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GEOTHERMAL WELL DRILLING ESTIMATES BASED ON PAST WELL COSTS

Robert N. Chappell*, Susan J. Prestwich*, Lowell G. Miller**, Howard P. Ross***

*U.S. DOE Idaho Operations Office, Idaho Falls, ID 83401
**EG&G Idaho, Inc., Idaho Falls, ID 83401
***University of Utah Research Institute, Salt Lake City, UT 84108

ABSTRACT

Well costs vary roughly exponentially with well depth. Plots indicating this have been made using data from nineteen geothermal wells of varying depths. These plots indicate both the average costs to drill wells and the costs to drill wells without problems. Average well costs are above estimates based on the assumption that the well proceeds according to plan. The average costs should be considered for planning programs in which large numbers of wells are involved. Estimates based on the assumption that the well can be drilled according to plan may be used for planning programs involving one or two wells, but the average costs should be considered in contingency planning.

INTRODUCTION

This is an attempt to look at well construction costs statistically, using actual costs of completed geothermal wells as the basis. The data base consists of nineteen wells drilled as part of the Department of Energy geothermal programs managed by the DOE Idaho and Nevada Operations Offices. Eight of the wells were completed at Raft River, seven were completed under the DOE Industry Coupled Program, three were completed under the Project Applications Program, and one was completed at the Idaho National Engineering Laboratory site near the eastern end of the Snake River Plain. There are a variety of well types, geological environments, depths and bore hole sizes represented, and although this is a small sample, trends can nevertheless be seen.

The objectives of this study are to provide general guidance for the geothermal well field developers, public or private individuals or groups considering the geothermal option, proposal writers or evaluators, and geothermal policy makers. Of course, when estimating the cost of a particular well, one should list the tasks to be done and the material to be purchased, estimate the cost of each and aggregate, so that the peculiarities of the site, anticipated production, and other variables can be taken into account. Data presented here should be used only as a general guide although there is one other important use. Aggregated estimates like the one just described are usually valid only if things proceed according to plan. Some have said that actual well costs often depend on two aspects of well drilling which are not quantifiable: the luck of the driller and the determination of the operator. Looking at past experience, which is the approach taken here, at least gives one some idea as to the levels these two unquantifiables have pushed past drilling costs.

DRILLING COSTS VS. DEPTH

Drilling costs versus depth are shown in figure 1. NOTE: The vertical scale is logarithmic. Logarithmic plots tend to create the illusion that little scatter of the data exists when in fact there is a considerable scatter. However, the logarithmic scale was used because of the general exponential trend of the data and to facilitate a linear regression analysis.

The mean regression line shown in figure 1 is not representative of costs which would result from an aggregated estimate obtained by listing tasks and materials, estimating their costs and aggregating. These estimated well costs are approximated by the heavy dashed line at the bottom. The mean line simply represents the average real costs of the nineteen wells in the sample, and this in turn is a strong function of the problems encountered and the determination of the owners to complete the wells. Note that aggregated estimate approximated by the dashed line is below all the well costs. This may at first seem irregular until one considers that this type of estimate is almost always optimistic because, by nature of the estimating procedure, only predictable tasks and material purchases are considered, and contingencies are not included.

Wells indicated by the circular symbols and the diamond symbol were paid for entirely by DOE; wells indicated by the square symbols were funded mostly by DOE and partly by private or local public entities. Wells indicated by the triangular symbols were paid for mostly by private concerns, most of whom have an oil background. Referring to figure 1 with this in mind, it is interesting to note that public or private ownership of the well had little to do with costs.

Note that the determination of the operators to complete three of the wells in spite of adverse drilling conditions resulted in anomalously high costs. In fact, they are so far above the mean that a statistician would consider them "outliers" and discard them. This was done, and figure 2 shows the effect of this action. Note that the mean lowered noticably. Also note that one well was considerably lower in cost then the others. This was due partly to this well being an injection well and partly to lack of problems encountered. This well was also eliminated as an "outlier". Without these four "outliers the standard deviation was lowered as shown in figures 1 and 2.

