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## AN EVALUATION OF DIRECT USE PROJECT DRILLING COSTS

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### ABSTRACT

This study evaluates drilling and completion costs from eleven low-to-moderate temperature geothermal projects carried out under the Program Opportunity Notice (PON) and User-Coupled Confirmation Drilling Programs. Projects under both programs are administered by the Department of Energy-Idaho Operations Office. The balance of PON projects were administered by other DOE field offices.

Several studies have evaluated geothermal drilling costs, particularly with respect to high temperature system drilling costs. This study evaluates drilling costs and individual cost elements for low-to-moderate temperature projects. It considers the effect of drilling depth, rock types, remoteness of location, rig size, and unique operating and subsurface conditions on the total drilling cost. This detailed evaluation should provide the investor in direct use projects with approximate cost projections by which the economics of such projects can be evaluated.

### INTRODUCTION

One of the key cost elements in the utilization of geothermal energy is the cost of drilling and completing a well to utilize the geothermal resource. Over the years a number of papers have been published to evaluate this key cost parameter. (Chappell, et al., 1979; Rowley & Carden, 1982; Carson & Lin, 1981; Carson, et al., 1983). In general, these papers address and emphasize the cost of drilling deep wells into moderate-to-high temperature geothermal resources. They demonstrate that all geothermal wells, including direct use wells, are more costly than oil and gas wells. Although they fail to pursue the cost of shallow wells any further, Chappell, et al., (1979) recommended a study on shallow well cost be made when more data became available.

The objective of this paper is to investigate the cost of wells drilled for direct use in greater detail. The well costs evaluated are from two programs administered by the

Department of Energy-Idaho Operations Office (DOE-ID), with EG&G Idaho providing technical assistance. The two programs are the Program Opportunity Notice (PON) Program and the User-Coupled Confirmation Drilling Program (UCCDP).

The PON projects were designed by DOE to demonstrate the technical and economic feasibility of the direct use of geothermal heat (Childs, et al., 1980). The PON demonstration projects are cost-shared between DOE and industrial or municipal entities. Typically, each project consists of an environmental report, exploration for the resource, drilling of the well, and design and construction of the system for fluid utilization and disposal. All projects have been completed, are in the final construction phases, or have been abandoned due to a lack of resource. One of the PON projects, Diamond Ring Ranch, South Dakota, utilizes an existing well. On another project in Boise, Idaho, a private limited partnership (which has not disclosed its costs) drilled and completed the wells. Drilling costs from the remaining ten PON projects under Idaho Operations Office contract are included in this study.

The UCCDP is a DOE-sponsored program designed to absorb the front-end risk of exploration, drilling and testing of wells to be used for direct use projects. It uses a variable cost share arrangement with industry (Gray, et al., 1980). One of the wells drilled in this program for the City of Alamosa, supplied a key data point for wells drilled to depths between 5,000 and 10,000 ft and is included for purposes of analysis.

This study evaluates the drilling cost, and the variables which affect cost, on eleven wells intended for direct use purposes. The well depths range from 275 ft to 10,054 ft, with wellhead temperatures ranging from 108°F to 181°F. Higher bottomhole temperatures occur in two of the deepest wells, those drilled for the City of Alamosa, Colorado, and Ore-Ida Foods, Oregon. However, well production rates on these two wells are too low to be useful. The projects, their well depths, and selected resource characteristics are presented in Table 1.

TABLE 1. PROJECT LOCATIONS AND RESOURCE CHARACTERISTICS

Year Completed	Project	Location	Well Depth (ft)	Wellhead Temperature (°F)	Maximum Well Discharge Rate (gpm)
1979	Haakon School	Philip, South Dakota	4,266	157	340
1979	St. Mary's Hospital	Pierre, South Dakota	2,176	108	375
1981	Elko Heat Company	Elko, Nevada	868	178	600
1979	Warm Springs State Hospital	Warm Springs, Montana	1,498	156	60
1980	Pagosa Springs	Pagosa Springs, Colorado	300	131	200
			275	148	700
			299	--a	
1981	Utah State Prison	Draper, Utah	1,000	181	600
1979	Monroe City	Monroe, Utah	1,500	165	330
1979	Utah Roses	Sandy, Utah	4,994	123	180
1980	Madison County	Rexburg, Idaho	3,943	72 <sup>b</sup>	30
1979	Ore-Ida Foods	Ontario, Oregon	10,054	380 <sup>b</sup>	2
1981	City of Alamosa	Alamosa, Colorado	7,118	190 <sup>b</sup>	--

a. Abandoned

b. Bottom hole temperature

#### COST EVALUATION

Drilling and completion costs, as defined in this report, follow the same format of categories as those employed by Carson, et al., (1983) in their generic models. These categories include site preparation, rig mobilization, casing, bits, cement, drill fluids, rentals (i.e., blowout preventers), well supervision, wellhead equipment and completion techniques such as development and stimulation. They do not include any exploration costs, nor do they include any pump testing costs, unless a short term test or airlift is conducted with the rig on the well.

