problem, and loss materials (cottonseed hulls, mica and cellophane flakes) were used to seal holes in the cinder beds that were being penetrated. The rate of drilling improved when the hard surface layers of basalt were penetrated, and more weight could be applied to the bit. A depth of 399 feet had been reached by 18 December, and as it was not possible to drill deeper with the 9⅞ inch bit at that stage due to the lack of an appropriate crossover sub to fit the drillpipe to the collars, the drillstring was removed from the hole and the 15½ inch hole opener was run in. Circulation was again a problem, and most of the hole opening was done without mud returns. Hole opening stopped on 23 December at a depth of 300 feet, and the rig was closed down for the Christmas period.

Work started again on 5 January, when a 9⅞ inch bit was run in and the hole was deepened from 399 feet to 458 feet, where the first core was taken using a diamond bit – 27 inches of basalt were recovered. 15½ inch hole opening was then resumed and by 9 January a depth of 401 feet had been reached. The hole was then opened to 20 inches and after a four day break, hole opening to 26 inches started. This work was completed by 28 January, and after reaming the hole, the 20 inch casing was run in. An obstruction stopped the casing from going below 103 feet, even with the centralisers removed, so a special reaming shoe was fabricated and used to straighten the hole. The casing was eventually run in and the annulus was cemented using 78 tons of cement in 107 pounds/cubic foot grout (refer to section 10, Cementing, of this report for full details).

After a break on 1 and 2 February, the cementing operation was completed, the blow out preventors were installed, and the 9⅞ inch hole was drilled to 1,057 feet by 7 February. An attempt was made to obtain a core, but as the hole appeared to be blocked at 937 feet, it was decided to delay the coring and proceed instead with the hole opening to 15½ inches and then to 20 inches, which was completed after many trips to change cutters, by 25 February. The hole was reamed and the 13⅜ inch casing was run and cemented by 28 February, using 79 tons of 104 pounds/cubic foot grout.

After another break, drilling started again with a 12¼ inch bit on 5 March and a depth of 1,437 feet had been reached by 9 March, when a failure was experienced in the BOP's. Reaming of the hole and centrepunching was done between 18 and 21 March, when drilling was able to continue using 8½ inch bits. A depth of 2,230 feet was reached on 25 March and the hole was then opened to 12¼ inches to a depth of 2,244 feet by 31 March. The hole was reamed, the 9⅝ inch casing was run and cemented, with difficulty, (which resulted in subsequent perforating and squeezing of cement into the 9⅝–13⅜ inch annulus when the Cement Bond Log was obtained – ref. section 12 on perforating and cementing in this report), and drilling with the 8½ inch bits started again on 5 April.

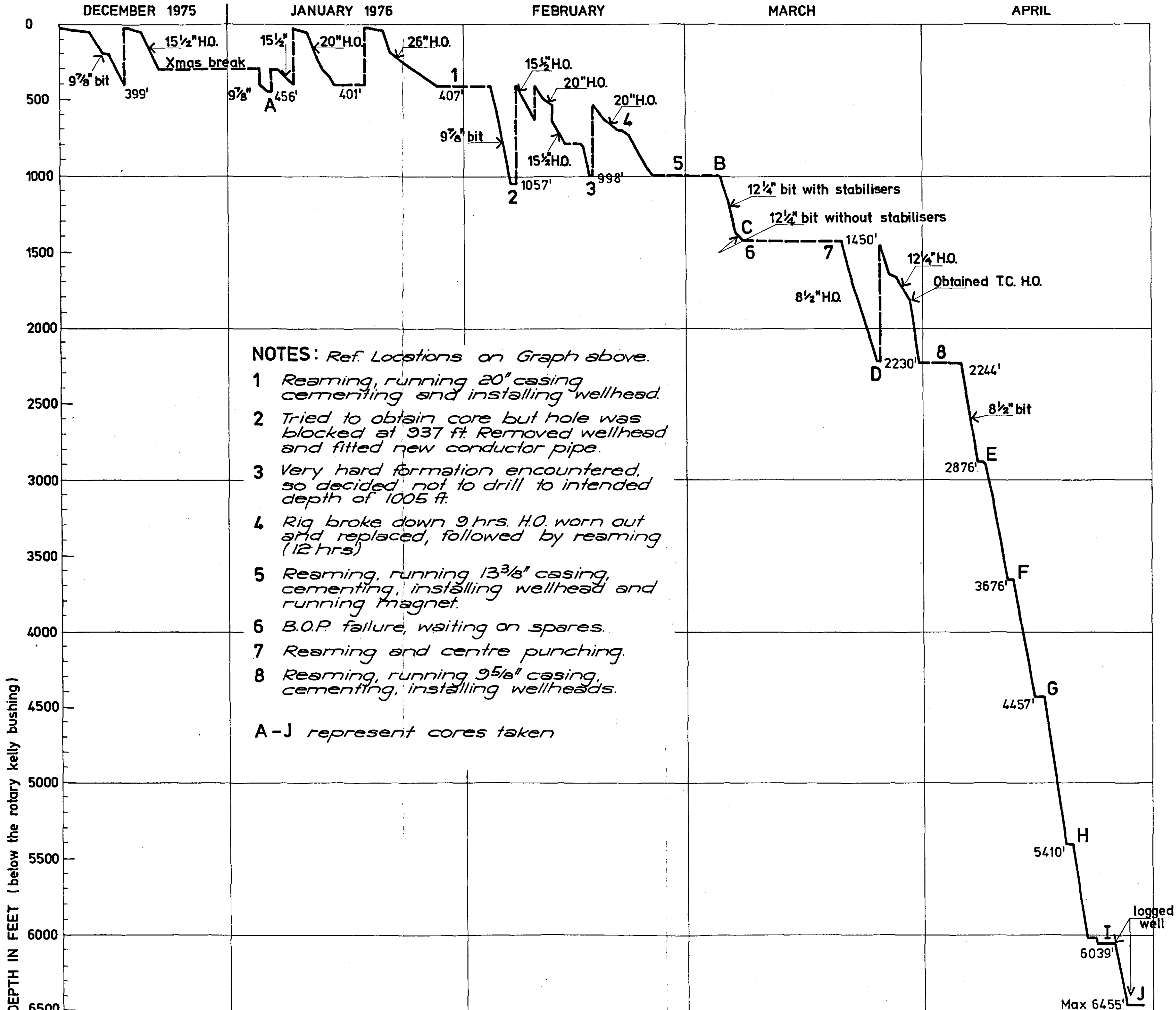


Figure 4 - Drilling & Operations Summary

From then on drilling proceeded at an average rate of 248 feet/day including cores which were taken at approximately 700 feet intervals, until a depth of 6,039 feet was reached on 23 April. No significant mud losses were noted over this section of the hole, but the mud return temperature increased to such an extent that a cooling tower had to be constructed and installed in the mud tank. This was operational by 17 April, when a depth of 4,956 feet had been reached. The maximum mud temperature did not exceed 70°C (ref. fig. 10).

The well was logged between 23 and 27 April, (ref. section 13, Completion Testing, of this report) and as the well was obviously hot, and permeability appeared to be improving although mud circulation had been maintained by the use of loss materials, it was decided to drill on for another two days, or 500 feet, or until the bit wore out, (whichever came first). This plan was followed, and the bit wore out at 6,446 feet. The mud was then conditioned, a core was obtained, and the logging was completed within the temperature limitations of the equipment.

The rig was on 'watchman only' status from 29 April to 24 May. During this period the slotted liner and wellhead valves were obtained from the mainland. The Cement Bond Log had indicated the possibility of voids in the $9\frac{5}{8}$–$13\frac{3}{8}$ inch annulus, and therefore equipment was obtained at the same time to perforate, pressure test the annulus, and, if necessary, control cement injection through the perforations and into voids in the annulus. This operation of perforating, testing and cementing took from 24 May to 1 June (ref. section 12, Perforating, Testing and Cementing, of this report). Temperature runs which had been made with the Kuster Geothermograph prior to 24 May indicated that the mud had stiffened up, and was quite hot at depth. Care was therefore taken in circulating out and conditioning the mud prior to running the 7 inch slotted/plain liner. The mud was then washed out of the well using $2\frac{7}{8}$ inch tubing, and after heating up overnight, completion tests on the well were started on 6 June (ref. section 13, Completion Testing, in this report). Work with the rig and pumps was completed on 8 June, and the well was allowed to heat up.

Cold water on the top of the well was airlifted out in an attempt to get the well to discharge, between 22 and 24 June. This operation was terminated prematurely when one of the two air hoses fell down the well. The well was subsequently flashed for four minutes on 2 July, and after cleaning out the cellar, recementing the top 8 feet of the $13\frac{3}{8}$–20 inch annulus, providing a drain for the cellar, and 1 inch steelwire rope bracing for the wellhead, the well was flashed for one hour on 19 July, and then for four hours on 22 July. Quotations are being obtained at the time of writing for further testing equipment and a comprehensive testing programme is being prepared.

Note: Air depths in this report are distances below the rotary kelly bushing, unless noted otherwise.

3. SURFACE EQUIPMENT

3.1 Wellheads

The wellheads used for each phase of the drilling are detailed on figs. 5, 6 and 7. Figure 7 also shows the final wellhead, and this and the cellar are shown in more detail on figure 8. A hole 8 feet deep below the cellar floor was excavated in the basalt for the 30 inch conductor pipe, which was cast into the concrete when the cellar was constructed. When the 20 inch casing had been cemented in it was cut off above the cellar floor as shown in fig. 5, stage II, and a reducing socket was welded on to enable the 12 inch BOP equipment to be installed, to provide protection while the hole was drilled to 1,000 feet. As no fluid pressure was encountered during the drilling of the 9⅞ inch hole to 1,057 feet it was quite safe to remove the BOP's and weld a 20 inch conductor pipe on to the casing, as shown in fig. 6, stage III. The BOP's were subsequently fitted to the 13⅜ inch casing while the hole was drilled to 2,244 feet. After running the 9⅝ inch production casing, the casing head flange was lowered and rewelded 13 inches above the cellar floor, to permit the installation of a 10 inch WKM valve as an additional safety feature in the wellhead (ref. fig. 7, stage V). Upon completion of the drilling, the final wellhead was installed (ref. fig. 7, stage VI and fig. 8).

3.2 Drilling Recorder

A Totco drilling recorder was used on the drilling rig. From 55 feet to total depth the weight on the anchored line, the rate of penetration, and the torque on the rotary table were recorded continuously.

3.3 Electrical Logging Equipment

A Gearhart-Owen portable skid mounted logging unit was purchased by the contractor and was used for running the following logs:

Standard E logs
Resistivity by induction
Gamma ray logs
Two arm caliper logs
Temperature logs
Cement bond logs

Section 15 of this report deals with the logging operations on the well. The same unit was used to lower and fire perforating charges in the 9⅝ inch casing (ref. section 12 of this report).

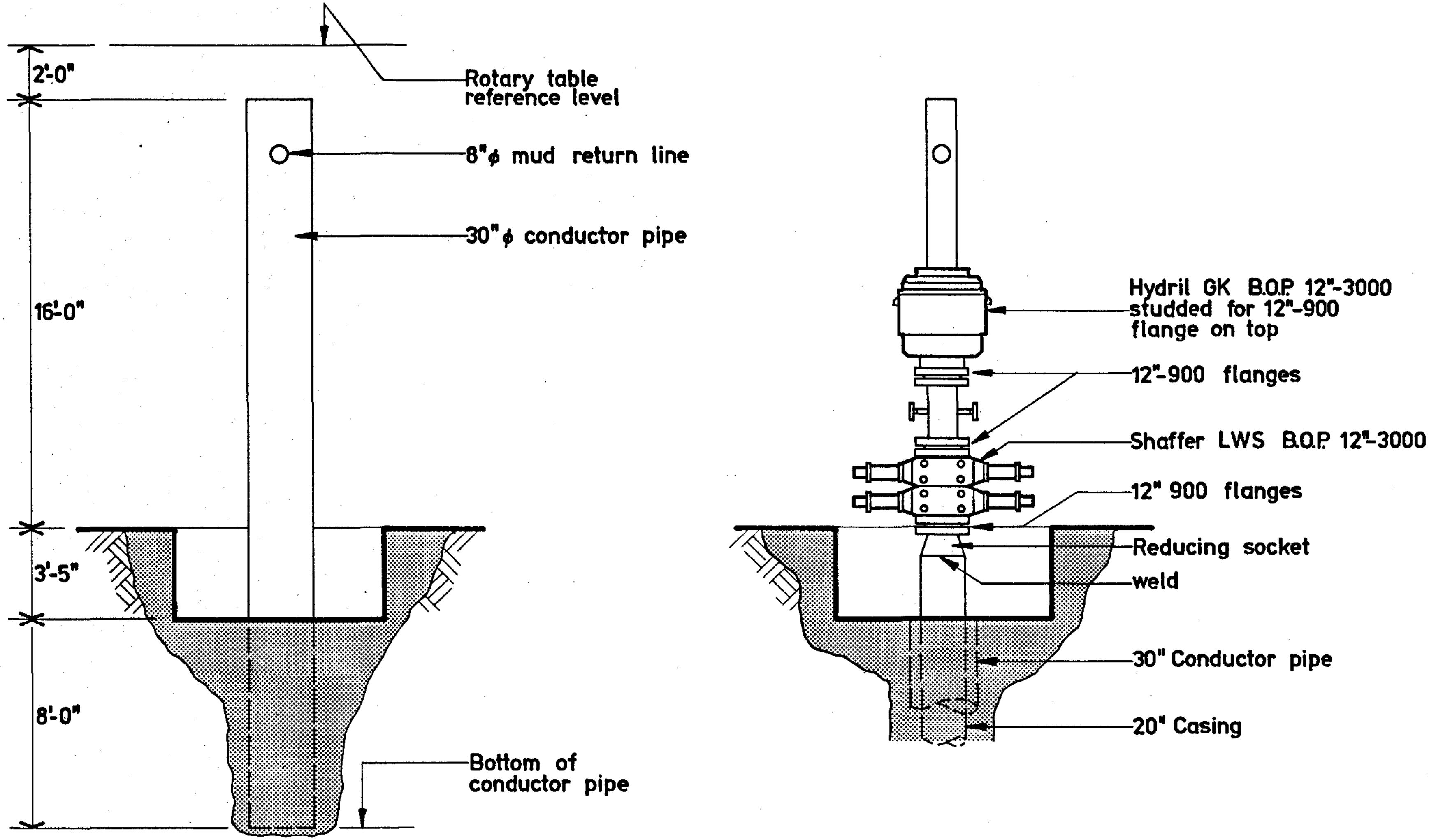
3.4 High Temperature Logging Equipment

As the high temperatures (in excess of 250°C) associated with geothermal wells destroy the insulation on electrical logging equipment, Kuster pressure and temperature recorders capable of operating up to 370°C had been obtained by the University of Hawaii. These were run into the well on a 0.082 inch stainless steel wire line through a lubricator/recovery tube.