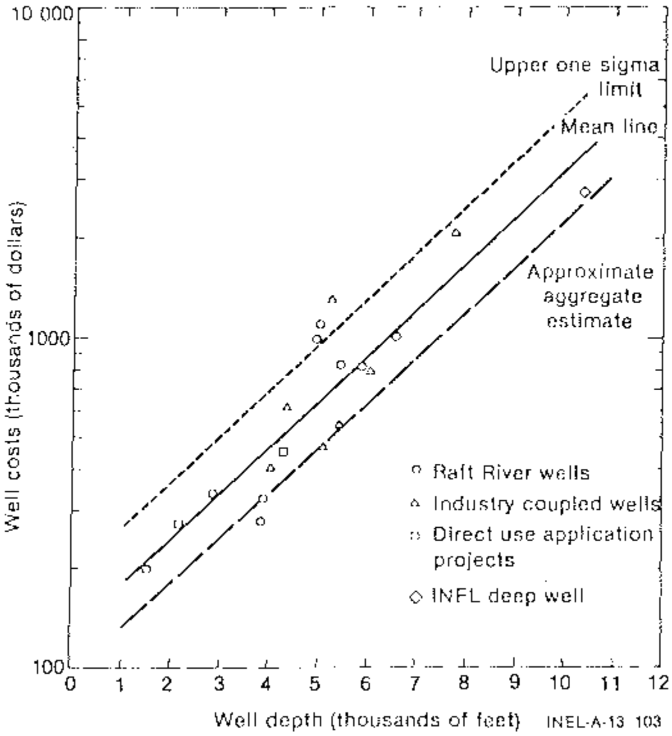

Figure 1 Well costs versus depth. All data included. Corrected to 1978 prices.

Figures 1 and 2 can be useful to various interests but in different ways. Policy makers interested in predicting costs for projects involving large numbers of wells will probably get best results by using the mean from Figure 2. Whereas, a developer contemplating one or two wells may wish to use the heavy dashed line, but consider the mean or the standard deviation coupled with information on expected drilling conditions in deciding on appropriate contingencies or for planning alternatives because once drilling has started, decisions must be made quickly.

DATA BASE DESCRIPTION

Table I shows well costs on which this paper was based. All well costs are for completed wells including the well head, special completion techniques such as acidizing, logging and all

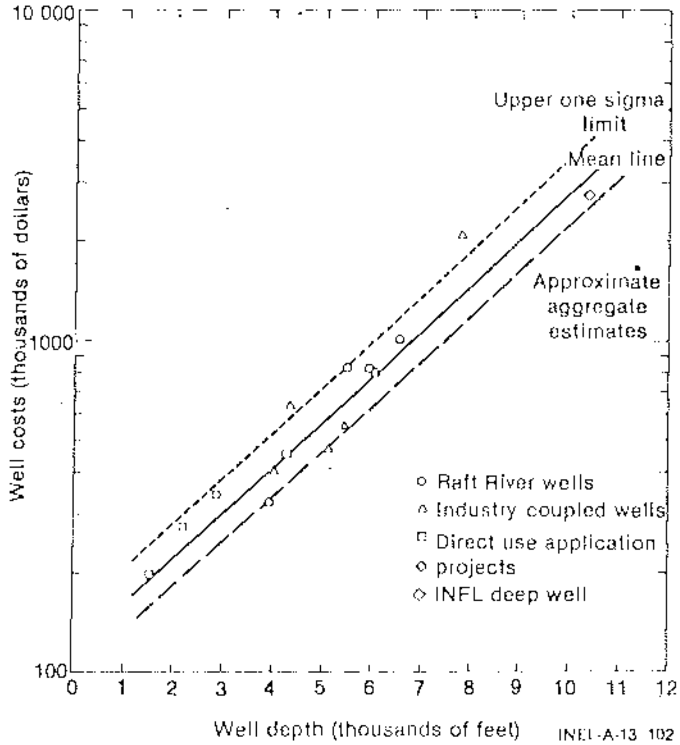

Figure 2 Well costs versus depth. "Outliers" excluded. Corrected to 1978 prices.

problem solving operations such as fishing, directional drilling, etc. Any flow testing which occurred after removing the drill rig was not included.

Two of the Raft River wells were multilegged wells. The depth on these wells could have been determined by adding all the legs together. However, the decision was made (somewhat arbitrarily) to use the depth of the deepest leg as the well depth.

