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ECONOMIC EVALUATION
OF THE
COMPREHENSIVE GROUNDWATER DEVELOPMENT PROJECT

Democratic Republic of Somalia

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I. Introduction

This economic evaluation is being undertaken two years into the well construction activities of the Comprehensive Groundwater Development Project (CGDP). It is being undertaken with a view to advancing knowledge of the costs and benefits of the project. However, the evaluaiton is not a thorough cost-benefit analysis of the groundwater project, since there is insufficient end user data to allow the quantification of benefits.

By being written two years into the groundwater project, much data has been collected concerning the hydrology of the project areas, the site selection procedures, and working conditions. This report will use all available information to look at both longterm costs and benefits. In particular, it will forecast the costs of continuing the groundwater project for the life of its heavy equipment, or through the year 1991.

The report consists of three distinct parts:

(1) an analysis of the full costs of the groundwater development program for a period of ten years, 1982-1991. This includes the first two years of drilling under CGDP, and the projected cost of continuing the project for eight more years.

(2) an analysis of projected benefits, measured by the number of water points completed, the approximate number of beneficiaries, and the qualitative type of benefits to be expected.

(3) an analysis of the long-term well operating and maintenance costs, with a look into the possible financing of these costs through the collection of user fees.

The time frame of this analysis, 1982-1991, is chosen as being the projected life of the most long-lived and expensive capital equipment purchased under CGDP, that is, the three rotary drill rigs. The costing of the program takes into account the following costs:

- all Water Development Agency (WDA) salary, materials, equipment, and workshop costs;
- well operating and maintenance costs;
- WDA administrative overhead;
- capital equipment costs.

By assuming an annual well-completion rate, an annualized average cost per well is estimated.

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It should be emphasized from the outset that the intent of this evaluation is to estimate the long-term cost to the Somali government of producing wells. This means that not all of the USAID CGDP project costs are included in the analysis, since the scope of the CGDP project was larger than the scope of this analysis. The 'extra' costs that are excluded from the long-term costing of the groundwater project are:

- expatriate salary costs; the expatriate consultant staff under CGDP is serving primarily as advisors and trainers of WDA groundwater personnel, and their costs do not represent recurring costs to the Somali government.

- expatriate housing and support costs.

- Somali training costs; this USAID program to send Somali technical personnel to the U.S. for university training is not a well production cost.

It is further noted that for this analysis, no assumption is made about future USAID support for the pending CGDP project, since such funding would not impact the long-term costs of the well-drilling program. Continued USAID financing would effectively shift the burden of costs, but would not alter the costs themselves. Also, any future expatriate costs, if and when incurred, would be excluded for the same reasons given above, ie. that they would not represent costs facing the Somali government of continuing the well-drilling program.

This report is meant to be used in several ways. First, it provides a financial guide to all future planning of the CGDP program. By explicitly determining direct, indirect, and capital costs, and by distinguishing between past or sunk costs and future cost projections, it is possible to estimate the annual financial needs of the project. Also, these estimates can be easily varied as more information on well-drilling rates, costs, and capital equipment life expectancy becomes available. Second, it can be used by the Somali government as a basis for requesting future foreign assistance, if necessary. The study looks at the degree to which the project can be self-financing by estimating what percentage of total costs are recoverable through user fees. It also looks at the foreign exchange requirements of continuing the groundwater project. Third, as more information becomes available on the alternatives to drilled wells in Somalia, such as surface reservoirs, this report will allow useful comparisons of costs of different technologies and development strategies. Similarly, as more information becomes available on project benefits, a more detailed cost-benefit analysis could be easily done and used as a basis for comparing technologies and development priorities. Fourth, the report can be used to compare the

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cost of constructing wells in Somalia with that of similar programs in other countries. In this way, it can be of use to policy and program offices of the various international donor agencies.

The report is divided into six chapters. Chapter I gives an overview of the contents and purpose of the report, and Chapter II summarizes the drilling program and costs of the first two years of CGDP. Detailed analysis of the equipment procurements, drilling rates, well-depths, and well locations is used in projecting the costs and benefits for the next eight years.

Chapter III details the costs associated with each aspect of the groundwater project, and divides these costs between direct, indirect, and capital costs.

Chapter IV looks into the project benefits, with particular emphasis on the number of probable beneficiaries, the projected water consumption rate, and the type of health and social benefits to be expected. Although the data available concerning human and livestock populations in the project areas is extremely limited, several sources have been consulted and contrasted in order that certain assumptions and 'village well profiles' be drawn up.

Chapter V is devoted to the question of financing the long-term operation and maintenance of the wells. Chapter VI offers final conclusions.

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II. Comprehensive Groundwater Development Project, Phase I: Wells Drilled and Costs

The Comprehensive Groundwater Development Project, financed by USAID, is devoted to groundwater development in the Bay and Central Rangeland Regions of Somalia. A major emphasis of the project is on technical assistance, and on the training of Somali counterparts in all aspects of well production and operation. A contracting team headed by Louis Berger International works with the Water Development Agency (WDA), within the Ministry of Mineral and Water Resources.

Although the original equipment procurements were issued in 1980, the project was mobilized upon arrival of the project team in July, 1981. Actual drilling activities began in January, 1982. The three year period between July 1981 and July 1983, which is the expiration date of the current Louis Berger contract, is referred to as CGDP-I.

2.1 The CGDP-I Well-Drilling Program

The CGDP-I well-drilling program has been focussed in the Bay Region, southwest of Mogadishu, and on the Hiiraan, Galgaduud, and Mudug Regions, in the Central Rangelands (see Figure 2.1). Of these two areas, the Bay Region is the more densely populated, and has been the site of more extensive drilling.

The project objectives are to complete 48 production wells in the two regions. CGDP-I will probably not meet these objectives, due to a wide variety of procurement delays, fuel shortages, equipment breakdowns, and delays in the site selection process. The number of exploratory, dry, and salty wells has been a higher percentage of the total number of wells drilled than was originally expected. By the end of CGDP-I in July, 1984, it is projected that there will be completed a total of 36 production boreholes, of which 24 will be fully operational well installations.

Table 2.1 contains a list of all the boreholes drilled under CGDP-I through the beginning of December, 1983. A summary of the drilling program is shown in Table 2.2, where it is seen that a total of 51 wells have been drilled, at an average depth of 93 meters. Of these, 21 have the potential of being production wells (pending the pump testing of each well), which implies that about 41% of all boreholes are potential production wells. The future 'success' rate will almost certainly be much higher, since (a) the current drilling program is in areas where there was little or no previously available hydrogeological data, and where many wells were exploratory in nature; and (b) the data collected