3.5 Cooling Tower

During early April, mud temperatures increased significantly, and the need for a cooling tower became urgent. The tower was designed on 10 and 11 April, built between 13 and 16 April, and operational on 17 April. In order to expedite construction it was designed in timber, and lined with 0.008 inch polythene.

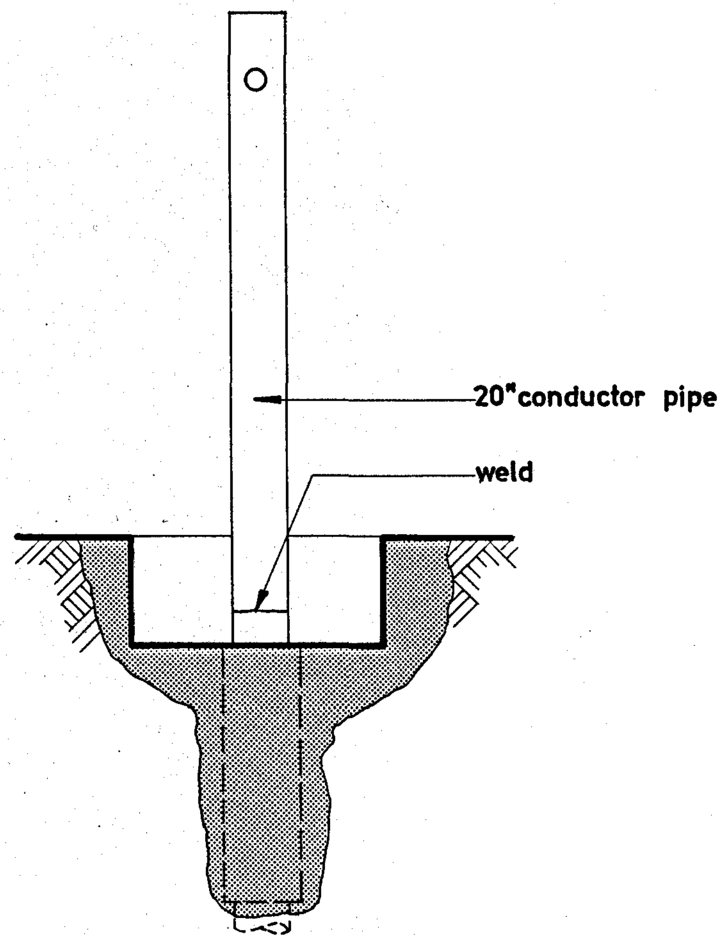
The fine mud spray blown out of the cooling tower was initially a problem which was solved by constructing a 'drift eliminator' and lifting it on to the top of the tower. There was no problem in controlling mud temperatures once the tower was operational – (ref. fig. 10).



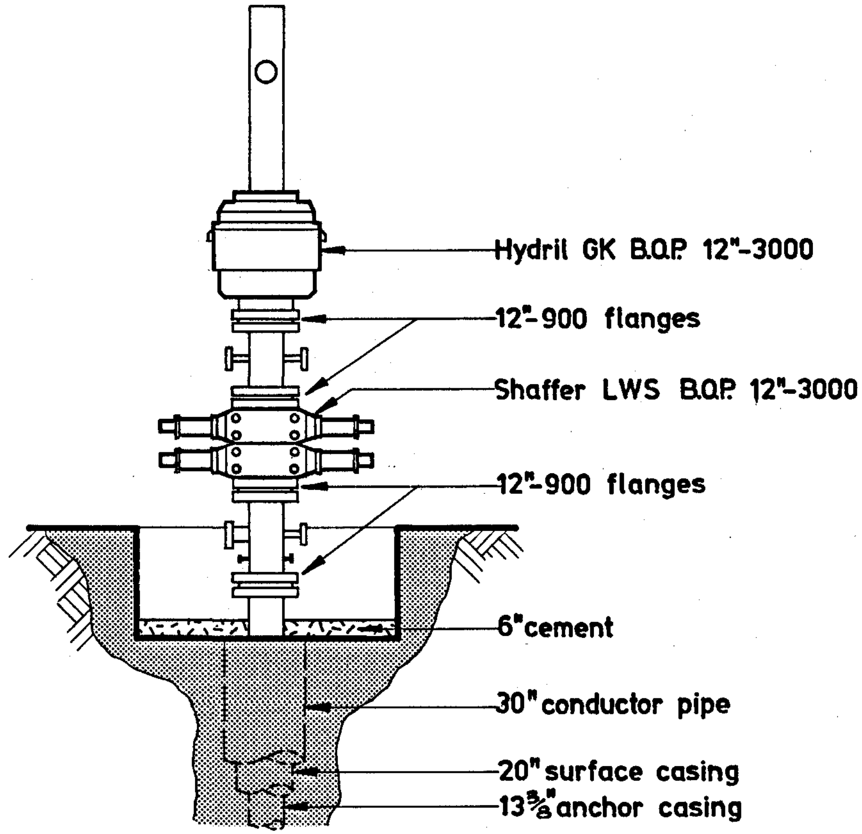
STAGE I
Drilling 0 to 407'
and hole opening (9⅞", 15½", 20", 26")

STAGE II
Drilling 407' to 1057' (9⅞")

Figure 5 - Wellheads

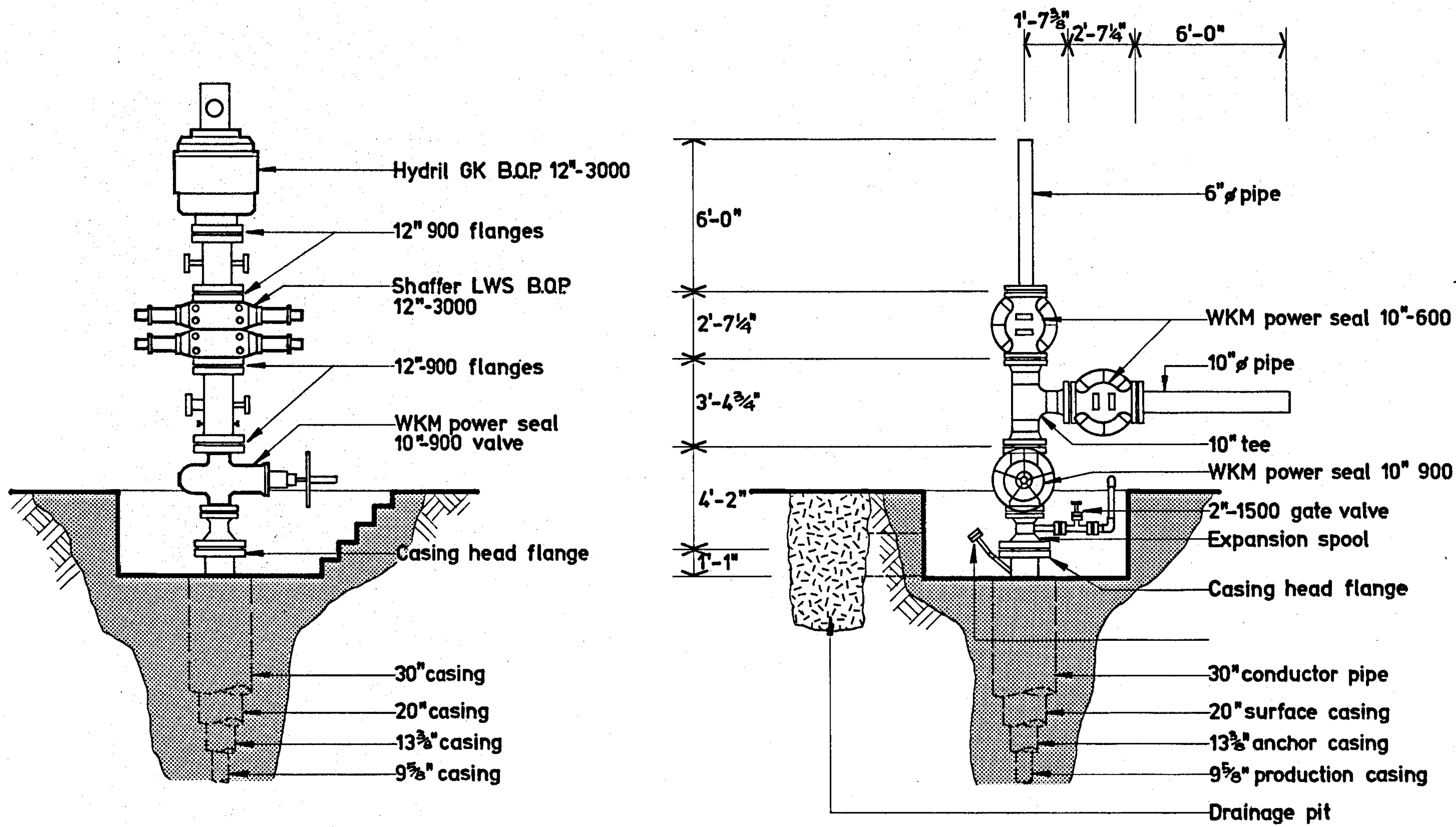


STAGE III
Hole opening 407' to 996' (15½",20")



STAGE IV
Drilling and hole opening 996' to 2240'
12¼"bits, plus 8½" and 12¼"

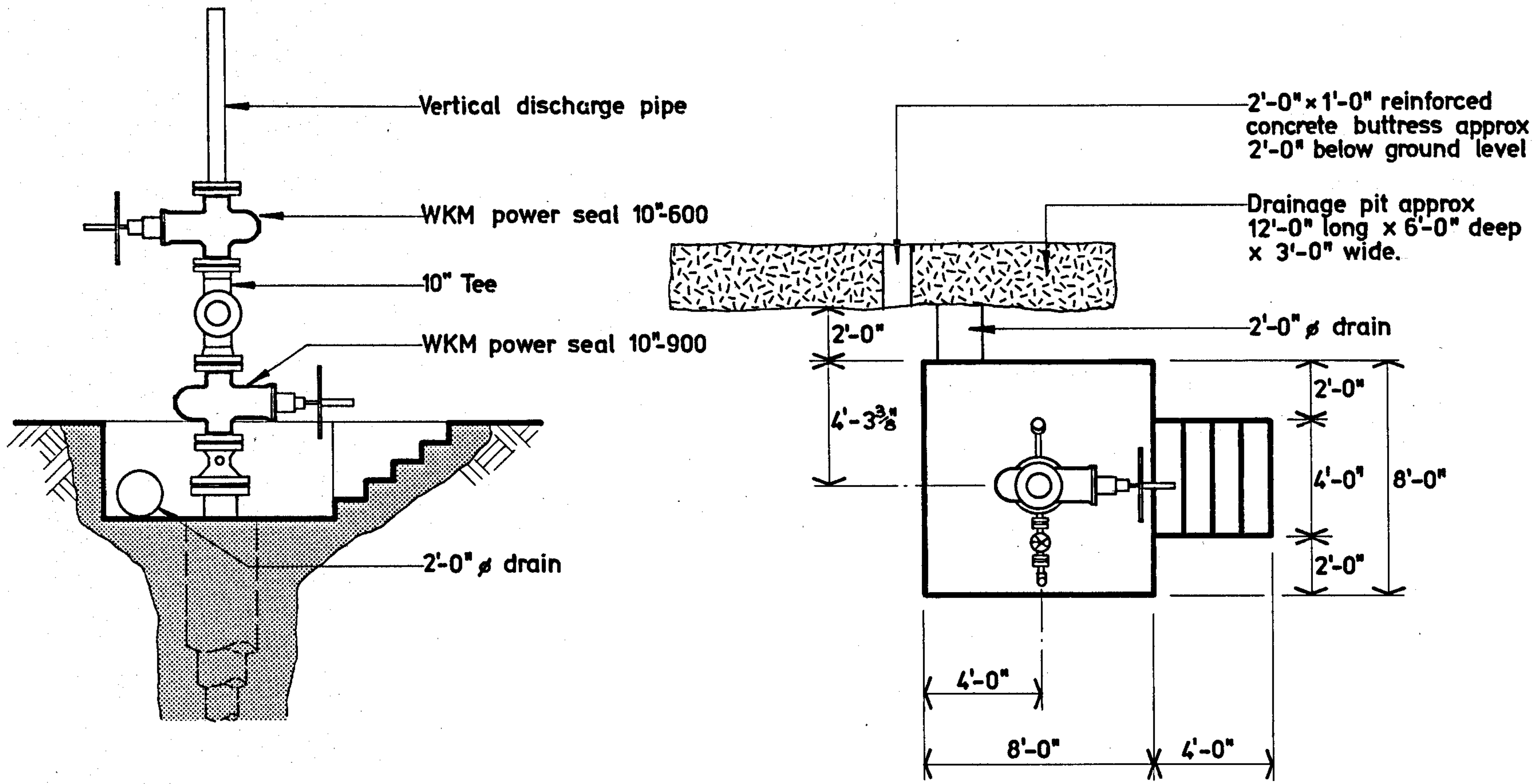
Figure 6 - Wellheads



STAGE V
Drilling 8½" from 2244 to 6000

STAGE VI - FINAL WELLHEAD

Figure 7 - Wellheads



PLAN OF CELLAR
(Diagonal bracing to wellhead omitted for clarity)