The plot of actual drilling cost data versus depth for the eleven direct use application wells is shown in Figure 1. Noted in the figure are the added costs of well construction modifications, or well rework. For example, the Elko Heat Company well required rework when leakage from the resource to a shallow water aquifer was discovered, and a partial bridging of the borehole just below the bottom of the liner was found. The City of Alamosa well required rework when clays in the open-hole portion of the wellbore squeezed into the borehole, thereby closing off the lower portion. In the St. Mary's well, an acid treatment was performed which resulted in increased flow. (Strawn, 1980) The plotted data point for the Warm Springs Hospital includes \$4000 for acid treatment. And finally, at the Ore-Ida Foods well, the project participants attempted to increase flow via perforations and a small (unpropped) hydraulic fracturing treatment. These additional costs are shown on Figure 1.

It should also be noted that the costs presented in Figure 1 have not been corrected for

escalation, since the wells were drilled and reworked over a period of just over two years (from 1979 to 1981). Monthly escalation factors would need to be considered to realistically adjust these drilling costs. The escalation or de-escalation costs are believed to be small, since the most recently completed wells (1981) were completed at unusually low costs considering the depths of the wells.

In previous studies, it has been demonstrated that drilling in igneous or volcanic rock is more expensive than drilling in sedimentary rock (Rowley and Carden, 1982). The data on Figure 1 do not conclusively support this conclusion. An argument can be made that the igneous and volcanic wells are not that significantly different from troublesome sedimentary wells. The cost of drilling in volcanic rocks (i.e., Madison County, Alamosa, and Ore-Ida Foods) does show a trend on the higher end of the costs plotted, but these wells encountered other problems. The Madison County well was unusually expensive, primarily because of lost circulation and well completion problems attributable to the prolific aquifers penetrated in the basalts of the Snake River Aquifer. As previously mentioned, Alamosa had squeezing clay problems caused by intervening sedimentary beds between volcanic strata. Lost circulation and deeper drilling tend to increase costs for these wells, even in the small population of data presented in Figure 1. However, these problems appear to mask a cause and effect relationship between costs and rock type.

On the low cost side of the data in Figure 1 are two wells (Utah State Prison and Utah Roses), both drilled within the Salt Lake Valley of Utah. These wells are believed to be on the low side of our curve for two reasons. They are in a