Figure 2.1

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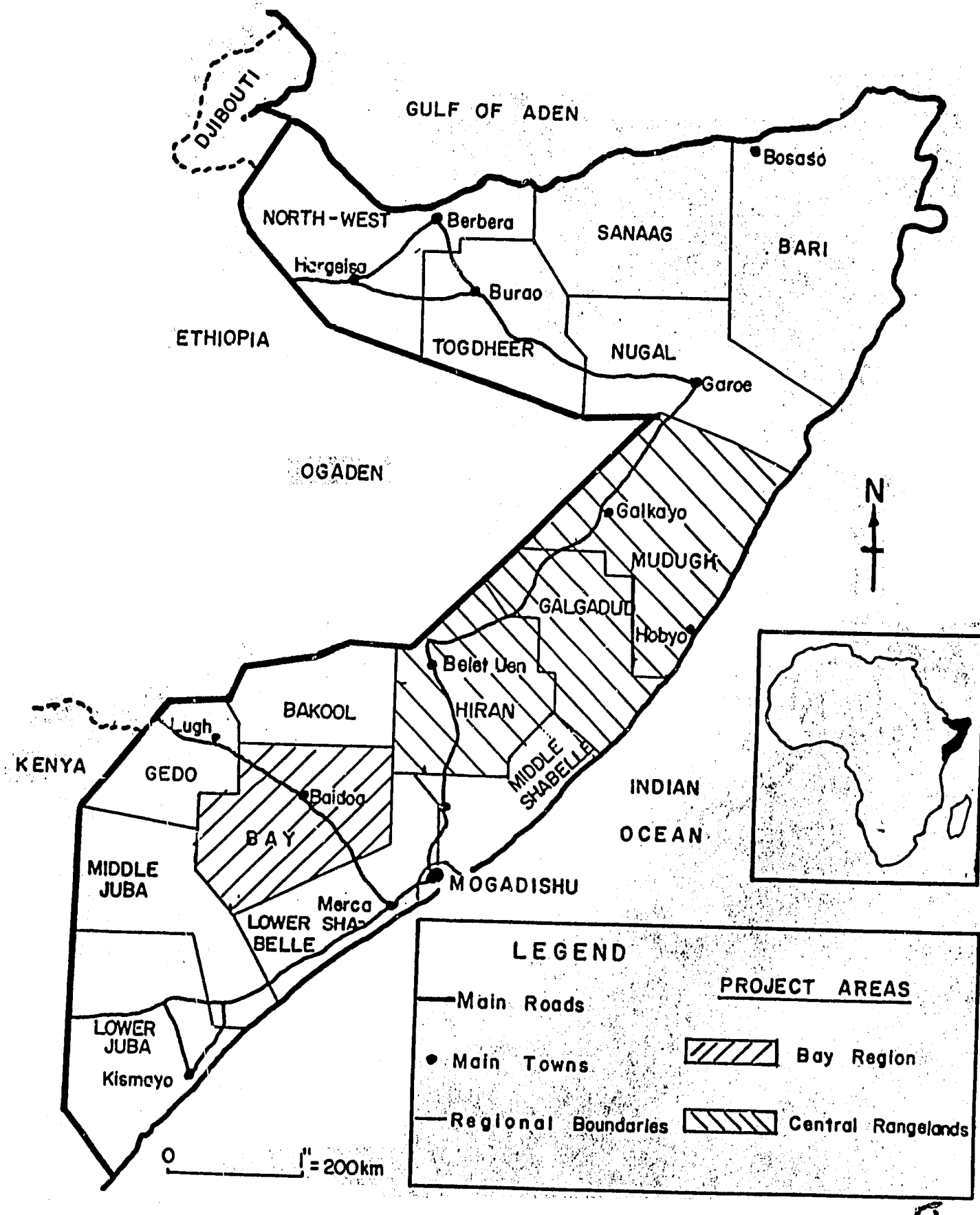

Table 2.1 Physical Characteristics of CGDP-I Boreholes

	Name	Region	Date Completed	Depth	Comment
1	Bonkay Farm I	Bay	2/82	19	Dry
2	Bonkay Farm II	Bay	2/82	201	Abandoned -- casing separated
3	Bonkay Farm III	Bay	4/82	160	PP-D
4	Tugerew I	Bay	6/82	42	PP-H
5	Gasarta	Bay	3/82	42	Dry
6	Waraji I	Bay	3/82	80	Dry
7	Waraji II	Bay	3/82	39	Dry
8	Tugerew II	Bay	3/82	48	Dry
9	Bur Halab	Bay	3/82	32	Dry
10	Sarmaan Dheere	Bay	4/82	85	PP-D
11	USAID Compound I	Bay	6/82	140	Observation well -- redrilled to seal off upper aquifer
12	Hareero Jiifo	Bay	8/82	80	PP-D
13	Shabelle Dugsilo	Bay	6/82	130	Salty
14	Warta Jaffay	Bay	7/82	97	Salty
15	Qansax Omane	Bay	7/82	89	Dry
16	Taflaaw	Bay	7/82	153	PP-D
17	Robay Gaduud	Bay	10/82	142	PP-D
18	Gaduufo Dhunte	Bay	9/82	80	PP-D
19	Buulo Fur I	Bay	10/82	94	Dry
20	Durei Ali Galle	Bay	10/82	118	PP-D
21	USAID Compound II	Bay	11/82	42	PP-D
22	Buulo Gaduud	Bay	1/83	188	Dry
23	Kurman	Bay	1/83	148	PP-H
24	Yaaq Braawe	Bay	1/83	10	PP-D
25	Dodole	Bay	1/83	24	PP-H
26	Shiidaalow I	Bay	1/83	67	Salty
27	Shiidaalow II	Bay	1/83	80	Salty
28	Bur Akaba I	Bay	1/83	54	Salty
29	Bur Akaba II	Bay	1/83	24	Salty
30	Bur Akaba III	Bay	1/83	62	Salty
31	Bur Akaba IV	Bay	2/83	63	Salty
32	Bur Akaba V	Bay	2/83	86	PP-H
33	Bur Heybo I	Bay	2/83	26	PP-H
34	Bur Heybo II	Bay	2/83	70	Dry
35	Bur Heybo III	Bay	2/83	60	Dry
36	Bur Heybo IV	Bay	3/83	25	Dry
37	Bur Heybo V	Bay	3/83	27	Dry
38	Bur Heybo VI	Bay	3/83	36	Dry
39	(no well)				
40	Bur Dijis	Bay	3/83	32	Dry

(Continued...)

Table 2.1 (continued...)

	Name	Region	Date Completed	Depth	Comments
41	Dolondole	Bay	4/83	166	PP-D
42	Buulo Fur II	Bay	5/83	130	PP
43	Aborey I	CR	6/83	120	Dry
44	Afar Irdood	CR	6/83	174	Dry
45	(no well)				
46	Qansax Dheere	Bay	6/83	103	PP
47	Aw Shiini	Bay	6/83	145	PP
48	More Ari	CR	6/83	102	PP
49	Maxaas I	CR	9/83	190	Dry
49A	Maxaas II	CR	9/83	182	Dry
50	Bonkay Farm IV	Bay	8/83	198	Salty
51	Mintaan	Bay	11/83	130	PP-D
52	Maleel	Bay	11/83	126	PP

Note: PP - Potential Production well, pending pump testing and installation, where:
D - signifies the probable use of a diesel pump.
H - signifies the probable use of a hand pump
The last few wells have not had the probable pump type designated yet.

Table 2.2 Summary of Drilled Well Characteristics, as of December 1983

Number of completed boreholes	51
Number of potential production wells:	
Diesel pumped	11
Hand pumped	5
Undetermined	5
Total --	21
Number of dry, salty, abandoned, or observation wells:	30
Potential production wells, as % of total # drilled:	41%
Average depth: (m)	
Production wells	100
Others wells	89
All boreholeles --	93

by the CGDP-I project will assist in the selection of future well sites.

2.2 CGDP-I Equipment Costs

A summary of the equipment procurement costs incurred during the period 4/1980 - 12/1983 is shown in Table 2.3. The details of all USAID procurements (PIOC's), contractor funds, and local support items, from which this summary is derived, are shown in Appendix A. Some of the equipment, tools, and well materials were procurred under USAID projects other than the CGDP-I project, such as the Bay Region Agricultural Development Project and the Central Rangelands Development Project. These procurement costs are also included in Table 2.3 and detailed in Appendix A.