Figure 8 - Plan & Elevation of Final Wellhead

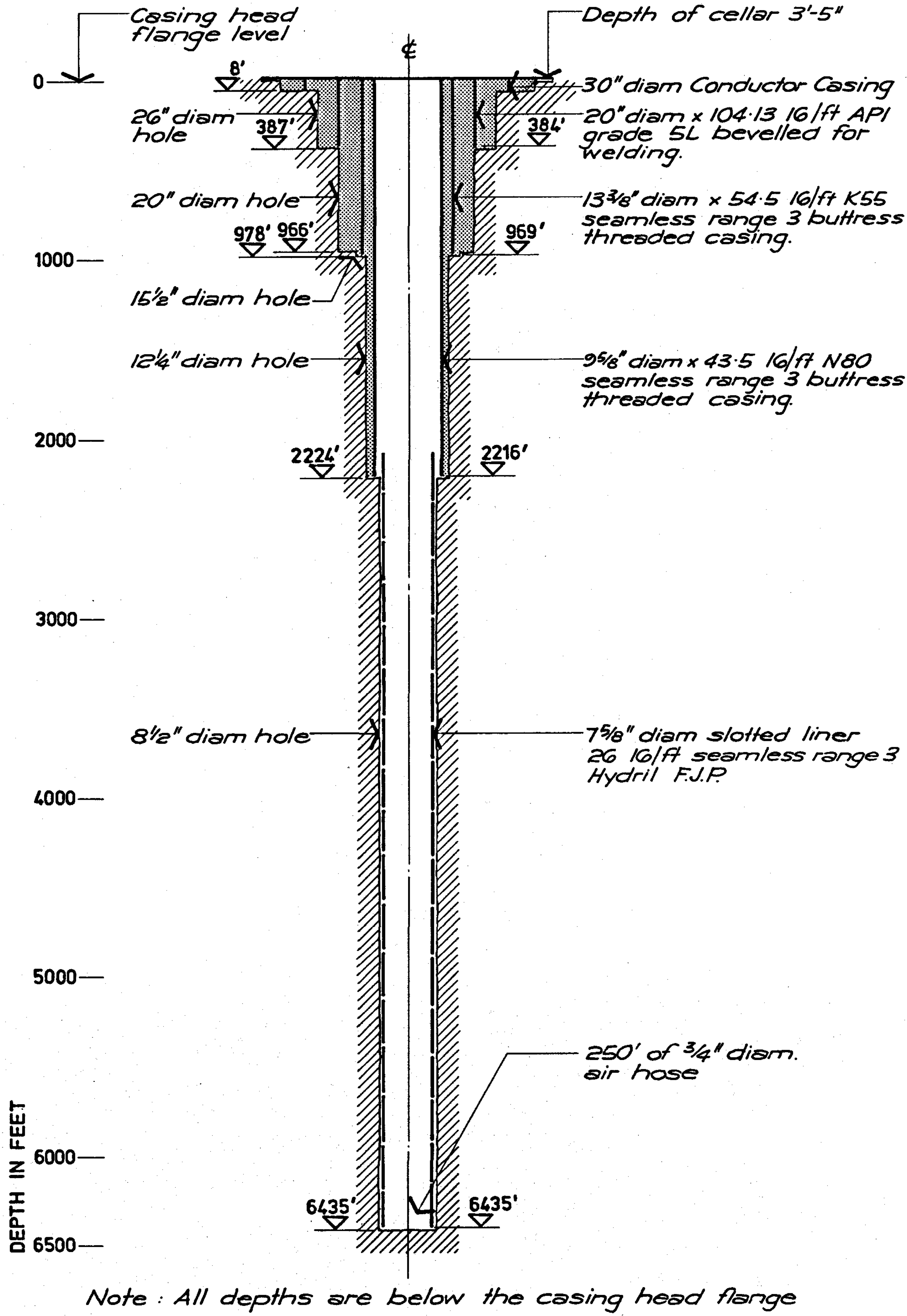


Figure 9 - Present Subsurface Well Status

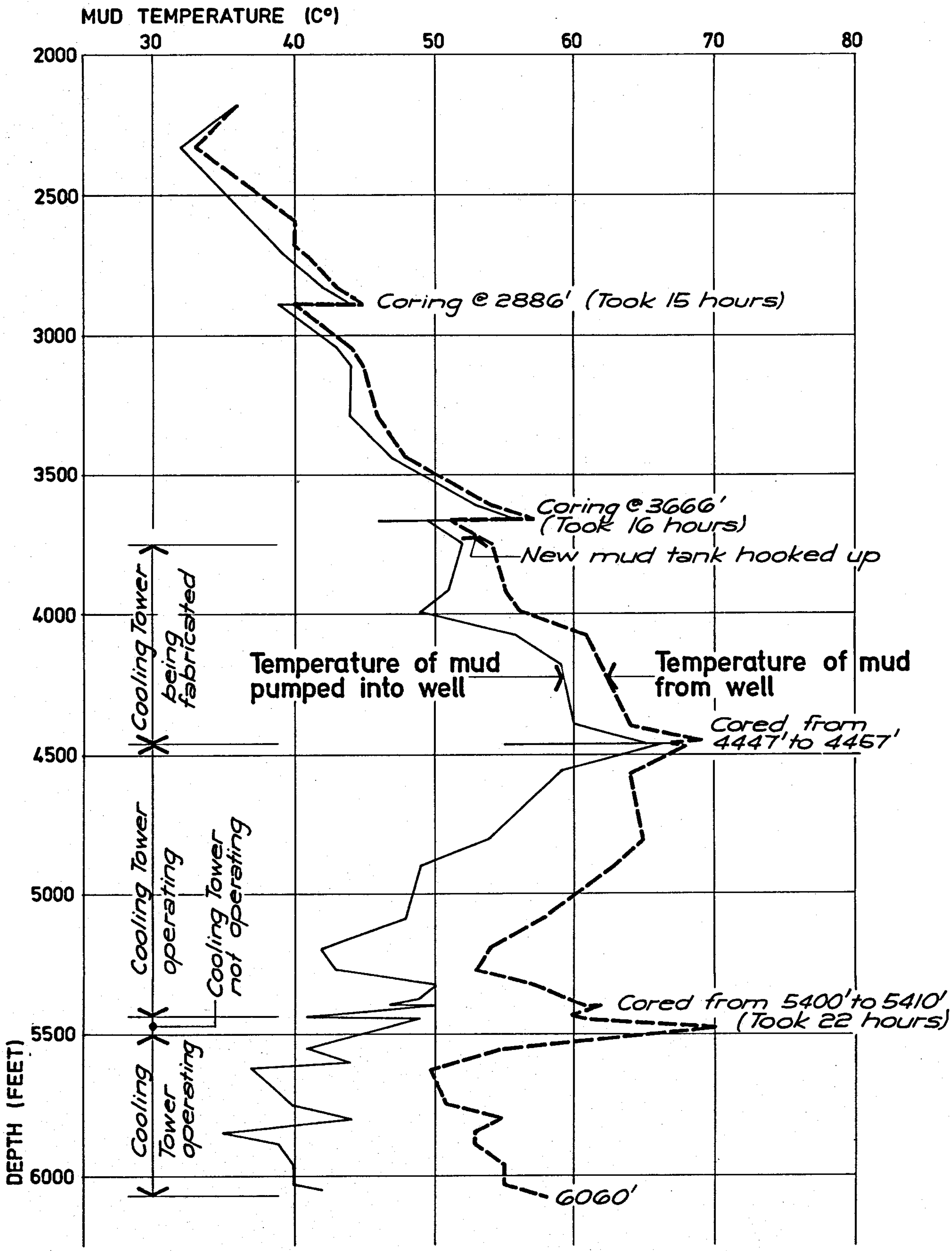


Figure 10 - Mud Temperatures

4. CASING AND LINER

4.1 Conductor Casing

When the excavation was made for the cellar, a hole 8 feet below the cellar floor was machine dug in the basalt and 30 inch diameter by ½ inch thick conductor pipe was positioned and cast in when the concrete cellar was constructed. An extension 19 feet long was subsequently welded on to facilitate mud returns to the tanks while drilling down to 458 feet. This was cut off flush with the cellar floor after cementing the 20 inch casing.

4.2 Surface Casing (ref. Appendix A)

Eight joints of 20 inch, 81.10 pounds/foot copper bearing structural steel casing, with ends bevelled for welding, totaling 422.93 feet were landed 384 feet below the final 13⅜ inch casing head flange level. A stab-in cement float shoe was welded to the bottom of the casing, and centralisers were omitted after difficulty was experienced in running the casing.

4.3 Anchor Casing (ref. Appendix B)

Twenty-seven joints of 13⅜ inch diameter J55, 54.50 pounds/foot butrress threaded casing, totaling 997.07 feet were landed 979 feet below the final casing head flange. A B&W float shoe was used and centralisers were positioned every 90 feet.

4.4 Production Casing (ref. Appendix C)

Fifty-six joints of 9⅝ inch diameter N80, 43.5 pounds/foot were landed 2,216 feet below the casing head flange. A B&W guide shoe and float collar were used, and centralisers were positioned every 90 feet.

4.5 Slotted/Plain Liner (ref. Appendix D)

One hundred and nine joints of 7 inch diameter K55, 23 pounds/foot, 8R thread were run into the well and sat on the bottom at 6,435 feet below the casing head flange. Thirty-nine joints of this casing had been supplied with thirty-two 2 inch by ½ inch parallel sided slots per foot, and these were positioned as shown in fig. 15. Thp bottom joint was fitted with a cone, to guide the liner down the hole and ease penetration through the mud, and a spade to prevent rotation while the left hand thread on the top liner sub was disengaged. The top liner sub (Joy Manufacturing Co. No. 8035–0001, 12753) had 7 inch 8 round thread on the bottom (screwed into the liner) and 7 inch Acme left hand thread on top, which was engaged by nine turns of the lifting tool which is fitted to the bottom of the drill pipe.

5. DRILLING BIT AND HOLE OPENER SUMMARY

The initial drilling and hole opening was done using milled steel bits and cutters on the hole openers. However, it was soon found that the performance of the tungsten carbide insert bits was significantly better, and consequently as supplies permitted, this type was used. (Ref. the abbreviated bit record in Appendix E). The increased performance of the tungsten carbide bits and cutters was particularly marked when opening the 8½ inch hole to 12¼ inch between 1,450 feet and 2,244 feet – the milled steel cutters on the hole opener made approximately 69 feet/day, and all other conditions being apparently equal, the tungsten carbide cutters made 350 feet/day. All drilling was done with mud weighing between 8.8 and 9.4 pounds/gallon (US), and pump pressures of from 100 psi to 750 psi depending upon the depth and jet size.

A problem was experienced in fitting the 20 inch hole opener through the 20 inch surface casing for drilling from 407 feet to 987 feet. Consequently the hard facing on the shirt tails was gas cut off to provide clearance between the hole opener and casing. This meant that the hole opener soon lost gauge and in one case the shirt tails wore right through and the ball bearings came out. Extensive reaming was required to bring the hole back to gauge.