Cost breakdowns were available for some of the wells. See table II. Unfortunately the breakdowns were not all made using uniform procedures, so there are some blanks and interpretations are difficult. Breakdowns are available for all three of the "outliers" which were omitted from figure 2 for excessive cost. They are Raft River #1, Raft River #5 and Industry Coupled #7. Unfortunately a breakdown was not available for the low "outlier," Raft River #7. Industry Coupled #6 was not discarded as an "outlier," but was, nevertheless, an expensive well.

The unusually high costs for Industry Coupled #6 and #7 were in drilling fluids, cementing and added rig time due to loss of circulation and caving to porous formations. This also occurred in INEL #1 but to a much lesser degree. Raft River #1 and #2 were high in drilling and miscellaneous costs. Raft River #1 experienced a collapsed casing and Raft River #2 was drilled 500 feet into hard basement rock for geological research.

TABLE I TOTAL WELL COSTS
(Corrected to 1978 Prices)

Description	Year Drilled	Depth (feet)	Casing Diameter (inches)/Depth (feet)	Cost (1000's)	Inflation Factor	Costs Corrected to 1978 (1000's)
Raft River #1	75	5007	13-3/8 to 3634	810	1.38	1,118
Raft River #2	76	6561	13-3/8 to 4227	800	1.26	1,008
Raft River #3	76	*5917 *5532 *5853	13-3/8 to 1385: 9-5/8 to 4255	662	1.26	834
Raft River #4A	77	2840	13-3/8 to 1820	305	1.12	342
Raft River #4B	78	*5427 *5115	13-3/8 to 1820: 9-5/8 to 3457	830	----	----
Raft River #5	78	4925	13-3/8 to 1500: 9-5/8 to 3408	995	----	----
Raft River #6	78	3888	13-3/8 to 1698	325	----	----
Raft River #7	78	3858	13-3/8 to 2044	275	----	----
Industry Coupled #1	74	4300		385	1.63	628
Industry Coupled #2	76	5100		370	1.26	466
Industry Coupled #3	75	4000		290	1.38	400
Industry Coupled #4	78	5400		550	----	----
Industry Coupled #5	78	6000	Bore diameter at surface was	800	----	----
Industry Coupled #6	78	7735	17-1/2 inches narrowing to	2,079	----	----
Industry Coupled #7	78	5200	8-3/4 inches at target depth.	1,232	----	----
Project Applications #1	79	1500	16 to 700: 7-7/8 to 1300	214	.93	199
Project Applications #2	79	2176	10-3/4 to 800: 7, 500 to 2176 (perphorated)	296	.93	275
Project Applications #3	78	4266	10-3/4 to 1000: 7-5/8 to 3722: 5 to 3900	452	----	----
INEL #1	79	10356	13-3/8 to 3359: 9-3/8 to 6796	2,960	.93	2,753

* Multilegged wells.

TABLE II COST BREAK DOWN
(Not Corrected to 1978 Prices)

Well Identification	Project Applications #2	Industry Coupled #6	Industry Coupled #7	Raft River #1	Raft River #3	Raft River #5	INEL #1
Well Depth	2176	7735	5200	5007	5917	4925	10356
Item Description							
Location Preparation	491	67,044	81,888	16,600	14,300	11,400	227,800
Mobilization and Demolilization	36,000	----	----	37,700	45,700	9,000	350,000
Drilling	72,910	687,131	404,201	319,600	185,400	418,800	749,750
Drill Bits	6,938	107,755	46,400	23,200	59,100	35,200	70,592
Drilling Fluid	26,958	181,643	104,149	3,500	4,000	----	92,710
Cementing	28,904	554,149	329,065	95,000	74,800	52,500	252,301
Equipment Rentals	5,208	111,321	70,467	56,900	69,900	72,700	89,168
Transportation	----	102,635	70,363	9,300	----	----	1,810
Supervision	26,260	36,400	24,600	In Drilling Cost	In Drilling Cost	21,900	71,400
Logging	12,510	----	----	58,200	58,000	123,000	51,330
Casing	23,435	159,481	72,780	91,400	83,600	45,700	339,585
Well Head	15,664	25,878	12,466	41,000	37,000	44,000	74,304
Miscellaneous	40,984	45,964	15,270	57,600	30,400	160,500	589,544
TOTAL	296,262	2,079,401	1,232,150	810,000	662,200	994,700	2,960,294

Mobilization and demobilization costs varied radically from one well to another indicating that these expenses may have been accounted for in different ways. This and other nonuniformities suggest that the Idaho Operations Office should consider instituting uniform accounting procedures for future well drilling programs. This would enable one to plot cost of various items versus depth as well as total cost which may prove useful in estimating using the aggregation approach.