The CGDP-I project has assembled a variety of heavy and sophisticated equipment: for a complete list see Table 3.13 in the next chapter. The project currently has:

- 3 Ingersoll Rand TH60 rotary drill rigs;
- light passenger vehicles and pickups;
- flatbed trucks, three of which have knuckle cranes, and fuel and water tankers;
- generators, welders, heavy duty test pumps, and workshop equipment for light and heavy vehicles;
- scientific test equipment for geophysical, hydrogeological, well logging, and water quality analysis;
- workshops for repairing both light and heavy vehicles;
- office and field (camping) equipment, and mobile radios for field communications;
- an inventory of well casings, screens, drill bits, cement, pipes, and fittings required for the complete installation of about 30 wells.

The total cost of this equipment is about $7.6 million. It is estimated that most capital requirements have been met through to the end of 1984, and that there is sufficient inventory of drilling materials, bits, and fittings to complete the scheduled number of wells.

Further analysis of these procurement costs is deferred to later in the next chapter. Much of the capital equipment procured under CGDP-I will be used throughout the 1980's, and its cost, both on an annualized and a per-well basis, must be compared with a full cost stream of the drilling program from now through 1991. The cost projections also include estimates of future capital expenditures on replacement equipment and vehicles. While it is projected that not all worn-out equipment will be replaced -- which means that the project could become somewhat less capital-intensive than it is now -- there is no consideration given

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Table 2.3 Summary of CGDP-I Procurements, including Bay and CR Procurements (as of 12/83)

Item category	CGDP-I PIOC #	CGDP-I	Bay & CR	Total Value
		- - CIF Value, US$ - -		
A. Heavy rigs				
- 3 TH60 drilling rigs, with accessories	#00001	1651580		1651580
- TH60 spare parts	#10015, 20007, 20034	268704		268704
- Extra drill rig tools (exc. drill bits)	#20007,20034	84448	87984	172432
- 2 SEMCO pump rigs	--		182400	182400
- Pump rig spare parts	--		17410	17410
Subtotal --		2004732	287794	2292526
B. Vehicles				
- Light vehicles (including down-the-hole video van)	#90047, 90049, 10001, 20007, 20022, 20034, and LBI(s)	856108		856108
- Heavy vehicles (including backhoe and trailers)	#10001,20022, 20034	426780	743704	1170484
Subtotal --		1282888	743704	2026592
C. Vehicle spares and workshop equipment				
- For light vehicles	#10001, 20015 20022, LBI	287582		287582
- For heavy vehicles	#20007, 20009 20014, 20034 00072	319488		319488
Subtotal --		607070		607070
D. Light equipment and spare parts				
- Generators, welders, test pumps and spare parts	#00007, 10024, 20007, 20034	252194	21160	273354
- Diesel and hand deepwell pumps	--	--	683344	683344
- Deepwell pump spare parts	--	--	100000	100000
Subtotal --		252194	804504	1056698
E. Logging equipment (including satellite navigators)	#20007,90140, 20034	267728		267728
F. Hydrogeological equipment	#20007, 20034	62960		62960
G. Water quality analysis equipment	#10018, 10019, 20007, 20034	45000		45000
H. Field equipment and campers	#10011, 20018, 20022, 20034	124462		124462
I. Office and radio equipment	#00007, 10024, 20007, 30016	176104		176104
J. Drill casing, bits, mud, and foam	#10001, 10007,	212580	518308	730888
K. Civil works tools, materials, and fittings	#10039, 00066, 30020	193050	55000	248050
Total (US$) --		5228768	2409310	7638078

Note: The total here does not equal the total value of all CGDP, LBI, Bay, and CR procurements, because some items not directly related to the well-drilling program were omitted. These items include expatriate house furnishings, spare parts for WDA drill rigs not used on this project, 2 experimental windmills and 2 Airstream trailers. See Appendix A.

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to altering the basic choice of drilling technology and/or the organization of the drilling units.

2.3 CGDP-I Operating Costs

By far the greatest cost of CGDP-I was the cost of equipment and supplies, procured and paid for by USAID. All local costs, however, were paid for by the WDA. These costs, which are shown in Table 2.4, include salaries; fuel costs; locally-obtainable materials such as pipe, cement, and lumber; insurance; office construction; and certain vehicle repair costs. The local contribution for 1983 -- the first full project calendar year -- was about $600,000, and the projected local cost for next year is projected to rise to about $750,000.

These costs will be used in Chapter III as a basis for projecting future project indirect (overhead) costs. Is is quite possible that as experience is gained and lessons are learned, operating cost savings and increased efficiencies will become possible. These will be addressed in later chapters.

Table 2.4 Local Budget (WDA contribution in Shillings)

Item/Year	1982 (April-Dec.)	1983	1984 (Budgetted)
Salaries			
Field Support	683560	1640000	2343000
Management allowance	358875	504000	1886400
Local Hire	80525	225000	321600
--Subtotal, salaries	1122960	2369000	4551000
Fuel			
Gasoline	n/a	800000	1030850
Diesel	n/a	1850000	3503830
Lubricants	n/a	15000	28560
--Subtotal, fuels	1411685	2665000	4563240
Local support items (inc. cement, pipe, field equipment, lumber)	487270	1762000	970000
Construction (civil works)	---	1300000	2800000
Insurance	1070	109000	83000
Port clearance fees	16270	300000	100000
Office/Garage construction	---	180000	---
Vehicle repair	---	400000	---
Other (inc. contingencies)	364960	---	---
Total -- (Somali Shillings)	3404215	9085000	13067240
Total -- (US dollars)	255572	585374	751855
(Exchange rate SS/US$)*	13.32	15.52	17.38

Note: (*) For 1982 and 1983, a weighted average of each month's exchange rate is used. For 1984, a continuation of the exchange rate effective in Dec. 1983 is assumed.

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III. CGDP Cost Analysis

3.1 Methodology

This chapter undertakes an analysis of the full long-term costs of the groundwater development program. The analysis is made for the ten-year period from 1982, when CGDP drilling began, to the end of 1991. Ten years is the estimated life of the three TH60 rotary drill rigs, which are the most long-lived and expensive capital equipment purchased under CGDP-I.

The cost estimations made here build upon the basic methodology laid out in the previous report entitled "Preliminary Economic Analysis of the Comprehensive Groundwater Development Project," LBI, May 1982. In this methodology, costs are divided into direct and indirect costs, and are broken down by activity and by resource inputs. Cost estimates for each activity are then put into an accounting matrix, which shows at a glance the cost breakdown of both individual wells and of the groundwater development program as a whole.

The cost accounting matrix shown in Figure 3.1 illustrates how the CGDP costs are broken down by activity, and is the same matrix that appears at the end of the chapter (Table 3.17) complete with all cost data. The six activities for which separate costs are specified are (1) site selection (including hydrological and geophysical research, planning, and socioeconomic evaluation); (2) drilling (including drilling, setting of the casing and screen, ongoing hydrogeological analysis, and well logging); (3) well testing (including pump testing and water quality analysis); (4) pump installation (including the construction of the water distribution facilities); (5) well operation and maintenance; and (6) central office, warehouse, and workshop support services. For the purpose of this analysis, certain assumptions are made about all of these activities -- especially concerning the location, drilling rate, and the useful life of the capital equipment -- and are discussed below.