6. CORING

Cores were taken with two Hycalog 6½ inch by 3½ inch diamond core bits, at the following intervals:

1.	456	to	458	feet	Core	recovered	2 feet
2.	1,057	„	1,068	„	„	„	1 foot
3.	1,412	„	1,423	„	„	„	2 feet
4.	2,230	„	2,240	„	„	„	10 feet
5.	2,876	„	2,886	„	„	„	10 feet
6.	3,666	„	3,676	„	„	„	10 feet
7.	4,447	„	4,457	„	„	„	10 feet
8.	5,396	„	5,406	„	„	„	10 feet
9.	6,029	„	6,039	„	„	„	10 feet
10.	6,446	„	6,456	„	„	„	10 feet

These cores are being analysed by the University of Hawaii, and will be included in a separate report. (Ref. also section 14, Geological Summary, in this report).

7. DEVIATION

A Totco double recorder mechanical drift indicator was used to establish the deviation as drilling progressed. There was considerable concern when the rate of change of deviation increased to 0.83°/foot between 1,725 and 1,767 feet. This was rectified by reaming this section of the hole, and drilling on with reduced weight for a limited period until it was apparent that the remedial measures had been effective, as noted by subsequent deviation recordings. There was no difficulty in keeping the deviation below 4° for the remainder of the hole. (Ref. Appendix F, Deviation recordings).

8. DRILLING FLUID SUMMARY

A fresh water based gel mud was used for all of the drilling and coring operations. Mud weight was maintained between 8.8 and 9.4 pounds/gallon, and viscosity of approximately 51 secs/1,000 cc. Sand content was generally held within 1 and 2 per cent of total volume.

Cottonseed hulls, cellophane and mica flakes were used as loss materials, particularly in the upper 1,000 feet of the hole where losses to the formation were more significant. The mud was treated with diesel before running the anchor casing and production casing. Tannex was used initially for thinning the mud, and Spersene was used in the deeper, hotter sections of the hole.

Total mud materials consumed during the dilling were:

Bentonite	4,939	bags	at	100 pounds
Spersene	31	„	„	50 pounds
Barite	410	„	„	100 pounds
CC16	41	„	„	50 pounds
Tannex	36	„	„	50 pounds
Soda bicarb	11	„	„	100 pounds
Q Broxin	60	„	„	50 pounds
Cottonseed	160	„	„	50 pounds
Micatex	66	„	„	50 pounds
Caustic soda	75	„	„	50 pounds
Jelflake	238	„	„	25 pounds
Cellex	128	„	„	25 pounds

9. SAMPLES

Cuttings were sampled intermittently from the surface to 680 feet due primarily to the lack of continuous mud circulation. Samples were taken from then on at 10 feet intervals, later decreasing to 5 feet intervals.

A preliminary inspection of the cuttings was made by Mr D. Palmiter, the University geologist on the site, and they were subsequently shipped to Honolulu for more detailed examination at the University. The results of this work will be included in a separate report.

10. CEMENTING

10.1 Equipment and Cement

Cement was shipped in containers by barge from Honolulu to Hilo, then trucked to the site where it was transferred to a 150 ton silo by compressed air. During grouting operations the cement was aerated and transferred by compressed air to a gravity hopper supported over a Halliburton jet mixer, to which water was supplied from the reservoir by one of the slush pumps. The grout was delivered to a small tank of approximately 60 gallons capacity where an air entraining agent was added, and it was then pumped out of this tank and down the well by the second slush pump.

The cement was type 1, conforming to ASTM Specification C-150-71, Federal Specification SS-C-192g. and AASHTO specification M-85-74.

Chemical composition of the cement was:
C_3S 54 per cent by weight
C_2S 19 " " " "
C_3A 7.4 " " " "
C_4AF 10 " " " "
Fineness: 3,650
SO_3: 2.25
Initial setting time: 2 hours 40 minutes
Final setting time: 5 hours 15 minutes
Compressive strength at 3 days: 2,650 psi
Compressive strength at 7 days: 3,560 psi

As noted above, a commercial air entraining agent (MB-VR Master Builders Neutralised Vinsol Resin Solution) was used to entrain an estimated 2 to 3 per cent of air.
2 per cent by weight of Bentonite was added manually to the grout at the jet mixer.
The temperatures encountered during drilling to 2,200 feet did not justify the use of HR4 retarder.

10.2 Cementing of the Surface Casing

The 422.93 feet of 20 inch casing were cemented on 31 January and 3 February, using 78 tons of cement. The casing had been run into the hole and filled with mud as it went in. The stinger on the end of the drill pipe was located in the stab-in float shoe and 1,200 gallons of water were pumped down to flush out the mud, followed by 1,200 gallons (4,325 pounds of cement) of lightweight (78 pounds/cubic foot) grout. This was followed by a predetermined quantity of 138,120 pounds of cement mixed with water to give grout with a mean density of 1,061 pounds/cubic foot and standard deviation of 2.8 pounds/cubic foot. No return of heavyweight grout, lightweight grout, or even water was obtained during this operation. Water was pumped down the annulus to flush any weak cement into the formation loss zones, and it was decided to finish the operation after a break.

On 3 February a tube welded to a sinker bar was lowered down the annulus on a line, and a core of rotten cement was recovered from a depth of 54 feet 6 inches. This was flushed out with high pressure water from a 1½ inch diameter tremie pipe, and a further ten minutes of pumping saw a full return of heavyweight grout which did not require topping up.

10.3 Cementing of the Anchor Casing

The 997 feet of 13⅜ inch casing were cemented on 28 February, using 79 tons of cement. The same basic procedure was used as for the surface casing – 8,010 pounds of cement were used for lightweight (86 pounds/cubic foot) grout followed by 145,560 pounds of cement for heavyweight (104 pounds/cubic foot and standard deviation of 2.2 pounds/cubic foot). Cementing started at 12.04 pm, and good returns of heavyweight cement had been obtained by the time it was stopped at 1.34 pm. Circulation was lost briefly, from 12.38 to 12.40 pm, when the heavyweight cement would have reached the shoe of the 20 inch casing.

Circulation was again lost while the cement in the drillpipe was carefully displaced with water, and the cement settled to between 40 and 50 feet down the annulus. At this stage a calculated weight of 73 tons of cement had been used. Grout was mixed again at 3.30 pm, and after some initial difficulty in getting the requisite density, the annulus was backfilled (3.3 tons were pumped to waste and 2.5 tons went into the annulus). Considerable difficulty was experienced in getting the equipment to operate satisfactorily and produce consistent grout quality.

The grout in the annulus subsequently settled a further 8 feet, and this was filled with 114 pounds/cubic foot grout after the rig had been removed and the cellar cleaned out, on 9 July, using 13 bags of cement, including waste.

10.4 Cementing of the Production Casing

The 2,244 feet of 9⅝ inch casing were cemented on 1 and 2 April, using 136 tons of cement. A Halliburton cementing head was screwed onto the top of the casing to facilitate installation of the top and bottom travelling plugs, and connection of the grouting pipework. 1,200 gallons of water were pumped away, followed by the bottom travelling plug and 1,200 gallons of lightweight grout (4,280 pounds of cement were used for grout with a mean density of 78.3 pounds/cubic foot and standard deviation of 10.3 pounds/cubic foot). The predetermined quantity of 3,000 cubic feet of heavyweight grout (153,238 pounds of cement mixed with water to give grout with a mean density of 100.2 pounds/cubic foot and a standard deviation of 2.7 pounds/cubic foot) where then pumped away between 12.00 and 1.30 am, followed by the top plug which was pumped down with mud.

At this stage there had been no return of lightweight grout, let alone heavyweight, so the annulus was flushed out with 760 cubic feet of water, followed immediately by the same volume of heavyweight cement using 70,655 pounds of cement to give grout with a mean density of 104 pounds/cubic foot and standard deviation of 5.2 pounds/cubic foot. There was still no return and it was not possible to pressurise the cement in the annulus, so the equipment was cleaned up and when samples taken earlier showed that the initial set had taken place, grout was batch mixed and pumped down the annulus. Difficulty was experienced with the equipment and a total of 43,610 pounds of cement was consumed during the batch mixing, which gave grout with a mean density of 90.6 pounds/cubic foot and standard deviation of 13 pounds/cubic foot, most of which was pumped to waste. It was suspected that airlocks were forming in the small size annulus.

In view of these problems it was decided to lift the wellhead and pour ready-mixed grout down the annulus. However, the annulus was found to be full on lifting the wellhead, so the equipment was cleaned up and work proceeded on fitting the new wellhead.

11. DAILY DRILLING REPORTS

4 December	Rig being assembled and reservoir being lined with Butyl rubber.
5 December	Lining of reservoir completed. Rig electrical work underway. Welders working on pipework.
6, 7 and 8 December	Work continued on assembling rig, particularly pipework associated with the new mud tanks and pumps. Mud materials arrived on site.
9 December	Filling of reservoir started. First batch of mud mixed. Kelly rotated for first time in late afternoon but no drilling as fabrication of equipment still continuing.
10 December	Drilling started at 7.30 am, finished at 5.35 pm. 3 feet of hole drilled – 9⅞ inch bit used with 20 feet collar. **Note:** the conductor pipe set 29 feet below rotary table (BRT).
11 December	Drilling continued in very hard formation. Twenty-four hour shifts started. 34 feet BRT at 5.00 pm.
12 December	Broke through the hard formation at 5.00 am and lost circulation. Drilling continued, pumping 5 to 7 gallons per minute of mud to clear cuttings and to cool and lubricate the bit, which is a technique that the contractor has used on this type of formation in the past. Reservoir was about half full; welders and electricians still working on site. 52 feet BRT.
13 December	Drilling progressing steadily in hard formation. Totco four pen recorder now operating. 150 tons cement silo delivered to site. 61 feet BRT.
14 December	Drilling in generally softer formation with hard, but thin, layers between. 146 feet BRT at midnight.
15 December	Drilling 9⅞ inch pilot hole and pumping loss materials with mud. Depth at mid-day (DAMD) 190 feet BRT.
16 December	Cement delivery started to silo. Still no circulation. New batch of mud mixed and pumped down hole. Removed bit from hole as it was worn out. Regained circulation by filling hole with mud and loss circulation material. Fitted tungsten carbide insert bit and ran it into hole. Lost circulation immediately but carried on drilling and pumping cement. DAMD 209 feet BRT.
17 December	Circulation returned overnight and disposal of loss materials plus cuttings became a problem. There was a slight loss of mud to the formation all the time. DAMD 305 feet BRT.
18 December	Circulation lost and regained overnight. Could not drill beyond 390 feet due to lack of crossover subs so pulled out of hole and started opening the hole to 15½ inches at 6.00 pm. DAMD 390 feet BRT.
19 December	Lost circulation at 38 feet. Continued drilling blind to conserve loss materials. DAMD 41 feet BRT.
20 December	Opening hole blind through hard formation. Crew constructing mud storage shed. DAMD 60 feet BRT.
21 December	DAMD 196 feet BRT.

22 December	Opening hole drilling blind. Crew tidying up around site. DAMD 248 feet BRT.
23 December	Opening hole drilling blind. Depth of 300 feet was reached at 4.30 pm. Pulled out of hole, filled it with mud and closed down operations for Christmas period. **Note:** Over the Christmas period vertical holes were drilled into the country for ⅝ inch anchor rods for the mast guide wires which were installed. Mud line valves were installed so that it would be possible to mix mud without interrupting drilling.
5 January	Work started at 8.00 am. General preparation and mixing mud took until approximately 4.30 pm. Mud was approximately 41 feet BRT indicating no significant loss to the formation over Christmas. Bottom of the hole was full of cuttings and had to be washed out before drilling could commence, using a 9⅞ inch bit.
6 January	9⅞ inch bit was removed from a depth of 456 feet at 8.00 am and a core was taken. Coring was terminated prematurely when the bit dropped into a small cavity, at a depth of 458 feet. Opening of the hole to 15½ inches from 300 feet started at 10.00 pm.
7 January	15½ inch hole opening continued in hard formation. DAMD 303 feet BRT.
8 January	15½ inch hole opening continued; pilot bit not clearing cuttings, therefore the opener was removed from the hole during the afternoon and the jets were plugged. Increased velocity from the pilot bit then cleared the cuttings – this problem is due to the blind drilling, low mud circulation rate and is not expected to recur when full circulation is obtained. DAMD 347 feet BRT.
9 January	15½ inch hole opening continued. DAMD 459 feet BRT. A depth of 401 feet had been reached by 4.00 pm. 15½ inch hole opener was then removed and replaced by the 20 inch hole opener.
10 January	20 inch hole opener – DAMD 45 feet BRT.
11 January	20 inch hole opener – DAMD 73 feet BRT.
12 January	20 inch hole opener – DAMD 213 feet BRT.
13 January	20 inch hole opener – DAMD 301 feet BRT. Formation hard and rough drilling. Circulation returned briefly last night.
14 January	20 inch hole opener – DAMD 353 feet BRT.
15 January	400.6 feet was reached with the 20 inch hole opener at 9.00 am. The hole opener was removed and the site tidied up in preparation for the long week-end. After a four day break started again on 19 January.
19 January	Rig was on standby until 1.45 pm. Instructions were received that the 20 inch casing had to be run. Drilling with a 26 inch hole opener started at 3.30 pm without circulation having been regained.
20 January	26 inch hole opener – DAMD 44 feet BRT. Circulation was regained at this depth using cinders as a loss material. The Emsco pumps were used with Jelflake in the mud at 1.00 pm. At 2.00 pm large mud returns were achieved.

