WATER AND SANITATION FOR HEALTH PROJECT

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A RE-EXAMINATION OF COSTS AND BENEFITS OF RURAL WATER SUPPLY PROJECTS IN CENTRAL TUNISIA

WASH FIELD REPORT NO. 298

APRIL 1990

Prepared for
the USAID Mission to Tunisia and
the Central Tunisia Development Authority (CTDA)
WASH Task No. 057 and 130

WASH Field Report No. 298

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by

Alan Wyatt

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RELATED WASH REPORTS

Organization of a Colloquium on Rural Water Supply and Sanitation, Kasserine, Tunisia, by Fred Rosensweig and Raymond B. Isley. January 1983. Field Report No. 67.

Evaluation of Health and Social Benefit of Springs Capped for Irrigation, Further Adapted for Domestic Use in Central Tunisia, by Raymond B. Isley. May 1983. Field Report No. 84.

Midterm Evaluation of the USAID/Tunisia Rural Potable Water Institutions Project, by Lee Jennings, Ridha Boukraa, Mohamed Frioui, Richard Swanson, Sereen Thaddeus, and Alan Wyatt. July 1989. Field Report No. 256. (French and English)

Plan de Travail de L'Unite d'Autogestion, by Lee Jennings, Sereen Thaddeus, and Alan Wyatt. September 1989. Field Report No. 276. (French only)

Health and Hygiene Education and Women's Involvement in the Tunisia Rural Potable Water Institutions Project, by Sereen Thaddeus. November 1989. Field Report No. 277. (French and English)

Engineering Design Considerations: Tunisia Rural Potable Water Institutions Project, by Alan Wyatt. November 1989. Field Report No. 279. (French and English)

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ACRONYMS

AIRD	Associates for International Resources and Development
B/C	benefit/cost
CRDA	Regional Commission for Agricultural Development
CTDA	Central Tunisia Development Authority
g/1	gallons/liter
IDA	Institute for Development Authority
IRR	internal rate of return
lpcd	liters per capita per day
km	kilometer
l	liter
m	meter
mm	millimeter
SCET	a Tunisian consulting firm
TD	Tunisian dinar (exchange rate in February 1989 was 1TD = $1.09 or $1 = 0.92 TD)
USAID	U.S. Agency for International Development
WASH	Water and Sanitation for Health Project

EXECUTIVE SUMMARY

This paper describes a benefit/cost (B/C) model developed for the Regional Commission for Agricultural Development (CRDA) of the USAID-funded Rural Potable Water Institutions Project in Kasserine, Tunisia, in response to one of the principal objectives of the project: to maximize water investments by improving site selection for new and improved water systems. The model is used to allocate investment funds for rural water supply projects, according to a ranking of candidate sites based on the B/C criterion. It was developed by WASH and CRDA staff under a technical assistance program delivered under the WASH project. The analysis is based on earlier work, but has updated cost data and takes a new approach to the assessment of benefits, as a result of which the projects are shown to have greater economic feasibility. However, this analysis is preliminary and based on limited data. A planned survey of water users is expected to yield additional data to refine the benefits calculation. Nonetheless this analysis should help the project staff to make sound investment decisions.

In 1987, a report on the economic feasibility of rural water projects prepared by the Institute for Development Anthropology (IDA) computed the B/C ratio and internal rate of return (IRR) for typical project sites. B/C ratios ranged from 0.69 to 1.65, and IRR values from 8 to 35 percent. The sites with higher well depths and lower populations did the poorest, while those with opposite conditions produced the best economic feasibility.

IDA's calculation of benefits was made from time savings for users and an estimate of the economic value of time, based on a small survey of rural water users in 1985. Some aspects of the calculation are questionable. All sites are assumed to yield uniform benefits, whether they are near or far from an existing source, and the benefits are assumed to derive only from time savings by men, which seems wrong and short-sighted.

The model described here is based on more recent cost data. It is driven by the characteristics of the candidate site—population, water consumption, estimated well depth—and computes full investment costs. These are high—mostly because drilled wells cost 350TD per m of depth, and wells are typically over 300 m deep. Thus, the well alone could cost more than 100,000TD. O&M costs over a 20-year period are based on engineering calculations and historical data, and include the salaries of government personnel involved in establishing and maintaining the systems. The model uses accounting ratios to calculate economic costs from market prices, based on previous economic studies for Tunisia

This revised model also uses travel time savings as the basic benefit, but with an empirical estimate of the value of time derived from the overall behavior of the rural population in the region. The new value of time is higher than in previous estimates, and is independent of the person traveling and of the intended use of water. The resulting benefits per family per year are higher than previously estimated. Although it is based on limited aggregate data, the revised approach reflects people's own valuation of benefits. It assesses what families are willing to pay in time or cash for water. A more precise assessment of project benefits can be expected from the results of the upcoming rural household survey.

A recalculation of benefits at sites studied in the IDA report provided a comparison between the two analyses. The new analysis yields consistently higher IRRs that can be attributed mostly to increased benefits resulting from the increased value of time. The model was applied to sites being considered for the next cycle of projects. As expected, the more economically attractive sites have higher populations, lower well depths, and longer (current) travel distances to water. B/C values ranged from 0.94 to 2.74 and IRR values from 10 percent to 44 percent. These sites have been ranked according to the B/C criterion, and are being implemented accordingly. Despite the preliminary nature of the benefits calculations, the B/C model can be *tentatively* applied to the task of general project selection. A set of tables has been prepared for rapid economic appraisal of future projects. The original project selection criteria were reviewed and an alternative approach based on this model has been proposed.

In summary, a revised B/C approach has been developed to assist in selecting project sites and maximizing investments. The results show that the economic feasibility of rural water projects may be better than previously estimated. This model should be updated when additional data on benefits have been collected. Also, the model can be applied to the task of studying and improving engineering designs used in the project.

Chapter 1

INTRODUCTION

One of the principal objectives of the Rural Potable Water Institutions Project is to maximize water investments by improving site selection for new and improved water systems. To this end, a number of studies have been conducted over the past few years by the Central Tunisian Development Authority (CTDA) and the Institute for Development Anthropology (IDA). These efforts include demographic studies, hydro-geologic studies, the water resources mapping studies (including a series of acetate overlay maps), studies on the site selection process, as well as project economic analyses. There is little doubt that all these inputs have improved the CTDA's selection of sites for water system development.

The essence of the site selection issue is that the available project funding be spent to do the most good. There are numerous ways of deciding how to allocate project resources. One approach would be to install water systems in the driest areas—the zones where populations are large, but good water sources are very far away. But to select sites on the basis of pure need (which could be equated with benefits) would be a poor way to allocate resources if costs were not taken into account. For example, where there are two sites with equal needs but different costs, the lower cost site should be ranked first. The traditional approach to allocations of this type is to use the benefit/cost (B/C) ratio, or the internal rate of return (IRR) to set priorities among candidate sites. Previous project economic analyses by IDA (Reeser 1987, and Reeser 1988) have used this approach.

In early 1989, as the engineer on the mid-term evaluation team, the consultant had the opportunity to review previous IDA/CTDA economic analyses. While they seemed to be basically sound, there were some aspects which were out of date (particularly costs), and some which seemed unconventional (particularly benefits). In addition, the local project implementation team was not really using the results or methodology of these analyses in project selection. In fact, some sites which appeared economically questionable were being developed. Thus it was decided to rework some of the calculations and re-examine the results. In June 1989, these modifications were reviewed with the CTDA staff, additional changes were made, and a revised approach was adopted. On a return visit by the consultant in August 1989, further minor refinements were agreed to. This report describes that updated approach. Its purposes are summarized in Box 1.

REPORT PURPOSES

- To update previous studies with more recent cost information
- To re-examine previous benefit calculations
- To re-compute benefit/cost ratios for typical projects, and evaluate differences with previous efforts
- To examine model sensitivity to assumed parameters for cost and benefits
- To apply the analysis procedures to seven candidate sites, and prioritize them
- To develop simple tables of economic analysis results for use in the site selection process

Box 1

This approach must still be considered preliminary. The calculation for assessment of benefits is based on limited data and several key assumptions. Field surveys will be needed to collect sufficient data for a more accurate calculation of project benefits. Nonetheless the current model gives a good approach for choosing between candidate sites. Future changes in benefit calculations would probably affect all sites equally, so the results of prioritizing sites would be unchanged. The current model cannot *definitively* answer whether, or to what extent, these sites are economically feasible (B/C > 1). Changes to benefit calculations will impact B/C ratios and IRRs, so that sites which now appear feasible may not seem so in the future. The current model is valid for *relative* site analyses (choosing how to allocate resources between sites), but not for *absolute* analyses (determining site economic feasibility, establishing new site selection criteria, or comparing the economic feasibility of rural water supply versus investments in schools, roads, agriculture projects, or other uses of development resources). The current model does give *preliminary* indications on these absolute economic issues.

Chapter 2

BACKGROUND INFORMATION ON THE PROJECT AND THE PROJECT AREA

The USAID/CTDA project area lies in Central Tunisia, and includes the Governorate of Kasserine and the northern part of the Governorate of Gafsa. The area consists of semi-arid high steppes, with an annual rainfall ranging from 200 to 400 mm. In general, the south is drier than the north.

The population of the region is about 300,000, with approximately half in rural and half in urban areas. Before the colonial period the local inhabitants were nomads, grazing sheep and goats in winter, and moving into Northern Tunisia in the hot dry summer. During the colonial period and later, efforts were made to settle them and encourage dry land agriculture. Today, rural dwellers still tend livestock and engage in farming (irrigated in some cases). Many have family members who have left the region for employment in the coastal cities or in Europe.

The rural population is highly dispersed. Densities outside towns is typically around 30 p/km^2. People often live within 5 to 15 km of a center where a school, mosque, water point, or other services may be found.

Water resources in the area are not plentiful. There are very few surface water sources. At the edge of hillsides and ridges, springs are occasionally found. In some areas, such as Sbiba for example, a phreatic aquifer can be found at depths of under 50 m, but many areas have only deep aquifers or no groundwater at all. In many areas reasonable quantities of water can be found only at depths of 300-400 m, and as deep as 500 m in others. Such deep wells generally can be afforded only by the government, or in government-sponsored drinking water points or irrigation projects.

Given this scarcity, people are used to hauling water from distant wells. Some collect rainwater in the winter, but most must supplement this resource for human and livestock consumption with transported or purchased water. It is generally acknowledged that water consumption and the quantity of water transported are far higher in summer than in winter. Most rural households have a subterranean cistern where they can store several weeks' supply. With the assistance of the government, about half of the families have been able to purchase 500 liter capacity donkey-drawn carts at a cost of around 750 Tunisian dinars (TD) each [1]. Those without carts can walk to a well with a donkey and transport around 40 liters. People not living close to a well would spend lots of time going back and forth.

Most people without donkey carts purchase water from a water seller. These vendors typically are individuals who have earned enough to buy a tractor and a 3500 liter tank. In order to make the most use of their investment, they use the tractor to enter the water-

[1] The exchange rate in February 1989 was 1TD = $1.09, or $1 = 0.92 TD. The 1988 per capita income in Tunisia was $1140 according to the 1988 World Bank World Development Report.

vending business. Vendors generally buy water from the public water points and sell at a price based on the distance traveled. Rough calculations have shown that these people are not getting rich selling water, especially because there appear to be quite a few of them in business. Many provide credit to families who purchase from them.

Clearly, the establishment of more and more public water points by the government and USAID will provide benefits in terms of reduced travel time and effort. From 1982 to 1986, USAID financed over 20 new water points. In 1987, just after the current project began, USAID/CTDA agreed on the following project selection criteria:

- 900 people (150 families) within a radius of 4 km from the site
- no other improved source of water within 4 km of the site
- available groundwater resources, with total dissolved solids (salinity) below 2.5 gallons/liter (g/l).

grams

Before 1987, for the earlier potable water project, USAID would not fund sites where groundwater depths exceeded 200 m. With the new project, USAID removed the depth requirement at the request of CTDA.

Chapter 3

PREVIOUS ECONOMIC STUDIES

3.1 First IDA Study

In August 1987, a feasibility study titled Economics of Water Point Development in Central Tunisia was conducted for IDA by Robert Reeser, an agricultural economist. Its main assumptions were:

- **Population and Water Use**—a 3 percent population growth rate based on a recent demographic study[2]. After reviewing a variety of sources, Reeser adopted an estimated consumption of 47 liters per capita per day (lpcd), based on 31 for people and 16 for livestock.

- **Investment Costs**—based on historical data from previous CTDA projects and estimates from well drilling firms and local engineers.

- **O&M Costs**—based on discussions with CTDA staff, included fuel (at a uniform 4 l/hr), oil, pump operator salary, miscellaneous small parts, and future component replacement costs.

- **Benefits**— based on travel time savings for male family members. The calculation was based on survey work in 1985 by Janet Smith (USAID) which resulted in an estimate of 60 hours per week per family for water hauling, and an estimate of the opportunity cost of the time for men. The result was benefits of 97TD per family per year for families within 4 km of a water point, and 20TD for those from 4 to 7 km away. Benefits are zero the first year (during construction), 33 percent the second year, 66 percent the third year, and 100 percent thereafter.

- **Economic Analysis**—Reeser used standard discounting procedures, with a discount rate of 15 percent (based on local interest rates) on a 15-year project period, and accounting ratios to adjust market prices and costs to economic values.

These assumptions are discussed in greater detail in Chapters 4 and 5.

The study computed the B/C ratio and IRR for typical project situations. Calculations were made for three well depths (125, 175, and 275 m) for projects with a 4 km and a 7 km radius of service. Two population densities (30 and 45 p/km^2) were used for the 4 km, and

[2] Reeser states that 3 percent was used, but sample calculations appear to show no population growth.

one (60 p/km2) for the 7 km zone. Thus a matrix of calculations was made, one for each project size with each depth. Results showed that B/C ratios ranged from 0.69 to 1.65, and IRR values from 7.7 percent to 34.8 percent. Of course, the sites with greater well depths and lower populations did the poorest, and the opposite conditions produced the best economic feasibility.

Reeser discussed project selection criteria and came up with the following observation. To reach an IRR of 15 percent (his assumed discount rate), there must be 1.5 families per m of well depth. In other words, a site where the well is 100 m deep should have 150 families (or 1,125 people) around it (within 4 km). A site with a well 300 m deep will need 450 families, or 3,375 people.

3.2 Second IDA Study

In February 1988, IDA published a second study, again by Robert Reeser, with the title: Computer Analysis of Sites for Water Point Development: Updating and Application. In many ways this study was very similar to the first, except that the methods were reviewed, updated, computerized, and applied to 10 candidate project sites. The following changes were made:

- **Population and Water Use**—same basic assumptions, except population estimates for specific sites were taken from maps under development by IDA and CTDA[3].

- **Investment Costs**—minor updates on drilling costs, but costs for pumping equipment and civil works unchanged.

- **O&M Costs**—changes in fuel consumption. Reeser adopted a uniform value of 12 l/hr, based on new data, but there was no link between well depth, or water level, and fuel consumption.

- **Benefits**—unchanged, except benefits are zero the first year and 100 percent the second year.

- **Economic Analysis**—accounting ratios unchanged, discount rate reduced from 15 percent to 10 percent, and project period changed to 20 years.

The report put the model into a Lotus 123 spreadsheet, and conducted the analysis for 10 candidate project sites. The results showed a positive IRR at 7 of the 10 sites, but an 8th site had an IRR just below zero. (See Box 7, where Reeser's results are compared with this

[3] Here sample calculations indicate that 3 percent was, in fact, used.

analysis). Reeser concluded that 8 of the 10 sites were economically feasible[4] and, as in the first study, that high-cost (very deep) wells and sparse population cause economic infeasibility.

3.3 Analysis of Project Zone of Service

While working with the project evaluation team in early 1989, this consultant conducted a brief analysis of the size of zone of service of the rural water projects. The Ministry of Plan had adopted a general target that all rural dwellers should have a source of good potable water within one hour's walk (one-way), or at a distance of about 3 km CTDA and USAID have informally adopted this standard in their project work in Central Tunisia.

The selection of level of service is very important, because it has a great influence on both the costs and benefits associated with these projects. A low radius of service (1 or 2 km) will mean water close at hand (low transport costs), but will necessitate many water points in a region, thus elevating investment costs. A high radius of service (6 or 7 km) will mean, on average, water further away (higher transport costs), but will require fewer water points in the same region, thus reducing investment costs. The issue was approached by estimating and mathematically adding investment and transport costs at a full range of radius values to find an optimal radius of a zone of service. Analysis procedures and results are shown in Appendix A. The results indicated that the optimal radius will depend on the water transport mechanism used—foot, donkey cart, or purchase from vendors. The results showed a range of optimal radius values from 2 to 7 km. Since any zone will have a mix of transport modes, a rough average of these radii should be used. In conclusion, it appeared that a radius of 3-4 km was optimal. Happily, this coincides with the Ministry of Plan's target.

[4] It is interesting to note that the other two sites (whose IRR values were about -7 percent, due to very low populations) were nevertheless developed by CTDA! However the current CTDA population estimates are much higher—on a par with other feasible sites.

Chapter 4

UPDATED COSTS

The revised cost model, including basic assumptions and derived cost values, is shown in Table 1. Since investment and O&M costs depend on the population and water demand, assumptions regarding these parameters are also given. Technical parameters which describe a hypothetical project are also shown as they are needed to compute costs. Table 2 repeats a portion of Table 1, the input assumptions, but notes the sources of these assumptions. In some cases the source is Reeser's values, if they appear to be accurate and still the best available information. In other cases new values are shown and the new source or assumption noted. Many costs are derived from the consultant's trip report on water system design (see References).

Table 3 also repeats another portion of Table 1—the derived cost values are shown along with formulas which show their derivation. Operating costs are shown for the first year of system operation, which is one year after the project begins, to account for a one-year construction period[5].

The results of the new cost model can be compared with Reeser's (before accounting ratios). For 300 m well depth the investment costs are:

	This analysis	Reeser (1988)
Well	105,000TD	104,400TD
Engine/Pump	27,955TD	21,000TD
Civil Works	53,941TD	32,000TD
Other	8,150TD	
Total	195,046TD	157,400TD

The new costs are often higher as they are based on more recent, experienced-based data, and include more cost elements.[6]

[5] The assumption that operating costs (and benefits) begin in year 1 after an initial year of construction is a revision of the model since the consultant's trip to Tunisia in June-July 1989

[6] These well costs use a unit cost of 350TD/meter, based on quotations for upcoming project wells (September 1989).

