A comparative Study on Water Well Drilling Costs in Kenya, Jean Doyen, 2003

FOREWORD

This paper presents the main findings of a comparative study on water well drilling costs in Kenya. It outlines the main factors influencing the costs per unit in various geological environments.

The study focused primarily on cost factors that can be influenced by geological investigations, well design and construction supervision.

Commissioned by the UNDP-World Bank Water and Sanitation Program, the study highlights factors and approaches that can lead to reduction in water well drilling costs. The information contained in the study report was obtained through letters of inquiry, discussions and records available at the Program's regional office in Nairobi.

Notably the study did not look into the potential cost savings from competitive bidding by private drilling contractors. In a liberal commercial environment, costs are likely to be further reduced and cost biases, due to taxation rules, etc., eliminated. There is a growing consensus that government and state corporation drilling operations are generally not cost effective due to inability of most governments to provide a favorable incentive structure. The same may apply for NGOs if their operations are not exposed to competition.

Nevertheless, we are issuing this as an informal paper as it contains technical and methodological information which should be of value to engineers and agency staff responsible for drilling water.

Jean H. Doyen
Regional Manager

EXECUTIVE SUMMARY

The high cost of drilling rural wells has affected access to water in the rural areas. This has necessitated the study on possible cost reduction methods, comparing water well drilling costs in Kenya as the basis for analyses.

Low cost approaches to rural water supply are explored in this study. An analysis of cost saving factors reveals that the following are potential cost reduction areas:

a) Drilled well depths: A 25% reduction if the drilling is not done beyond optimum yield depths.
b) Well siting and success rates: Drilling success rate should be defined as striking of water in sufficient quantity and not maximization of output.
c) Establishment costs: Community initiatives on a demand driven basis need to be grouped in order not to loose economies of scale effects.
d) Cased diameter and well design: 7.5% could be saved on the total cost if the diameter is reduced.
e) Test pumping and yields: 7% saving is possible if a 3-hour test for rural handpump drilled wells is applied.

Other suggestions on cost reduction are that there should be changes in the standard practice and design, plus an improvement in the supervisory process.

The report argues that the definition of well drilling success needs to be reviewed. In future studies it is suggested that the following factors be given more attention:
- Case studies of on-going programs
- Desk reviews of available information on drilling costs
- Siting costs
- Drilling plant
- Geology
- Drilling methodology
- Supervision
- Well design and construction
- Development and pump testing

- Overhead costs

These issues should be given special attention through systematic monitoring and evaluation in all projects. Common indicators and systems for well drilling performance should be developed by a global lead agency, e.g. UNICEF.

The study has not fully considered the effect of competition by the private sector in water well drilling. There is evidence that competition combined with adequate incentives can reduce the cost per borehole by as much as 50%.

BACKGROUND

The report outlines major findings of a drilling cost study, and serves as a guide to some of the important issues highlighted in the main report.

Development of low-cost approaches in rural water supplies has been recognized as a prerequisite to the improvement of service coverage. A common approach to the development of rural water supply is the installation of hand pumps on drilled wells (boreholes) on dug wells. The high cost of drilling has been noted by many as a major aspect. The UNDP-World Bank International Handpump Workshop of 1992 served to focus on the following concerns:

- Disparity between the low costs of handpumps and high costs of drilled wells.
- Significant reductions in the costs of handpumps and improvements in reliability.

Drilling costs for some programs in Kenya have been studied as a preparatory step towards a wider study in the East African Region. The objectives of the study were to:

- Establish the factors that can considerably reduce the drilling costs.
- Indicate achievable cost levels.

Methodology

Information for the study was obtained through letters of invitation, discussions and analysis of records at the agencies' main offices and field projects.

Information on costs was gathered according to a standardized group of indicators wherever possible. The degree of compatibility varies from program to program. Costs were largely grouped according to siting, supervision, mobilization, drilling rate, supply of materials, installation, development and testing, well completion, and overheads.

The costs were compared and an analysis carried out to determine the sensitivity of various cost reduction or increasing factors. All costs were compared based on 1996 cost level.

Historical Trend

As the two programs are on going, the component costs could be estimated to varying degrees, and full results are yet to be realized. An analysis of Program A's costs and performance over time was carried out. This facilitated a discussion based on actual results, and was more revealing in terms of potential cost saving factors:

- Drilling cost (per meter) has fallen by 35%, during the 1988-1996 period; this is probably due to competition.