21 January	26 inch hole opener – DAMD 63 feet BRT. Circulation continued until the hard surface layer was penetrated at 68 feet BRT at 4.30 pm. Lost 15,000 gallons of mud overnight.
22 January	26 inch hole opener – DAMD 193 feet BRT. Good progress made; blind drilling all the way. 20 inch casing being welded into doubles and cement disposal equipment being assembled.
23 January	26 inch hole opener – DAMD 226 feet BRT.
24 January	26 inch hole opener – DAMD 294 feet BRT. Cinders plus Jelflake used to regain circulation without difficulty.
25 January	26 inch hole opener – DAMD 307 feet BRT. Drilling with circulation proceeding slowly.
26 January	26 inch hole opener – DAMD 350 feet BRT. Drilling with circulation all day.
27 January	26 inch hole opener – DAMD 362 feet BRT. Circulation maintained with loss of 600–700 gallons of mud per hour.
28 January	26 inch hole opener – DAMD 407 feet BRT – this was the maximum depth reached with the 26 inch hole opener. It was then removed and the 26 inch reamer was run in at 1.00 pm.
29 January	Reaming completed at 9.00 am and casing was run in. The second length would not go past a depth of 103 feet, even with the centralisers removed. It was therefore removed from the hole and the rig was on standby from 1.00 pm while a special reaming shoe and fittings were fabricated.
30 January	The special reamer was run into the hole at 9.00 am, and the hole was reamed all day. Casing was then run into the hole that evening.
31 January	Preparations were made for cementing, which started at 1.00 pm. (Ref. item 10.2 – cementing of surface casing.
1 and 2 February	Rig closed down for break.
3 February	Top of cement found at 54 feet 6 inches BRT using a sinker bar and coring tube. Flushed out annulus to remove rotten cement with high pressure water. Pumped heavyweight cement down annulus and had full return. Cut 30 inches conductor pipe flush with cellar floor and fitted reducing cone and BOP's to the 20 inch casing.
4 February	Mixed mud and began drilling at mid-day with 9⅞ inch tungsten carbide bit which drilled much faster than the milled steel bits.
5 February	9⅞ inch bit – DAMD 620 feet BRT. Mud being lost at 600–700 gallons per hour but circulation being maintained.
6 February	870 feet. Drilling was proceeding at the fastest rate so far. Mud losses continuing.
7 February	Reached 1,050 feet at 1.00 am. Mud was conditioned and the hole cleaned with the intention of taking a core but the hole was found to be bridged at 937 feet. Pulled out core barrel and ran in 15½ inch hole opener. Drilling started about 11.00 pm.

8 February	$15\frac{1}{2}$ inch hole opener – DAMD 467 feet BRT. Hole opening proceeding slowly all day with good mud returns.
9 February	550 feet. Drilling slowly all day with fairly large mud losses.
10 February	638 feet at 9.30 am. Pulled out and started drilling with the 20 inch hole opener at 1.30 pm with circulation.
11 February	499 feet. Hole opening proceeding with small losses until at 4.30 pm circulation was lost. Opening then continued; drilling blind while more mud was mixed. Slight increase in mud return temperature was noted mid-day. Mud in at 77°F – out at 85°F.
12 February	542 feet. Drilling continued slowly with circulation. Tripped out at 1.15 pm and ran back in with the $15\frac{1}{2}$ inch hole opener.
13 February	$15\frac{1}{2}$ inch opener – DAMD 725 feet BRT. Large losses of mud between 5.00 and 7.00 am, but circulation was regained.
14 February	Hole opening with $15\frac{1}{2}$ inch hole opener stopped at 6.00 am with a depth of 784 feet. Contractor closed down for the week-end.
15 February	Rig closed down. General maintenance carried out.
16 February	$15\frac{1}{2}$ inch hole opener – DAMD 806 feet BRT. Drilling started at 10.00 am. Circulation was maintained all day. 20 inch hole opener being rebuilt.
17 February	995 feet. Drilling rate slowed down until at 3.45 pm and at depth of 998 feet the $15\frac{1}{2}$ inch hole opener was removed and replaced by the 20 inch hole opener which had been rebuilt and had the hard facing cut off. Reaming of the hole from 400–543 feet started at 9.30 pm.
18 February	20 inch hole opener – DAMD 541 feet BRT. Hole opening continued with circulation all day.
19 February	637 feet. Slow progress – drilling with circulation.
20 February	678 feet. Mud circulation OK but about 8,000 gallons lost overnight. Second 20 inch hole opener arrived from Honolulu.
21 February	697 feet. Six bolts on the rig jack shaft sheared off and rig was out of action from 1.00 am to 10.00 am. All of the hard facing was gas cut off the second 20 inch hole opener. At 3.00 am the first 20 inch hole opener was removed – it was worn out on the teeth and gauge and had lost ball bearings.
22 February	728 feet. The rebuilt hole opener was run in and the hole was reamed until 8.00 am, when hole opening re-started.
23 February	833 feet. John Englebretsen (drilling supervisor, NZ MWD) arrived from New Zealand to expedite progress.
24 February	941 feet. Drilling proceeding slowly. Site being tidied up.
25 February	986 feet. Very slow progress being made with the 20 inch hole opener and as it had been in the hole for three days it was decided at mid-day to remove it and sound the hole with two lengths of $13\frac{3}{8}$ inch casing totalling 40 feet.
26 February	The hole was reamed all day and the mud was conditioned in anticipation of running the $13\frac{3}{8}$ inch casing.

27 February	Reaming was completed and the casing was run in under adverse weather conditions (very hard rain) which delayed welding of the cementing head to the top of the casing. The drilling string was then run into the casing and located in the float shoe between 7.00 and 10. 00 pm.
28 February	Pressure tested cement system. Filled mud tank and pumps with water. Burst water pump delivery hose so all water was flushed out of the well by the cementing pump, which was subsequently used for pumping grout. Cementing started at 12.04 pm (ref. section 10.3 of this report), and after completing the job the equipment was cleaned up and the rig closed down for a programmed four day break.
29 February, 1 and 2 March	Rig closed down. One GM pump engine and the Caterpillar generator engine were overhauled by respective manufacturers. Work started on preparation of $13\frac{3}{8}$ inch casing and casing head flange for welding.
3 March	Work proceeding on the welding of the casing head flange after rectifying initial misalignment. Wellhead and conductor pipe were then installed.
4 March	The float shoe and cement below were drilled out with a $12\frac{1}{4}$ inch bit. The shoe had been set at 990 feet BRT. After radiographing the casing head flange a magnet was run into the hole and the mud was conditioned prior to obtaining the core (four pieces of metal were recovered). The core barrel was run in and was on the bottom at 1,056 feet at 11.00 pm.
5 March	$12\frac{1}{2}$ inch bit – DAMD 992 feet BRT. A core was cut to 1,066 feet and at 6.00 am the barrel was removed from the hole. A 12 inch core of broken dense basalt was obtained. Drilling with $12\frac{1}{4}$ inch bit and stabilisers 30 feet and 60 feet up started at 10.00 am. Tuboscope inspection gear and operator arrived on site.
6 March	$12\frac{1}{4}$ inch bit – DAMD 1,151 feet BRT. Drilling proceeded quickly all day.
7 March	1,372 feet. Drilling proceeded at a good rate until at 6.10 pm, the chain drive linking the two draw works engines broke. Drilling started again at 9.50 pm after repairing and checking the rig.
8 March	1,413 feet. Drilling had proceeded slowly all night and on removal of the $12\frac{1}{4}$ inch bit it was found to have a failed roller bearing in one cone. A core was taken by 6.00 pm. Clarence Mason (drilling supervisor, Reynolds Electrical Co, Las Vegas) arrived from Nevada. The rig was on standby until 3.30 am on 9 March waiting for the second $12\frac{1}{4}$ inch bit from Honolulu.
9 March	1,437 feet. Reaming started at 6.30 am and drilling at 7.35 am. No stabilisers were used and no torquing-up problems were experienced. On tripping out at 11.00 am the pipe rams closed in on a drill collar due to a fault in the BOP's. The rig was then on repair until 12.00 mid-day.
10 to 15 March	Tuboscoping started under poor weather conditions. Rig on repair time and rig equipment being improved. John Englebretsen left on 12 March.
16 March	A tool string to centrepunch the bottom of the $12\frac{1}{4}$ inch hole with an $8\frac{1}{2}$ inch was assembled and run into the hole. The tools were then pulled up inside the $13\frac{3}{8}$ inch casing pending BOP spares arrival.
17 March	Tuboscoping completed. Rig maintenance continuing.
18 March	Decided to ream the $12\frac{1}{4}$ inch hole from 990 feet to 1,413 feet with the $12\frac{1}{4}$ inch bit and near bit reamer followed by stabilisers. Centrepunch set up was therefore removed and reaming started at 11.00 pm.

19 March	Reaming until 11.30 pm. BOP spares arrived at 3.00 pm.
20 March	Ran in 500 feet of $9\frac{5}{8}$ inch casing to sound the hole and ran to bottom without difficulty at 12.30 pm. Casing was then removed, the hole was centrepunched at 10.30 pm and the $8\frac{1}{2}$ inch drill string was assembled.
21 March	$8\frac{1}{2}$ inch bit – DAMD 1,475 feet BRT. Weight was kept off the bit to prevent excessive deviation until a full set of stabilisers was within the $8\frac{1}{2}$ inch hole.
22 March	1,691 feet. Drilling rate varied between 40 feet and 5 feet per hour.
23 March	1,802 feet. The bit was replaced after drilling to 1,776 feet. Deviation was increasing so weight on the bit was reduced.
24 March	1,992 feet. Drilling continued with reduced weight and a number of deviation recordings were taken to check progress.
25 March	2,230 feet was reached at 7.30 am and 10 feet of core was taken. Gearhart-Owen's logging operator arrived and a decision was made to take logs before casing this section of the hole.
26 March	$12\frac{1}{4}$ inch bit – DAMD 1,495 feet BRT. After various difficulties it was decided to forego logging and hole opening started again at 8.00 am.
27 March	1,649 feet. Poor progress made during the night so the hole opener was replaced in the early morning and again at 9.00 pm. Formation was very rough and hard.
28 March	1,666 feet. Hole opening in hard, rough formation at 0.5 to 1 foot per hour. Tripped out from 1,666 feet at 10.00 am and fitted $12\frac{1}{4}$ inch tungsten carbide bit, and nearbit reamer, and two stabilisers to cut through the hard formation. Started drilling again at 4.30 pm with care as there was no pilot bit to prevent deviation from the $8\frac{1}{2}$ inch hole.
29 March	$12\frac{1}{4}$ inch hole opener – DAMD 1,744 feet BRT. Tripped out of the hole at midnight from a depth of 1,710 feet and refitted the $12\frac{1}{4}$ inch hole opener. Drilling again at 5.30 am. Pulled out at 3.30 pm from 1,751 feet and refitted the $12\frac{1}{4}$ inch tungsten carbide insert bit and two $12\frac{1}{4}$ inch stabilisers. Drilling with care again at 9.00 pm. The rate was twice as fast as with the hole opener.
30 March	$12\frac{1}{4}$ inch hole opener – DAMD 1,811 feet BRT. At 6.35 am, at a depth of 1,811 feet the $12\frac{1}{4}$ inch bit was removed and replaced by a $12\frac{1}{4}$ inch hole opener with medium formation cutters. There were no more hard formation cutters available on site. 1,865 feet at 5.00 pm. The $12\frac{1}{4}$ inch tungsten carbide insert hole opener arrived and was fitted. Drilling again at 10.40 pm.
31 March	$12\frac{1}{4}$ inch hole opener – DAMD 2,055 feet BRT. Reached 2,244 feet at 6.00 pm. Pulled up to 970 feet then reamed to bottom and tripped out.
1 April	Removed Hydril and replaced the $13\frac{3}{8}$ inch pipe as the cement return was expected to rise up the wellhead due to the hydrostatic head necessary to discharge it through the long reject pipe. Started running the $9\frac{5}{8}$ inch casing at mid-day and completed it at 6.00 pm. Prepared cementing equipment and pumped 1,200 gallons of water, bottom travelling plug and 1,200 gallons of lightweight cement.