TABLE 1

OVERALL COST MODEL

DETAILED ASSUMPTIONS:

DEMAND:	
POPULATION 1989	1500
POPULATION GROWTH RATE:	3.0%
FAMILY SIZE	6
WATER CONSUMPTION (lpcd):	50
CONSUMPTION GROWTH RATE:	1.0%
TECHNICAL PARAMETERS	
TOTAL WELL DEPTH (m):	300
WELL STATIC WATER LEVEL(M)	100
PUMPING RATE (l/s)	10
SPECIFIC CAPACITY (l/s/M):	0.5
DISTRIBUTION PIPING LENGTH (m)	1000
RESERVOIR SIZE RATIO	0.5
PUMP/ELECTRIC MOTOR EFFICIENCY	54.9%
ENGINE + GENERATOR EFFICIENCY	17.4%
INVESTMENT UNIT COSTS	150
WELL COST PER m DEPTH	350TD
ENGINE COST/KVA - COEFFICIENT	2,204TD
ENGINE COST/KVA - EXPONENT	0.518
PUMP COST PER m^3/hr/m	1.50TD
DISTRIBUTION PIPING	17TD
STANDPOST, TROUGH, ETC	12,000TD
RESERVOIR COST EXPONENT	0.527
RESERVOIR COST COEFFICIENT	2563
UNIT OPERATING COSTS	
FUEL PRICE (TD/L)	0.29
OIL PRICE (TD/L)	1.2
FUEL & OIL PRICE ESCALATION	3%
FUEL & OIL TRANSPORT COSTS	10%
FUEL LOSS/WASTE/PILFERAGE	10%
OPERATOR ANNUAL SALARY	720TD
OTHER IN-KIND ANNUAL LABOR	500TD
MISCELLANEOUS SMALL PARTS	300TD
OVERHAUL FREQUENCY (HRS)	5000
OVERHAUL COST	2,234TD
PUMP REPLACEMENT FREQUENCY	5 yrs
ENGINE REPLACEMENT FREQUENCY	15000 hrs
WELL RECONDITIONING COST	15,000TD
WELL RECONDITIONING IN YEAR	11
REGIONAL MAINT.CREW COST	174,000TD
# OF SYSTEMS FOR PRORATING	150
FINANCIAL ASSUMPTIONS	
DISCOUNT RATE	12.0%
PROJECT PERIOD (YRS)	20

INITIAL CALCULATIONS: 08-Aug-89

		ACCOUNTING RATIO	SHADOW PRICE
DEMAND:			
POPULATION 1990	1545		
NUMBER OF FAMILIES	258		
BASE WATER CONS. (m^3/day/fam)	0.30		
BASE WATER CONS. (m^3/day)	77		
BASE WATER CONS. (m^3/yr/fam)	110		
BASE WATER CONS. (m^3/yr)	28,196		
TECHNICAL PARAMETERS			
TOTAL PUMPING HEAD (m):	142		
REQUIRED ENGINE SIZE (KVA):	40		
PUMPING HOURS/DAY IN 1st YEAR	2.1		
PUMPING HOURS IN FIRST YEAR	760		
AVER. ANN PUMP. HRS OVER 20 YRS	1170		
OVERHAUL FREQUENCY (years)	4		
ENGINE REPLACEMENT FREQ.(yrs)	13		
FUEL CONSUMPTION (L/HR)	14.5		
OIL CONSUMPTION (L/HR)	0.36		
FUEL CONSUM./MONTH 1st YEAR (L)	922		
RESERVOIR SIZE (m^3)	50		
TOTAL INVESTMENT COSTS			
WELL COST	105,000TD	0.913	95,813TD
ENGINE/PUMP COST	22,551TD	1.000	22,551TD
RESERVOIR COST	20,142TD	0.725	14,603TD
DISTRIBUTION PIPING	17,000TD	0.725	12,325TD
OTHER CIVIL WORKS COSTS	12,000TD	0.725	8,700TD
ENGINEERING, GOVT SALARIES	8,150TD	1.000	8,150TD
TOTAL	184,843TD		162,141TD
FIRST YEAR OPERATING COSTS (1990)			
NET FUEL AND OIL PRICE/YR	4,283TD	0.800	3,426TD
OPERATOR SALARY	720TD	0.650	468TD
OTHER LABOR	500TD	0.650	325TD
MISC SMALL PARTS	300TD	0.850	255TD
ENGINE OVERHAUL	0TD	0.850	0TD
PUMP REPLACEMENT COST	0TD	1.000	0TD
ENGINE REPLACEMENT COST	0TD	1.000	0TD
WELL RECONDITIONING	0TD	0.900	0TD
REGIONAL COST PER SYSTEM	1,160TD	0.825	957TD
TOTAL	6,963TD		5,431TD

TABLE 2

ASSUMPTIONS AND SOURCES

INITIAL ASSUMPTIONS:

DEMAND:		
POPULATION 1989	1500	Typical value for project site, many different values used here.
POPULATION GROWTH RATE:	3.0%	From Reeser, but commonly used by CTDA.
FAMILY SIZE	6	Figure currently used by CTDA. Reeser used 7.5.
WATER CONSUMPTION (lpd):	50	Derived from Reeser's 47 lpcd. Also AUI uses 50.
CONSUMPTION GROWTH RATE:	1.0%	Estimated. AUI also uses 1%. Reeser had 0%
TECHNICAL PARAMETERS		
TOTAL WELL DEPTH (m):	300	Typical value for project site, many different values used here.
STATIC WATER LEVEL (m):	100	In the absence of site-specific data, a value of 1/3 of well depth used.
PUMPING RATE (l/s)	10	Average used in 14 recent ODTC projects.
SPECIFIC CAPACITY (l/s/M)	0.5	In the absence of site-specific data, this value, from DRE, is used.
DISTRIBUTION PIPING LENGTH	1000	Average used in 14 recent ODTC projects.
RESERVOIR SIZE RATIO	0.5	AUI design guideline. This gives size from mean daily consumption.
PUMP/ELECTRIC MOTOR EFFICIENCY	54.9%	Estimated from local catalogs. Based on pump 67%, electric motor 82%.
ENGINE + GENERATOR EFFICIENCY	17.4%	Estimated from local catalogs and field experience - engine 20%, generator - 87%
INVESTMENT UNIT COSTS		
WELL COST PER m DEPTH	350TD	In the absence of site specific data this estimate by CTDA and RSH used.
ENGINE COST/KVA-COEFFICIENT	2,204TD	Cost function derived from local catalogs. See Wyatt trip report in References.
ENGINE COST/KVA-EXPONENT	0.518	Cost function derived from local catalogs. See Wyatt trip report in References.
PUMP COST PER m^3/hr/m	1.50TD	Estimated average cost in 14 recent ODTC projects.
DISTRIBUTION PIPING	17TD	Average cost in 14 recent ODTC projects.
STANDPOST, TROUGH, ETC	12,000TD	Average cost in 14 recent ODTC projects.
RESERVOIR COST EXPONENT	0.527	Cost function derived from local catalogs. See Wyatt trip report in References.
RESERVOIR COST COEFFICIENT	2563TD	Cost function derived from local catalogs. See Wyatt trip report in References.
UNIT OPERATING COSTS		
FUEL PRICE (TD/L)	0.29	Current market price. Reeser had 0.27 in 1987, and 1988.
OIL PRICE (TD/L)	1.2	Current market price. Reeser had 1.025 in 1987, and 1988
FUEL & OIL PRICE ESCALATION	3%	Estimated. Reeser had 0%
FUEL & OIL TRANSPORT COSTS	10%	Based on conversations with operators. Reeser had same value.
FUEL LOSS/WASTE/PILFERAGE	10%	Estimated. Reeser had 0%
OPERATOR ANNUAL SALARY	720TD	Based on conversations with operators. Reeser had same value.
OTHER IN-KIND ANNUAL LABOR	500TD	Estimated in-kind contribution of community members. Reeser had 0.
MISCELLANEOUS SMALL PARTS	300TD	Based on recent ODTC estimate. Reeser had 330.
OVERHAUL FREQUENCY (HRS)	5000	Estimate. Based on conversation with local mechanics + engineers.
OVERHAUL COST	2,234TD	15% of engine cost. Based on conversation with local mechanics + engineers.
PUMP REPLACEMENT FREQUENCY (yrs)	5	Estimate. Based on conversation with local mechanics + engineers.
ENGINE REPLACEMENT FREQ.(hrs)	15,000	Estimate. Based on conversation with local mechanics + engineers.
WELL RECONDITIONING IN YEAR	11	Based on discussion with DRE and CTDA staff
REGIONAL MAINT.CREW COST	174,000TD	Based on discussion with DRE and CTDA staff
# OF SYSTEMS FOR PRORATING	150	Based on conversation with local officials.
FINANCIAL ASSUMPTIONS		
DISCOUNT RATE	12.0%	Estimated from local interest rates. Reeser had 15% in '87, 10% in '88.
PROJECT PERIOD (YRS)	20	Typical life of drilled wells.

TABLE 3

CALCULATED VALUES AND FORMULAS

INITIAL CALCULATIONS:

DEMAND:		
POPULATION 1990	1545	1989 value + growth (usually 3%)
NUMBER OF FAMILIES	258	Population / family size
BASE WATER CONS. (m^3/day/fam)	0.30	Lpcd * family size / 1000
BASE WATER CONS. (m^3/day)	77	Lpcd * family size * number of families / 1000
BASE WATER CONS. (m^3/yr/fam)	110	Lpcd * family size * 365 / 1000
BASE WATER CONS. (m^3/yr)	28,196	Lpcd * family size * number of families * 365 / 1000
TECHNICAL PARAMETERS		
TOTAL PUMPING HEAD (m):	122	Well depth/3 + (pumping rate/specific capacity) + 15 for tank + 5% for friction
REQUIRED ENGINE SIZE (KVA):	40.0	[pumping rate * total head * grav. constant] / [effic's * cosine (0.8)]] + 25%
PUMPING HOURS PER DAY IN 1ST YEAR	2.1	volume per day / pumping rate
PUMPING HOURS IN FIRST YEAR	765	hours per day * 365
AVER. ANN PUMP HRS OVER 20 YRS	1170	average found from 20 year table (Benefit/Cost tabulation)
OVERHAUL FREQUENCY (years)	4	(overhaul frequency in hours / hours use per year), rounded
ENGINE REPLACEMENT FREQ (yrs)	13	(engine life in hours / hours use per year), rounded
FUEL CONSUMPTION (L/HR)	14.5	(pumping rate * total head * grav. const)/(effic.* fuel energy content)
OIL CONSUMPTION (L/HR)	0.36	2.5% of fuel consumption, which is typical.
FUEL CONSUM./MONTH 1st YEAR (L)	922	hourly consumption * use.
RESERVOIR SIZE (m^3)	50	(mean daily consumption * size ratio), rounded up to nearest multiple of $25m^3$
TOTAL INVESTMENT COSTS		
WELL COST	105,000TD	depth * cost per m
ENGINE/PUMP COST	22,551TD	size * cost per kva + rate * head * cost per m^3/hr/M.
RESERVOIR COST	20,142TD	from size and cost formula.
DISTRIBUTION PIPING	17,000TD	from length and unit cost
OTHER CIVIL WORKS COSTS	12,000TD	from initial assumption
ENGINEERING, GOVT SALARIES	8,150TD	based on engineering fee on 20 sites and CTDA salaries for 30 systems.

TOTAL	169,843TD	
FIRST YEAR OPERATING COSTS		
NET FUEL AND OIL PRICE/YR	4,283TD	(consumption + waste) * price + transport
OPERATOR SALARY	720TD	from initial assumption
OTHER LABOR	500TD	from initial assumption
MISC SMALL PARTS	300TD	from initial assumption
ENGINE OVERHAUL	0TD	not in first year
PUMP REPLACEMENT COST	0TD	"
ENGINE REPLACEMENT COST	0TD	"
WELL RECONDITIONING	0TD	"
REGIONAL COST PER SYSTEM	1,160TD	total regional cost / # of systems maintained
	----------	
TOTAL	6,963TD	

The new model assumes accounting ratios to calculate shadow prices from market values, as did Reeser. While available data are limited, several economic studies were collected and reviewed. The table below shows assumed accounting ratios for labor and commodity categories. There is little variation among sources for some items, but a wide variation for others. For example, diesel fuel varied from 1.38, in a 1984 World Bank irrigation project appraisal report, to 0.60 (for diesel energy) in the 1987 SCET irrigation studies. The high value in the World Bank report was chosen because of high subsidies which were in place at the time. These subsidies have been lifted, so more recent estimates are lower. Nonetheless, reliable current estimates for these accounting ratios are not available. So the best possible estimate was made based on these data and specific anecdotal information on the different commodities. This analysis uses these best estimates in the table below.

In Chapter 6, sensitivity of the model to these accounting ratios is explained. In general, the sensitivity is low. However, the model is rather sensitive to the accounting ratio for unskilled labor, as this is applied to the total project benefits. As can be seen in the table, the variation among sources is low for this parameter.

	Source				Values Used in This Analysis
	World Bank (1984)	Reeser (1987)	SCET (1987)	AIRD (1987)	
General					
Unskilled Labor	0 75	0 65	0.65	—	0 65
Semiskilled labor	—	0 82	—	0 86	0.825
Skilled Labor	0 80	1.00	1 00	—	1 00
Local Materials					0 80
Imported Materials					1 00
Specific					
Well Drilling	—	0 85	0 909	—	0.913[1]
Civil Works	0 54	0 77	0.955		0.725[2]
Diesel Fuel, Oil	1 38	0 70	(0 60)	0 98	0.80[3]
Small Parts	0.63	0 85	—	0.75	0 85[4]
Overhauls	—	—	—		0 85[5]
Pumps, Engines	0 77 (local)	0.85	0.68 (local)		1 00[6]
Maintenance Labor					0 825[7]
70 hp Tractor	0 77	0 97	0 97	0.94	—
Well reconditioning	—	—	—	—	0 90[8]

NOTES

1 1/2 Imported Materials + 1/2 Semiskilled Labor = (1+ 825)/2 = 0.913
2 1/2 Local Materials + 1/2 Unskilled Labor
3 Local Material
4 3/4 Local Material + 1/4 Imported Material
5 3/4 Local Material + 1/4 Imported Material
6 Imported Material
7 Semiskilled labor
8 1/2 Local Material + 1/2 Skilled Labor

KEY DIFFERENCES BETWEEN THE IDA MODEL AND THE NEW COST MODEL

- Reeser used older cost data, not based on experience with the current ty pe of project. Real historical data are used here.
- Reeser did not account for the causal link between depth, pumping rate, and fuel consumption. This analysis uses relevant engineering formulas.
- Reeser did not include overhaul costs, costs of regional support crews, e ngineering, and government agents' salaries, all of which are directly li nked to the establishment and O&M of these systems and are included here.

Box 2

Chapter 5

BENEFIT CALCULATIONS

5.1 IDA Approach

Reeser's calculation of benefits of rural water projects is based on time savings for users and an estimate of the economic value of time. He assumes, logically, that creation of a water point will save time for the families nearby by reducing the distance they have to travel.

Reeser estimates the time savings from data collected by Smith, in a rural survey of 40 families, in 1985. Those results indicated that the average family spends about 60 hours per week collecting water. Reeser assumes the new project will save half of this time, but gives no basis for this assumption. The time spent on collecting water was estimated as 37 percent by men, 39 percent by women, and 29 percent by children. Reeser assumes that the benefit of the water project will be that men won't have to go for water any more; women can now do it because the well is closer. Social convention dictates that a woman may not travel with a donkey cart to a distant well. So the benefits can be found from the earning power of the men who no longer have to haul water. He uses the local minimum wage at the time (0.362TD), multiplied by the employment rate (72 percent), multiplied by the accounting ratio for unskilled labor (65 percent) to estimate the value of the men's time.

To review:

Benefits = 60 hrs/wk * 50% savings * 37% men * 0.362 TD/hr * 72% empl.* 52 weeks * 65% economic value

= 577 hrs/yr * 0.261 TD * 65% (accounting ratio)

= 97 TD / family / year.

Reeser used this value for all people living within 4 km of a new water point. He also assumed people living from 4 to 7 km would get fewer benefits, being further away, and used a value of 20TD per family per year, or one-fifth of the benefits for the closer residents, for them.

There are several questionable aspects to this calculation. First of all, the figure of 60 hours per week seems high. The consultant's experience from visiting more than 10 villages in Central Tunisia and discussing these issues with countless people (in February 1989) is that on average people don't spend anywhere near this amount of time. People with donkey carts of 500 liter capacity won't travel that much. Perhaps the difference between this finding and Smith's is due to the more widespread use of donkey carts which has been promoted by the government in the past several years. Unfortunately, little is known about how or from whom Smith collected the reported numbers.

Secondly, the assumption that the benefits derive only from time savings by men seems wrong and short-sighted. Men, women, and children all participate in the collection of water, and women are generally believed to play a major if not predominant role in the collection and use of water. Their role may be much more dominant in the use than in the collection and transport of water. It is true, however, that a long trip to a distant well is more likely to be the job of a man. If men are liberated from this task because the water is closer, they do, in theory, have the opportunity to earn more money. But the women or children still have to collect the water. In fact they may have a new burden. Their time certainly has a value as well. At present there are insufficient recent reliable data on who collects water, distances traveled, mode of transport, and time spent. Despite the inability to be precise on these issues, the most important point in the benefit calculation remains that the distance traveled will be less, no matter who is going for water, how, or for what purpose.

5.2 The Revised Approach

A true benefits calculation would be based on the change in consumer surplus as a result of the project. This type of calculation would have to be based on current and future price of water, be it price in currency or in time to collect it, and a demand function, relating price and consumption. Separate demand information might be needed for drinking water, livestock watering, and small irrigation. Unfortunately such demand data are simply not available for rural Tunisia. The estimation of these demand data requires a major field study.

In order to make some improvements in the computation of benefits, a revised approach was developed based on the limited data available currently. This approach uses travel time savings as the basic benefit. In addition, the approach uses an empirical estimate of the value of time, derived from the overall behavior of the rural population in the region. This value of time is independent of the person traveling and of the intended use of water.

Project Radius and Distance Savings

The computation of travel distance savings must be based on a definition of the travel distance before and after the site water supply project. While investigating a location as a site for a water system, CTDA staff visit the area and determine where the population usually goes for water. Typically this involves travel to a well, which might be 6, 8, 10 or even 12 km away. Some villagers may travel themselves, and some will buy from vendors who make the trip. This represents the one-way travel distance before the project.

The travel distance after the project can be established in several ways. One approach, consistent with the long-term norm of the Ministry of Plan, would be to assume everyone within a 3 km radius is a beneficiary, and that the average travel distance after the project would be 1.5 km (one way), which assumes that the population density is uniform within that 3 km radius. Reeser did something like that but used 4 km, and assumed that people as far as 7 km away would also benefit to a lesser degree.

Discussions with CTDA staff led to another approach. It seemed most logical to think of a project radius, not of 3 km but of a distance equal to one-half the distance to the closest existing well. For example, a site with an existing well 10 km away would have a project radius of 5 km. Anyone who lived 6 km away from the site would tend to go to the existing well, rather than the new one, even after the new one was built. Then the new travel distance would be equal to one-half the project radius, or 2.5 km for the example above. In the end, the average travel distance savings would be, by simple mathematics, three-fourths of the distance to the existing well.

This approach argues that people at very isolated sites would tend to have more distance savings than those not very far from an existing source. This logical effect is certainly an improvement over Reeser's uniform use of 4 km and 7 km. It was recognized that such a calculation is still approximate because, in reality, populations are not uniformly distributed, and wells are not evenly spaced around a topographically uniform countryside. Trying to be any more precise would force the method to be totally site-specific, which was undesirable in such an analysis. This approach does represent a more realistic and logical model of these small water projects and the way people behave.