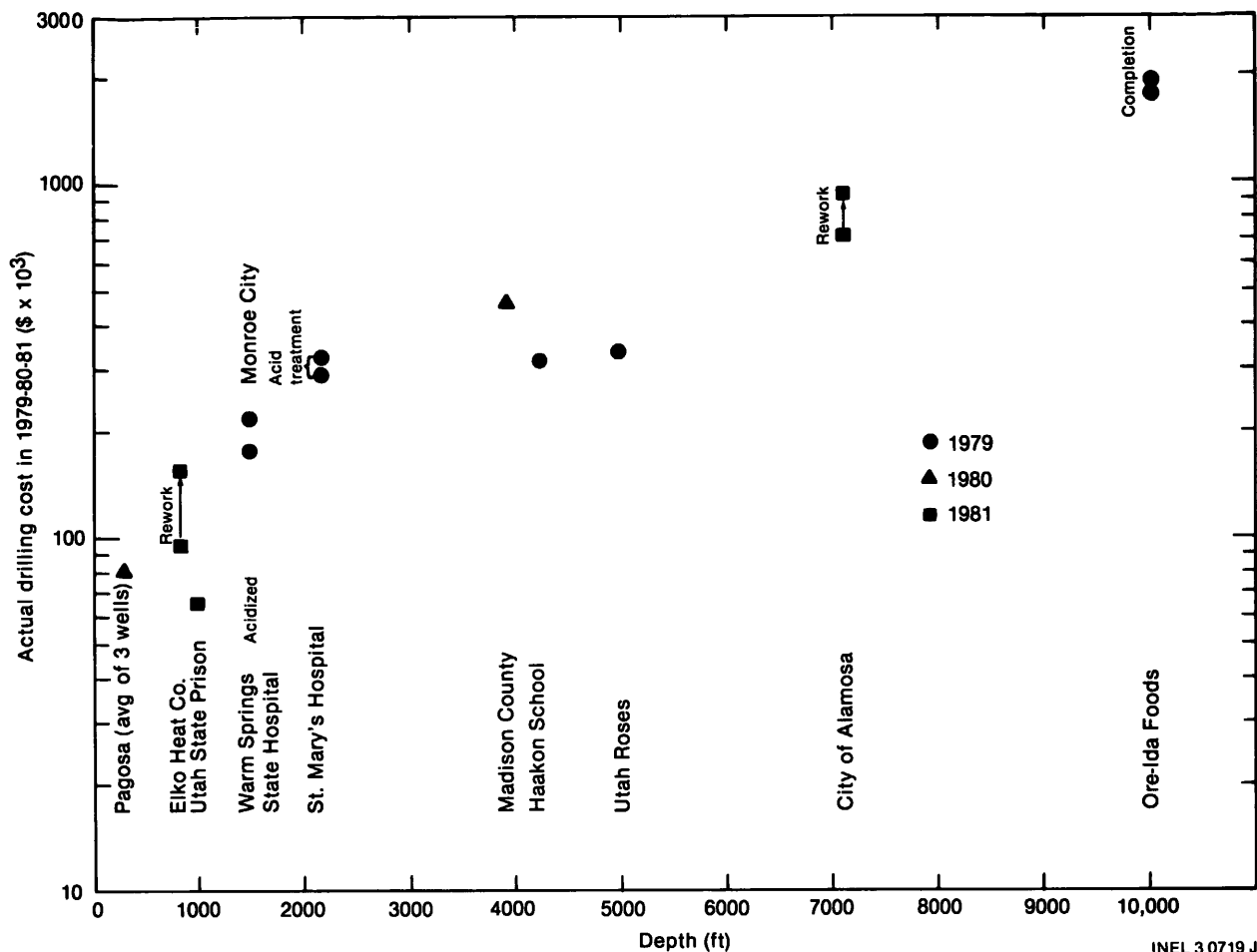


Figure 1. Actual drilling cost versus depth for eleven direct use projects.

large metropolitan area with considerable drilling activity and rig availability so that drilling services, rig mobilization, and transportation costs, are highly competitive. Secondly, the drilling in sedimentary rocks at Utah Roses and fractured metamorphic rocks at Utah State Prison offered no major drilling problems. These factors result in a lower drilling time and rig rental cost, which is the greatest portion of total drilling costs.

Considering the remaining data points, which are all in sedimentary environments, the remaining discussions will analyze the various wells and the problems that they encountered. In the 3900-5000 ft interval, the three wells show a significant scatter. However, between these two extremes, the Haakon School project (a Madison Aquifer completion) was drilled at an intermediate cost. The cost of this well appears closer to the lower cost trend of some of the sedimentary formation drilling costs, but is in a more isolated location from well drilling equipment and services than at Utah Roses. The well at Madison County was not drilled to the target depth. Thus, with an oversized rig used for the depth completed, higher rig mobilization costs and rig rental rates resulted than would be anticipated. This factor, plus some drilling

problems, resulted in a relatively high cost per foot of borehole completed for the Madison County well.

Another possible reason for the low cost of the Haakon School well is that it was drilled on a footage rate contract and encountered no unusual drilling and well completion problems. The St. Mary's Hospital well was also drilled into the Madison Aquifer, but it was drilled on a day rate contract. Being on hospital grounds, drilling was restricted to daylight hours. In addition, the St. Mary's Hospital well was completely cased, the casing cemented, then later perforated and the well acidized. Even though the Haakon School well is nearly double the depth (4266 ft) of the St. Mary's Hospital well (2176 ft), the cost of the two wells is nearly equivalent. It appears that the footage rate contract, which provides more driller incentive to resolve problems and make footage, was beneficial for the Haakon School well and probably is somewhat lower than what a typical Madison Aquifer well would cost. Footage rate contracts should be obtained to minimize costs, especially when drilling is restricted to limited hours during the day, unless drillers ask excessive rates for a footage-rate contract.

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The City of Pagosa Springs drilled three wells under the DOE-funded portion of the PON. One of the wells is abandoned, but the other two (a 300 ft well and a 275 ft well) are being utilized for the district heating system. Severe problems were encountered when starting the drilling through a gravel and boulder section. This resulted in excessively high costs. (EG&G Idaho, Inc. and Lawrence Berkeley Laboratory, 1981) The average cost of all three wells is indicated in Figure 1. Although the large boulder and gravel section caused higher than normal costs, the drillers had overcome the problem by the time they started the third well, and there is little doubt that additional wells would have exhibited lower costs. The first well in an area can be expected to be of higher cost due to the uncertainties of drilling for the first time into the subsurface strata of that area.