- Increased standards for well development, pump testing, and well design have increased costs by as much as 36%.

- The result: savings have not been realized, overall costs are US $ 8,400 in **1996, and US** $ 8,300 in 1988.

Actual Costs

An analysis of the results of the drilling campaign of Program A reveals other factors which affect the overall drilling costs. The most important observations were as follows: a Drilling depth was 43% too deep on one campaign. Average depth was m, while 52 m is sufficient for hand pump yields. Quality of supervision is an important factor. Proper well siting is important: Location achieved 51 % success, and geophysical techniques 89%.

When looking at the costs of rural drilled wells in Kenya, a figure of US $ 8,000 is often given for a 70 m well. There are, however, a number of ways of presenting the overall cost per well, as shown below:

Estimation method	Cost $
Estimation cost 70m well (drilling operations only)	7,300
Estimated cost 70m (including testing)	8,400
Estimated cost 70m well (including siting and supervision)	9,500
Cost of successful well alone (average drill depth 84m)	10,650
Cost of successful well at 89% success rate (including failure)	11,430

The final figure of US $ 11,430 per well may seem high, but comes close to the real cost, and the success rate is high compared to some programs. The table demonstrates the importance of looking at all factors included in the overall dollar figure.

Cost-Saving Factors for Rural Drilled Wells
A sensitivity analysis of various quantifiable factors affecting drilling costs as identified in the cost comparison was carried out. This was applied largely to the rural drilled wells, as most factors on the peri-urban wells need to be considered individually. The results of this sensitivity analysis are as follows:

a) Drilled Depth
- Potential to reduce overall costs for rural programs by up to 25% or US $2,850 out of US $11,430, reducing drilled depths to achieve yields concomitant with hand pumps (2 M3 per hr was taken).
- Wells are drilled deeper to maximize yields, whatever the need; some are drilled deep to strike water and improve success rates, and often dry wells are drilled deepest of all.

b) Well Siting and Success Rates
- Costs could rise by as much as 32% or US $3,700 out of US $11,430, if proper siting methods (including geophysics) are not used.
- Danger in focusing on higher success rates: very high rates are uneconomic if costs of success outweigh the gains.
- Need to review the definition of success as applied to rural handpump programs: success in terms of water strike and success in terms of increased yields are not the same: high (and un-utilized) yields are not economical.
- The answer is improved supervision with the correct hydro-geological and economic criteria in force.

c) Establishment Costs
- If campaigns are not in economic lots (50 wells or more), costs could rise by as much as 25%, or US $2,900 per well out of US $11,430.
- Care will need to be taken to group community initiatives on demand driven approaches in order not to lose economies of scale.

d) Cased Diameter and Well Design
- Reduction in well diameters from 152 mm to 125 mm would give 7.5% saving or $850 from a total cost of $11,430. A further reduction to 102 mm would only result in an additional 2% saving.
- Scope for further reductions in design, such as casing only the collapsing formations, and leaving stable basement un-cased, such as is carried out in Uganda.
- In Kenya, a 152 mm-cased diameter is a standard requirement; reflecting advanced technology.

This study suggests that:
- Current standards are constraining the achievement of lower per capita costs.
- Standards for rural handpump drilled wells need to be established separately.

Test pumping and Yields

- A saving of 7% or US $ 760 from US $ 11,430 would result from a reduced requirement for 24 hour discharge and 12 hour recovery to a shorter 3 hour test for rural handpump drilled wells.

The longer test is a standard requirement in Kenya. The reasoning behind this is to maintain high standards, and to obtain as much hydro-geological information about the aquifer concerned as possible. These are sound arguments, particularly where abstraction rates will be high.

For rural handpump drilled wells, abstraction rates are so low that depletion of groundwater resources is not a problem. The information needed for these lower yielding wells will be obtained from a shorter test, and still enable analysis of relevant aquifer parameters.

Rural and Peri-Urban Drilled Wells

Rural Drilled Wells:
Rural drilled wells are characterized by the following factors:

- Less densely populated areas, serve about 250 people per well.
- Lower yields are sufficient (approximately 1 M3 per hour).
- Abstraction rates are low, e.g. 10 M3 per day if handpumps are installed

The current volume of rural well drilling in Kenya is approximately 250 per year, which is below the requirements of 650 per year to reach official development targets by 2010. Although information was gathered from a wider range, two long-established programs were compared in detail.