The population served by the project must be computed in relation to the project radius. CTDA staff typically collect population data within a radius of 3 km and 6 km. If the project radius is 4 km, an estimated beneficiary population can be found by adding the population within 3 km and a prorated portion of the population between 3 and 6 km, as shown in Box 3 below.

Time Savings

The time savings can be directly computed from distance savings, the average speed of travel, and the number of trips taken per year (which in turn depends on the water consumed and the transport capacity), as described in Box 4 below. These calculations were made for the people who use donkey carts.

POPULATION COMPUTATION

Population for a Project Radius of R when 3 < R < 6	=	Population inside 3 km	+	Land Area from 3 => R	*	Population Density of area 3 => 6 km

This assumes that the population density in the area from 3km to R is the same as the population density from 3 to 6 km, which will not always be accurate, but seems reasonable. Algebraic simplifications leads to:

$$\text{Population for Project Radius of R when } 3 < R < 6 = \frac{[P_3 \times (6^2 - R^2)] + [P_6 \times (R^2 - 3^2)]}{(6^2 - 3^2)}$$

where :

P_3 = Population within 3 km

P_6 = Population within 6 km

Box 3

Value of Time

The average value of time for water users in rural Central Tunisia can be estimated from their current overall behavior. The choice people must make in obtaining water is between spending time in the donkey cart and buying water from vendors. Knowledge about people's behavior when faced with this choice (time or money) leads to an estimate of the value of time. Local villagers and government officials estimate that currently about 50 percent buy their water from vendors and 50 percent use 500 liter donkey carts. If half choose one option and half choose the other, it could be said that the average family is indifferent to the two options. Thus we can write an equation equating the cost of the two options, as shown in Box 5. This notion that behavior can lead to an assessment of the value of time is fundamental to this approach and is derived from field work by Whittington, et al. (see References).

TIME SAVINGS COMPUTATION

Time Savings/Family/Yr = Time Savings/Trip * Trips/Family/Yr

$$= \frac{2 \times (D_1 - D2)}{S} * \frac{P \times Q \times 365}{C}$$

where·

- D = Distance to closest existing source of water, km
- D_1 = Travel distance before project, km = D
- D_2 = Travel distance after project, km = (D/2)/2 = D/4
- S = Travel speed, km/hr - (A value of 5 km/hr was generally used)
- P = People per family - (A value of 6 was generally used)
- Q = Water use, l/person/day - (50 l/p/d was generally used)
- C = Cart water capacity - (A value of 500l was generally used)

Combining the simplifications and assumed values above, the result is:

$$\text{Time Savings/Family/Yr} = \frac{2 \times (D - D/4)}{5} * \frac{6 \times 50 \times 365}{500}$$

= 65.7 D , in hours/family/year

@ D = 4 km = 263 hours/year or 5.0 hours/week
@ D = 6 km = 394 hours/year or 7.6 hours/week
@ D = 8 km = 526 hours/year or 10.1 hours/week
@ D = 10 km = 657 hours/year or 12.6 hours/week

Note that these savings are far less than the values used by Reeser (30 hrs/week or 1560 hours/yr). However if Reeser's value of 37% male labor is applied the "valued" time savings falls to 577 hrs/yr or 11.1 hrs/week, which is similar to the values above.

It is also important to realize that if only 40 l/trip are carried, as would be the case of a person walking with a donkey, the results are very much higher. Thus the quantity hauled is a very important variable.

Box 4

VALUE OF TIME ESTIMATION

MEANS OF OBTAINING WATER: BUYING FROM VENDORS or USING DONKEY CART

COST OF OBTAINING WATER:

$$\text{Price of water paid to vendor} = \left[\text{Value-of-time}\right] \cdot \left[\text{Travel Time}\right] + \left[\text{Price of water paid at well}\right]$$

By re-arranging we obtain:

$$\text{Value-of-time} = \frac{\text{Price of water paid to vendor} - \text{Price of water paid at well}}{(\text{Travel Time})}$$

Given that

Vendor Price (TD) = (2 + 0.75 x D) for 3.5 m3 of water.
0.571 + 0.214 D , in TD/m3

where D = distance traveled (one way)

Note: this formula is based on informal surveys in several communities in the CTDA area in February 1989.

Price at Well (TD) = 0.100 TD for 0.5 m3 = 0.200 TD/m3

Travel Time (hrs/m3) = (2 D / S) / C

where:
S = Travel speed, km/hr - (5 km/hr)
C = Cart water capacity - (0.5 m3)

The following results are obtained:

D	Value-of-time
3km	0.423 TD
6km	0.345 TD
9km	0.320 TD

Note that the value-of-time does not depend heavily on the travel distance. For benefit calculations the value-of-time @ 6 km was used, as this distance seems the best overall estimate of the "average" travel distance for the Kasserine/Gafsa rural population. Note that the current minimum agricultural wage is 0.400 TD, indicating that the above values of time are rather high

Box 5

Benefit Calculations

An overall assessment of benefits can be obtained by multiplying the estimated average value of time by the travel time savings per family per year. Box 6 shows the results. The economic value of these benefits was found by multiplying the direct benefits by the assumed accounting ratio for unskilled labor (0.65, as discussed in Chapter 4). These results can be multiplied by the number of families in the project radius to get total project benefits.

BENEFITS COMPUTATION

Travel Distance Before	Project Radius	Travel Distance After	Distance Savings	Time Savings per family/yr	Value-of-Time	Benefits per family per yr	Economic Benefits per family per yr
4km	2km	1.0km	3.0km	263 hrs	0.345TD	91TD	59TD
6	3	1.5	4.5	394	0.345	136	88
8	4	2.0	6.0	525	0.345	182	118
10	5	2.5	7.5	657	0.345	227	148
12	6	3.0	10.0	788	0.345	272	177

Box 6

The values of benefits per family per year are somewhat higher than those calculated by Reeser, who estimated 98TD for people up to 4 km away, and 20TD for people out to 7 km. The difference between Reeser's results and these is mostly due to higher value of time in this analysis.

There are a number of aspects of this benefit calculation which must be discussed. First of all, value of time was estimated from behavior of the group as a whole, and thus is used to compute benefits for the group, that is, the average value of time is used to get the average family benefits. It is very likely that many families will have a higher value of time, and others much lower. But there are insufficient data to estimate these variations, and average values must be used.

Secondly, the benefits could be computed differently—by adding the cash savings of those who buy from vendors and the value of travel time savings of those who do not. True financial benefits to families who use vendors could be computed by estimating the drop in vendor prices due to decreased travel distance, using the simple price formula shown in Box 5. There does appear to be sufficient competition among vendors so that decreased travel distances will lead to cash savings for the buyers. However, the calculation of the value of travel time savings for those who do not buy from vendors becomes difficult. These people will have a value of time different from our global estimate (probably lower). In fact, there are no data upon which to estimate the value of time for these people. Thus it appears better to compute benefits for all families based on travel time savings, using the one available value of time estimate.

Thirdly, this approach, because it is based on people's behavior, reflects people's own valuation of benefits. It assesses, although with only limited data, what families are willing to pay (in time or cash) for water—which helps estimate the value they place on it. This computation of benefits does not assume people are using the water for any particular purpose, so it makes no inferences about benefits associated with use. For example, no grand assumptions are made on the improved condition of livestock in the area, or increased family revenue or nutrition from irrigation water. People's behavior permits the measurement of their own assessment of all these benefits. Nor does this computation make any assumptions about what people might do in the free time they have now that water is closer. It could be stated, however, that rural people do not fully appreciate the potential health benefits from larger quantities of cleaner water, and that these benefits are not counted. This is probably true, but the quantitative assessment of these benefits is very difficult.

Fourthly, this approach assumes that people's consumption of water is basically inelastic, that is, it assumes that people will consume the same amount of water (50 lpcd) before and after the project. This is probably not true, although the extent of the increase in consumption could be small for some families and large for others, and may change over time. A general increase of 1 percent in per capita water consumption per year is assumed to try to address this issue.

A much better assessment of project benefits is possible, given the upcoming field research planned for the project. Such field data collection should assess the behavior of different types of water users before and after the installation of water systems in several villages. Surveys should collect data from randomly selected families in selected communities. Questions should examine behavior (water use, time spent, cash spent, person traveling) for families who before the project walked for water, who went in donkey carts, or who bought from vendors. Families who use two or three of these collection methods should also be surveyed. Additional data on income, occupations, family size, education level, and basic health conditions should also be collected at the same time, for correlation with water use patterns. Surveys should be conducted before and after water systems are installed, allowing quantitative assessment of behavioral and consumption changes, as well as cash or time savings, leading to better estimates of benefits.

Chapter 6

RESULTS

6.1 Comparison of Benefits and Costs

Costs and benefits were combined in a Lotus 123 worksheet, using a 20-year project period. A discount rate of 12 percent was used, based on current bank lending rates. Initial investments are assumed to occur in year zero, during construction. Benefits and operating costs are assumed to start in the first year, and continue through the twentieth year. Tables 4, 5, 6 and Figure 1 show inputs and results for a hypothetical example of 1,500 people within a project radius of 4 km, with a previous travel distance of 8 km and an estimated well depth of 300 m. Results show a B/C ratio of 1.25 and an IRR of 16.7 percent.

Table 4

BASIC INPUT OUTPUT COMPUTER SCREEN

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 20-Feb-90

INPUTS:		RESULTS:	
SITE:	SAMPLE	INITIAL FIN. INVESTMENT	176,693TD
DELEGATION:		INITIAL INVEST/PERSON	118TD
GOUVERNORAT:		TOTAL ECON. PV COST	234,884TD
POPULATION 3 KM 1989:	1500	TOTAL ECON COST/PERSON	157TD
POPULATION 6 KM 1989:	1500	TOTAL ECON. COST/m^3	0.279TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	1170
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	12,060TD
POPULATION SERVED 1989	1500	COMMUN. CONTRIB. TO O&M	7,720TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	300	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	100	TOTAL ECON. PV BENEFITS	293,809TD
PUMPING RATE (l/s):	10	NET PRESENT VALUE	58,925TD
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	1.25
DISCOUNT RATE:	12%	IRR	16.7%
ESTIMATED WELL COST/m	350TD		

Table 5

INITIAL BENEFIT AND COST CALCULATIONS

DETAILED ASSUMPTIONS:

DEMAND:	
POPULATION 1989	1500
POPULATION GROWTH RATE:	3.0%
FAMILY SIZE	6
WATER CONSUMPTION (lpd):	50
CONSUMPTION GROWTH RATE:	1.0%
TECHNICAL PARAMETERS	
TOTAL WELL DEPTH (m):	300
WELL STATIC WATER LEVEL(M)	100
PUMPING RATE (l/s)	10
SPECIFIC CAPACITY (l/s/M):	0.5
DISTRIBUTION PIPING LENGTH (	1000
RESERVOIR SIZE RATIO	0.5
PUMP/ELECTRIC MOTOR EFFICIEN	54.9%
ENGINE + GENERATOR EFFICIENC	17.4%
INVESTMENT UNIT COSTS	
WELL COST PER m DEPTH	350TD
ENGINE COST/KVA - COEFFICIEN	2,204TD
ENGINE COST/KVA - EXPONENT	0.518
PUMP COST PER m^3/hr/m	1.50TD
DISTRIBUTION PIPING	17TD
STANDPOST, TROUGH, ETC	12,000TD
RESERVOIR COST EXPONENT	0.527
RESERVOIR COST COEFFICIENT	2563
UNIT OPERATING COSTS	
FUEL PRICE (TD/L)	0.29
OIL PRICE (TD/L)	1.2
FUEL & OIL PRICE ESCALATION	3%
FUEL & OIL TRANSPORT COSTS	10%
FUEL LOSS/WASTE/PILFERAGE	10%
OPERATOR ANNUAL SALARY	720TD
OTHER IN-KIND ANNUAL LABOR	500TD
MISCELLANEOUS SMALL PARTS	300TD
OVERHAUL FREQUENCY (HRS)	5000
OVERHAUL COST	2,234TD
PUMP REPLACEMENT FREQUENCY	5 yrs
ENGINE REPLACEMENT FREQUENCY	15000 hrs
WELL RECONDITIONING COST	15,000TD
WELL RECONDITIONING IN YEAR	11
REGIONAL MAINT.CREW COST	174,000TD
# OF SYSTEMS FOR PRORATING	150
FINANCIAL ASSUMPTIONS	
DISCOUNT RATE	12.0%
PROJECT PERIOD (YRS)	20
PARAMETERS FOR BENEFIT CALCULATION	
PREVIOUS MEAN TRAVEL DISTANCE	8
NEW MEAN TRAVEL DISTANCE (km	2
DONKEY CART CAPACITY (L)	500
DONKEY CART TRAVEL SPEED (KM	5
VALUE OF TIME (TD/HR)	0.345TD

INITIAL CALCULATIONS:

		ACCOUNTING RATIO	SHADOW PRICE
DEMAND:			
POPULATION 1990	1545		
NUMBER OF FAMILIES	258		
BASE WATER CONS. (m^3/day/fam)	0.30		
BASE WATER CONS. (m^3/day)	77		
BASE WATER CONS. (m^3/yr/fam)	110		
BASE WATER CONS. (m^3/yr)	28,196		
TECHNICAL PARAMETERS			
TOTAL PUMPING HEAD (m):	142		
REQUIRED ENGINE SIZE (KVA):	40		
PUMPING HOURS/DAY IN 1st YEAR	2.1		
PUMPING HOURS IN FIRST YEAR	760		
AVER. ANN PUMP. HRS OVER 20 YRS	1170		
OVERHAUL FREQUENCY (years)	4		
ENGINE REPLACEMENT FREQ.(yrs)	13		
FUEL CONSUMPTION (L/HR)	14.5		
OIL CONSUMPTION (L/HR)	0.36		
FUEL CONSUM./MONTH 1st YEAR (L)	922		
RESERVOIR SIZE (m^3)	50		
TOTAL INVESTMENT COSTS			
WELL COST	105,000TD	0.913	95,813TD
ENGINE/PUMP COST	22,551TD	1,000	22,551TD
RESERVOIR COST	20,142TD	0.725	14,603TD
DISTRIBUTION PIPING	17,000TD	0.725	12,325TD
OTHER CIVIL WORKS COSTS	12,000TD	0.725	8,700TD
ENGINEERING, GOVT SALARIES	8,150TD	1.000	8,150TD
TOTAL	184,843TD		162,141TD
FIRST YEAR OPERATING COSTS (1990)			
NET FUEL AND OIL PRICE/YR	4,283TD	0.800	3,426TD
OPERATOR SALARY	720TD	0.650	468TD
OTHER LABOR	500TD	0.650	325TD
MISC SMALL PARTS	300TD	0.850	255TD
ENGINE OVERHAUL	0TD	0.850	0TD
PUMP REPLACEMENT COST	0TD	1.000	0TD
ENGINE REPLACEMENT COST	0TD	1.000	0TD
WELL RECONDITIONING	0TD	0.900	0TD
REGIONAL COST PER SYSTEM	1,160TD	0.825	957TD
TOTAL	6,963TD		5,431TD
BENEFIT CALCULATION			
SAVINGS TRAVEL DISTANCE (1 way)	6		
DAYS BETWEEN TRIPS 1st YEAR	1.67		
TRIPS PER YEAR 1st YEAR	219		
TOTAL TRAVEL SAVED/FAMILY(km/yr	2628		
TIME SAVINGS/FAMILY (hrs/yr)	526		
TIME SAVINGS/FAMILY/WEEK (hrs)	10.1		
ANNUAL BENEFITS/FAMILY 1st YEAR	181TD	0.650	118TD
TOTAL BASE YEAR BENEFITS	46,693TD	0.650	30,350TD