Direct costs, or variable costs, are defined as those costs that are directly attributable to the work going on at a given well at a given time. They include all the materials used in the production of a well, the fuel consumed in the process of drilling, testing, and finalizing a well, and the perdiems paid to the field crew for time spent at the well site. Indirect costs are those costs that do not vary with the actual production rate, and that are relatively independent of work on individual wells. These costs include all office overhead and capital recovery costs -- of which,

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Figure 3.1 Cost Matrix for Estimating Groundwater Development Costs (*)

Activity	DIRECT COSTS			INDIRECT COSTS				CAPITAL COSTS				TOTAL COSTS
	Labor	Materials	Fuel	Labor	Materials	Fuel	Misc. Overhead	Heavy Rigs	Heavy Vehicles	Light Vehicles	Light Equipment	
1. Site Selection (inc. hydrological, geophysical, and socioeconomic evaluation)												
2. Well Drilling (inc. well drilling, setting of casing and screen, and logging)												
3. Well testing (inc. pump and water quality testing)												
4. Final Installation (inc. civil works and pump installation)												
5. Well Operation and Maintenance												
a. Operations (for 10 years)												
b. Maintenance (for 10 years)												
Subtotal												
6. Central Office (inc. admin., GSO, workshop, warehouse)												
Total of column												
Percent of Total Cost (%)												
Average Cost per Well												

Note: (*) See Figure 3.2 for breakdown of direct and indirect costs.

it will be seen, capital recovery costs are by far the larger. A complete breakdown of both kinds of costs is shown in Figure 3.2.

It will be seen below that indirect costs are much larger than direct costs. This is due to the large capital investment that has gone into the CGDP-I project, a cost which is amortized over the life of the equipment (which varies depending on the kind of equipment) and which is divided among the relatively small number of wells projected to be drilled per year.

The analytical results obtained here can be used:

- to provide a financial guide to the WDA and other agencies for all future planning of the CGDP program. It can also be used by the WDA in planning and preparing budgets for other groundwater projects, assuming the choice of drilling technology is similar;

- to assist in gaining cost savings and greater program efficiencies;

- to assist in calculating water user charges based on either average or marginal costs (see Chapter V);

- on the basis of projected demand and water revenues, the cost projections shown at the end of the chapter can be used by the WDA as a basis for requesting future foreign assistance.

- to provide government and international agencies with data necessary for comparing drilled wells with alternative drilling technologies and/or alternative water supply sources.

Of course, the cost projections calculated here should be updated over time as more wells are constructed, operated, and maintained.

3.2 Assumptions

The experience gained through the first two and one half years of CGDP-I suggests that the following assumptions can be made about the continuation of the groundwater development program:

(1) The three TH60 rotary rigs can be expected to complete about 30 boreholes per year. This has been the rate achieved during CGDP-I, including all of the delays experienced in the drilling program. (On average, two of the three rigs were active at any given time.)

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Figure 3.2 Cost Breakdown into Direct and Indirect Costs

Category	Direct costs	Indirect costs (Overhead)
Labor:	Field perdiems for work crews and crew managers	Salaries Living allowances Field Perdiems for central office staff Expatriate chief mechanic
Materials:	Well casing, screen Drilling supplies (inc. tri-cone bits) Pumps, pipes, fittings and cement for final well installations Analytical supplies for water quality tests	Office equipment and supplies Field equipment Supplies for routine maintenance Warehouse supplies
Fuel:	On-site fuel Fuel for transport of materials and men to and from sites	Fuel for central office and warehouse vehicles, and fuel used by other vehicles while on overhead Lubricants
Misc.:		Insurance Port clearance Office and warehouse rent (actual or imputed)
Capital Recovery costs:		Drill rigs and spares Drill pipe and hammer bits Heavy vehicles and spares Light vehicles and spares Light equipment (eg. pumps, welders, generators) and all spare parts Workshop tools

(2) Of these 30 boreholes/year, about 18, or sixty percent, will be production boreholes. This is a slightly higher percentage than has been experienced during CGDP-I, but as discussed in the previous chapter, it is reasonable to expect it to increase.

(3) The average well will be, as in CGDP-I, about 100 meters deep, drilled first with a 8" hammer bit and then reamed to 12 1/4", and cased with about 75 meters of casing and 25 meters of screen. Non-production wells, which include exploratory, collapsed, salty, and abandoned wells, are assumed to average 100 meters in depth and be drilled with a hammer bit only.

(4) Of the 18 production wells produced each year, about 10 will be fitted with a diesel pump, and 8 with handpumps. This is consistent with the experience of CGDP-I. The choice between diesel and hand-powered pumps is usually made on the basis of well capacity, depth, local user population, and accessibility for maintenance.

(5) The well-drilling program will continue in the Bay Region and Central Rangelands, with two rigs operating in Bay and one rig in the the Central Rangelands. The WDA office in Baidoa will continue to serve as a base for the Bay Region operations, and the various WDA regional offices will serve the Central Rangelands.

(6) The WDA will take on all of the well production and administrative responsibilities now handled by either the WDA, the CGDP-I consultants, or both. No assumption is made concerning future USAID support for the project, since the cost of providing expatriate technical assistance is not included in this analysis.

(7) The number of WDA employees on this project will be sufficient to complete all the tasks necessary to a successful well-drilling program. They will be permanent government employees, which means that their salaries will not depend on work accomplished in the field. (Only their field perdiems will vary.)

(9) The cost projections are made for the period 1984 to 1991, and are based on the real costs incurred in 1982 and 1983. This total ten-year period, 1982-1991, is chosen as being the projected life-span of the three drill rigs in Somalia, if adequately maintained. (They were first used in

January, 1982.) Since much of the capital equipment will require replacement prior to 1991, it is assumed that sufficient capital expenditures will be made during the interim years to replace all necessary equipment. (Due to certain program improvements, however, not all of the capital equipment procured during CGDP-I and retired before 1991 will require replacement.) Full capital procurement costs and schedules are detailed below.

Certain assumptions are also made concerning economic parameters. For the purpose of simplifying the analysis, it is assumed that:

(1) All future costs are estimated in constant 1983 prices, thus eliminating the price distortions caused by inflation. WDA wages and field perdiems are those effective as of December 1983, and equipment procurement prices are adjusted to the same date. The average cost of the materials used are shown in Table 3.1.

(2) Since inflation is not considered in the projection of costs, real interest rates are used. These are estimated at about 15%, which reflects the high opportunity cost of capital in Somalia.

(3) The exchange rate effective December 1983, which is US$ = 17.38 Somali shillings, is used throughout the analysis. For previous years, weighted averages of historic exchange rates are used.

3.3 The Estimation and Allocation of Fuel Costs

Before further discussion of project direct and indirect costs, one particular cost item -- fuel -- must be discussed in detail. Since fuel is consumed by vehicles involved in every aspect of the project, it must be made clear how the total fuel cost is to be allocated (a) between each of the six project activities, and (b) between direct and indirect costs within each one of those activities. This is done in two steps, as shown in Tables 3.2 and 3.3.

Table 3.2 shows the projected vehicle requirements of each project department, based on the past experience of CGDP-I. It is noted that fewer vehicles than are in the current CGDP-I fleet are seen to be required in the future: the difference is a future requirement of only 32 light vehicles, as opposed to the current number of 40, and only 17 heavy vehicles, one less than the

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Table 3.1 Costs of Materials and Equipment (adjusted to December 1983)

Item	Source	CIF Cost	Usage rate	Average Cost
Concrete				$44.40/m3
Cement	Nairobi	$7.50/bag	3 bags/m3 concrete	::
Gravel (*)	Bur Akaba	SS 600/m3	.3 m3/m3 concrete	::
Sand (*)	Baidoa	SS 60/m3	.6 m3/m3 concrete	::
Drilling fluid				$3.60/m
Bentonite	USA	$17.10/sack	20 sacks/100 m	::
Drilling foam	USA	$770/barrel	1/2 barrel/100 m	::
Drill bits				
12 1/4" tricone bit	USA	$ 3,200	1 per 1,000 meters	$3.20/m
8" hammer and bit	USA	$11,810		
Well casing				
16" ID	USA	$144/m		
8 5/8" OD steel	USA	$75.60/m		
8 5/8" OD PVC	USA	$20.80/m		
Well screen				
8 5/8" OD steel	USA	$103.60/m		
8 5/8" OD PVC	USA	$54.60/m		
Pumps				
Helical Rotor Diesel	UK	$20,020		
Helical Rotor Handpump	UK	$ 1,925		
Heavy Vehicles				$65,000
Flatbeds	USA	$53,000		::
Water tankers	USA	$70,200		::
Fuel Tankers	USA	$70,200		::
Light Vehicles				$21,000
Pickups/Crew cabs	USA	$21,500		::
Passenger vehicles	USA	$19,000		::
Generators (GM/Isuzu)	USA	$24,600		

Note: (*) Costs for Bay Region only. Costs for Central Rangelands will probably not be any lower: although sand is readily available, gravel may have to come come from as far away as Mogadishu.