The programs are as explained below:

- Program A is the contracted well-drilling, 70m depth including reconnaissance survey, well-siting costs and hydro-ecological supervision.
- Program B is the in-house program, 60m depth, without supervising or reconnaissance charges but with hand pump installation.

Both programs involve use of the following methods: rotary drilling plant, drilling through overlying sediments (regolith) into basement rock, using DTH (down the hole) hammer in consolidated formations, and polymer-mud drilling in collapsing formations.

The comparison of the total costs between the different programs is of limited utility. More revealing is an analysis of the individual component factors, which indicated the following as the important cost factors:
Drilled depths Pump testing Mobilization Well design Exemption from taxation (granted by GOK**)**

Peri-urban Drilled Wells:
Within this study peri-urban wells are characterized as follows:

- Drilled largely for more densely populated areas.
- Abstraction rates are high, e.g. 200 m' per day, or more.
- High-discharge mechanical pumps installed with associated infrastructure.

These differences are very important when considering drilling costs. There are, naturally, common cost factors between the two, but they can only be compared directly in terms of cost per capita, and are considered separately in this cost study.

Four programs of peri urban wells were compared, all involving commercial drillers, and a range of geological (sedimentary, volcanic, and metamorphic) and logistical environments, drilled depths (20 to 315 m), including the rotary drilling plant. Costs were in general much higher than for rural drilled wells, for a variety of reasons. (Mean drilling costs are indicated in the table below.)

Program Sample size	Comparative Cost in UDS			
	Mean cost per well	Depth (m)	Cost /m	Cost/spec'
C (4)	48,800	140	350	1,260
D (8)	7,900	30	295	30
E(4)	10,000	50	210	380
F(1 5)	32,510	210	155	13,530

Spec': Specific capacity, as M3 per day per m of draw-down.

The two important factors affecting well costs were; drilled depths and logistics. The most expensive wells involved drilled depths of over 300 m. This is intuitively what one would expect.

Costs for the different programs were quantitatively analyzed by a comparison of their overall efficiency as defined by the cost per unit specific capacity.

The findings of the comparison are as follows:
- The lower cost per unit specific capacity between Programs D and E is best attributed to better hydro-geological supervision.
- The high cost per unit specific capacity for Program F is due to single mobilizations, and greater drilled depths.
- Over drilling on peri-urban wells varied between 1.5 and 26%, with an average of 11 %.
- Over drilling is roughly inversely proportional to the degree of supervision of drilling operations.
- Drilling into basement was approximately 50% less expensive than drilling into un-consolidated sediments and 40% less than a combination of volcanic and sediments.
- Drilling into volcanic can be most expensive, but is highly variable.
- Program A: per capita rural cost of US $ 46 for 250 people against Program C's peri-urban cost of US $ 9 for 6,000 people. Both costs are for borehole drilling only.

Conclusion and Recommendations

Cost saving factors - Technical:
The table below illustrates achievable savings when the factors discussed above are progressively applied.

Breakdown of costing	Cost in $
Cost of successful well drilled to 84 m (including failure and 89%	11,430
success rate)	
Cost of successful well drilled to 52 m (including failure)	8,600
Cost of successful well including failure at reduced diameter (from 152 to 125 mm 0)	7,940
Cost of successful well including failure with reduced testing (from 24 to 3 hours)	7,200

Percentage reductions:
Substantial savings are possible by as much as 40% when items identified here are combined. This is attainable with existing plants, operators, and siting methodology, if changes in standard practice and design; and improvements in supervision are put in place.

From the analysis of drilled depths, it is clear that there is a danger in focusing on higher success rates. A high success rate is better, if one looks at success from the point of high yields (i.e., higher yields to mean greater success) in a rural handpump program; there is the danger of a runaway situation. In a sense, the desire for greater success is inflating costs.

The current situation is that rural wells are being constructed to give high yields, and are forced to conform to higher standards that are appropriate to peri-urban wells, than a dug well. This amounts to a substantial over-designs.