2 April	Cemented the $9\frac{5}{8}$ inch casing (ref. section 10.4, Cementing of Production Casing). As noted, considerable difficulty was experienced with getting a full return to the surface and backfilling down the annulus was necessary. The equipment was cleaned up during the mid-afternoon and the casing head flange was cut off.
3 April	The casing head flange was machined for welding and a length of approximately 18 inches of $13\frac{3}{8}$ inch casing was cut off and prepared for welding. 6 inches of cement from the previous cementing job was broken out of the cellar and general work continued around the site in preparation for the next drilling operation.
4 April	The casing head flange was re-welded and radiographed. 10 inch valve and blow-out preventers fitted.
5 April	Wellhead completed and checked. Started running in the drill string at 5.00 pm. Drilled out cement from 2,175 feet at 8.00 pm with $8\frac{1}{2}$ inch bit – depth at midnight (DAMN) 2,234 feet BRT.
6 April	DAMN 2,506 feet. Drilling well all day. Deviation holding between 3° and 4°.
7 April	2,825 feet. Drilling well all day. Setting up of new mud tank started.
8 April	2,886 feet. Obtained a core from 2,876 feet between 1.00 and 3.00 pm, with 100 per cent recovery. Reamed the hole from 2,876 feet to 2,886 feet, starting at 10.00 pm.
9 April	3,106 feet. Drilling well all day.
10 April	3,445 feet. Drilled a record for this project of 339 feet in the last twenty-four hours.
11 April	3,666 feet. Mud temperatures increased to 56 °C in, 57 °C out. Tripped out of hole at 9.00 pm to take a core.
12 April	3,788 feet. 100 per cent recovery obtained of core from 3,666 feet to 3,676 feet. Drilling again by 12.45 pm.
13 April	3,996 feet. Hard drilling in the morning but at 9.00 am rate of penetration increased from 5 feet per hour to 15 feet per hour. New mud tank being used so that mud temperatures reduced slightly. Construction of cooling tower started.
14 April	4,227 feet. Drilling well all day. Cooling tower ready for erection by evening.
15 April	4,447 feet. Cooling tower lifted into mud tank and lined with polythene. Mud temperatures 65 °C in, 69 °C out. Started trip-out from 4,447 feet at 1.00 pm to take a core.
16 April	4,596 feet. Core recovered at 10.00 am. Plumbing and fans fitted to the cooling tower.
17 April	4,956 feet. Cooling tower now operating effectively.
18 April	5,244 feet. Drilling well all day. 100 per cent circulation; no problems. Mud temperatures 48 °C in, 58 °C out. Very little torque on bit – easy drilling.
19 April	5,400 feet. Conditioned mud between 11.00 and 12.00 am, then tripped out for a core which was obtained by 10.34 pm with 100 per cent recovery.

20 April	5,622 feet. Drilling started again at about 9.00 am. Drift eliminator and ladder were fitted to the cooling tower. Mud temperatures varied between 41 °C–53 °C in and 60 °C–65 °C out.
21 April	5,968 feet. Drilling well all day. Started losing circulation at about 10.00 pm. 85 per cent returns. Added loss materials and reduced loss to 5 per cent by midnight. Mud temperatures 35 °C–40 °C in and 51 °C–53 °C out.
22 April	6,029 feet. Conditioned mud from 5.30–6.30 am. Tripped out for a core which was obtained by 4.45 pm with 100 per cent recovery. Mud losses had continued at about 15 per cent whilst coring.
23 April	6,060 feet. Drill string was run back into the hole and after conditioning mud the hole was reamed and deepened to 6,060 feet from 5.30–7.30 am. Mud was conditioned while waiting for the logging unit operator to arrive. At 5.30 pm the logging winch drum collector unit was found to have a short and had to be replaced. The drillpipe was therefore lifted up inside the production casing and the pipe rams were closed while waiting on the replacement parts.
24 April	Drill string was removed from the hole and logging started at 11.00 am. Collector ring spares arrived by 8.40 pm.
25 April	Logging continued all morning with the Gearhart-Owen equipment. (Ref. section 13, Completion Testing). The 8½ inch bit was then run into the hole circulating every twenty joints to condition the mud and reduce the temperature. Drilling started at a depth of 6,060 feet at 10.00 pm, with approximately 95 per cent mud returns. Temperatures were 46 °C in and 63 °C out. Depth at midnight was 6,091 feet.
26 April	6,330 feet. Drilling 8½ inch with 85 inch mud returns. Temperatures were 43 °C–58 °C in and 58 °C–67 °C out.
27 April	6,446 feet. Failure of the bit was suspected due to rhythmic torquing up on the rotary table at 8.45 pm. The mud was then conditioned and a trip out was made from 1.00–4.30 pm, followed immediately by logging. A temperature of 140 °C was reached at 4,100 feet and it was still rising. Started to trip in for a core at 10.00 pm.
28 April	6,456 feet (bottom of core). A core with 100 per cent recovery was obtained at 11.30 am. The actual coring had been completed at 7.30 am and this is the time from which heating up of the well has been subsequently measured. Started laying down drillpipe into the racks.
29 April	Completed Kuster geothermal graph run at 1.00 am after fifteen hours heating. Laid down drillpipe and collars on the racks by 9.30 am. Cleaned up around the site.
30 April	General cleaning up around the site.
1 to 23 May	Rig on 'watchman only' status. Temperature runs by University of Hawaii staff.
24 May	Mud was cleared from the well down to 1,191 feet with water and a 100 foot cement plug was placed.
25 May	Checked the level of the top of the cement plug and pressured-up on it to 1,150 psi. Pulled out of the hole by 10.00 am and waited for the perforator to arrive plus explosive charges.

26 May	Waiting for perforator and explosive charges.
27 to 31 May	Perforating, testing and cementing of $9\frac{5}{8}$–$13\frac{3}{8}$ inch annulus (ref. section 12).
1 June	Completed perforating. Drilled out the cement plug below 1,091 feet. Circulated out and conditioned mud in big stages initially (1,191 feet – 2,663 feet – 3,360 feet – 3,509 feet) and reducing to every pipe length below 3,500 feet.
2 June	Circulating out, conditioning and cooling hot mud. Mud temperatures increased from 25°C–40°C in and from 40°C–52°C out between 4,000 and 5,500 feet.
3 June	Continued cooling and conditioning mud to bottom of hole. Reamed out to 6,455 feet. Tripped out of hole and laid down collars and excess drillpipe on the racks. Started running 7 inch casing at 4.00 pm.
4 June	Completed running the liner and sat it on the bottom then disconnected and removed the drillpipe and went back into the hole with $2\frac{7}{8}$ inch diameter tubing pumping down water every 60 feet to flush out the mud, making four passes over every section of liner.
5 June	Completed washing out the well then removed the drillpipe and tubing and laid it down on the racks.
6 June	Started completion testing (ref. section 13).
7 June	Completed first stage of the completion testing with the rig in position. Dismantled the drilling wellhead and started the final expansion spool and 10 inch/900 WKM master valve.
8 to 21 June	Work with the rig and pumps was completed by 10.30 am on 8 June and the well was allowed to heat up. Temperature and pressure runs were made under the guidance of W. Chen. The contractor tidied up around the site and started to remove some of his equipment. Surplus mud materials were taken to HT & T's yard in Hilo.
22 June	Rig being removed from the site. Ran $\frac{3}{4}$ inch diameter air hose 350 feet down the well and airlifted water out with a 170 CFM 100–110 psi compressor. The compressor appeared to be inadequate for the job as a continuous discharge was not obtained.
23 June	Obtained a second identical compressor and by mid-day a continuous discharge of air and water at a rate of 10–15 gpm was obtained. Stopped while rig substructure was removed and fitted temperature and pressure gauges to the wellhead as well as $\frac{1}{4}$ inch diameter bleed line. Started again at 3.00 pm and kept compressors going all night.
24 June	The water discharge started to heat up at about 3.00 am and increased very slowly through the morning and early afternoon, until at approximately 2.00 pm when the water temperature was 76°C, 250 feet of air hose fell down the well. Water continued to discharge naturally from the well at a rate of 5–10 gallons per minute until the master valve was closed that evening.

The well was subsequently flashed using the same technique as described above for a short period on 2 July, followed by the installation of bracing to the wellhead and the provision of drainage to the cellar between 8 and 18 July. During this period the cold water on top of the well was bled off each day, and on 19 July the well was flashed for one hour, followed by a four hour public display and test on 22 July.

12. PERFORATING, TESTING AND CEMENTING

A Cement Bond Log (CBL) was run by Gearhart-Owen (GO) as part of the logging of the well on 25 April, to 2,230 feet. This log indicated a lack of bond (and by implication, absence of cement) from 40 feet to 220 feet and from 320 feet to 868 feet. Arrangements were therefore made for Halliburton to send a RTTS (Retrievable-Test-Treat-Squeeze) tool plus operator over from the mainland, and for GO to send a perforating tool, explosive charges and operator.

This operation started on 24 May with a temperature run to check downhole temperatures to 1,200 feet, followed by the placing of a cement plug in the 9⅝ inch casing from 1,091 feet to 1,191 feet. A pressure test of 1,150 psi was applied to the plug the next day, and on 27 May when the GO operator and equipment arrived, another CBL was run to verify the earlier CBL. Perforating and testing for circulation then began, the actual sequence that was followed being shown in Appendix G. The perforating gun could fire any number of charges at one time, but only in a straight vertical line. When it became apparent that circulation was not going to be obtained easily, the decision was made to perforate one hole at each point to conserve the charges for the complete examination of the suspect area, within practical and economic limitations. The charges were exploded electrically, in intimate contact with the inside of the 9⅝ inch casing, and produced a ⅝ inch diameter hole (verified by a surface test) which, the manufacturer was confident, would not penetrate the 13⅜ inch casing.

Circulation in the annulus was eventually obtained between 54 feet and 172 feet, after perforating the entire suspect area at intervals of approximately 25 feet and attempting to obtain circulation in the annulus between perforations by setting the RTTS tool between them and pressurising to approximately 1,200 psi across them.

On 29 May, cement was squeezed into the annulus in two stages – from 172 feet to 153 feet and from 153 feet to 54 feet, and after waiting for nineteen hours the cement in the 9⅝ inch casing was drilled out and the RTTS was run in to pressure test the two stages to 1,200 psi. Both were found to be leaking, so were flushed out with high pressure water, and cement was again squeezed into the annulus, using ½ per cent calcium chloride (which was all that could be obtained) as an accelerator. The cement in the 9⅝ inch casing was again drilled out, and the cement in the annulus withstood the 1,200 psi pressure test when the RTTS was run in twenty-four hours later.

A significant improvement was noted when the CBL was re-run, but as there was still doubt about three small areas, these were perforated to vent any trapped liquid. (It should be noted that the CBL is not reliable if the cement is less than three days old).

The 100 feet cement plug below 1,091 feet was drilled out on 1 June, and then work proceeded with conditioning the mud and running the 7 inch diameter slotted/plain liner.

13. COMPLETION TESTING

The slotted/plain 7 inch diameter liner was installed on 4 June, and the mud was washed out of the hole on 4 and 5 June. Pumping water through the 2⅞ inch diameter washpipe to the bottom of the well stopped at 8.30 pm on 5 June, from which time the well started to heat up.

A casing caliper was not available, so this test was omitted – 100 gpm of cold water is normally pumped away during this test and this goes down the well and out into the country in the permeable region, helping to define the permeable zones in the well.

Completion tests therefore started on 6 June, with a temperature run to establish the original downhole condition prior to the 'water loss' run (ref. curve A in fig. 11). The water loss run started at 1.25 pm with 340 gallons of water per minute being pumped down the well. This pumping rate was reduced to 108 gpm from 2.30 pm to 4.00 pm, as advice received indicated that the large amount of cold water could 'swamp' any small permeable zones. The temperature run obtained is shown in fig. 11, curve B. The wellhead pressure was approximately 600 psi when pumping at 340 gpm, and approximately 400 psi when pumping at 108 gpm. When the pumps were stopped on completion of the test and the valves to the wellhead opened, water flowed out of the well for over an hour.

Permeability of the formation was then investigated by lowering the pressure gauge to three levels (4,000 feet; 5,200 feet and 6,455 feet) down the well, and recording the pressure when pumping at 0, 108, 200 and 300 gals/minute at each of these levels (ref. fig. 11, curves C. The pressure difference between 0 and 300 gpm was approximately 700 psi at 4,000 feet and 5,200 feet, and was beyond the instrument range at 6,455 feet. As these results indicated that the well was relatively impermeable, water was pumped down the well at the maximum possible rate in an endeavour to clear the formation of mud, cuttings and loss materials, as follows:

From	10.30 to 10.40 pm	–	530 gpm	and	wellhead	pressure	650 psi
„	10.40 „ 10.47	„	–630 gpm	„	„	„	700 psi
„	10.47 „ 10.55	„	–300 gpm	„	„	„	600 psi
„	10.55 „ 11.00	„	–200 gpm	„	„	„	525 psi
„	11.00 „ 11.06	„	–100 gpm	„	„	„	450 psi

The above pressures were read on the rig pressure gauge, which was probably reading about 100 psi low. It was felt that there had been a slight improvement as a result of the above pumping, but the well was still relatively impermeable.

The 100 gpm 'water loss' run was then repeated on 7 June between 8.00 am and 11.00 am, after pumping away 300 gpm for three minutes. (Ref. fig. 11, curve D). The well was then allowed to heat up, and another temperature run was made on 8 June, after 27½ hours of heating – (ref. fig. 11, curve E).