Table 3.2 Projected Vehicle Requirements, 1984-1991

Department	Passenger Vehicles	Pickups	Heavy Vehicles	Notes on heavy vehicles
Central Office	3	-	-	
General Services	2	-	1	Flatbed
Workshop/Garage	-	2	1	Mechanic's service truck
Drilling:				
- Drill Rigs	-	7	9	3 rigs, 3 flatbeds, 3 water tankers (also, 3 flatbed trailers)
- Baidoa Base	-	-	3	Flatbed, fuel tanker, water tanker
- Central Rangeland Base	-	-	3	Flatbed, fuel tanker, water tanker
Hydrology/Geophysics	2	3	-	
Pump Test/Installation (*)	1	3	2	2 pump rigs
Logging	2	-	-	
Socioeconomics	2	-	-	
Water Quality	1	-	-	
Civil Works	-	4	3	2 flatbeds, 1 backhoe
Total --	13	19	5 --	Heavy rigs
			16 --	Heavy trucks
			1 --	Backhoe

Notes: (*) The light vehicle is the video van.

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Table 3.3 Estimated Yearly Fuel Costs and Allocation of Costs

Vehicle type	Fuel Consumption	Fuel costs (*) (US$/year)	Allocation of costs
1. Heavy vehicles			
3 drill rigs	384 lts/day*12 days/month	46197	100% direct drilling costs
2 pump rigs	225 lts/day*18 days/month	27068	100% direct costs: - 50% pump testing - 50% pump installation
16 heavy trucks	45 lts/day*25 days/month	60152	75% direct, 25% indirect: - 70% drilling - 15% central admin. - 15% civil works
1 Backhoe	negligible	--	--
2. Light vehicles			
17 gasoline vehicles	35 lts/day*25 days/month	60596	25% office, GSO, workshops, all indirect costs. The remaining 75%, 2/3 direct and 1/3 indirect: - 20%, hydrology and drilling - 15% civil works - 5% each, well logging, water quality, socioeconomics and pump testing
15 diesel vehicles	35 lts/day*25 days/month	43861	
Subtotal		104456	
3. Generators, etc.	negligible	--	--
Total cost, US$/year		237873	

Note: (*) Fuel costs as of 12/83, net of government taxes, are:
4.84 SS/lt = $0.27/lt, for diesel fuel.
5.90 SS/lt = $0.34/lt, for gasoline.

current number of 18. (See Table 3.13 for details on the current vehicle fleet).

Table 3.3 shows the estimated fuel consumption, cost, and allocation of fuel costs based on past experience and the projected 1984 fuel budget. The projected fuel consumption is calculated on a per-vehicle basis, and thus reflects the projected reduction in vehicle fleet size. The allocation of total fuel costs shown here is used to determine the direct costs for each well drilled (Section 3.4), and the indirect fuel costs for each project activity (Section 3.5). The fuel prices shown are economic costs, ie. net of all government taxes.

It is noted that the actual distance of the project headquarters and regional offices to the well-sites is not taken into consideration when projecting direct costs. It is not possible to do so, since actual distances cannot be known at this time. Instead, average CGDP-I fuel costs are used as an appropriate indicator, since the area of future drilling activities will be the same as in the past.

3.4 Direct Costs for Individual Wells

In this section the direct costs of each well undertaken under the CGDP project are estimated, using the assumptions concerning well sizes, depths, and drilling rate made above. The direct costs are broken down into the first five categories shown in Figure 3.1. The sixth category, the central office and warehouse, has no component of direct 'per-well' costs, and is discussed in the next section on indirect costs.

3.4.1 Site Selection

The category of site selection activities includes the work of project geophysicists, hydrogeolists, and socioeconomists. As there are no material costs involved in the site selection process, the only costs for this activity are field perdiems and fuel costs (see Table 3.4).

The geophysicists are assumed to be involved only a few days per well during the initial selection of the well site. The hydrologists are involved for a longer period, as they return to the well site during drilling, and are responsible for the analysis of cuttings necessary not only for proper well design but for the purpose of assisting in the selection of future well sites. The socioeconomic crew is scheduled to conduct a series of three meetings with each village being considered for a well in order to determine the village's need for water and interest in contributing to

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Table 3.4 Site Selection Direct Costs, per well (US$)

Item	Units	Cost (US$)
	- - - - Production Wells - - - -	
1. Labor (Field perdiems)		
- Hydrogeologist	12 days*100 SS/day	69
- Assistant hydrogeologist	12 days*75 SS/day	52
- Geophysicist	4 days*100 SS/day	23
- Assistant geophysicist	4 days*75 SS/day	17
- Socioeconomist	3 days*100 SS/day	17
- Assistant socioeconomist	3 days*75 SS/day	13
Subtotal		191
2. Materials		
- negligible for hydrologists and geophysicists		—
- none for socioeconomists		—
Subtotal		—
3. Fuel		
- Heavy vehicles	See Table 3.3	—
- Light vehicles	"	967
Subtotal		967
Total (US$/well)		1158

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the cost of well construction and maintenance. (Details on the series of programmed meetings, called the Tuulo Village Assessment and Participation Process (TVAPP) are contained in the CGDP-I Exploratory Report.) The socioeconomic team will also be involved in the long-term monitoring of the completed wells, which is discussed in Section 3.4.5.

3.4.2 Well Drilling, Logging, and Development

Table 3.5 shows the labor, materials, and fuel costs of drilling, logging, and developing both exploratory and production wells. The labor costs (perdiems) include sufficient time for rig setup and removal as well as actual drilling time. The time required to drill a production well is approximately twice that for an exploratory well, because extra time is needed to ream out the borehole, case it, and develop it. (Well development consists of using the drill rig compressor to help remove fine particles from the well and surrounding aquifer.) The total cost of well casing includes not only well casing and screen, but the 16" conductor collar around the top 5 meters of the well, and the cost of gravel packing, if necessary. Of course, the costs shown here vary from well to well, but are an average based on CGDP-I.

Included in the materials cost are costs for steel casing and screen. Although PVC casing is less expensive, it is assumed that mostly steel casing will be used: PVC lacks the structural strength required in wells as deep as most of those drilled in CGDP-I. PVC has the advantage, however, of being usable in highly corrosive waters. If PVC is extensively used in the future, then these two cost items can be correspondingly reduced.

3.4.3 Well Testing

Well testing consists of two steps (see Table 3.6): (1) testing by a pump crew to test the aquifer characteristics (such as potential yield and transmissivity); and (2) water quality chemical analysis. Pump testing is done by a pump crew, and requires running a test pump for periods of 24 to 48 hours. Water quality tests are performed for 12-18 different components, and require an average of two samples per well.