Table 6

20 YEAR TABULATION OF BENEFITS AND COSTS

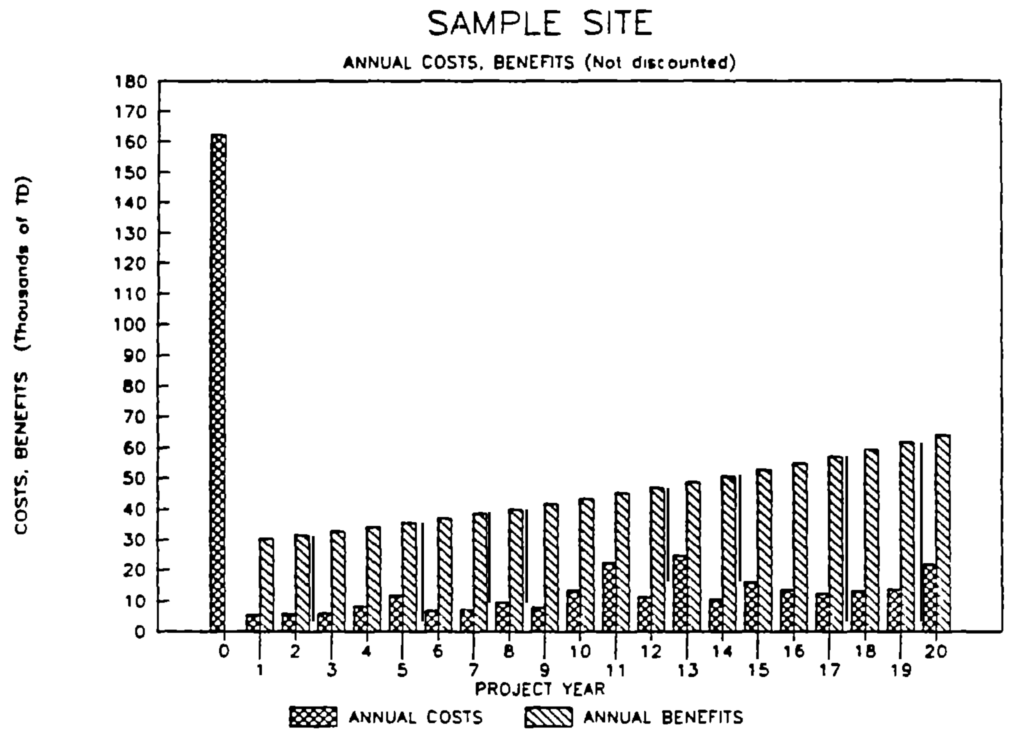
BENEFIT / COST TABULATION   SAMPLE SITE

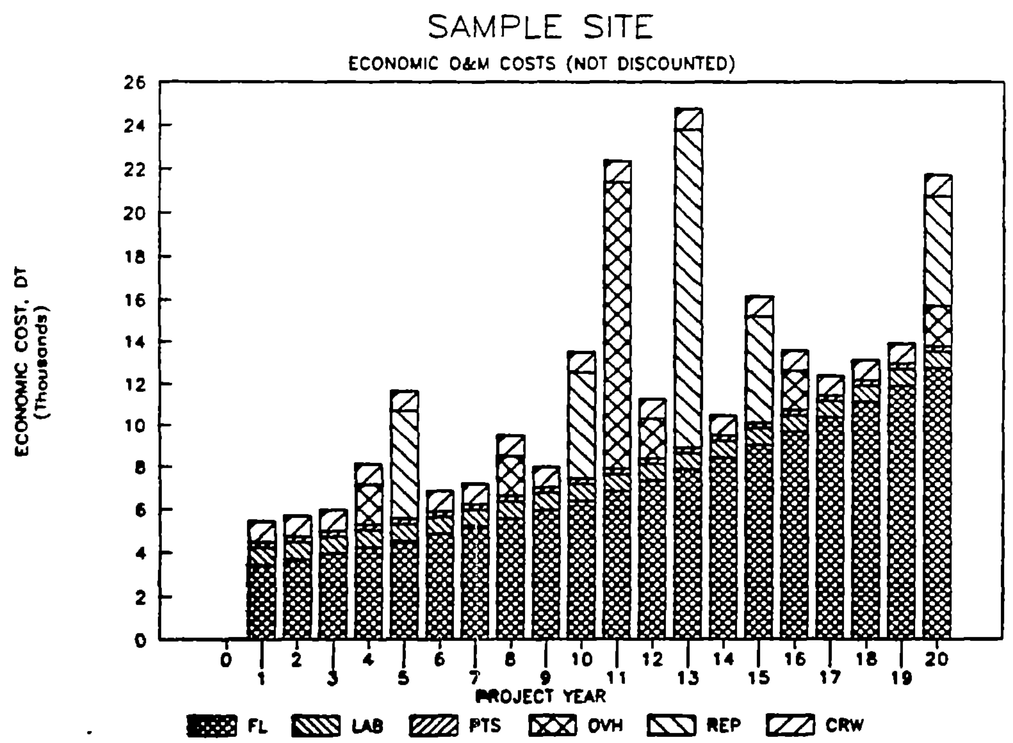
21-Feb-90

PROJECT YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
YEAR	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
POPULATION	1500	1545	1591	1639	1688	1739	1791	1845	1900	1957	2016	2076	2139	2203	2269	2337	2407	2479	2554	2630	2709
WATER DEMAND (m3/day)	77	80	84	87	90	94	98	102	106	110	115	119	124	129	134	140	145	151	157	164	170
PUMPING HOURS per day	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.4	3.6	3.7	3.9	4.0	4.2	4.4	4.5	4.7
INVESTMENT COSTS, TD																					
Well	95813	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	66329	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	162141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OPERATING COSTS, TD																					
Fuel, Transport, Oil	0	3426	3671	3934	4215	4517	4840	5186	5557	5954	6380	6836	7325	7848	8410	9011	9655	10346	11086	11878	12728
Operator, Other Labor	0	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793
Misc Small Parts	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
Overhauls+Well Reconditi	0	0	0	0	1899	0	0	0	1899	0	0	13500	1899	0	0	0	1899	0	0	0	1899
Major Replacements	0	0	0	0	0	5103	0	0	0	0	5103	0	0	14896	0	5103	0	0	0	0	5103
Regional Mainten. Crew	0	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957
Total	0	5431	5676	5939	8119	11625	6845	7191	9461	7959	13488	22341	11229	24750	10415	16119	13560	12351	13091	13883	21735
O&M COSTS PER m3	0	0.185	0.186	0.187	0.246	0.338	0.192	0.193	0.245	0.198	0.322	0.513	0.248	0.525	0.212	0.316	0.256	0.224	0.228	0.232	0.350
TOTAL ANNUAL COSTS	162141	5431	5676	5939	8119	11625	6845	7191	9461	7959	13488	22341	11229	24750	10415	16119	13560	12351	13091	13883	21735
DISCOUNTED COSTS	162141	4849	4525	4227	5160	6596	3468	3253	3821	2870	4343	6422	2882	5672	2131	2945	2212	1799	1702	1612	2253
PRESENT VALUE OF COSTS	234884																				
PV OF COSTS PER PERSON	157																				
PV COST PER m3	0.279																				
BENEFITS																					
NUMBER OF FAMILIES	250	258	265	273	281	290	299	307	317	326	336	346	356	367	378	389	401	413	426	438	452
BENEFITS PER FAMILY	0	118	119	120	121	123	124	125	126	128	129	130	131	133	134	135	137	138	140	141	142
TOTAL BENEFITS	0	30350	31574	32846	34170	35547	36979	38470	40020	41633	43310	45056	46872	48761	50726	52770	54896	57109	59410	61804	64295
DISCOUNTED BENEFITS	0	27099	25170	23379	21715	20170	18735	17402	16163	15013	13945	12952	12031	11175	10379	9641	8955	8318	7726	7176	6665
PRESENT VALUE OF BENEFITS	293809																				
PV OF BENEFITS PER PERSON	196																				
PV BENEFITS PER m3	0.349																				
BENEFITS / COSTS	1.25																				
NET PRESENT VALUE	58925																				
NPV PER PERSON	39																				
NET ECONOMIC "CASH FLOW"	-162141	24919	25897	26907	26050	23922	30135	31279	30559	33674	29823	22715	35643	24011	40311	36651	41337	44758	46320	47921	42560
INTERNAL RATE OF RETURN	16.7%																				
CUMULATIVE COST (000 DT)	162	167	172	176	181	187	191	194	198	201	205	212	215	220	222	225	228	229	231	233	235
CUMULATIVE BENEFIT (000DT)	0	27	52	76	97	118	136	154	170	185	199	212	224	235	245	255	264	272	280	287	294
CUMULATIVE NPV (000 DT)	-162	-140	-119	-100	-84	-70	-55	-41	-28	-16	-6	0	9	15	23	30	36	43	49	55	59

FIGURE 1

Model Results





The results from this new model and Reeser's results are compared in Box 7. (Details of the results are given in Appendix C.) To be consistent, several of Reeser's inputs were used as inputs here—for example, discount rate (10 percent), populations (see Box 7), and drilling costs (see Box 7)[1]. It is clear that the new analysis yields consistently higher IRRs, indicating the economic feasibility of these projects is much higher than initially calculated. This difference can be attributed mostly to increased benefits, in turn due to the increased value of time.

COMPARISON OF ECONOMIC ANALYSES

SITE	ASSUMED POPULATION	ASSUMED WELL COST	REESER IRR	THIS ANALYSIS IRR	THIS ANALYSIS B/C
Biadha	1104	525 TD/m	3.6%	12.4%	1.16
Zannouche	1752	439	8.6%	20.1%	1.59
El Jadida	938	362	-0.5%	5.7%	0.80
Ouled Zid	333	398	-7.4%	-3.8%	0.40
Ouled Boullalegue	439	362	-7.0%	-3.7%	0.41
Kodiat Tricha	1393	348	4.9%	13.3%	1.19
Serg Lahmar	956	348	0.9%	7.8%	0.89
Toulabia	814	348	1.4%	9.1%	0.97
Brahim Zahhar	2315	348	11.5%	23 1%	1.68
Ouled Ahmed	2181	348	16.7%	32.3%	2.24

Note In order to compare to Reeser's results, the new model was computed using 10% discount rate, and using a project radius of 4km (old travel distance of 8 km), for all sites

Box 7

6.2 Results—Model Sensitivity

An analysis such as this will be sensitive to the input parameters to some extent. A model can be said to be sensitive to a particular variable if a moderate change in the variable leads to a large change in the results. Ideally, sensitive parameters should be identified, and careful determination made of input data for these variables.

Some parameters are site-specific, such as well depth, population, and distance traveled. Other parameters should be considered internal to the model, such as discount rate, value of time, or accounting ratios. Still other variables will be well-defined and subject to little

[1] Reeser derived his population estimates from the Water Resources Mapping Study Maps. After Reeser completed his study in Feb. 1988, field work was conducted by OTDC on actual populations around most of these sites. Most had higher populations than Reeser's estimates, so current economics will be different.

variation, such as the diesel fuel price, or the cost of piping. Model sensitivity to site-specific parameters is not of much concern, as such parameters are so fundamental to a project that field survey data will be collected and entered into the model. Similarly, sensitivity to variables which change little may be interesting but not of much consequence. But if the model is highly sensitive to internal or poorly defined parameters like value of time or discount rate, this fact must be recognized and results used with a comprehension of the sensitivity to the assumed values.

A full sensitivity analysis was not carried out for lack of time. However, sensitivity to selected key parameters, including population, well depth, original distance traveled, discount rate, water use (lpcd), value of time, and pumping rate, was studied.

Using the base case of 1,500 people, 8 km old travel distance, and 300 m well depth, and results of a B/C ratio of 1.25 and an IRR of 16.7 percent, the sensitivity of the model can be gauged. Box 8 shows B/C and IRR values for alternative assumptions.

Sensitivity can also be examined by calculating large tables of results for multiple input values. Sensitivity to population, well depth, and travel distance is given in Tables 8, 9, and 10. Sensitivity to the other parameters is shown in Appendix B. Sensitivity to all these parameters is relatively strong, with the exception of pumping rate. The model is quite insensitive to pumping rate because a high pumping rate leads to high pump costs, but also to short pumping periods, decreased engine running periods, and decreased and forestalled maintenance. The pump capital cost and discounted maintenance cost trade off fairly equally.

Additional sensitivity analysis was performed on the economic conversion factors (accounting ratios) to assess their importance. The results are shown graphically in Figure 2. The accounting ratios were decreased (and increased) by fixed percentages and the absolute value and the percentage change in the B/C ratio computed. For example, a 20 percent drop in the accounting ratio for semiskilled labor (from 0.825 to 0.660) results in a change in the B/C ratio from the base case value of 1.25 to 1.31, which is a 4 percent change. Clearly the model is not very sensitive to this accounting ratio, at least under conditions like the base case included here. In fact, Figure 2 shows that only the unskilled labor accounting ratio has a significant impact on the results, because it impacts all the project benefits. As noted earlier, this parameter is generally accepted to be in the range of 0.6-0.7, so this sensitivity has no major impact on the usefulness of the model.

Other parameters, whose sensitivity remains to be investigated, include:

- population growth rate
- engine/pump efficiency
- distribution piping length (impacts both costs and benefits)
- fuel price
- fuel price escalation

- parts cost
- travel speed
- water transport capacity
- water market price
- vendor price for water

The last few variables in this list could significantly impact the benefits. For this reason, field data collection on benefits is necessary.

SENSITIVITY OF THE ECONOMIC ANALYSIS MODEL

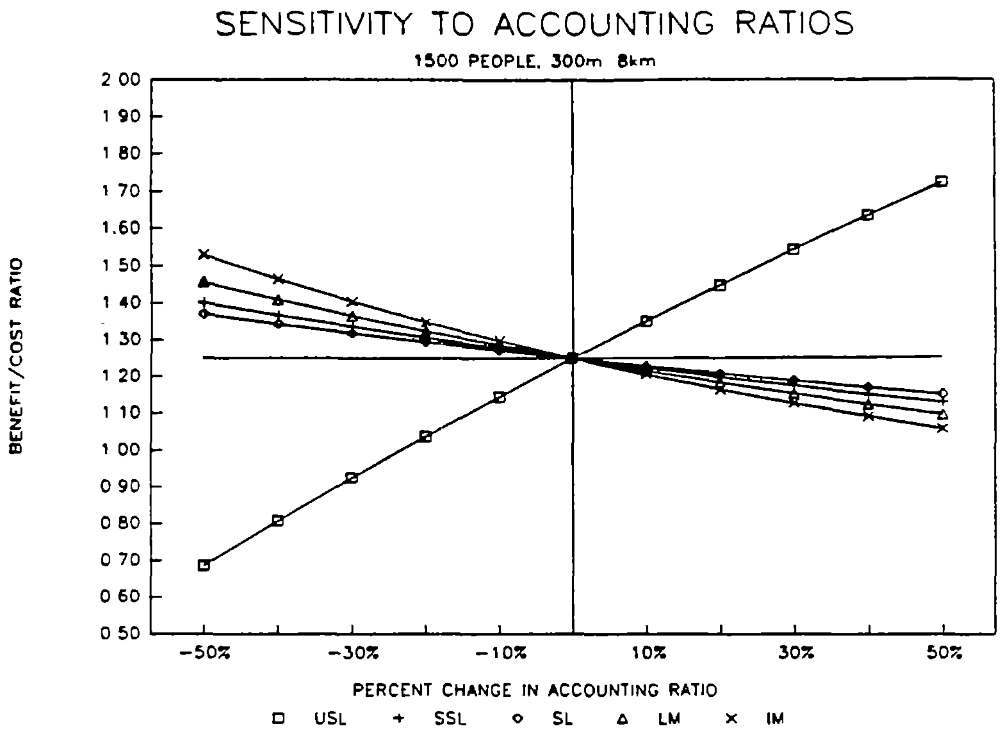
BASE CASE: 1500 people, 8 km old travel distance, 300 m well depth

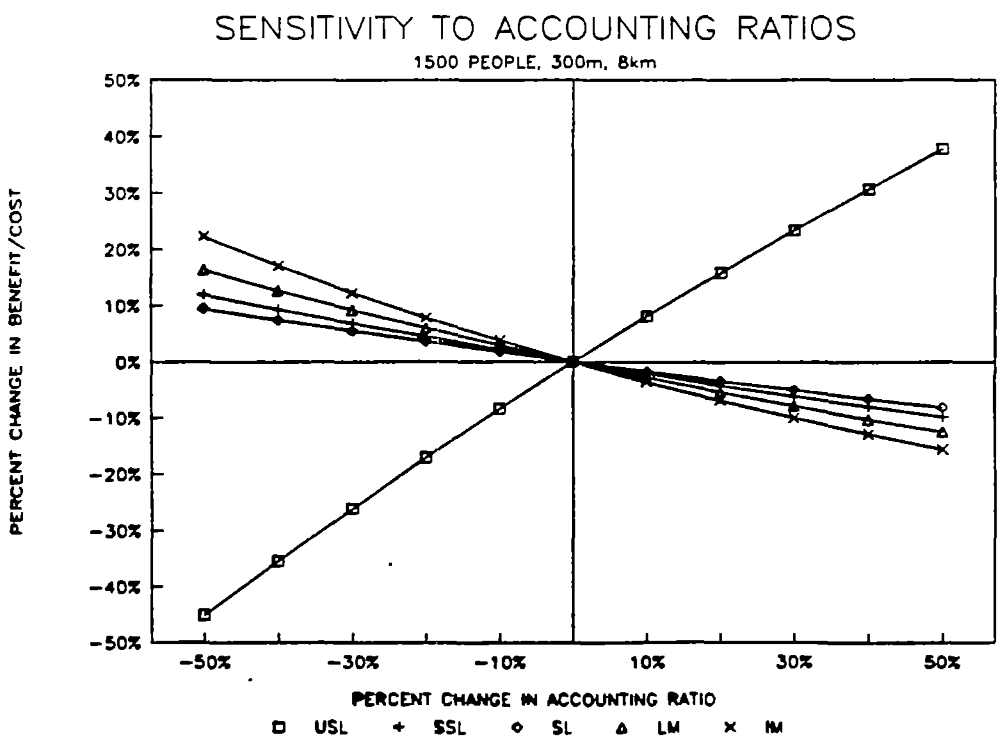
VARIABLE	LOW	BASE CASE	HIGH
POPULATION	1000	1500	2000
B/C =	0.90	1.25	1.53
IRR =	9.6%	16.7%	22.4%
WELL DEPTH	200	300	500
B/C =	1.58	1.25	0.89
IRR =	22.6%	16.7%	9.3%
TRAVEL DISTANCE	4	8	12
B/C =	0.63	1.25	1.88
IRR =	2.1%	16.7%	27.4%
DISCOUNT RATE	9%	12%	15%
B/C =	1.45	1.25	1.09
IRR =	16.7%	16.7%	16.7%
WATER CONSUMPTION	30	50	75
B/C =	0.84	1.25	1.67
IRR =	8.6%	16.7%	25.3%
VALUE OF TIME	0.300	0.345	0.400
B/C =	1.09	1.25	1.45
IRR =	20.5%	16.7%	20.3%
WELL COST PER METER	250	350	450
B/C =	1.42	1.25	1.12
IRR =	20.2%	16.7%	14.1%

Box 8

FIGURE 2

Sensitivity to Accounting Ratios





Chapter 7

APPLICATION OF RESULTS

7.1 Evaluation of Proposed Sites

The model can be applied to sites which are being considered for the next cycle of projects. For these cases, data on the current travel distances were collected and used. Well depths and costs were estimated. Detailed results are given in Appendix D and summarized in Table 7.

Sites were ranked in order of IRR (and therefore B/C). The sites could also be ranked by total economic benefits, which would lead to a somewhat different ranking. From the results it can be seen that there are 4 sites with high IRR values (ranging from 30 percent to 44 percent) and 3 with modest IRR values (10 percent to 15 percent). As expected, the more economically attractive sites have higher populations, lower well depths, and longer (current) travel distances to water. Nearly all sites appear to be economically feasible (B/C > 1), given the current approach to benefits. One site has a B/C of 0.94, which should still be considered very close to economic feasibility, given the precision of these calculations If project funds allow, all should be developed in the order of economic priority. It will be most interesting to recheck the calculations when the wells are finished and the actual depths are known

7.2 General Site Selection Tables

Despite the uncertainty in the benefits and significant model sensitivity, the B/C model can be ***tentatively*** applied to the task of general project selection. An expanded table of calculations was made to help in the site selection process, with the results in Tables 8-12 and Figure 3.

Tables 8-10 show B/C ratios for a wide range of population, well depth, and distance traveled. Similar tables could be generated for the IRR, an example of which is shown in Table 11. Table 12 was derived (by interpolation) from Tables 8-10, and represents a project selection matrix. It shows minimum required population and required families to achieve B/C > 1, assuming a 12 percent discount rate, for discrete well depths. Figure 3 shows the results of Table 12 in graphical format.

With this table a prospective site can be quickly screened for economic feasibility. If the numbers shows favorable results, more detailed study and investigation will be warranted.

A question remains as to the usefulness and accuracy of the criteria agreed to by USAID and CTDA. Simply considering 900 people within 4 km is not enough information to determine economic feasibility, using this approach. Depending on well depth (100—500 m), the B/C ratio could range from 0.60 to 1.46, as shown in Table 9. At the typical depth of 300 m, the B/C ratio would be 0.84. More criteria are needed.

Reeser's criterion of families per meter of well depth might have been useful, but computation of this parameter yields nonlinear results (see Table 12) and is not very useful. Definition of improved criteria must await more field work on project benefits. In the meantime, Tables 8-12 and this computer model can be used to select and prioritize sites, as described in Section 7.1.