SHALLOW WELL COSTS

The shallowest well used in this study is 1500 feet. It is obvious from figures 1 and 2 that if the straight line fits were extrapolated to shallow well depths, the cost would be unreasonably high. Thus it appears that a break must occur in the lines meaning that cost variation with depth is different for shallow wells.

The importance of shallow well costs to direct use of geothermal heat makes such a cost study important. Unfortunately, however, the writers had too little data on shallow wells to warrant their inclusion.

CORRECTION FOR INFLATION

Well costs have been increasing over the past ten years at a higher rate than the national average inflation rate, partly due to environmental and institutional barriers and partly due to the high demand for drill rigs. W.A. Glass shows costs for an average well at the Geysers increased from $400,000 to $1,000,000 between 1972 and 1977[1]

As the data in table I were first put together to obtain figures 1 and 2, the inflation correction was made by calling drilling companies, mud companies etc. and asking them for prices in the 1974 to 1978 time period. However, many companies responded by simply stating that prices had increased at about ten percent per year. Some, however, gave actual prices which indicated that some items such as drill rig rental had increased by more than twenty-five percent in some years and averaged about fifteen percent per year.

These data were weighted by the impact of each item on the total cost using data from table II, and the inflation factors shown by the circular symbols in figure 3 were obtained. Later the data from the table on page 88 of reference 2 were converted to inflation factors. These are shown by the square symbols in figure 3. Since the factors from reference 2 data were so close to factors generated by the writers and the data base was broader (although from oil and gas wells), the reference 2 based factors were used.

CONCLUSIONS

Drilling costs for geothermal wells between 1500 and 10,000 feet deep appear to rise roughly exponentially with depth. However, costs at any given depth vary appreciably according to drilling conditions and unexpected problems. The result is

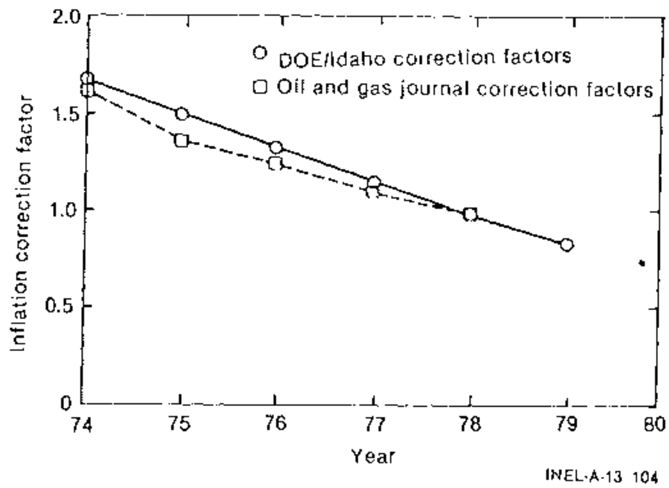

Figure 3 Inflation factors for correcting to 1978 prices.

that the mean cost is considerably higher than would be predicted by the aggregation method of estimating. Therefore, when planning a well, the mean cost along with drilling conditions should be considered for contingency planning. When planning large programs involving many wells however, the mean costs would provide a better estimate.

Since 1974, well drilling costs have almost doubled. This is higher than the natural inflation rate. Such an increase, makes inflation a vital consideration in long range planning.

REFERENCES

1. Glass, W.H., 1977 Drilling Methods and Costs at the Geysers, Papers presented at Geothermal State-of-the-Art, Geothermal Resources Council annual meeting held May 9 - 11, 1977, San Diego, California.

2. Article in Oil and Gas Journal, Vol. 77, No. 21, May 14, 1979.