3.4.4 Pump Installation and Construction of the Local Distribution System

The costs of the installation of both diesel and hand-powered pumps, as well as the associated distribution

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Table 3.5 Well Drilling, Development, and Logging Direct Costs, per well (US$)

Item	Non-Production Wells (1) Units	Cost (US$)	Production Wells Units	Cost (US$)
1. Labor (Field perdiems)				
- Chief driller	15 days*100 SS/day	86	24 days*100 SS/day	138
- 10 crew members	15 days*75 SS/day	647	24 days*75 SS/day	1036
- Well log operator	2 days*100 SS/day	14	2 days*100 SS/day	12
- Assistant logger	2 days*75 SS/day	11	2 days*75 SS/day	9
Subtotal		759		1194
2. Materials				
- Drilling fluid (mud/foam)	$3.60/m, test hole	360	$3.60/m, 6" hole	360
			$3.60/m, 12" reaming	360
- Tricone bits	(Assumed only hammer bits used, see capital costs)		$3,200/bit, good for 1,000 meters	320
- Conductor collar	5m steel casing @ $144/m	720	5m steel casing @ $144/m	720
- Cement	.5 m3 @ $44.40	22	.5 m3 @ $44.40	22
- Casing	8" steel casing (2)	1890	8" steel casing, 75m	5670
- Screen			8" steel screen, 25m	2590
- Gravel for packing			3 m3 @ $34.50	104
Subtotal		2992		10146
3. Fuel				
- Drill rig	See Table 3.3	962	See Table 3.3	1925
- Heavy vehicles	"	658	"	1316
- Light vehicles	"	363	"	725
Subtotal		1983		3966
Total (US$/well)		5734		15305

Note: (1) Non-production wells include exploratory, collapsed, salty, and abandoned wells.
(2) Cost based on casing abandoned or crushed.

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Table 3.6 Well Testing Direct Costs, per well (US$)

Item	--- Production Wells --- Units	Cost (US$)
1. Labor (Field perdiems)		
- Pump crew supervisor	3 days*100 SS/day	17
- 4 pump crew members	3 days*75 SS/day	39
- Water quality supervisor	2 days*100 SS/day	12
- 1 water quality assistant	2 days*75 SS/day	9
Subtotal		76
2. Materials		
- none for pump test		--
- water quality test materials	15 component tests for two samples @ $8/test	240
Subtotal		240
3. Fuel		
- Pump rigs	See Table 3.3	752
- Heavy vehicles	"	--
- Light vehicles	"	290
Subtotal		1042
Total (US$/well)		1358

systems, are shown in Table 3.7. The civil works crew, which is responsible for all surface improvements, arrives on the site first. When finished, they are replaced by the pump crew, which, using the pump rig derricks, installs the pump.

It is expected that diesel pumps will be used for high capacity and/or deep wells, and the hand pumps are to be used for lower capacity and more shallow wells. The distribution system for a diesel pump, as planned, consists of a 45,000 lt. storage tank, several water points and wash stands, and two livestock drinking troughs. The pump house is expected to be constructed by the villagers themselves, using local materials. The distribution system for handpump installations consists only of the top slab for the well itself, with the possibility of a few washstands.

It is assumed that of the 18 boreholes completed each year, an average of 10 will be fitted with diesel pumps and 8 with handpumps. The three civil works construction crews will each complete six installations per year, which is the same work rate as the three drill rigs.

Under CGDP-I, two windmill pumps have been ordered. Since the installation and operation of these pumps is still completely experimental, the possibility of their widespread use in the future cannot be foreseen. The cost of these pumps, therefore, is not shown here.

3.4.5 Well Operation, Maintenance and Monitoring Costs

Unlike the previous four sets of costs, which are incurred once only, these costs recur on a periodic basis. The operating and routine maintenance costs are calculated on an annual basis, and the major overhaul costs are calculated on a three-year basis (see Table 3.8).

The projected operation and maintenance costs are small compared with the initial well production costs, but are, of course, essential to the securing of project benefits. The quality of the routine maintenance program will in a large way determine the functional life of the well and water distribution system.

In the case of diesel pumps, pump operating costs consist of WDA personnel costs, fuel costs, and overhead. Two WDA employees (who will come, if possible, from the village itself) are required to run a diesel well, one as a pump attendant and one as a fee collector. Fuel costs are based on an average pumping time of six hours per day, and two liters per hour

Table 3.7 Direct Costs for Pump Installation and Distribution System, per well (US$)

Item	Diesel Pumped Wells Units	Diesel Pumped Wells Cost (US$)	Hand Pumped Wells Units	Hand Pumped Wells Cost (US$)
1. Labor (Field perdiems)				
- Civil Works supervisor	36 days*100 SS/day	207	3 days*100 SS/day	17
- 6 crew members	36 days*75 SS/day	155	3 days*75 SS/day	13
- Pump crew supervisor	3 days*100 SS/day	17	3 days*100 SS/day	17
- 4 pump crew members	3 days*75 SS/day	13	3 days*75 SS/day	13
Subtotal		393		60
2. Materials				
- Pipes, pipe fittings, steel, wood, meters	For storage tank, water points, troughs	6000	Included in price of hand pump	--
- cement	600 bags/site @ $7.50	4500	10 bags @ $7.50	75
- gravel	32 m3 @ 600 SS/m3	1105	2 m3 @ SS 600/m3	69
- sand	120 m3 @ 60 SS/m3	414	2 m3 @ SS 60/m3	7
- cinder blocks	3000 blocks, 6 SS/bl.	1036	None	--
- Pump and drive pipe	Diesel Helical Rotor	20018	Mono hand pump	1925
Subtotal		33072		2076
3. Fuel				
- Pump rigs	See Table 3.3	752	See Table 3.3	752
- Heavy vehicles	"	564	"	--
- Light vehicles	"	870	"	435
Subtotal		2186		1187
Total (US$/well)		35651		3323

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Table 3.8 Well Operation and Maintenance Direct Costs, per well (US$)

Item	Diesel Pump Wells Units	Diesel Pump Wells Cost (US$)	Hand Pump Wells Units	Hand Pump Wells Cost (US$)
A. Operating Costs (per year)				
1. Labor				
- Pump operator	$40/month	480	--	--
- Fee collector/ass't operator	$40/month	480	--	--
2. Fuel				
- For pump	2 lt/hr * 6hrs/day	1220	--	--
- For transport of fuel	2 tr/mo.*50lt/trip	334	--	--
3. Overhead (*)	Office support, 100% of direct costs	3142	--	--
Total (US$/well)		5656		--
B. Routine Maintenance/Socioeconomic Monitoring (per year)				
1. Labor (Field perdiems)				
- Two man maintenance crew	4 visits/year * 1 day/visit * SS 75/day	35	2 visits/year * 1 day/visit * SS 75/day	17
- Two man monitoring team	2 visits/year, 1 day SS 75/day per pers	17	2 visits/year, 1 day SS 75/day per pers	17
2. Materials	Assume 1% of initial pump system costs	200	Assume 1% of initial pump system costs	20
3. Fuel - Light vehicles	35 lts/day*6 days	71	35 lts/day*4 days	48
4. Overhead (*)	Logistics/support	320	Logistics/support	100
Total (US$/well)		643		202
C. Major Overhaul Costs (assumed every 3 years)				
1. Labor (Field perdiems)				
- Pump crew supervisor	6 days*100 SS/day	35	3 days*100 SS/day	17
- 5 man pump crew	6 days*75 SS/day	155	3 days*75 SS/day	78
2. Materials	Assume 10% of initial pump system costs	2000	Assume 5% of initial pump system costs	100
3. Fuel				
- Pump rigs	225 lts/day*6 days	376	225 lts/day*3 days	188
- Light vehicles	35 lts/day*6 days	71	35 lts/day*3 days	36
4. Overhead (*)	Logistics/support	2700	Logistics/support	420
Total (US$/well)		5337		839

Note: (*) Office overhead is included here because it is not part of the existing WDA office staff or functions. The cost of well operation and maintenance will increase each year as more wells go into operation. The full cost, including overhead, is in a sense, a direct cost: it is directly related to the number of wells.