Table 7

CTDA USAID/TUNIS RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337 21-Feb-90

ECONOMIC ANALYSIS OF PROPOSED SITES

SITE	BHENNA	KEF LAFRACH	MAGSEM BOURAHLI	MENZEL GAMMOUDI	HENCHIR EL KHEIMA	EL HAZZA	FIDH EL METHNANE	TOTAL	MEAN
DELEGATION	FOUSSANA	MAJEL BEL ABBES	SNED	GAFSA NORD	FERIANA	FOUSSANA	SBEITLA		
GOUVERNORAT	KASSERINE	KASSERINE	GAFSA	GAFSA	KASSERINE	KASSERINE	KASSERINE		
POPULATION 3 KM	2208	924	1404	1068	1140	1830	1524	10098	1443
POPULATION 6 KM	3000	2400	3000	2400	1800	3054	2100	17754	2536
POPULATION SERVED	2677	1307	2350	1857	1219	2555	1524	13489	1927
OLD DISTANCE TO WATER	10	8	10	10	7	10	6		8.7
PROJECT RADIUS	5	4	5	5	3.5	5	3		4.4
TOTAL WELL DEPTH	300	350	250	300	200	250	300	1950	279
WELL COST / M	350TD	350TD	350TD	350TD	350TD	350TD	350TD	350TD	350TD
PUMPING RATE (l/s)	10	10	10	10	15	10	7	72	10.3
SPECIFIC OUTPUT (l/s/m)	0.5	0.5	0.5	0.5	1.5	0.5	0.3		0.6
STATIC WATER LEVEL (m):	150	130	60	60	80	60	110		93
DISCOUNT RATE	12%	12%	12%	12%	12%	12%	12%		12%
INITIAL FIN. INVESTMENT	186,832TD	197,369TD	159,210TD	171,912TD	144,087TD	159,210TD	172,863TD	1,191,483TD	170,212TD
INVESTMENT/PERSON	70TD	151TD	68TD	93TD	118TD	62TD	113TD	88TD	96TD
TOTAL PV ECON COST	318,805TD	257,111TD	224,115TD	225,267TD	185,856TD	228,118TD	237,929TD	1,677,201TD	
PV ECON COST/PERSON	119TD	197TD	95TD	121TD	152TD	89TD	156TD	124TD	133TD
PV ECON COST/m3	0.212TD	0.350TD	0.170TD	0.216TD	0.271TD	0.159TD	0.278TD		0.237TD
TOTAL PV ECON BENEFITS	655,520TD	255,940TD	575,321TD	454,751TD	208,999TD	625,649TD	223,882TD	3,000,062TD	428,580TD
ANNUAL BENEFITS/FAMILY	147TD	118TD	147TD	147TD	103TD	147TD	88TD		128TD
NET PRESENT VALUE	336,715TD	(1,171TD)	351,206TD	229,484TD	23,143TD	397,532TD	(14,046TD)	1,322,863TD	188,980TD
BENEFITS / COSTS	2.06	1.00	2.57	2.02	1.12	2.74	0.94		1.78
I.R.R.	36%	12%	40%	30%	14%	44%	10%		27%
RANKING:									
BY B/C	3	6	2	4	5	1	7		
BY IRR	3	6	2	4	5	1	7		
BY NPV	3	6	2	4	5	1	7		
TOTAL PV ECON BENEFITS	1	5	3	4	7	2	6		

Table 8

RESULTS - BENEFIT / COST RATIO

20-Feb-90

DISCOUNT RATE = 12%
OLD TRAVEL DISTANCE (km) 6
WELL COST PER METER = TD350

FAMILIES	POPUL.	TOTAL WELL DEPTH, m								
		100	150	200	250	300	350	400	450	500
83	500	0.64	0.54	0.47	0.42	0.37	0.34	0.31	0.29	0.26
100	600	0.76	0.64	0.56	0.49	0.44	0.40	0.37	0.34	0.31
117	700	0.87	0.74	0.64	0.57	0.51	0.46	0.42	0.39	0.36
133	800	0.98	0.83	0.72	0.64	0.57	0.52	0.47	0.44	0.40
150	900	1.09	0.92	0.80	0.71	0.63	0.57	0.52	0.48	0.45
167	1000	1.15	0.97	0.85	0.75	0.67	0.61	0.56	0.52	0.48
183	1100	1.24	1.06	0.92	0.81	0.73	0.66	0.61	0.56	0.52
200	1200	1.34	1.13	0.99	0.87	0.78	0.71	0.65	0.60	0.56
217	1300	1.43	1.21	1.06	0.93	0.84	0.76	0.70	0.64	0.60
233	1400	1.52	1.29	1.12	0.99	0.89	0.81	0.74	0.68	0.63
250	1500	1.60	1.36	1.18	1.05	0.94	0.85	0.78	0.72	0.67
267	1600	1.69	1.43	1.24	1.10	0.99	0.90	0.82	0.76	0.70
283	1700	1.77	1.50	1.31	1.15	1.04	0.94	0.86	0.79	0.73
300	1800	1.86	1.58	1.37	1.21	1.08	0.98	0.90	0.83	0.77
317	1900	1.91	1.62	1.41	1.25	1.12	1.01	0.93	0.85	0.79
333	2000	1.95	1.66	1.44	1.28	1.15	1.04	0.95	0.88	0.82
350	2100	2.02	1.72	1.49	1.32	1.19	1.08	0.99	0.91	0.84
367	2200	2.10	1.78	1.55	1.37	1.23	1.12	1.02	0.94	0.88
383	2300	2.16	1.83	1.60	1.41	1.27	1.15	1.05	0.97	0.90
400	2400	2.24	1.90	1.65	1.46	1.31	1.19	1.09	1.00	0.93
417	2500	2.31	1.96	1.70	1.50	1.35	1.23	1.12	1.03	0.96
433	2600	2.34	1.98	1.72	1.53	1.37	1.24	1.14	1.05	0.97
450	2700	2.41	2.04	1.77	1.57	1.41	1.28	1.17	1.08	1.00
467	2800	2.48	2.10	1.82	1.61	1.45	1.31	1.20	1.11	1.03
483	2900	2.54	2.15	1.87	1.65	1.48	1.35	1.23	1.14	1.05
500	3000	2.53	2.15	1.87	1.66	1.49	1.35	1.24	1.14	1.06

Table 9

RESULTS - BENEFIT / COST RATIO

20-Feb-90

DISCOUNT RATE = 12%
OLD TRAVEL DISTANCE (km) 8
WELL COST PER METER = TD350

FAMILIES	POPUL.	TOTAL WELL DEPTH, m								
		100	150	200	250	300	350	400	450	500
83	500	0.85	0.72	0.63	0.56	0.50	0.45	0.41	0.38	0.35
100	600	1.01	0.86	0.74	0.66	0.59	0.53	0.49	0.45	0.42
117	700	1.16	0.98	0.85	0.75	0.68	0.61	0.56	0.52	0 48
133	800	1.31	1.11	0.96	0.85	0.76	0.69	0.63	0.58	0.54
150	900	1.46	1.23	1.07	0.94	0.84	0.77	0.70	0.64	0.60
167	1000	1.53	1.30	1.13	1.00	0.90	0.82	0.75	0.69	0.64
183	1100	1.66	1.41	1.23	1.08	0.97	0.88	0.81	0.75	0.69
200	1200	1.78	1.51	1.32	1.16	1.05	0.95	0.87	0.80	0.74
217	1300	1.91	1.62	1.41	1.25	1.12	1.01	0.93	0.86	0.79
233	1400	2.03	1.72	1.50	1.32	1.19	1.08	0.99	0.91	0.84
250	1500	2.14	1.81	1.58	1.39	1.25	1.14	1.04	0.96	0.89
267	1600	2.25	1.91	1.66	1.47	1.32	1.19	1.09	1.01	0.93
283	1700	2.37	2.00	1.74	1.54	1.38	1.25	1.15	1.06	0.98
300	1800	2.48	2.10	1.82	1.61	1.44	1.31	1.20	1.10	1.02
317	1900	2.55	2.16	1.88	1.66	1.49	1.35	1.24	1.14	1.06
333	2000	2.60	2.21	1.92	1.70	1.53	1.39	1.27	1.17	1.09
350	2100	2.69	2.29	1.99	1.76	1.58	1.44	1.32	1.21	1.13
367	2200	2.80	2.37	2.06	1.83	1.64	1.49	1.36	1.26	1.17
383	2300	2.88	2.45	2.13	1.88	1.69	1.53	1.40	1.30	1.20
400	2400	2.98	2.53	2.20	1.94	1.74	1.58	1.45	1.34	1.24
417	2500	3.08	2.61	2.27	2.01	1.80	1.63	1.49	1.38	1.28
433	2600	3.12	2.65	2.30	2.03	1.83	1.66	1.52	1.40	1.30
450	2700	3.21	2.72	2.37	2.09	1.88	1.71	1.56	1.44	1.33
467	2800	3.30	2.80	2.43	2.15	1.93	1.75	1.60	1.48	1.37
483	2900	3.39	2.87	2.49	2.21	1.98	1.80	1.64	1.51	1.40
500	3000	3.37	2.86	2.49	2.21	1.98	1.80	1.65	1.52	1.41

Table 10

RESULTS - BENEFIT / COST RATIO

20-Feb-90

DISCOUNT RATE = 12%
OLD TRAVEL DISTANCE (km) 10
WELL COST PER METER = TD350

FAMILIES	POPUL.	TOTAL WELL DEPTH, m								
		100	150	200	250	300	350	400	450	500
83	500	1.07	0.90	0.78	0.69	0.62	0.56	0.52	0.48	0.44
100	600	1.26	1.07	0.93	0.82	0.74	0.67	0.61	0.56	0.52
117	700	1.45	1.23	1.07	0.94	0.84	0.77	0.70	0.65	0.60
133	800	1.64	1.39	1.20	1.06	0.95	0.86	0.79	0.73	0.67
150	900	1.82	1.54	1.34	1.18	1.06	0.96	0.87	0.81	0.75
167	1000	1.91	1.62	1.41	1.25	1.12	1.02	0.93	0.86	0.80
183	1100	2.07	1.76	1.53	1.36	1.22	1.11	1.01	0.93	0.87
200	1200	2.23	1.89	1.64	1.46	1.31	1.19	1.09	1.00	0.93
217	1300	2.38	2.02	1.76	1.56	1.40	1.27	1.16	1.07	0.99
233	1400	2.54	2.15	1.87	1.65	1.48	1.35	1.23	1.14	1.05
250	1500	2.67	2.27	1.97	1.74	1.56	1.42	1.30	1.20	1.11
267	1600	2.82	2.39	2.07	1.83	1.65	1.49	1.37	1.26	1.17
283	1700	2.96	2.51	2.18	1.92	1.73	1.57	1.43	1.32	1.22
300	1800	3.10	2.63	2.28	2.01	1.81	1.64	1.50	1.38	1.28
317	1900	3.19	2.70	2.35	2.08	1.86	1.69	1.55	1.42	1.32
333	2000	3.25	2.76	2.40	2.13	1.91	1.74	1.59	1.47	1.36
350	2100	3.37	2.86	2.49	2.20	1.98	1.80	1.65	1.52	1.41
367	2200	3.49	2.97	2.58	2.28	2.05	1.86	1.70	1.57	1.46
383	2300	3.60	3.06	2.66	2.35	2.11	1.92	1.76	1.62	1.50
400	2400	3.73	3.16	2.75	2.43	2.18	1.98	1.81	1.67	1.55
417	2500	3.85	3.26	2.83	2.51	2.25	2.04	1.87	1.72	1.60
433	2600	3.90	3.31	2.87	2.54	2.28	2.07	1.90	1.75	1.62
450	2700	4.01	3.40	2.96	2.62	2.35	2.13	1.95	1.80	1.67
467	2800	4.13	3.50	3.04	2.69	2.41	2.19	2.00	1.85	1.71
483	2900	4.24	3.59	3.12	2.76	2.47	2.24	2.05	1.89	1.76
500	3000	4.21	3.58	3.11	2.76	2.48	2.25	2.06	1.90	1.77

Table 11

RESULTS - INTERNAL RATE OF RETURN

20-Feb-90

DISCOUNT RATE = 12%
OLD TRAVEL DISTANCE (km) 8
WELL COST PER METER = TD350

FAMILIES	POPUL.	TOTAL WELL DEPTH, m								
		100	150	200	250	300	350	400	450	500
83	500	9%	6%	4%	2%	1%	-1%	-2%	-3%	-4%
100	600	12%	9%	7%	5%	3%	2%	0%	-1%	-2%
117	700	15%	11%	9%	7%	5%	3%	2%	1%	-0%
133	800	17%	14%	11%	9%	7%	5%	4%	3%	1%
150	900	20%	16%	13%	11%	9%	7%	5%	4%	3%
167	1000	21%	17%	14%	12%	10%	8%	6%	5%	4%
183	1100	24%	19%	16%	13%	11%	9%	8%	6%	5%
200	1200	26%	21%	18%	15%	13%	11%	9%	7%	6%
217	1300	28%	23%	19%	16%	14%	12%	10%	9%	7%
233	1400	30%	25%	21%	18%	15%	13%	11%	10%	8%
250	1500	33%	27%	23%	19%	17%	14%	13%	11%	9%
267	1600	35%	29%	24%	21%	18%	16%	14%	12%	10%
283	1700	37%	31%	26%	22%	19%	17%	15%	13%	11%
300	1800	39%	32%	27%	24%	21%	18%	16%	14%	12%
317	1900	41%	34%	29%	25%	22%	19%	17%	15%	13%
333	2000	42%	35%	30%	26%	22%	20%	17%	15%	14%
350	2100	44%	36%	31%	27%	23%	21%	18%	16%	14%
367	2200	46%	38%	33%	28%	25%	22%	19%	17%	15%
383	2300	48%	40%	34%	29%	26%	23%	20%	18%	16%
400	2400	50%	42%	35%	31%	27%	24%	21%	19%	17%
417	2500	52%	43%	37%	32%	28%	25%	22%	20%	18%
433	2600	54%	45%	38%	33%	29%	26%	23%	21%	18%
450	2700	56%	46%	40%	34%	30%	27%	24%	21%	19%
467	2800	58%	48%	41%	36%	31%	28%	25%	22%	20%
483	2900	60%	50%	42%	37%	32%	29%	26%	23%	21%
500	3000	60%	50%	43%	37%	33%	29%	26%	24%	21%

Table 12

PROJECT SELECTION MATRIX

MINIMUM REQUIRED POPULATION

DISCOUNT RATE = 12%

ORIG. DISTANCE =	6	8	10
PROJECT RADIUS =	3	4	5
WELL DEPTH,m			
100	820	590	470
150	1030	720	560
200	1210	840	650
250	1420	1000	750
300	1620	1140	850
350	1870	1280	970
400	2170	1420	1090
450	2400	1580	1200
500	2700	1750	1320

MINIMUM REQUIRED NUMBER OF FAMILIES

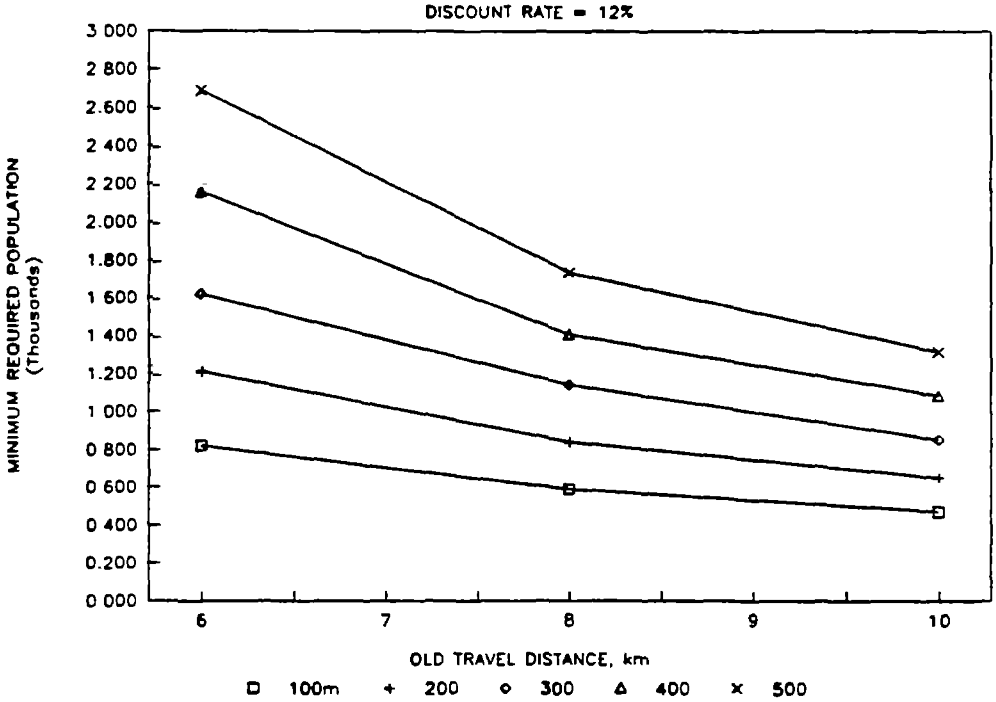
DISCOUNT RATE = 12%

ORIG. DISTANCE =	6	8	10
PROJECT RADIUS =	3	4	5
WELL DEPTH,m			
100	137	98	78
150	172	120	93
200	202	140	108
250	237	167	125
300	270	190	142
350	312	213	162
400	362	237	182
450	400	263	200
500	450	292	220

FIGURE 3

Minimum Required Population by Well Depth

DISCOUNT RATE = 12%



Chapter 8

PERSPECTIVES AND CONCLUSIONS

This analysis yields the following conclusions:

1. A revised B/C model has been developed which can be used to prioritize candidate sites and give preliminary information on project economic feasibility. The results show that economic feasibility of the rural water projects may be greater than previously expected. This change can be attributed mostly to a significant increase in benefits, despite some increase in costs.

2. The project selection criteria need further review. The simple criterion of 900 people inside a 4 km radius with water at least 4 km away does not necessarily lead to economically feasible sites. More improved criteria will be needed, but their development depends on further field data collection. Use of the tables in this report, or direct use of the computer model, will serve as a short-term project selection approach.

3. The sensitivity of the model to various input parameters appears high. This indicates that more data are needed.

   - Benefits: Implement planned investigation of water consumption, method used and family member who transports water, travel distances, vendor prices, etc. Apply results to develop an improved methodology for assessment of benefits.

   - Economic Analysis: Further investigation of accounting prices, with national level planners or economists.

   - Costs: Collect more empirical data on O&M costs. For investment costs there are only minor uncertainties.

   Such improved data should be collected and the model revised.

4. Although not discussed in detail in this report, the model will be useful for engineering analysis. The insensitivity of the economics to pumping rate is a good example of useful design information coming out of an economic analysis. Another interesting exercise would be to look at the economic tradeoff of adding a more extensive water distribution system, which would increase costs somewhat but might increase benefits substantially. In essence the model can become a tool for optimizing the project designs.

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REFERENCES

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APPENDIX A

Model of Water Point/Water Transport Costs

APPENDIX A: MODEL OF WATER POINT/WATER TRANSPORT COSTS

The objective of this brief modeling exercise was to investigate the planning target of a 3km radius as a "zone of service" of a water point. That is investments should be made, in the long run, so that no one has to go more than 3km to clean potable water. This target figure has been adopted by the project, and in fact corresponds to a de facto national norm. More precisely, the Ministry of Plan confirmed that 3 km was the common rule of thumb. However, they prefer a target of 1 hour travel time (one way), as a target level of service for rural water programs. Since 3 km/hr is a common walking speed, these two figures correspond, at least on flat terrain.