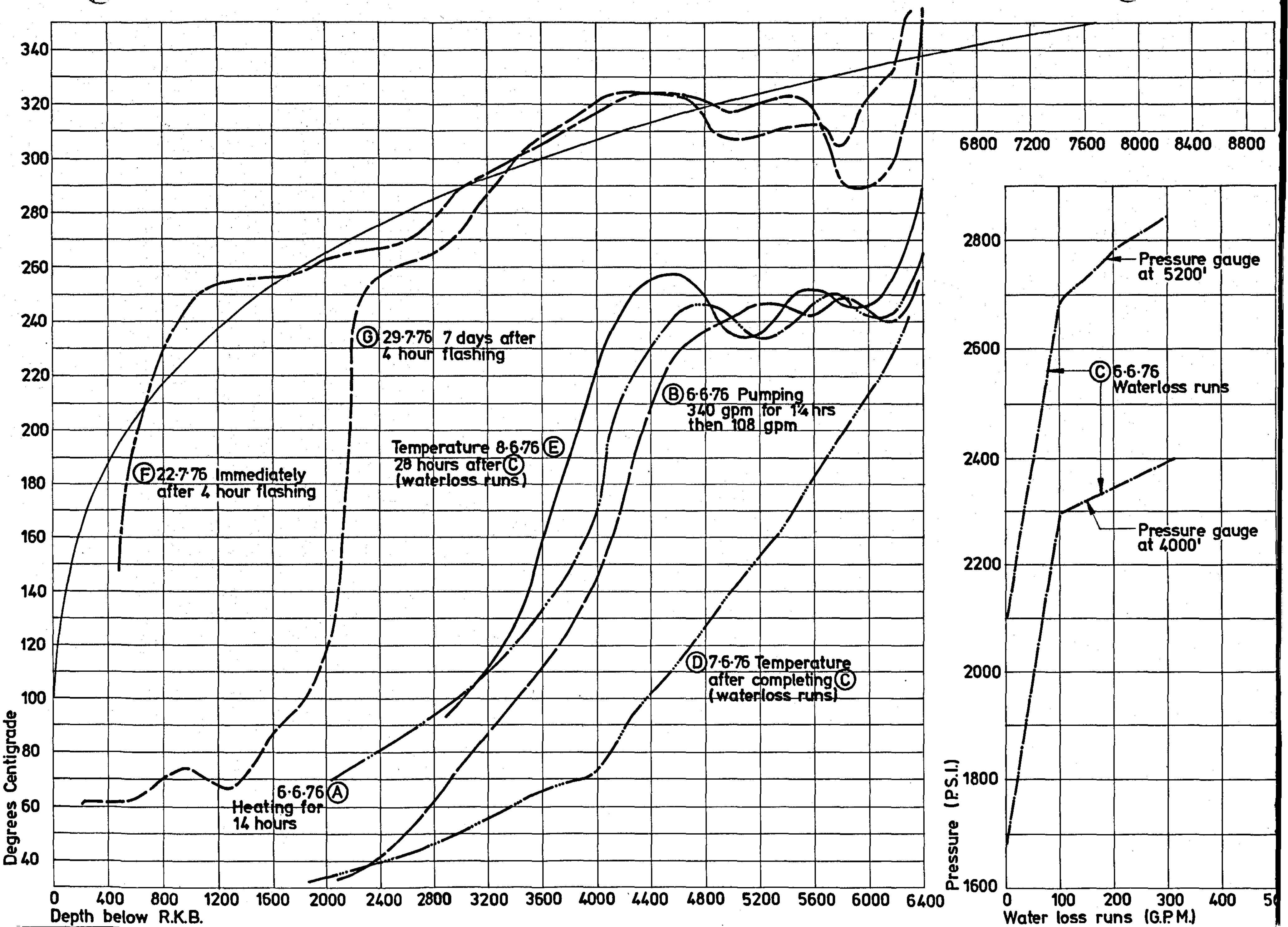


Figure 11 - Completion Tests

On 22 July a temperature run was made after flashing the well for four hours – (ref. fig. 11, curve F) – and the temperature profile now appears to have stabilised at curve G – (ref. fig. 11) which was recorded on 29 July.

The well was logged on 25 and 27 April using Gearhart-Owen equipment. The depth to which it could be logged was limited by the temperature, to 3,450 feet. A summary of the log is as follows:

No.	Description	Run on 25 April	Run on 27 April
A 1 2 3	Std. Resistivity 16 inch normal " " 64 " " Self potential } ie the Std. E-log	Taken to 3,450 feet	Not re-run due to thermal gradient
B 4 5 6	Self potential Res. by induction 16 inch " " " 40 " ('6FF40' type)	Not run due to faults	Run to 3,450 feet
C 7 8 9	Natural gamma ray Casing collar locator Slow neutron	Taken to 3,450 feet	Not re-run due to thermal gradient
D 10	Two arm caliper	Delayed to 27 April	Taken to 3,800 feet
E 11	Temperature	Run to 3,500 feet – finally to 4,100 feet	
F 12	Cement Bond Log	Run to 2,230 feet	

14. GEOLOGICAL SUMMARY

(This section was written by Dr G. A. Macdonald of the University of Hawaii)

Regional Geology

The drill hole is located on the east rift zone of Kilauea Volcano, approximately twenty-five miles east of the summit caldera of the volcano, at 600 feet altitude. The rift zone consists of innumerable more or less vertical fissures, many of which have led magma to the surface and fed eruptions. Historic eruptions in the general vicinity of the drill hole include those of 1790, 1840, 1955, 1960 and 1961. Around the eruptive vents ejecta piled up, forming spatter cones and ramparts. Below the surface the fissures remained filled with lava which consolidated as dikes. Between the cones on the surface, and between the dikes at depth, the rocks are mostly lava flows. At and near the surface the lava flows are of normal pahoehoe and aa type.

During the last decade lava flows advancing into the ocean along the south coast of Kilauea have formed pillow lavas, and submarine photographs and observations from submersibles show widespread pillow lavas on the slopes of the volcano below sea level. It is believed that the part of the volcano that was built below sea level consists mostly of pillow lavas. In other parts of the world the formation of pillow lavas, by contact of molten lava with water, has been accompanied by much granulation of the lava to form sandy-textured glassy material called hyaloclastite; and it is presumed that more or less hyaloclastite formed with the pillow lavas in the submarine part of Kilauea. However, waves and marine currents may have removed much of the sandy hyaloclastite from the upper submarine slopes of the volcano.

The lavas of Kilauea, so far as is known, are all basalt, and all tholeiitic. The principal difference among them is in the proportion of olivine phenocrysts. In some tholeiitic basalts the latter are absent, and in some oceanites their abundance reaches as much as 50 per cent. Most of the basalts of Kilauea contain scattered small olivine phenocrysts.

Above sea level the vesicularity of the lavas ranges from less than 2 per cent in the massive centre of some aa flows, to as much as 30 per cent averaging about 15 per cent. Below sea level samples dredged from the slopes decrease in both abundance and size of vesicles with increasing depth of water, and at a depth of approximately 6,000 feet the vesicles have essentially disappeared.

Even above sea level, permeability of the rocks depends very little on vesicularity. The vesicles are too poorly connected to allow free movement of water through them. The permeability is commonly high, but it results from fractures, spaces between the fragments in aa clinker, inter-flow spaces, and lava tubes.

In the Island of Hawaii, as in the other Hawaiian Islands, the main ground-water body is a Ghyben-Herzberg lens of fresh water floating on salt ocean water that saturates the basal part of the island.

Fresh water extends approximately forty times as far below sea level as it does above sea level. The water table rises inland, from sea level at the coast, at a rate of approximately two to eight feet per mile, depending on rock permeability and the amount of recharge in the area. Within the rift zones, dikes are less permeable than the intervening lava flows and retard the lateral movement of ground water, which may be confined between them far above the level at which the water table of the normal Ghyben-Herzberg lens would occur.

At the site of HGP-A the normal Ghyben-Herzberg water table would be expected to be approximately 8 feet above sea level, but dike confinement might result in a water table as much as 100 feet above sea level. However, other wells in the vicinity lack the normal Ghyben-Herzberg relationship, apparently because heating of the underlying salt water has decreased its density to the extent that it no longer can float the cooler fresh water. If this condition exists at HGP-A, the water table may be close to sea level and the shallow ground water be brackish.

Geology of the Drill Hole

The study of the rock samples from the HGP-A drill hole has begun. Microscopic thin sections are being made, and the physical properties of the rocks, including thermal and electrical conductivity, density, and porosity, are being determined. Later, samples will be selected for chemical analysis. The following descriptions are based wholly on examinations made in the field, with a hand magnifier.

Cores were taken through the following intervals:

A.	456 – 458	feet below rotary table
B.	1,057 – 1,068	" " " "
C.	1,412 – 1,423	" " " "
D.	2,230 – 2,240	" " " "
E.	2,876 – 2,886	" " " "
F.	3,666 – 3,676	" " " "
G.	4,447 – 4,457	" " " "
H.	5,396 – 5,406	" " " "
I.	6,029 – 6,039	" " " "
J.	6,446 – 6,456	" " " "

In addition, cutting samples were taken every ten feet through the part of the hole below 1,000 feet, and every five feet through part of the interval. In the upper part of the hole cutting samples were taken whenever return mud circulation was attained.

The rocks penetrated by HGP-A at and near the surface are normal olivine-bearing tholeiitic basalt of Kilauea, of both aa and pahoehoe types, with vesicularity ranging from about 5 to 25 per cent. The surficial lavas are highly jointed, with most of the joints dipping more than 70°. Ordinary appearing lavas, presumably of subaerial origin, continued well below sea level, as would be expected because of the sinking of the island since the lavas were formed. (The island is at present sinking at a rate of approximately 2 feet per century). Core B, between 1,057 and 1,068 feet below rotary table (eg 450 feet below sea level) consists of dark grey dense basalt with a few pahoehoe-type vesicles. The lava was probably formed subaerially. On the other hand, the lower part of Core C, from 1,412 to 1,423 feet below rotary table, is partly glassy and appears probably to be subaqueous pillow lava.

Core E, from 2,876 to 2,886 feet, consists at the top of 3 feet of fine grained olivine-bearing grey basalt with about 3 per cent of pahoehoe-type vesicles less than 0.5 mm across. It is probably tholeiitic. This grades downward through a thickness of about 4 inches into dense black tachylite (basalt obsidian), which constitutes the remaining 7 feet of the core. The tachylite is intensely fractured, and the fracture surfaces commonly are altered to a thin coating of serpentine, showing that the fracturing is old, and not the result of drilling. Some of the fracture surfaces are slickensided, and many of them bear many tiny cubes of pyrite. This very abnormal thickness of basaltic glass must be the result of very rapid chilling of the molten lava by water.

Between about 3,682 feet and 3,760 feet (BRT) the cuttings consist of sandy material with angular grains averaging about 1.5 mm in diameter. It appears to have been essentially loose at depth. The material appears to be hyaloclastite.

All the cores below 3,000 feet depth (BRT) show some degree of alteration, with a greenish colouring owing to the formation of secondary chlorite. Tiny cubes of pyrite also are present in all, and become more abundant with increasing depth. Below 1,200 feet (BRT) secondary zeolite and calcite appear in the cores, and remain moderately abundant to about 4,000 feet, but below that depth they decrease. The final core, taken from 6,446 to 6,456 feet, has at the top four inches of dense dark grey basalt bounded by a contact which runs across the core nearly at 90°. The contact is moderately lobate but shows very little effect of chilling. The rest of the core, below the contact is dense but greenish grey, with many spots of chlorite and much pyrite, it is intensely fractured, many of the fractures somewhat slickensided, and some covered with a white coating as much as 1 mm thick. The white material is partly calcite, but mostly zeolite (?).

The highly fractured character of most of the cores is noteworthy. Even cores that appear quite solid as they emerge from the core barrel may fall apart on handling. This characteristic was worrisome during drilling, because of the possibility that the fractured material might cave into the hole, and the caving possibility remains, particularly after the mud is removed from the hole. The hyaloclastite also has caving possibilities.

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KRTA Casing Record – HGP-A
Hole Size 26 inch
Started 30 January : Completed 30 January 1976
Joint 1 thru Joint 8 81.10 lbs/foot

Joint No.	Measured Length (feet)	Cumulative Length (feet)
1	67.33	67.33
2	60.08	127.41
3	65.20	192.61
4	60.00	252.61
5	65.20	317.81
6	65.20	383.01
7	30.00	413.01
8	9.92	422.93

Note:

Welded joints, copper bearing structural steel.

21 feet 7 inches was cut off originally leaving the top of the 20 inch casing 2 feet 6 inches below the rotary table.

Subsequently a further 18 feet 6 inches was cut off to leave the 20 inch casing flush with the cellar floor.