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(see Appendix B). It is likely that pumping times will vary from a high of twelve hours per day during the peak of the two dry seasons, to almost no pumping at all when surface water is readily available to villagers at no charge. (Projected water usage rates are discussed in more detail in Chapter 4.) Overhead is calculated at 100%, which is based on the WDA 1982 operating budget.

In the case of handpumps, it is not presently foreseen that user fees will be charged (since the user will be doing the work himself and the water volume would be small), or that pump attendents will be required. There are, therefore, no projected handpump operating costs.

The helical rotor diesel and handpumps chosen for this project are notable for their extremely low maintenance requirements, and have relatively few spare part requirements. The main cost in spare parts over the life of the pumps will be in parts for the diesel engines. Also, a major overhaul of either kind of pump, which is scheduled for every four years, requires the use of the pump rig to assist in pulling the pump from the well.

The last cost included in this section is that of the ongoing socioeconomic monitoring of each well site. The socioeconomic crew is scheduled to visit each site once a year.

The full ten-year stream of operating and maintenance costs for each type of well is shown in Table 3.9. The net present value of this cost stream is used below to compare well construction and operating costs.

3.4.6 Summary of Direct Costs

A summary of the five categories of direct costs appears in Table 3.10. The total direct cost of drilling and constructing a diesel-pump well is about $53,500, and the total direct cost of a hand-pumped well is about $21,150. If the costs of drilling the exporatory wells are included, then the full direct cost of constructing each kind of well is $58,000 and $26,000, respectively.

The well construction costs are best compared with operating and maintenance costs by assuming a minimum lifespan of each well. Here it is assumed that the average well will operate for 10 years, and the ten-year discounted stream of operating and maintenance costs are included as direct costs in Table 3.10. For diesel pumps, operating costs are about 45% of total direct costs, and for handpumps, less than 10%. When indirect costs are included, of course, operating costs are a much smaller proportion of total well costs (see below).

Table 3.9: Ten-Year Stream of Well Operation, Maintenance and Monitoring Costs (US$)

Pump type/ Year of Operation	1	2	3	4	5	6	7	8	9	10
A. Diesel Pumps										
1. Operating Costs	5656	5656	5656	5656	5656	5656	5656	5656	5656	5656
2. Routine Costs (Maintenance and Monitoring)	643	643	643	643	643	643	643	643	643	643
3. Periodic Costs (Major Overhaul)	--	--	5337	--	--	5337	--	--	5337	--
Total, Diesel Pumps	6299	6299	11636	6299	6299	11636	6299	6299	11636	6299
Net Present Value (i=15%) = 44789										
B. Hand Pumps										
1. Operating Costs	--	--	--	--	--	--	--	--	--	--
2. Routine Costs (Maintenance and Monitoring)	202	202	202	202	202	202	202	202	202	202
3. Periodic Costs (Major Overhaul)	--	--	839	--	--	839	--	--	839	--
Total, Hand pumps	202	202	1041	202	202	1041	202	202	1041	202
Net Present Value (i=15%) = 2492										

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Table 3.10 Summary of Well Direct Costs ($)

	Diesel Pumped		Hand Pumped	
	US$	(%)	US$	(%)
1. Site Selection/ Research	1158	1.13	1158	4.10
2. Well Drilling, Logging, and Development	15305	14.88	15305	54.21
3. Well Testing	1358	1.32	1358	4.81
4. Final Installations	35651	34.66	3323	11.77
Subtotal	53472	51.99	21144	74.90
5. Cost of Non-Production wells (12/year) (1)	4595	4.47	4595	16.28
Subtotal	58067	56.45	25739	91.17
6. Operation, Maintenance and Monitoring for 10 years (2)	44789	43.55	2492	8.83
Total direct costs per well	102856	100.00	28231	100.00

Note: (1) Assumes cost of 12 exploratory, salty, abandoned, and collapsed wells/year shared by each of 18 production wells/year. The cost includes site selection costs (Table 3.4) and drilling costs (Table 3.5).
(2) See Table 3.9.

3.5 Indirect Costs

The indirect costs of the groundwater project are, as shown in Figures 3.1 and 3.2, all costs associated with the central office, warehouse, and workshop, in addition to all costs that do not vary with the actual number of wells produced each year. As for the analysis of direct costs, indirect costs are divided into three main categories: labor, materials, and fuel. A fourth small category, miscellaneous, is included here for such items as insurance, rents, and port clearance fees. Capital costs, which are a special kind of indirect costs, are discussed separately in the next section.

3.5.1 Labor

Table 3.11 shows the total estimated staff requirements for the continuation of the comprehensive groundwater development project. The staff is divided into five categories, as follows:

(1) central office, warehouse, and workshop; a total central staff of 65 people, which is about the same as are currently employed by WDA for the CGDP-I project, is assumed.

(2) well site selection; four hydrological crews, each consisting of one senior hydrologist and one assistant; one geophysical crew to operate the geophysical vehicle; and two socioeconomic crews, one for each project region.

(3) well drilling and logging; three drill crews, one for each drill rig, each consisting of two senior drillers and ten workers; and two logging crews, one for each region (and for each of the two logging vehicles).

(4) testing crews; well testing is performed by both the pump crews and the water quality chemists. The pump crews, which consist of one foreman and four workers, divide their time evenly between pump testing and pump installation. The water quality crew, which consists of one senior chemist and two assistants, is assumed to cover both project areas.

(5) final installations; the surface distribution systems are constructed by one of three civil construction crews, each consisting of one foreman and six workers (and with additional labor provided by each village). The pumps themselves are installed by the pump crews, as described above.

Table 3.11 Estimated Future Staff Requirements and Salaries

	Number of Staff	Monthly Salary	Monthly Allowance	Yearly Cost	Yearly Cost
		(. . . Somali Shillings . . .)			(US$)
Central Office Staff:					
Project manager	1	1200	5000	74400	
Deputy project manager	1	750	4000	57000	
Water resourcer planner	1	750	3500	51000	
Financial controller	1	750	3500	51000	
Accountant, cashier	2	750	1500	54000	
Drilling coordinator	1	920	3000	47040	
Chief mechanic	1	750	4000	57000	
Baidoa coordinator	1	750	1500	27000	
Store and fuel officers	5	750	1200	117000	
Transport officer	1	750	1500	27000	
Personnel officer	1	1200	1300	30000	
Clearance officer	1	750	1500	27000	
Mechanics, electricians	6	560	1200	126720	
Heavy truck drivers	16	540	1200	334080	
Ass't drivers, mechanics	10	540	800	160800	
Clerks, guards, cleaners	16	540	500	199680	
Subtotal --	65			1440720	82895
Well Site Selection Staff:					
Hydrologists	4	750	2000	132000	
Ass't hydrologists	4	600	1500	100800	
Geophysicist	1	750	2000	33000	
Ass't geophysicist	1	600	1500	25200	
Socioeconomist	2	750	1500	54000	
Ass't socioeconomist	2	600	1200	43200	
Subtotal --	14			388200	22336
Well Drilling and Logging Staff:					
Chief drillers	6	920	1500	174240	
Drill rig crews	30	560	1000	561600	
Log operator	2	750	1500	54000	
Ass't log operator	2	600	1000	38400	
Subtotal --	40			828240	47655
Pump Rig Crews: (*)					
Chief of Pump Rig	2	750	1500	54000	
Pump rig crews	8	600	1000	153600	
Subtotal --	10			207600	11945
Water Quality Staff:					
Chief chemist	1	920	2000	35040	
Ass't chemist	2	750	1500	54000	
Subtotal --	3			89040	5123
Civil Works Crews:					
Chief of construction	3	750	1500	81000	
Civil works crews	18	560	1000	336960	
Subtotal --	21			417960	24048
Total --	153			3371760	194002

Note: (*) Pump rig crews do both pump installation and periodic maintenance.