The choice for a radius of service is a difficult one. A small radius will mean water is close at hand, and thus takes less time, effort and cost to transport to the home. This savings, monetary, and non-monetary, is an important benefit of water point investments[1] . Another way to think of it is to compute the cost of water transport, with water available at different distances. Thus for a small radius the transport cost will be low, and for a large radius the transport cost will be high. Different transport methods should be considered, including walking, using a donkey cart, or buying water from a private vendor. An assumption will have to made as to the "value of time", and since this is difficult, calculations have been made at a variety of values.

However, a small radius requires that a greater number of wells must be dug, tanks constructed, etc. Overall investment and operating costs (in a region) will rise as radius decreases.

So, a very fundamental tradeoff develops between water point capital and running costs on the one hand, and the cost of hauling water, on the other. One is high where the other is low. If we add these two costs together, there will be a radius where costs are minimized, which we can consider an optimal radius. The model developed here attempts, in an approximate fashion, to evaluate this tradeoff, and compute the optimal radius. The analysis computes the total net present value of these two costs, that is investments are taken at face value, but future running and transport costs are discounted to the present.

Due to the limited amount of time available in an project evaluation effort, only a rough analysis could be developed, but the preliminary results appear useful. The approach appears valid, and can be improved with additional data collection efforts if desired. The next few pages show preliminary results, sample calculations, and some of the key formulas used. Before reviewing those details, the basic conclusions of the analysis should be stated:

* Depending on the value of time used, and the mode of transport used, the optimal radius will vary from 2.2 to 6.2 km. As the value of time increases, the optimal radius decreases, and as consumption increases, the optimal radius decreases.

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[1] Additionally, with water being closer, there will be extra benefits, although more indirect, resulting to greater water use, such as irrigation and improved health and hygiene (theoretically). In this analysis only the first of these benefits, the time savings, will be considered.

* The rule of thumb of 3 km appears adequate. The model results tend to lean a bit more toward 4 km, but this analysis is approximate, and there doesn't appear to be any major reason to recommend any change form the 3 km target. It is interesting to note that the optimal radius corresponds even better to 1 hour travel time. That is, for walkers, whose speed is estimated at 3 km/hr the optimal radius is from 2.2 to 3.8 km. For people using donkey carts, with an estimated speed of 5 km/hr the optimal radius is 4.1 to 6.2 km.

* The transport mechanism known as vendors appears to be quite competitive economically with other mechanisms. That is it appears to be as economically interesting to encourage the private vendors, as to assist people to purchase donkey carts.

* The total cost of transporting water, for all the families served, can be very high. In fact the transport cost greatly exceeds the running costs of the water point (cost of fuel, maintenance, etc.). These costs can even be considered a counterpart contribution to the project, by the beneficiaries. Also, over 20 years the transport costs can reach the same order of magnitude as the investment by the Government.

SUMMARY OF RESULTS:

1. WALKING MODEL

INPUTS			RESULTS.		
SPEED	CONSUMPTION	VALUE OF TIME	COST PER PERSON ● 3 km RADIUS	OPTIMAL RADIUS	COST PER PERSON ● OPTIMAL RADIUS
3 km/hr	30 l/p/d	0.050 TD/hr	254 TD	3.8 km	240 TD
3 km/hr	30 l/p/d	0.150 TD/hr	487 TD	2.6 km	480 TD
3 km/hr	50 l/p/d	0.050 TD/hr	344 TD	3.2 km	343 TD
3 km/hr	50 l/p/d	0 150 TD/hr	733 TD	2.2 km	680 TD

2. DONKEY CART MODEL

INPUTS			RESULTS:		
SPEED	CONSUMPTION	VALUE OF TIME	COST PER PERSON ● 3 km RADIUS	OPTIMAL RADIUS	COST PER PERSON ● OPTIMAL RADIUS
5 km/hr	30 l/p/d	0.250 TD/hr	291 TD	6.2 km	229 TD
5 km/hr	30 l/p/d	0.500 TD/hr	319 TD	4.8 km	280 TD
5 km/hr	50 l/p/d	0 250 TD/hr	322 TD	5.2 km	276 TD
5 km/hr	50 l/p/d	0.500 TD/hr	368 TD	4.1 km	347 TD

3. VENDOR MODEL

INPUTS	RESULTS:		
CONSUMPTION	COST PER PERSON ● 3 km RADIUS	OPTIMAL RADIUS	COST PER PERSON ● OPTIMAL RADIUS
30 l/p/d	249 TD	4.7 km	212 TD
50 l/p/d	336 TD	4.1 km	317 TD

WALKING MODEL

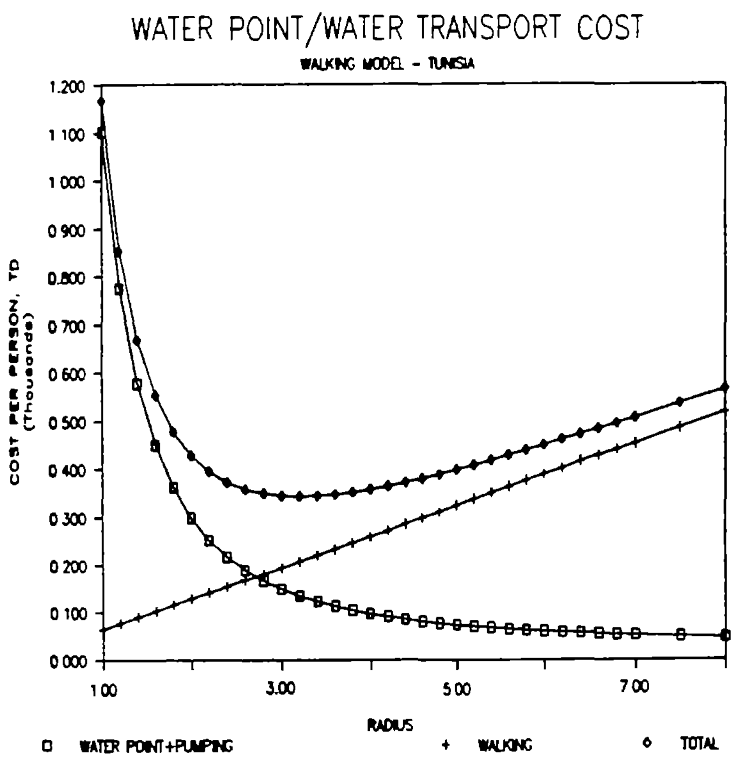
INPUT ASSUMPTIONS	
PEOPLE PER HOUSEHOLD =	6
POPULATION DENSITY, P/km2	35
WATER USE, L/P/DAY =	50
WALKING SPEED, KM/HR =	3
TRIP CAPACITY L/TRIP =	40
VALUE OF TIME, TD/HR =	0.050 TD
PROJECT AREA, km2 =	10000
WATER POINT RADIUS, km =	3
INITIAL COST WATER POINT=	150,000 TD
PUMPING COST, TD/m3 =	0.20 TD
DISCOUNT RATE =	10.0%
PERIOD, YRS =	20

RESULTS	
NUMBER OF WATER POINTS =	278
PEOPLE PER WATER POINT =	1260
HOUSEHOLDS/WATER POINT =	210
INITIAL COST WATER POINT=	150,000 TD
INITIAL WP INVESTMENTS =	41,666,667 TD
ANNUAL RUNNING COST/WP =	4,599 TD
PV PUMPING COST PER WP =	39,154 TD
TOTAL PV PUMPING COST =	10,876,078 TD
TRIPS PER DAY =	7.50
WALKING COST PER WP =	244,712 TD
TOTAL WALKING COST =	67,975,485 TD
WP+PUMPING+WALKING =	120,518,230 TD
COST PER PERSON	
WATER POINT	119 TD
WATER POINT+PUMPING	150 TD
WALKING	194 TD
WP + PUMPING + WALKING	344 TD

RESULTS OF INFLUENCE OF WATER POINT RADIUS

COST PER PERSON :

RADIUS	WATER POINT	WP + PUMPING	WALKING	WP+PUMPING +WALKING
0.20	26,786 TD	26,817 TD	13 TD	26,830 TD
0.40	6,696 TD	6,728 TD	26 TD	6,753 TD
0.60	2,976 TD	3,007 TD	39 TD	3,046 TD
0.80	1,674 TD	1,705 TD	52 TD	1,757 TD
1.00	1,071 TD	1,103 TD	65 TD	1,167 TD
1.20	744 TD	775 TD	78 TD	853 TD
1.40	547 TD	578 TD	91 TD	668 TD
1.60	419 TD	450 TD	104 TD	553 TD
1.80	331 TD	362 TD	117 TD	478 TD
2.00	268 TD	299 TD	129 TD	428 TD
2.20	221 TD	252 TD	142 TD	395 TD
2.40	186 TD	217 TD	155 TD	372 TD
2 60	158 TD	190 TD	168 TD	358 TD
2 80	137 TD	168 TD	181 TD	349 TD
3.00	119 TD	150 TD	194 TD	344 TD
3.20	105 TD	136 TD	207 TD	343 TD
3.40	93 TD	124 TD	220 TD	344 TD
3.60	83 TD	114 TD	233 TD	347 TD
3.80	74 TD	105 TD	246 TD	351 TD
4.00	67 TD	98 TD	259 TD	357 TD
4.20	61 TD	92 TD	272 TD	364 TD
4.40	55 TD	86 TD	285 TD	371 TD
4.60	51 TD	82 TD	298 TD	380 TD
4 80	47 TD	78 TD	311 TD	388 TD
5.00	43 TD	74 TD	324 TD	398 TD
5.20	40 TD	71 TD	337 TD	407 TD
5 40	37 TD	68 TD	350 TD	417 TD
5.60	34 TD	65 TD	363 TD	428 TD
5.80	32 TD	63 TD	375 TD	438 TD
6.00	30 TD	61 TD	388 TD	449 TD
6.20	28 TD	59 TD	401 TD	460 TD
6.40	26 TD	57 TD	414 TD	472 TD
6.60	25 TD	56 TD	427 TD	483 TD
6.80	23 TD	54 TD	440 TD	494 TD
7.00	22 TD	53 TD	453 TD	506 TD
7.50	19 TD	50 TD	486 TD	536 TD
8.00	17 TD	48 TD	518 TD	566 TD
8.50	15 TD	46 TD	550 TD	596 TD
9.00	13 TD	44 TD	583 TD	627 TD
9.50	12 TD	43 TD	615 TD	658 TD
10.00	11 TD	42 TD	647 TD	689 TD
11.00	9 TD	40 TD	712 TD	752 TD
12.00	7 TD	39 TD	777 TD	815 TD
13.00	6 TD	37 TD	842 TD	879 TD
14.00	5 TD	37 TD	906 TD	943 TD
15.00	5 TD	36 TD	971 TD	1,007 TD



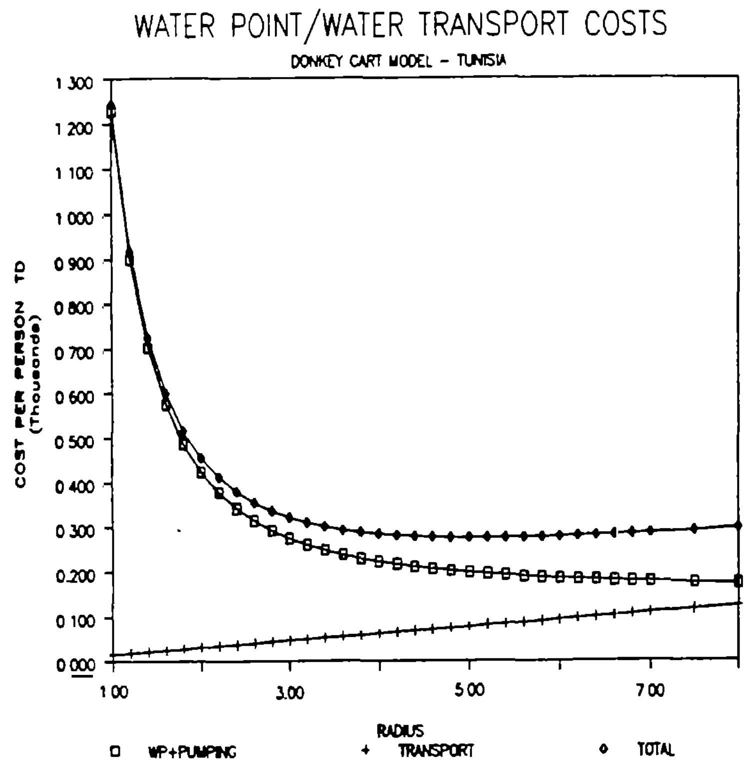
DONKEY CART MODEL

INPUT ASSUMPTIONS

PEOPLE PER HOUSEHOLD =	6
POPULATION DENSITY, P/km2	35
WATER USE, L/P/DAY =	50
WALKING SPEED, KM/HR =	5
TRIP CAPACITY L/TRIP =	500
VALUE OF TIME, TD/HR =	0 250 TD
PROJECT AREA, km2 =	10000
WATER POINT RADIUS, km =	3
INITIAL COST WATER POINT=	150,000 TD
INITIAL COST OF CART+TANK=	750 TD
PUMPING COST, TD/m3 =	0 20 TD
DISCOUNT RATE =	10.0%
PERIOD, YRS =	20

RESULTS

NUMBER OF WATER POINTS =	278
PEOPLE PER WATER POINT =	1260
HOUSEHOLDS/WATER POINT =	210
INITIAL COST WATER POINT=	150,000 TD
INVESTMENT IN CARTS+TANKS	43,750,000 TD
INITIAL INVESTMENTS =	85,416,667 TD
ANNUAL RUNNING COST/WP =	4,599 TD
PV PUMPING COST PER WP =	39,154 TD
TOTAL PV PUMPING COST =	10,876,078 TD
TRIPS PER DAY =	0.60
TRANSPORT COST PER WP =	58,731 TD
TOTAL TRANSPORT COST =	16,314,116 TD
WP+PUMPING+TRANSPORT =	112,606,861 TD
COST PER PERSON:	
WATER POINT	244 TD
WATER POINT+PUMPING	275 TD
TRANSPORT	47 TD
WP + PUMPING + TRANSPORT	322 TD



RESULTS OF INFLUENCE OF WATER POINT RADIUS

COST PER PERSON :

RADIUS	WATER POINT	WP + PUMPING	TRANSPORT	WP+PUMPING +TRANSPORT
0.20	26,911 TD	26,942 TD	3 TD	26,945 TD
0.40	6,821 TD	6,853 TD	6 TD	6,859 TD
0.60	3,101 TD	3,132 TD	9 TD	3,142 TD
0.80	1,799 TD	1,830 TD	12 TD	1,843 TD
1.00	1,196 TD	1,228 TD	16 TD	1,243 TD
1.20	869 TD	900 TD	19 TD	919 TD
1.40	672 TD	703 TD	22 TD	724 TD
1.60	544 TD	575 TD	25 TD	599 TD
1.80	456 TD	487 TD	28 TD	515 TD
2.00	393 TD	424 TD	31 TD	455 TD
2.20	346 TD	377 TD	34 TD	412 TD
2.40	311 TD	342 TD	37 TD	379 TD
2.60	283 TD	315 TD	40 TD	355 TD
2.80	262 TD	293 TD	44 TD	336 TD
3.00	244 TD	275 TD	47 TD	322 TD
3.20	230 TD	261 TD	50 TD	310 TD
3.40	218 TD	249 TD	53 TD	302 TD
3.60	208 TD	239 TD	56 TD	295 TD
3.80	199 TD	230 TD	59 TD	289 TD
4.00	192 TD	223 TD	62 TD	285 TD
4.20	186 TD	217 TD	65 TD	282 TD
4.40	180 TD	211 TD	68 TD	280 TD
4.60	176 TD	207 TD	71 TD	278 TD
4.80	172 TD	203 TD	75 TD	277 TD
5.00	168 TD	199 TD	78 TD	277 TD
5.20	165 TD	196 TD	81 TD	276 TD
5.40	162 TD	193 TD	84 TD	277 TD
5.60	159 TD	190 TD	87 TD	277 TD
5.80	157 TD	188 TD	90 TD	278 TD
6.00	155 TD	186 TD	93 TD	279 TD
6.20	153 TD	184 TD	96 TD	280 TD
6.40	151 TD	182 TD	99 TD	282 TD
6.60	150 TD	181 TD	103 TD	283 TD
6.80	148 TD	179 TD	106 TD	285 TD
7.00	147 TD	178 TD	109 TD	287 TD
7.50	144 TD	175 TD	117 TD	292 TD
8.00	142 TD	173 TD	124 TD	297 TD
8.50	140 TD	171 TD	132 TD	303 TD
9.00	138 TD	169 TD	140 TD	309 TD
9.50	137 TD	168 TD	148 TD	316 TD
10.00	136 TD	167 TD	155 TD	322 TD
11.00	134 TD	165 TD	171 TD	336 TD
12.00	132 TD	164 TD	186 TD	350 TD
13.00	131 TD	162 TD	202 TD	364 TD
14.00	130 TD	162 TD	218 TD	379 TD
15.00	130 TD	161 TD	233 TD	394 TD

VENDOR MODEL

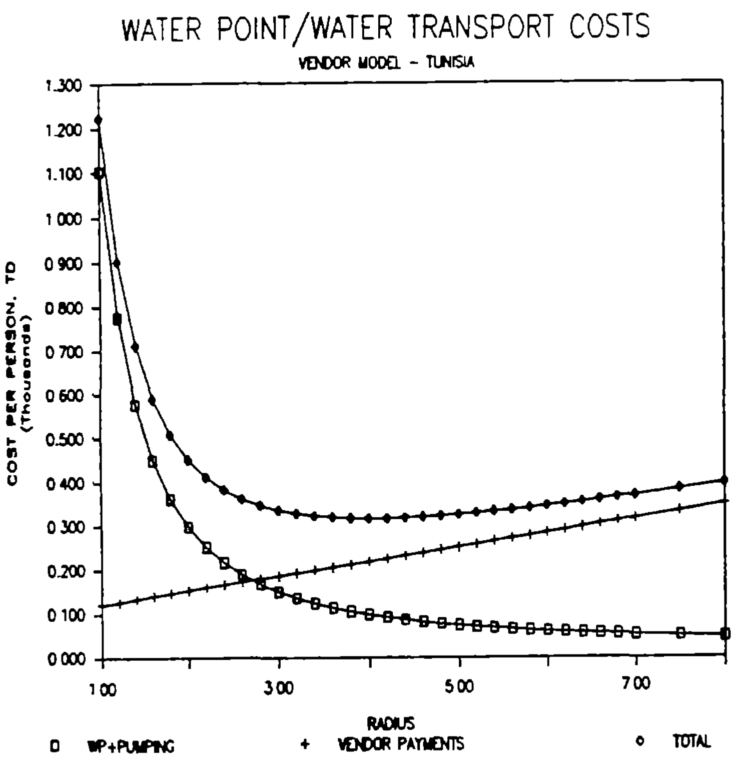
INPUT ASSUMPTIONS	
PEOPLE PER HOUSEHOLD =	6
POPULATION DENSITY, P/km2	35
WATER USE, L/P/DAY =	50
TRIP CAPACITY, L/TRIP =	3500
VENDOR WATER PRICE = 2TD + 0.75TD/km	
PROJECT AREA, km2 =	10000
WATER POINT RADIUS, km =	3
INITIAL COST WATER POINT=	150,000 TD
PUMPING COST, TD/m3 =	0.20 TD
DISCOUNT RATE =	10.0%
PERIOD, YRS =	20