KRTA Casing Record – HGP-A
Hole Size 20 inch
Started 27 February : Completed 27 February 1976
Joint 1 thru Joint 27 : Size 13⅜ inch OD 54.50 lbs/foot
Grade J55 Thread Buttress

Joint No.	Measured Length (feet)	Cumulative Length (feet)	Remarks
1 } 2 }	74.58	74.58	997.07 — 29.00 top of casing to cellar floor
3	31.75	106.33	
4	43.92	150.25	968.07
5	43.00	193.25	1.08 cellar floor to CHF
6	46.33	239.58	
7	46.08	285.66	969.15 = depth of casing below
8	46.58	332.24	CHF
9	29.25	361.49	
10	28.00	389.49	
11	33.00	422.49	
12	29.92	452.41	
13	31.33	483.74	
14	32.75	516.49	
15	30.50	546.99	
16	29.50	576.49	
17	32.00	608.49	
18	32.58	641.07	
19	30.42	671.49	
20	36.42	707.91	
21	40.00	747.91	
22	46.58	794.49	
23	43.92	838.41	
24	46.16	884.57	
25	46.00	930.57	
26	43.50	974.07	
27	23.00	997.07	

KRTA Production Casing Record – HGP-A
Hole Size 12¼ inch
Started 1 April : Completed 1 April 1976
Joint 1 thru Joint 56 : Size 9⅝ inch OD 43.5 lbs/foot
Grade N.80 Thread BTC Total Depth 2,244 feet

Joint No.	Measured Length (feet)	Cumulative Length (feet)	Remarks
1	45.68	45.68	
2	40.55	86.23	
3	39.85	126.08	
4	37.55	163.63	
5	38.59	202.22	
6	39.93	242.15	
7	38.29	280.44	
8	40.80	321.24	
9	36.43	357.67	
10	39.55	397.22	
11	40.97	438.19	
12	46.30	484.49	
13	41.62	526.11	
14	42.59	568.70	
15	45.68	614.38	
16	44.72	659.10	
17	46.47	705.57	
18	46.68	752.25	
19	42.43	794.68	
20	40.34	835.02	
21	47.43	882.45	
22	44.26	926.71	
23	39.89	966.60	
24	37.68	1,004.28	
25	37.22	1,041.50	
26	39.13	1,080.63	
27	37.51	1,118.14	
28	37.51	1,155.65	
29	39.38	1,195.03	
30	36.51	1,231.54	
31	38.34	1,269.88	
32	39.01	1,308.89	
33	38.85	1,347.74	
34	36.80	1,384.54	
35	39.54	1,424.08	
36	40.34	1,464.42	
37	40.30	1,504.72	
38	37.72	1,542.44	
39	39.09	1,581.53	
40	40.63	1,622.16	
41	37.59	1,659.75	
42	36.68	1,696.43	
43	39.97	1,736.40	
44	38.93	1,775.33	
45	33.93	1,809.26	
46	43.26	1,852.52	
47	39.55	1,892.07	
48	38.38	1,930.45	
49	39.09	1,969.54	
50	39.26	2,008.80	
51	40.38	2,049.18	
52	39.51	2,088.69	
53	40.72	2,129.41	
54	37.26	2,166.67	
55	36.59	2,203.26	
56	40.38	2,243.64	

KRTA Casing Record – HGP-A
Hole Size 8½ inch
Started 3 June : Completed 4 June 1976
Joint 1 thru Joint 109 : Size 7 inch OD 23 lbs/foot
Grade K.55 Thread 8R Type L.C.T

Joint No.	Measured Length (feet)	Cumulative Length (feet)	Remarks
1	41.06	41.06	Slotted liner
2	38.93	79.99	
3	39.39	119.38	
4	39.66	159.04	Slotted liner
5	39.60	198.64	
6	39.64	238.28	
7	39.64	277.92	Slotted liner
8	39.26	317.18	
9	39.65	356.83	
10	38.28	395.11	Slotted liner
11	39.64	434.75	
12	39.60	474.35	
13	39.65	514.00	Slotted liner
14	39.66	553.66	
15	39.37	593.03	
16	39.60	632.63	Slotted liner
17	39.63	672.26	
18	39.62	711.88	Slotted liner
19	39.63	751.51	
20	39.63	791.14	Slotted liner
21	39.62	830.76	
22	39.61	870.37	Slotted liner
23	39.62	909.99	
24	39.63	949.62	Slotted liner
25	39.63	989.25	
26	39.58	1,028.83	Slotted liner
27	39.63	1,068.46	
28	39.63	1,108.09	Slotted liner
29	39.68	1,147.77	
30	39.63	1,187.40	Slotted liner
31	39.65	1,227.05	
32	39.56	1,266.61	Slotted liner
33	39.60	1,306.21	
34	39.66	1,345.87	Slotted liner
35	39.68	1,385.55	
36	39.04	1,424.59	Slotted liner
37	39.64	1,464.23	
38	39.62	1,503.85	Slotted liner
39	39.01	1,542.86	
40	39.62	1,582.48	Slotted liner
41	39.63	1,622.11	
42	39.64	1,661.75	Slotted liner
43	39.63	1,701.38	
44	39.62	1,741.00	Slotted liner
45	39.25	1,780.25	
46	39.65	1,819.90	Slotted liner
47	39.60	1,859.50	
48	39.62	1,899.12	Slotted liner
49	39.60	1,928.72	
50	39.58	1,978.30	Slotted liner
51	39.72	2,018.02	
52	39.70	2,057.72	Slotted liner
53	39.60	2,097.32	
54	39.60	2,136.92	Slotted liner
55	39.63	2,176.55	
56	39.61	2,216.16	Slotted liner

KRTA Casing Record – HGP-A
Hole Size $8\frac{1}{2}$ inch
Started 3 June : Completed 4 June 1976
Joint 1 thru Joint 109 : Size 7 inch OD 23 lbs/foot
Grade K.55 Thread 8R Type L.C.T

Joint No.	Measured Length (feet)	Cumulative Length (feet)	Remarks
57	39.62	2,255.78	
58	39.62	2,295.40	Slotted liner
59	39.25	2,334.65	
60	39.62	2,374.27	Slotted liner
61	39.63	2,413.90	
62	39.56	2,453.46	Slotted liner
63	39.64	2,493.10	
64	39.25	2,532.34	
65	39.62	2,571.97	Slotted liner
66	39.62	2,611.59	
67	39.63	2,651.22	
68	39.61	2,690.82	
69	39.62	2,730.45	Slotted liner
70	39.62	2,770.07	
71	39.62	2,809.69	
72	39.63	2,849.32	
73	39.63	2,888.95	Slotted liner
74	39.60	2,928.55	
75	39.58	2,968.13	
76	39.60	3,007.73	
77	39.68	3,047.41	Slotted liner
78	39.05	3,086.46	
79	39.58	3,126.04	
80	39.60	3,165.64	
81	39.61	3,205.25	Slotted liner
82	39.60	3,244.85	
83	39.05	3,283.90	
84	39.00	3,322.90	
85	39.62	3,362.52	
86	39.75	3,402.27	Slotted liner
87	39.60	3,441.87	
88	39.61	3,481.48	
89	38.95	3,520.43	
90	39.61	3,560.04	
91	39.61	3,599.65	Slotted liner
92	39.61	3,639.26	
93	39.60	3,678.86	
94	39.61	3,718.47	
95	39.61	3,758.08	
96	39.60	3,797.68	Slotted liner
97	39.64	3,837.32	
98	39.63	3,876.95	
99	39.61	3,916.56	
100	39.60	3,956.16	
101	39.63	3,995.79	Slotted liner
102	39.61	4,035.40	
103	39.64	4,075.04	
104	39.65	4,114.69	
105	39.61	4,154.30	
106	39.60	4,193.90	Slotted liner
107	39.01	4,232.91	
108	39.60	4,272.51	
109	39.62	4,312.13	

Appendix E Bit Record

Bit	Hole Opener	Make	Size	Type	Serial	Depth In	Depth Out	Drilled Feet	Hours	Remarks
1		Smith	9⅞"	L.4	14H, 694A	27	209	182	103½	T7, B4, 0¼"
	2	Smith	15½"	M		27	638	611	200½	T4, B4, 0½"
	3	Smith	15½"	M	10460	638	998	360	64	T2, B2, I
	4	Smith	20"	M		27	543	516	167	T2, B2, I
5		Smith	9⅞"	F.3	669H	209	1,057	848	89½	T1BT, B2, I
	6	Smith	20"			543	697	154	72	T4, B8, 0½"
	7	Smith	20"			697	987	290	74	T2, B2, I
	8	Smith	26"			27	407	380	201	T2, B2, I
9		Smith	12¼"	F.57	821CC	998	1,437	439	58½	T1, B8, 0½"
10		Smith	12¼"	F.57	393CJ	1,437	1,450	13	2	
11		Security	8½"	S.86F	572093	1,450	1,776	326	35¾	T2, B2, 0⅛"
12		Security	8½"	S.86F	573070	1,776	2,230	454	48	—
	13	Grant	12¼"		19932	1,450	1,649	199	22½	T8, B8
	14	Grant	12¼"		19932	1,649	1,659	10	7¾	—
	15	Grant	12¼"		19932	1,659	1,666	7	7¾	8.4.I
16		Smith	12¼"	F.57	393CJ(RR)	1,666	1,712	46	—	—
	17	Grant	12¼"		19932	1,712	1,751	39	9	—
18		Smith	12¼"	F.57	393CJ(RR)	1,751	1,812	61	10¾	2.2.OK
	19	Smith	12¼"	TC insert		1,812	1,865	53	4¾	3.2.OK
	20	Security	12¼"	TC insert		1,865	2,240	375	19¼	—
21		Security	8½"	S86F	630264	2,244	2,876	632	46	—
22		Security	8½"	S86F	578184	2,876	3,666	790	63	4.2.I
23		Security	8½"	S86F	630100	3,666	4,447	781	68	—
24		Security	8½"	S86F	588791	4,447	5,400	953	57½	2.8.I – Loose cone
25		Security	8½"	S86F	630069	5,400	6,060	660	46	—
26		Security	8½"	S86F	580940	6,060	6,445	385	32½	6.8.I – All cones loose

Appendix F Deviation Recordings

Date	Depth of station (feet)	Distance apart (feet)	Deviation (degrees)	Diff. in dev. between stations (degrees)	Rate of change of dev. (degrees/foot)
12 February	500		0°–20′		
		480		10′	0.02
16 March	980		0°–30′		
		100		1°–20′	0.80
9 "	1,080		1°–50′		
		280		40′	0.14
16 "	1,360		2°–30′		
		115		50′	0.43
22 "	1,475		3°–20′		
		165		20′	0.12
22 "	1,640		3°–40′		
		85		15′	0.18
22 "	1,725		3°–55′		
		42		35′	0.83
23 "	1,767		4°–30′		
		28		40′	0.02
23 "	1,795		3°–50′		
		39		6′	0.00
23 "	1,825		3°–56′		
		100		6′	0.00
24 "	1,925		3°–50′		
		95		10′	0.11
24 "	2,020		4°– 0′		
		95		0′	0.00
25 "	2,115		4°– 0′		
		210		30′	0.14
6 April	2,325		3°–30′		
		120		15′	0.13
6 "	2,445		3°–15′		
		105		15′	0.14
7 "	2,550		3°– 0′		
		220		50′	0.23
7 "	2,770		3°–50′		
		156		20′	0.13
9 "	2,926		3°–30′		
		274		30′	0.11
10 "	3,200		3°–00′		
		120		0′	0.00
10 "	3,320		3°–00′		
		153		2′	0.01
11 "	3,473		2°–58′		
		967		13′	0.01
16 "	4,440		2°–45′		

Appendix G Record of Perforating and Testing for Circulation

Date	Perforated at: (feet)	RTTS set at: (feet)	Remarks
27 May	842, 844		BH test – 1,200 psi. No circulation
	370, 372		
		423	No circ. between 370 and 842
	829, 830		
		835	" " " 830 and 842
		825	" " " 829 and 372
28 May	600, 601		" " " (Midnight 28 May)
		423	" " " 600 and 372
		610	" " " 601 and 829
	814		
		807	" " " 814 and 601
	800		
		792	" " " 800 and 601
	784		
		773	" " " 784 and 601
	763		
		749	" " " 763 and 601
	696		
		749	" " " 696 and 763
	734		
		701	" " " 734 and 696
		749	" " " 734 and 763
		835	" " " } Checks that RTTS
		825	" " " } was operating
		807	" " " } satisfactorily.
		792	" " " } Checking RTTS.
		773	" " " }
	646		
		624	" " " 646 and 601
		650	" " " 646 and 696
	623		
		614	" " " 623 and 601
		634	" " " 623 and 646
	670		
		675	No circ. between 670 and 696
		650	" " " 670 and 646
	682		
		675	" " " 682 and 670
		688	" " " 682 and 696
			Tripped out and checked RTTS
			while waiting on perforator.
29 May	486		Started at 8.00 am approximately.
		518	No circ. between 486 and 600
		455	" " " 486 and 372
	543		
		579	" " " 543 and 600
		518	" " " 486 and 543
	429		
		455	" " " 429 and 486
		392	" " " 429 and 372
	453		
		465	" " " 453 and 486
		400	" " " 453 and 429
	400		
		410	" " " 400 and 429
		392	" " " 400 and 372
	514		
		518	" " " 514 and 543
		510	" " " 514 and 486
	571		
		579	" " " 571 and 600
		559	" " " 571 and 543

Date	Perforated at: (feet)	RTTS set at: (feet)	Remarks
	Checking of the top suspected void from 50ft–250ft		
29 May	244		
	153		
	24		
		235	No circ. between 153 and 244
		142	Circ. „ 153 and 54
	202		
		180	No circ. between 202 and 153
			„ „ „ 202 and 244
	174		
		162	„ „ „ 174 and 153
		182	„ „ „ 174 and 202
	172		
		162	Circ. „ 172 and 153