The Elko Heat Co. well is another shallow well that appeared to have a cost slightly higher than anticipated. Part of the cost problem for shallow wells such as this and the Pagosa Springs wells is the need for pressure control while drilling. A blowout preventer was required for well control to avoid the use of excessive amounts of mud. This added the costs of a large, heavy assembly for transportation, rental, installation and removal. Its size may also force increased rig size and cost. The Elko well (a good producer) has a shut-in wellhead pressure of more than 50 psi so the blowout preventer was required. The rework required on the Elko well, however, nearly doubled its cost from \$96,000 to \$165,000. The combination of the blowout preventer and rework added significantly to the cost of this well.

The Utah State Prison well has already been discussed, but as concluded earlier had ready access to services, a competitive rig situation, and easy drilling. These elements allowed for drilling a 1000 ft well for \$65,000.

Our cost assessment of the two 1500 ft wells (Monroe City and Warm Springs Hospital) is that both were excessively high in cost. Monroe City was a footage-rate contract, but it encountered significant problems and a fishing job which resulted in extra payments to the driller under the "unusual drilling conditions" clause of the contract. In addition, the drilling rig was being extended to the extreme limits of its capability. Warm Springs Hospital encountered sloughing conditions due to a daylight-drilling-only situation. This required daily wellbore clean out to return to the depth attained on the previous evening. This repetitious drilling was a costly operation. Based upon the problems noted, both of these wells could have been drilled for a lower cost.

#### CONCLUSIONS

As these direct use wells are designed to serve as demonstration wells, the costs should serve as a benchmark for future direct use projects. These are basically "wildcat" wells that provide

much needed information and field experience. These demonstration wells provide insight on a number of potential problems, some solutions to these problems, and techniques that can be used to reduce drilling costs, such as using a footage-rate contract where daytime operations only are allowed.

Our conclusion on low-to-moderate temperature wells is that the drilling cost estimate should be based upon unique operating conditions which may be imposed by the drill site location and the rig size. The actual costs plotted in Figure 1 should also provide the direct-use developer with some concept of the magnitude of a contingency cost that may be added to the basic well cost. The enclosed well cost estimates can be helpful in planning the development of a direct use geothermal resource.

In comparison to other geothermal wells, the technique used by Rowley and Carden (1982) has been used in Figure 2 to compare the drilling costs of these direct heat wells to those reported by Carson and Lin (1981) for higher temperature resources. This analysis shows the direct use drilling costs follow the trend of other geothermal wells, but still remain above the U.S. oil/gas average. This is not surprising since the geothermal well requires larger flow rates and a larger wellbore, with attendant higher costs. Since the geothermal drilling industry is still in its infancy, drilling "wildcats" and developing drilling techniques to handle the unique problems associated with exploiting these systems, it is not surprising that we need to continue to develop our learning experience curve.

#### ACKNOWLEDGEMENT

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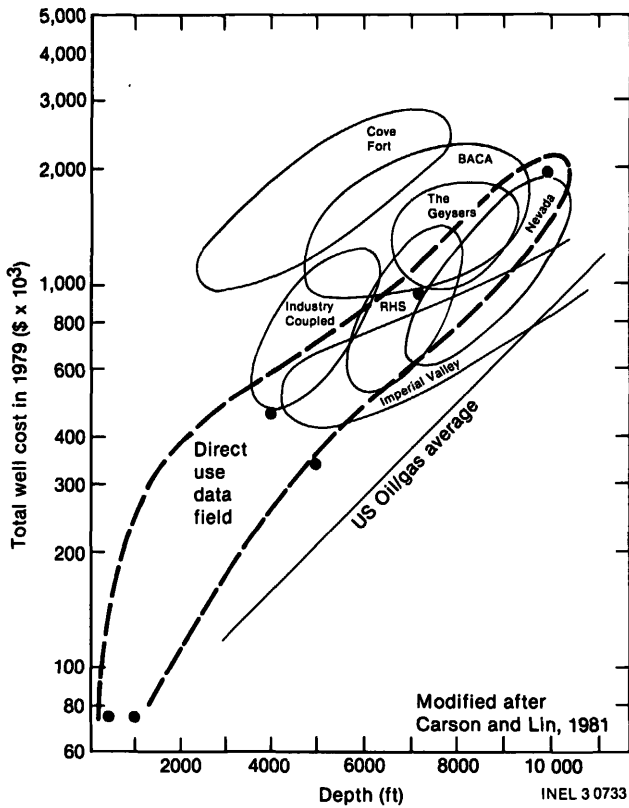


Figure 2. Comparison of direct use drilling costs to other geothermal wells and the U.S. oil/gas average.

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