RESULTS	
NUMBER OF WATER POINTS =	278
PEOPLE PER WATER POINT =	1260
HOUSEHOLDS/WATER POINT =	210
INITIAL COST WATER POINT=	150,000 TD
INITIAL WP INVESTMENTS =	41,666,667 TD
ANNUAL RUNNING COST/WP =	4,599 TD
PV PUMPING COST PER WP =	39,154 TD
TOTAL PV PUMPING COST =	10,876,078 TD
TRIPS PER MONTH PER FAM.=	2.57
VENDOR PAYMENTS PER WP =	234,464 TD
TOTAL VENDOR PAYMENTS =	65,128,762 TD
WP+PUMPING+PAYMENTS =	117,671,507 TD
COST PER PERSON:	
WATER POINT	119 TD
WATER POINT+PUMPING	150 TD
VENDOR PAYMENTS	186 TD
WP + PUMPING + PAYMENTS	336 TD

RESULTS OF INFLUENCE OF WATER POINT RADIUS

COST PER PERSON :

RADIUS	WATER POINT	WP + PUMPING	VENDOR PAYMENTS	WP+PUMPING +PAYMENTS
0.20	26,786 TD	26,817 TD	94 TD	26,911 TD
0.40	6,696 TD	6,728 TD	101 TD	6,828 TD
0.60	2,976 TD	3,007 TD	107 TD	3,115 TD
0.80	1,674 TD	1,705 TD	114 TD	1,819 TD
1.00	1,071 TD	1,103 TD	120 TD	1,223 TD
1.20	744 TD	775 TD	127 TD	902 TD
1.40	547 TD	578 TD	134 TD	711 TD
1.60	419 TD	450 TD	140 TD	590 TD
1.80	331 TD	362 TD	147 TD	508 TD
2.00	268 TD	299 TD	153 TD	452 TD
2.20	221 TD	252 TD	160 TD	412 TD
2.40	186 TD	217 TD	166 TD	383 TD
2.60	158 TD	190 TD	173 TD	363 TD
2.80	137 TD	168 TD	180 TD	347 TD
3.00	119 TD	150 TD	186 TD	336 TD
3.20	105 TD	136 TD	193 TD	328 TD
3.40	93 TD	124 TD	199 TD	323 TD
3.60	83 TD	114 TD	206 TD	320 TD
3.80	74 TD	105 TD	212 TD	318 TD
4.00	67 TD	98 TD	219 TD	317 TD
4.20	61 TD	92 TD	225 TD	317 TD
4.40	55 TD	86 TD	232 TD	318 TD
4.60	51 TD	82 TD	239 TD	320 TD
4.80	47 TD	78 TD	245 TD	323 TD
5.00	43 TD	74 TD	252 TD	326 TD
5.20	40 TD	71 TD	258 TD	329 TD
5.40	37 TD	68 TD	265 TD	333 TD
5.60	34 TD	65 TD	271 TD	337 TD
5.80	32 TD	63 TD	278 TD	341 TD
6.00	30 TD	61 TD	285 TD	345 TD
6.20	28 TD	59 TD	291 TD	350 TD
6.40	26 TD	57 TD	298 TD	355 TD
6.60	25 TD	56 TD	304 TD	360 TD
6.80	23 TD	54 TD	311 TD	365 TD
7.00	22 TD	53 TD	317 TD	370 TD
7.50	19 TD	50 TD	334 TD	384 TD
8.00	17 TD	48 TD	350 TD	398 TD
8.50	15 TD	46 TD	367 TD	413 TD
9.00	13 TD	44 TD	383 TD	427 TD
9.50	12 TD	43 TD	400 TD	442 TD
10.00	11 TD	42 TD	416 TD	458 TD
11.00	9 TD	40 TD	449 TD	489 TD
12.00	7 TD	39 TD	482 TD	520 TD
13.00	6 TD	37 TD	514 TD	552 TD
14.00	5 TD	37 TD	547 TD	584 TD
15.00	5 TD	36 TD	580 TD	616 TD



BASIC FORMULAS:

WALKING MODEL

Number of water points = Project Area / (4 * $radius^2$)
People per water point = (4 * $radius^2$) * Population density
Households per water point = People per water point / Persons per household
Initial WP investments = Initial Cost per water point * Number of water points
Annual running cost/wp = Water use (l/p/d) * 365 * People per water point * Pumping cost (TD/m^3) / 1000
PV pumping cost per wp = Annual running cost/wp * PVA
Total PV pumping cost = PV pumping cost per wp * Number of water points
Trips per day = (Water use (l/p/d) * Persons per household) / Trip capacity
Walking Cost per WP = (Radius/Speed) * Value of time * Trips per day * 365 * Households per wp * PVA
Total walking cost = Walking Cost per WP * Number of water points
WP+Pumping+Walking = Initial WP investments + Total PV pumping cost + Total walking cost

NOTE: PV = Present Value, WP-Water Point

$$PVA = [(1+i)^n - 1] / [i(1+i)^n]$$

i = discount rate
n = project period, yrs

DONKEY MODEL

Formulas are the same except:

Initial investments = (Initial WP investment * Number of WPs) + (Initial Cpost of Cart + Tank * Number of Households)

VENDOR MODEL

Formulas are the same as the Walking Model except:

Trips per Month per Family = Trip capacity / (Water use (l/p/d) * Persons per household)
Vendor Payments per WP = Trips per Month per Family * 12 * [2+(0.75*Radius)]

APPENDIX B

Results of Sensitivity Analyses

SENSITIVITY OF THE BENEFIT / COST RATIO TO THE DISCOUNT RATE

20-Feb-90

TOTAL WELL DEPTH (m) = 300
OLD TRAVEL DISTANCE (km) = 8
WELL COST PER METER = TD350

FAMILIES	POPUL.	DISCOUNT RATE 10%	11%	12%	13%	14%	15%
83	500	0.56	0.53	0.50	0.47	0.45	0.42
100	600	0.66	0.62	0.59	0.56	0.53	0.50
117	700	0.76	0.72	0.68	0.64	0.61	0.58
133	800	0.85	0.80	0.76	0.72	0.68	0.65
150	900	0.94	0.89	0.84	0.80	0.76	0.72
167	1000	1.00	0.95	0.90	0.85	0.81	0.77
183	1100	1.08	1.03	0.97	0.93	0.88	0.84
200	1200	1.16	1.10	1.05	0.99	0.95	0.90
217	1300	1.24	1.17	1.12	1.06	1.01	0.97
233	1400	1.31	1.25	1.19	1.13	1.08	1.03
250	1500	1.38	1.31	1.25	1.19	1.14	1.09
267	1600	1.45	1.38	1.32	1.26	1.20	1.15
283	1700	1.52	1.45	1.38	1.32	1.26	1.20
300	1800	1.59	1.51	1.44	1.38	1.32	1.26
317	1900	1.63	1.56	1.49	1.42	1.36	1.31
333	2000	1.67	1.60	1.53	1.46	1.40	1.34
350	2100	1.73	1.65	1.58	1.52	1.45	1.39
367	2200	1.79	1.71	1.64	1.57	1.51	1.44
383	2300	1.84	1.76	1.69	1.62	1.55	1.49
400	2400	1.90	1.82	1.74	1.67	1.61	1.54
417	2500	1.96	1.88	1.80	1.73	1.66	1.59
433	2600	1.98	1.90	1.83	1.75	1.68	1.62
450	2700	2.04	1.96	1.88	1.80	1.73	1.67
467	2800	2.09	2.01	1.93	1.85	1.78	1.71
483	2900	2.14	2.06	1.98	1.90	1.83	1.76
500	3000	2.14	2.06	1.98	1.91	1.84	1.77

SENSITIVITY OF THE BENEFIT / COST RATIO TO THE TRAVEL DISTANCE

DISCOUNT RATE = 12
TOTAL WELL DEPTH (m) = 300
WELL COST PER METER = TD350

20-Feb-90

FAMILIES	POPUL.	OLD TRAVEL DISTANCE (km).													
		5 0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	10.0	10.5	11.0	11.5	12 0
83	500	0.31	0.34	0.37	0.40	0.44	0.47	0.50	0.53	0.56	0.62	0.65	0.68	0.72	0 75
100	600	0.37	0.40	0.44	0.48	0.51	0.55	0.59	0.63	0.66	0.74	0.77	0.81	0.85	0.88
117	700	0.42	0.46	0.51	0.55	0.59	0.63	0.68	0.72	0.76	0.84	0.89	0.93	0.97	1 01
133	800	0.48	0.52	0.57	0.62	0.67	0.71	0.76	0.81	0.86	0.95	1.00	1.05	1.09	1.14
150	900	0.53	0.58	0.63	0.69	0.74	0.79	0.84	0.90	0.95	1.06	1.11	1.16	1.21	1 27
167	1000	0 56	0.62	0.67	0.73	0.79	0.84	0.90	0.95	1.01	1.12	1.18	1.23	1.29	1.35
183	1100	0.61	0.67	0.73	0.79	0.85	0.91	0.97	1.03	1.10	1.22	1.28	1.34	1 40	1.46
200	1200	0.65	0.72	0.78	0.85	0.91	0.98	1.05	1.11	1.18	1.31	1.37	1.44	1.50	1.57
217	1300	0 70	0 77	0.84	0.91	0.98	1 05	1.12	1.19	1.26	1.40	1.47	1.54	1.61	1 68
233	1400	0.74	0.82	0.89	0.96	1.04	1.11	1.19	1.26	1.34	1.48	1.56	1.63	1.71	1 78
250	1500	0 78	0 86	0.94	1.02	1.09	1.17	1.25	1.33	1.41	1.56	1.64	1.72	1.80	1 88
267	1600	0 82	0.91	0 99	1.07	1.15	1.23	1.32	1.40	1.48	1.65	1.73	1.81	1.89	1.97
283	1700	0.86	0.95	1.04	1.12	1.21	1.29	1.38	1.47	1.55	1.73	1.81	1.90	1.98	2 07
300	1800	0 90	0 99	1.08	1.17	1.26	1.35	1 44	1.53	1.63	1.81	1.90	1.99	2.08	2.17
317	1900	0 93	1.02	1.12	1.21	1 30	1.40	1.49	1.58	1.67	1.86	1.95	2 05	2 14	2 23
333	2000	0.96	1.05	1.15	1.24	1.34	1.43	1.53	1.62	1.72	1.91	2.01	2.10	2 20	2.29
350	2100	0.99	1.09	1 19	1.29	1.38	1.48	1.58	1 68	1.78	1.98	2.08	2.18	2.27	2 37
367	2200	1.03	1 13	1.23	1 33	1 44	1.54	1.64	1.74	1.85	2.05	2.15	2.26	2 36	2.46
383	2300	1 06	1.16	1.27	1.37	1 48	1.58	1.69	1.80	1.90	2.11	2.22	2.32	2.43	2.53
400	2400	1 09	1.20	1.31	1.42	1.53	1.64	1.74	1.85	1.96	2.18	2.29	2 40	2.51	2.62
417	2500	1.12	1.24	1.35	1 46	1.57	1.69	1.80	1.91	2.02	2.25	2.36	2 47	2.59	2.70
433	2600	1 14	1.26	1.37	1.48	1.60	1.71	1.83	1.94	2.05	2.28	2.40	2.51	2.62	2.74
450	2700	1.17	1.29	1.41	1.53	1.64	1.76	1.88	1.99	2.11	2.35	2.46	2.58	2.70	2.82
467	2800	1.21	1.33	1.45	1.57	1.69	1.81	1.93	2.05	2.17	2.41	2.53	2.65	2.77	2.89
483	2900	1.24	1.36	1.48	1.61	1.73	1.85	1.98	2.10	2.23	2.47	2.60	2.72	2.84	2 97
500	3000	1.24	1.36	1.49	1.61	1.73	1.86	1.98	2.11	2.23	2.48	2.60	2.73	2.85	2.97

SENSITIVITY OF THE BENEFIT/COST RATIO TO QUANTITY OF WATER CONSUMED (LPCD)

DEPTH - 300 m — WELL COST PER METER - TD350

DISCOUNT RATE - 12% — OLD TRAVEL DISTANCE - 8 km

FAMILIES	POPUL.	QUANTITY (LPCD)								
		20	30	40	50	60	70	80	90	100
83	500	0.21	0.31	0.40	0.50	0.59	0.68	0.76	0.84	0.90
100	600	0.25	0.37	0.48	0.59	0.69	0.80	0.89	0.96	1.05
117	700	0.29	0.42	0.55	0.68	0.80	0.88	0.99	1.09	1.19
133	800	0.33	0.48	0.62	0.76	0.89	0.99	1.10	1.21	1.32
150	900	0.37	0.53	0.69	0.84	0.96	1.09	1.21	1.33	1.44
167	1000	0.40	0.59	0.76	0.90	1.05	1.19	1.32	1.44	1.53
183	1100	0.44	0.64	0.83	0.97	1.13	1.28	1.42	1.52	1.64
200	1200	0.48	0.69	0.89	1.05	1.21	1.37	1.50	1.62	1.74
217	1300	0.52	0.74	0.93	1.12	1.29	1.46	1.57	1.71	1.83
233	1400	0.55	0.80	0.99	1.19	1.37	1.50	1.66	1.81	1.93
250	1500	0.59	0.84	1.05	1.25	1.44	1.58	1.74	1.88	1.98
267	1600	0.62	0.89	1.10	1.32	1.50	1.66	1.83	1.97	2.08
283	1700	0.66	0.91	1.16	1.38	1.55	1.73	1.89	2.01	2.17
300	1800	0.69	0.96	1.21	1.44	1.62	1.81	1.97	2.09	2.22
317	1900	0.73	1.00	1.26	1.49	1.68	1.86	2.00	2.17	2.31
333	2000	0.76	1.05	1.32	1.53	1.74	1.93	2.08	2.22	2.37
350	2100	0.80	1.09	1.37	1.58	1.81	1.98	2.15	2.30	2.44
367	2200	0.83	1.13	1.42	1.64	1.85	2.02	2.19	2.35	2.43
383	2300	0.86	1.17	1.45	1.69	1.91	2.08	2.26	2.42	2.50
400	2400	0.89	1.21	1.50	1.74	1.97	2.15	2.32	2.40	2.57
417	2500	0.90	1.25	1.53	1.80	1.98	2.18	2.37	2.46	2 62
433	2600	0.93	1.29	1.57	1.83	2.04	2.24	2.43	2.53	2.68
450	2700	0.96	1.33	1.62	1.88	2.09	2.30	2.40	2.57	2.74
467	2800	0.99	1.37	1.66	1.93	2.15	2.34	2.45	2.63	2.75
483	2900	1.02	1.41	1.70	1.98	2.20	2.39	2.51	2.69	2.80
500	3000	1.05	1.44	1.74	1.98	2.22	2.44	2.57	2.74	2.85

SENSITIVITY OF THE BENEFIT / COST RATIO TO THE VALUE-OF-TIME

DEPTH = 300 m WELL COST PER METER = TD350
DISCOUNT RATE = 12% OLD TRAVEL DISTANCE = 8 km

FAMILIES	POPUL.	TD0.150	TD0.200	TD0.250	TD0.300	TD0.350	TD0.400	TD0.450	TD0.500
83	500	0.22	0.29	0.36	0.43	0.50	0.58	0.65	0.72
100	600	0.26	0.34	0.43	0.51	0.60	0.68	0.77	0.85
117	700	0.29	0.39	0.49	0.59	0.69	0.78	0.88	0.98
133	800	0.33	0.44	0.55	0.66	0.77	0.88	0.99	1.10
150	900	0.37	0.49	0.61	0.73	0.86	0.98	1.10	1.22
167	1000	0.39	0.52	0.65	0.78	0.91	1.04	1.17	1.30
183	1100	0.42	0.56	0.71	0.85	0.99	1.13	1.27	1.41
200	1200	0.45	0.61	0.76	0.91	1.06	1.21	1.36	1.51
217	1300	0.49	0.65	0.81	0.97	1.13	1.30	1.46	1.62
233	1400	0.52	0.69	0.86	1.03	1.20	1.38	1.55	1.72
250	1500	0.54	0.73	0.91	1.09	1.27	1.45	1.63	1.81
267	1600	0.57	0.76	0.95	1.14	1.34	1.53	1.72	1.91
283	1700	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
300	1800	0.63	0.84	1.05	1.26	1.47	1.67	1.88	2.09
317	1900	0.65	0.86	1.08	1.29	1.51	1.73	1.94	2.16
333	2000	0.66	0.89	1.11	1.33	1.55	1.77	1.99	2.22
350	2100	0.69	0.92	1.15	1.38	1.61	1.83	2.06	2.29
367	2200	0.71	0.95	1.19	1.43	1.66	1.90	2.14	2.38
383	2300	0.73	0.98	1.22	1.47	1.71	1.96	2.20	2.45
400	2400	0.76	1.01	1.26	1.52	1.77	2.02	2.28	2.53
417	2500	0.78	1.04	1.30	1.56	1.83	2.09	2.35	2.61
433	2600	0.79	1.06	1.32	1.59	1.85	2.12	2.38	2.65
450	2700	0.82	1.09	1.36	1.63	1.90	2.18	2.45	2.72
467	2800	0.84	1.12	1.40	1.68	1.96	2.24	2.52	2.79
483	2900	0.86	1.15	1.43	1.72	2.01	2.29	2.58	2.87
500	3000	0.86	1.15	1.44	1.72	2.01	2.30	2.59	2.87

SENSITIVITY OF B/C TO PUMPING RATE FOR VARIOUS WELL CAPACITIES

DEPTH - 300 m WELL COST PER METER - TD350
DISCOUNT RATE - 12% OLD TRAVEL DISTANCE - 8 km

PUMPING RATE, L/S	SPECIFIC WELL CAPACITY 0.10	0.25	0.50	1.00	2.00	5.00
1						
2	1.28	1.31	1.32	1.33	1.33	1.33
3	1.24	1.29	1.30	1.31	1.32	1.32
4	1.23	1.29	1.31	1.32	1.32	1.33
5	1.20	1.27	1.30	1.31	1.32	1.32
6	1.19	1.27	1.30	1.32	1.33	1.33
7	1.16	1.25	1.29	1.30	1.31	1.32
8	1.12	1.23	1.27	1.29	1.30	1.31
9	1.11	1.22	1.27	1.29	1.30	1.31
10	1.08	1.20	1.25	1.28	1.29	1.30
11	1.05	1.19	1.24	1.27	1.28	1.29
12	1.02	1.17	1.22	1.26	1.27	1.28
13	1.00	1.15	1.21	1.25	1.27	1.28
14	0.97	1.13	1.20	1.24	1.26	1.27
15	0.94	1.11	1.18	1.22	1.24	1.26
16	0.93	1.10	1.18	1.22	1.25	1.26
17	0.90	1.08	1.17	1.21	1.23	1.25
18	0.88	1.07	1.15	1.20	1.23	1.24
19	0.85	1.05	1.14	1.19	1.21	1.23
20	0.83	1.03	1.12	1.18	1.21	1.22