Cost saving program strategy:
Arguments have been put forward that larger casing diameters on higher yielding rural wells and the current testing requirements enable the installation of larger pumps and expansion of the schemes in the future. This upgrading potential may be desirable, but the evidence here suggests that we are putting this argument ahead of the need to develop adequate supplies for the current rural population. In many cases rural wells are being over drilled to obtain higher yields, with a justification that they will serve a larger population in future, within the lifespan of the drilled well itself.

Normally it would be more economical to use savings identified here to serve a wider current rural population, or to develop higher yielding supplies in areas where populations have outgrown their current supplies.

Cost saving factors - Financial:
The other factor which limits lowering of costs for rural drilled wells are the difficulties in monitoring costs while programs are on going. This is largely because prevailing accounting methods do not facilitate effective cost monitoring. Detailed information can be more easily obtained on the type of expenditure than can be found for specific program outputs such as the cost of an individual drilled well.

In general, better-cost information is available for contracted drilling programs, largely due to the tendering and cost analysis process. Nonetheless, there are persistent difficulties, which result basically from poor cost monitoring. If we are to find ways to reduce drilling costs, one must be able to work out spending at field level with ease. A more standardized and improved methodology for monitoring program costs is clearly needed.

Recommendations:
a) Measures to reduce costs:

The cost comparison carried out demonstrates that the following changes in policy and procedure can achieve savings of up to 40%

- Reduction in drilled depths to only those necessary to obtain sufficient discharge for installation of handpumps (25% potential saving).
- Reduction in cased diameter and test pumping requirements (15% potential saving).

Complementary to this is the need to further review conservative policy and practice where cost savings may be achieved and in particular the need to:

- Develop standards and guidelines for rural handpump drilled wells. These should review existing standard practice and design, especially with regard to well design for different formations.
- Reconsider the definition of success as applied to rural handpump programs. Success in terms of higher yields instead of water strike is uneconomic.

b) Improved cost monitoring:

There is a need to improve cost monitoring so as to facilitate the achievement of cost reductions. These measures include:

- The development of more standardized record-keeping of costs and program outputs. There is need to account as diligently as possible for service provisions at field levels. A number of agencies are moving to this form of program accounting.
- Establishing guidelines for the optimum economic well cost for particular programs.
- The development of incentives for improvements in efficiency to enable adaptive implementation planning at the field level.

Future Prospects

Comparison in this study is a preliminary one, and the limited amount of data analyzed. This means that the conclusions reached should not be regarded as absolute. Persistent difficulties remain with a wide range of factors deserving further study and greater attention than has been possible here. The UNDP-World Bank RWSG-ESA acknowledges this, and wishes to initiate a wider debate on these issues. It welcomes contributions and the benefit of wider experience from other programs in the Region.

Generic terms of reference for future cost studies, which outlines approaches and factors deserving further attention, include the following:

Case studies of on-going programs will help keep cost considerations firmly in the field context. They should enable economic guidelines to be developed in an adaptive way appropriate to those programs, and establish the most effective measures. They should also enable actual cost savings to be achieved while programs.

Further desk reviews of available information on drilling costs. Provision of cost information from other programs in the region will enable the establishment of a database of consistent and comparable quality. This could, in turn, facilitate the transfer of experience from one program to the other.

Other factors, which deserve greater attention, include the following:

Siting costs:

The economics of well siting deserves to be considered along with other technical factors when developing operational guidelines. The cost of siting is significant (10% of well cost), and the establishment of the most economic point deserves further attention.

Drilling plant:

From this study, it was clear that many, rigs currently in use in Kenya are oversized for the purposes of rural handpump drilled wells. Considerable savings should be possible from the selection of an appropriate plant.

Geology:

The rural program geology was very similar, so different geology could not be compared.

Drilling methodology:

A comparison of a wider range of drilling methods could reveal further cost savings, particularly where different methodologies can be employed in the same formation.

Supervision:

This comparison has indicated the importance of supervision on drilled depths in particular. Future work could focus on the quantification of this aspect.

Well design and construction:

As indicated above, appropriate standards for design and practice need to be established; costs for a wider range of techniques and designs need to be compared.

Development and pump testing:

There is further scope for study on the methodologies, costs and requirements for both of them.

Overhead costs:

This type of information is often difficult to obtain, and is often subjectively assessed. As it relates in many ways to an operator's or agency's efficiency, it should be included in any standardized cost monitoring.