SENSITIVITY OF RESULTS TO ACCOUNTING RATIOS

	UNSKILLED LABOR			SEMI-SKILLED LABOR			SKILLED LABOR		
50%	0.98	1.72	38%	1.24	1.13	-10%	1.50	1.15	-8%
40%	0.91	1.63	31%	1.16	1.15	-8%	1.40	1.17	-7%
30%	0.85	1.54	23%	1.07	1.18	-6%	1.30	1.19	-5%
20%	0.78	1.45	16%	0.99	1.20	-4%	1.20	1.21	-3%
10%	0.72	1.35	8%	0.91	1.22	-2%	1.10	1.23	-2%
0%	0.65	1.25	0%	0.83	1.25	0%	1.00	1.25	0%
-10%	0.59	1.15	-8%	0.74	1.28	2%	0.90	1.27	2%
-20%	0.52	1.04	-17%	0.66	1.31	4%	0.80	1.30	4%
-30%	0.46	0.92	-26%	0.58	1.34	7%	0.70	1.32	6%
-40%	0.39	0.81	-35%	0.50	1.37	9%	0.60	1.34	7%
-50%	0.33	0.69	-45%	0.41	1.40	12%	0.50	1.37	10%

	LOCAL MATERIALS			IMPORTED MATERIALS		
50%	1.20	1.10	-12%	1.50	1.06	-15%
40%	1.12	1.12	-10%	1.40	1.09	-13%
30%	1.04	1.15	-8%	1.30	1.13	-10%
20%	0.96	1.18	-5%	1.20	1.17	-7%
10%	0.88	1.22	-3%	1.10	1.21	-4%
0%	0.80	1.25	0%	1.00	1.25	0%
-10%	0.72	1.29	3%	0.90	1.30	4%
-20%	0.64	1.33	6%	0.80	1.35	8%
-30%	0.56	1.37	9%	0.70	1.41	12%
-40%	0.48	1.41	13%	0.60	1.47	17%
-50%	0.40	1.46	16%	0.50	1.53	22%

APPENDIX C

Detailed Benefit/Cost Results for Early Project Sites

APPENDIX C

Detailed Benefit/Cost Results for Early Project Sites

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	BIADHA	INITIAL FIN. INVESTMENT	172,741TD
DELEGATION:	SNED	INITIAL INVEST/PERSON	156TD
GOUVERNORAT:	GAFSA	TOTAL ECON. PV COST	216,848TD
POPULATION 3 KM 1989:		TOTAL ECON COST/PERSON	196TD
POPULATION 6 KM 1989:		TOTAL ECON. COST/m3	0.350TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	861
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	8,293TD
POPULATION SERVED 1989	1104	COMMUN. CONTRIB. TO O&M	4,538TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	200	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	67	TOTAL ECON. PV BENEFITS	251,599TD
PUMPING RATE (l/s):	10	NET PRESENT VALUE	34,751TD
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	1.16
DISCOUNT RATE:	10%	IRR	12.4%
ESTIMATED WELL COST /m	525TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	BRAHIM ZAHHAR	INITIAL FIN. INVESTMENT	199,990TD
DELEGATION:	SBIBA	INITIAL INVEST/PERSON	86TD
GOUVERNORAT:	KASSERINE	TOTAL ECON. PV COST	313,244TD
POPULATION 3 KM 1989:		TOTAL ECON COST/PERSON	135TD
POPULATION 6 KM 1989:		TOTAL ECON. COST/m3	0.241TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	1805
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	18,370TD
POPULATION SERVED 1989	2315	COMMUN. CONTRIB. TO O&M	12,960TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	350	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	117	TOTAL ECON. PV BENEFITS	527,583TD
PUMPING RATE (l/s):	10	NET PRESENT VALUE	214,339TD
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	1.68
DISCOUNT RATE:	10%	IRR	23.1%
ESTIMATED WELL COST /m	348TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	EL JADIDA	INITIAL FIN. INVESTMENT	213,871TD
DELEGATION:	SNED	INITIAL INVEST/PERSON	228TD
GOUVERNORAT:	GAFSA	TOTAL ECON. PV COST	268,136TD
POPULATION 3 KM 1989:		TOTAL ECON COST/PERSON	286TD
POPULATION 6 KM 1989:		TOTAL ECON. COST/m3	0.509TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	732
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	9,731TD
POPULATION SERVED 1989	938	COMMUN. CONTRIB. TO O&M	6,147TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	400	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	133	TOTAL ECON. PV BENEFITS	213,768TD
PUMPING RATE (1/s):	10	NET PRESENT VALUE	(54,368TD)
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	0.80
DISCOUNT RATE:	10%	IRR	5.7%
ESTIMATED WELL COST /m	362TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	KODIAT TRICHA	INITIAL FIN. INVESTMENT	195,192TD
DELEGATION:	SBEITLA	INITIAL INVEST/PERSON	140TD
GOUVERNORAT:	KASSERINE	TOTAL ECON. PV COST	267,106TD
POPULATION 3 KM 1989:		TOTAL ECON COST/PERSON	192TD
POPULATION 6 KM 1989:		TOTAL ECON. COST/m3	0.341TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	1086
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	12,458TD
POPULATION SERVED 1989	1393	COMMUN. CONTRIB. TO O&M	8,029TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	350	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	117	TOTAL ECON. PV BENEFITS	317,461TD
PUMPING RATE (1/s):	10	NET PRESENT VALUE	50,355TD
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	1.19
DISCOUNT RATE:	10%	IRR	13.3%
ESTIMATED WELL COST /m	348TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	OULED AHMED	INITIAL FIN. INVESTMENT	142,139TD
DELEGATION:	FERIANA	INITIAL INVEST/PERSON	65TD
GOUVERNORAT:	KASSERINE	TOTAL ECON. PV COST	222,105TD
POPULATION 3 KM 1989:		TOTAL ECON COST/PERSON	102TD
POPULATION 6 KM 1989:		TOTAL ECON. COST/m3	0.181TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	1701
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	13,041TD
POPULATION SERVED 1989	2181	COMMUN. CONTRIB. TO O&M	8,398TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	200	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	67	TOTAL ECON. PV BENEFITS	497,045TD
PUMPING RATE (l/s):	10	NET PRESENT VALUE	274,940TD
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	2.24
DISCOUNT RATE:	10%	IRR	32.3%
ESTIMATED WELL COST /m	348TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	OULED BOUAL	INITIAL FIN. INVESTMENT	213,871TD
DELEGATION:	GAFSA NORD	INITIAL INVEST/PERSON	487TD
GOUVERNORAT:	GAFSA	TOTAL ECON. PV COST	246,632TD
POPULATION 3 KM 1989:		TOTAL ECON COST/PERSON	562TD
POPULATION 6 KM 1989:		TOTAL ECON. COST/m3	1.001TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	342
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	6,664TD
POPULATION SERVED 1989	439	COMMUN. CONTRIB. TO O&M	3,186TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	400	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	133	TOTAL ECON. PV BENEFITS	100,047TD
PUMPING RATE (l/s):	10	NET PRESENT VALUE	(146,585TD)
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	0.41
DISCOUNT RATE:	10%	IRR	-3.7%
ESTIMATED WELL COST /m	362TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	OULED ZID	INITIAL FIN. INVESTMENT	163,089TD
DELEGATION:	GAFSA NORD	INITIAL INVEST/PERSON	490TD
GOUVERNORAT:	GAFSA	TOTAL ECON. PV COST	188,598TD
POPULATION 3 KM 1989:		TOTAL ECON COST/PERSON	566TD
POPULATION 6 KM 1989:		TOTAL ECON. COST/m3	1.009TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	260
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	5,053TD
POPULATION SERVED 1989	333	COMMUN. CONTRIB. TO O&M	1,969TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	250	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	83	TOTAL ECON. PV BENEFITS	75,890TD
PUMPING RATE (1/s):	10	NET PRESENT VALUE	(112,709TD)
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	0.40
DISCOUNT RATE:	10%	IRR	-3.8%
ESTIMATED WELL COST /m	398TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	SERG LAHMAR	INITIAL FIN. INVESTMENT	189,028TD
DELEGATION:	SBEITLA	INITIAL INVEST/PERSON	198TD
GOUVERNORAT:	KASSERINE	TOTAL ECON. PV COST	243,536TD
POPULATION 3 KM 1989:		TOTAL ECON COST/PERSON	255TD
POPULATION 6 KM 1989:		TOTAL ECON. COST/m3	0.454TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	746
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	9,921TD
POPULATION SERVED 1989	956	COMMUN. CONTRIB. TO O&M	5,692TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	350	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	117	TOTAL ECON. PV BENEFITS	217,870TD
PUMPING RATE (1/s):	10	NET PRESENT VALUE	(25,666TD)
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	0.89
DISCOUNT RATE:	10%	IRR	7.8%
ESTIMATED WELL COST /m	348TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	TOUALBIA	INITIAL FIN. INVESTMENT	150,589TD
DELEGATION:	KASS. SUD	INITIAL INVEST/PERSON	185TD
GOUVERNORAT:	KASSERINE	TOTAL ECON. PV COST	191,918TD
POPULATION 3 KM 1989:		TOTAL ECON COST/PERSON	236TD
POPULATION 6 KM 1989:		TOTAL ECON. COST/m3	0.420TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	635
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	7,148TD
POPULATION SERVED 1989	814	COMMUN. CONTRIB. TO O&M	3,976TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	250	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	83	TOTAL ECON. PV BENEFITS	185,509TD
PUMPING RATE (l/s):	10	NET PRESENT VALUE	(6,410TD)
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	0.97
DISCOUNT RATE:	10%	IRR	9.1%
ESTIMATED WELL COST /m	348TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	ZANNOUCHE	INITIAL FIN. INVESTMENT	179,502TD
DELEGATION:	SNED	INITIAL INVEST/PERSON	102TD
GOUVERNORAT:	GAFSA	TOTAL ECON. PV COST	250,975TD
POPULATION 3 KM 1989:		TOTAL ECON COST/PERSON	143TD
POPULATION 6 KM 1989:		TOTAL ECON. COST/m3	0.255TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	1366
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	12,023TD
POPULATION SERVED 1989	1752	COMMUN. CONTRIB. TO O&M	7,890TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	250	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	83	TOTAL ECON. PV BENEFITS	399,276TD
PUMPING RATE (l/s):	10	NET PRESENT VALUE	148,301TD
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	1.59
DISCOUNT RATE:	10%	IRR	20.1%
ESTIMATED WELL COST /m	439TD		

APPENDIX D

Detailed Benefit/Cost Results for Candidate Project Sites

APPENDIX D

Detailed Benefit/Cost Results for Candidate Project Sites

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	BNENNA	INITIAL FIN. INVESTMENT	186,832TD
DELEGATION:	FOUSSANA	INITIAL INVEST/PERSON	70TD
GOUVERNORAT:	KASSERINE	TOTAL ECON. PV COST	318,805TD
POPULATION 3 KM 1989:	2208	TOTAL ECON COST/PERSON	119TD
POPULATION 6 KM 1989:	3000	TOTAL ECON. COST/m3	0.212TD
ORIG. TRAVEL DIST.(km)	10	AVERAGE OPER. HRS / YR	2088
PROJECT RADIUS(km):	5	AVERAGE ANN. O&M COST	24,392TD
POPULATION SERVED 1989	2677	COMMUN. CONTRIB. TO O&M	18,044TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	657
TOTAL WELL DEPTH(m):	300	ECON BENEFIT/FAM/1st YR	147TD
STATIC WATER LEVEL (m)	150	TOTAL ECON. PV BENEFITS	655,520TD
PUMPING RATE (1/s):	10	NET PRESENT VALUE	336,715TD
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	2.06
DISCOUNT RATE:	12%	IRR	35.6%
ESTIMATED WELL COST /m	350TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	EL HAZZA	INITIAL FIN. INVESTMENT	159,210TD
DELEGATION:	FOUSSANA	INITIAL INVEST/PERSON	62TD
GOUVERNORAT:	KASSERINE	TOTAL ECON. PV COST	228,118TD
POPULATION 3 KM 1989:	1830	TOTAL ECON COST/PERSON	89TD
POPULATION 6 KM 1989:	3054	TOTAL ECON. COST/m3	0.159TD
ORIG. TRAVEL DIST.(km)	10	AVERAGE OPER. HRS / YR	1993
PROJECT RADIUS(km):	5	AVERAGE ANN. O&M COST	13,670TD
POPULATION SERVED 1989	2555	COMMUN. CONTRIB. TO O&M	9,139TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	657
TOTAL WELL DEPTH(m):	250	ECON BENEFIT/FAM/1st YR	147TD
STATIC WATER LEVEL (m)	60	TOTAL ECON. PV BENEFITS	625,649TD
PUMPING RATE (1/s):	10	NET PRESENT VALUE	397,532TD
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	2.74
DISCOUNT RATE:	12%	IRR	43.5%
ESTIMATED WELL COST /m	350TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	FIDH EL METHN.	INITIAL FIN. INVESTMENT	172,863TD
DELEGATION:	SBEITLA	INITIAL INVEST/PERSON	113TD
GOUVERNORAT:	KASSERINE	TOTAL ECON. PV COST	237,929TD
POPULATION 3 KM 1989:	1524	TOTAL ECON COST/PERSON	156TD
POPULATION 6 KM 1989:	2100	TOTAL ECON. COST/m3	0.278TD
ORIG. TRAVEL DIST.(km)	6	AVERAGE OPER. HRS / YR	1698
PROJECT RADIUS(km):	3	AVERAGE ANN. O&M COST	13,210TD
POPULATION SERVED 1989	1524	COMMUN. CONTRIB. TO O&M	8,551TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	394
TOTAL WELL DEPTH(m):	300	ECON BENEFIT/FAM/1st YR	88TD
STATIC WATER LEVEL (m)	110	TOTAL ECON. PV BENEFITS	223,882TD
PUMPING RATE (l/s):	7	NET PRESENT VALUE	(14,046TD)
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	0.94
DISCOUNT RATE:	12%	IRR	10.3%
ESTIMATED WELL COST /m	350TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	HEN. EL KHEIMA	INITIAL FIN. INVESTMENT	144,087TD
DELEGATION:	FERIANA	INITIAL INVEST/PERSON	118TD
GOUVERNORAT:	KASSERINE	TOTAL ECON. PV COST	185,856TD
POPULATION 3 KM 1989:	1140	TOTAL ECON COST/PERSON	152TD
POPULATION 6 KM 1989:	1800	TOTAL ECON. COST/m3	0.271TD
ORIG. TRAVEL DIST.(km)	7	AVERAGE OPER. HRS / YR	634
PROJECT RADIUS(km):	3.5	AVERAGE ANN. O&M COST	8,590TD
POPULATION SERVED 1989	1219	COMMUN. CONTRIB. TO O&M	5,095TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	460
TOTAL WELL DEPTH(m):	200	ECON BENEFIT/FAM/1st YR	103TD
STATIC WATER LEVEL (m)	80	TOTAL ECON. PV BENEFITS	208,999TD
PUMPING RATE (l/s):	15	NET PRESENT VALUE	23,143TD
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	1.12
DISCOUNT RATE:	12%	IRR	14.1%
ESTIMATED WELL COST /m	350TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	KEF LAFRACH	INITIAL FIN. INVESTMENT	197,369TD
DELEGATION:	MAJEL BEL AB.	INITIAL INVEST/PERSON	151TD
GOUVERNORAT:	KASSERINE	TOTAL ECON. PV COST	257,111TD
POPULATION 3 KM 1989:	924	TOTAL ECON COST/PERSON	197TD
POPULATION 6 KM 1989:	2400	TOTAL ECON. COST/m3	0.350TD
ORIG. TRAVEL DIST.(km)	8	AVERAGE OPER. HRS / YR	1019
PROJECT RADIUS(km):	4	AVERAGE ANN. O&M COST	12,765TD
POPULATION SERVED 1989	1307	COMMUN. CONTRIB. TO O&M	8,182TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	526
TOTAL WELL DEPTH(m):	350	ECON BENEFIT/FAM/1st YR	118TD
STATIC WATER LEVEL (m)	130	TOTAL ECON. PV BENEFITS	255,940TD
PUMPING RATE (l/s):	10	NET PRESENT VALUE	(1,171TD)
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	1.00
DISCOUNT RATE:	12%	IRR	11.6%
ESTIMATED WELL COST /m	350TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	MAGSEM BOUR.	INITIAL FIN. INVESTMENT	159,210TD
DELEGATION:	SNED	INITIAL INVEST/PERSON	68TD
GOUVERNORAT:	GAFSA	TOTAL ECON. PV COST	224,115TD
POPULATION 3 KM 1989:	1404	TOTAL ECON COST/PERSON	95TD
POPULATION 6 KM 1989:	3000	TOTAL ECON. COST/m3	0.170TD
ORIG. TRAVEL DIST.(km)	10	AVERAGE OPER. HRS / YR	1832
PROJECT RADIUS(km):	5	AVERAGE ANN. O&M COST	12,981TD
POPULATION SERVED 1989	2350	COMMUN. CONTRIB. TO O&M	8,451TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	657
TOTAL WELL DEPTH(m):	250	ECON BENEFIT/FAM/1st YR	147TD
STATIC WATER LEVEL (m)	60	TOTAL ECON. PV BENEFITS	575,321TD
PUMPING RATE (l/s):	10	NET PRESENT VALUE	351,206TD
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	2.57
DISCOUNT RATE:	12%	IRR	40.1%
ESTIMATED WELL COST /m	350TD		

CTDA USAID/TUNISIA RURAL POTABLE WATER INSTITUTIONS PROJECT No. 664 0337

PROJECT SITE ECONOMIC ANALYSIS 21-Feb-90

INPUTS:		RESULTS:	
SITE:	MENZEL GAMM.	INITIAL FIN. INVESTMENT	171,912TD
DELEGATION:	GAFSA NORD	INITIAL INVEST/PERSON	93TD
GOUVERNORAT:	GAFSA	TOTAL ECON. PV COST	225,267TD
POPULATION 3 KM 1989:	1068	TOTAL ECON COST/PERSON	121TD
POPULATION 6 KM 1989:	2400	TOTAL ECON. COST/m3	0.216TD
ORIG. TRAVEL DIST.(km)	10	AVERAGE OPER. HRS / YR	1448
PROJECT RADIUS(km):	5	AVERAGE ANN. O&M COST	11,332TD
POPULATION SERVED 1989	1857	COMMUN. CONTRIB. TO O&M	6,801TD
POP. GROWTH RATE:	3.0%	TIME SAVINGS/FAM/YR	657
TOTAL WELL DEPTH(m):	300	ECON BENEFIT/FAM/1st YR	147TD
STATIC WATER LEVEL (m)	60	TOTAL ECON. PV BENEFITS	454,751TD
PUMPING RATE (1/s):	10	NET PRESENT VALUE	229,484TD
DISTRIB. LENGTH (m):	1000	BENEFITS / COSTS	2.02
DISCOUNT RATE:	12%	IRR	29.5%
ESTIMATED WELL COST /m	350TD		

WASH