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Labor costs for well operation and maintenance are not included here, since they are fully costed in the previous section on direct costs.

Table 3.11 shows that the total yearly salaries for the entire groundwater project staff, which includes about 150 people, is approximately $200,000. This is the combined cost of each person's basic government salary and monthly living allowance. Indirect labor costs, which are shown in Table 3.12, consist of field perdiems paid to members of the central staff for site visits.

The total yearly cost of labor is projected to be about $200,000, or about 60% of total yearly indirect costs.

3.5.2 Materials

The yearly cost of office, warehouse, workshop, and routine maintenance supplies is estimated at $56,000 per year. This figure is taken from the proposed 1984 WDA budget, as shown in Table 2.4. If anything, this figure is felt to be quite conservative, since it represents a reduction of 45% from the level of expenditure on materials incurred in 1983.

3.5.3 Fuel

The amount of fuel consumed by the vehicles assigned to the central office staff, GSO, warehouse, and workshop, as well as the amount of fuel consumed by the well production crews during work not specifically associated with any one well, is projected to be about $70,000 per year. The number of vehicles assigned to the central office staff was shown above in Table 3.2, and the assumptions that underlie the fuel consumption costs were spelled out in Table 3.3. The total indirect fuel costs are about 30% of total fuel costs, and about 16% of total indirect costs.

3.5.4 Summary of Indirect Costs

The total of the above three categories of indirect costs, plus a fourth category of miscellaneous costs, is about $340,000 per year (see Table 3.12). When a well production rate of 18 wells per year is assumed, these costs amount to about $19,000 per well.

3.6 Capital Costs

Capital costs are, properly speaking, part of the groundwater project indirect costs, but since they form such a large part of these costs they are discussed separately. Capital costs are defined as the cost of

Table 3.12 Estimated Yearly Indirect Costs

	Shillings	US$	(%)
1. Labor:			
Total WDA salaries	3371760	194002	
Central Staff Perdiems (1)	26050	1499	
Subtotal —	3397810	195501	57.12
2. Materials:			
Office, field and warehouse supplies —	970000	55811	16.31
3. Fuel: (2)			
Gasoline	526579	30298	
Diesel	642513	36969	
Lubricants	28560	1643	
Subtotal —	1197652	68910	20.13
4. Miscellaneous:			
Insurance	83000	4778	
Port Clearance	100000	5754	
Office/warehouse rent (3)	200000	11507	
Subtotal —	383000	22037	6.44
Total —	5948462	342259	100.00

Notes: (1) Project manager, 5 days/month @ SS 150/day.
Deputy project manager and drilling coordinator, 5 days/month @ SS 100/day.
10 heavy truck drivers, 7 light truck drivers, and 1 cashier, 18 days/month @ SS 75/day.

(2) See Table 3.3.

(3) Since WDA offices are owned by the government, this figure is an imputed rent based on comparable office, warehouse, and workshop space.

the capital equipment used in the course of the project, including the financial cost of the investment. Capital costs are dependent not only upon the procurement cost of the equipment, but upon the interest rate and the life-span of the equipment.

The total capital expenditure to date under CGDP-I is $6.1 million (see Table 3.14): these are, in effect, sunk costs. (The difference between this figure, and the figure of $7.7 million shown at the bottom of Table 2.3, is the cost of non-capital equipment procurements. All materials used in wells, such as pumps, pipe, cement, drilling supplies, casing, and tri-cone bits, were included as direct costs in Section 3.4, not as capital costs.)

Although much of the capital equipment procured in CGDP-I is expected to be operable through 1991, certain items will have to be replaced. Table 3.13 summarizes the assumed life expectancy of the equipment, and is used as a guide to projected future procurement costs. The existing inventory of spare parts is also used to determine how much will have have to be spent on spare parts in the future.

Table 3.14 shows the projected procurement schedule for each of six categories of capital equipment, <u>assuming normal equipment life</u> (defined as ten years service for the drill and pump rigs). For light and heavy trucks, the number of replacement vehicles is shown together with the projected cost. For light equipment, it is impossible to project if and when each of the various pieces will need replacement: instead, a flat sum equal to 10% of the initial value is assumed as the annual cost of maintenance and replacement. It is noted that the planned expenditure on spare parts for all types of vehicles is less in 1984 than in subsequent years, due to the existing inventory of spare parts. <u>The total projected value of the capital procurements required between 1984 and 1991 is $7.3 million</u>, which is only slightly more than the sunk capital costs.

The assumptions concerning capital costs were varied, below, when total well costs were calculated. The capital procurement scedules for shortened and extended equipment life -- 7 and 15 years for the drill and pump rigs, respectively -- are shown in Appendix D.

3.7 Summary of All Well Production, Operation, and Maintenance Costs

In summary, all costs associated with the comprehensive groundwater development project have been divided into three categories: direct per-well costs, indirect

Table 3.13 CGDP-I Capital Equipment and Projected Life

Item	Date Procurred	Projected Life	Notes
A. Heavy Rigs (5 vehicles)			
3 TH60 Rotaty Drill Rigs	1981	1992	
2 SEMCO pump rigs	1984	1992	
B. Heavy Trucks (18 vehicles)			
2 Flatbed trucks	1981	1985	Heavy duty
2 Water tankers	1981	1985	Heavy duty
1 Fuel tanker	1981	1985	Heavy duty
4 Water tankers	1983	1986	Medium duty
3 Knuckle crane flatbeds	1983	1986	Medium duty
3 Flatbeds (2 w/ 'A-frame')	1983	1986	Medium duty
1 Fuel tanker	1983	1986	Medium duty
1 Mechanic's service truck	1983	1992	Heavy duty
1 Backhoe (w/ trailer)	1984	1992	Occasional use only
3 Flatbed trailers	1984	1992	
C. Light Vehicles (40 vehicles)			
12 Pickups	1981	1984	
5 Suburbans	1981	1984	
3 Logging vehicles	1981	1986	
1 Jeep Station Wagon	1982	1985	
11 Pickups	1983	1985	
6 Passenger vehicles	1983	1986	
1 Mechanics truck	1983	1987	
1 Video van	1984	1992	Occasional use only
D. Other Light Equipment			
2 GM/Isuzu generators	1981	1986	
2 Welders	1981	1986	
4 portable generators	1982	1986	
3 Welders	1982	1987	
3 GM/Isuzu generators	1983	1988	
2 Welders	1983	1988	
3 Test pumps	1983	1992	
30 Deep-well diesel pumps	1983	1992	
30 Deep-well hand pumps	1983	1992	
E. All Other Support Equipment			
All other capital equipment, such as logging, hydrogeological, water quality, radio, office and workship equip.	1981-83	1992	With spare parts

Note: The projected life of capital equipment is approximate only, at best, and these estimates are varied in the analysis. Proper maintenance is is assumed and budgetted for in the analysis.

Table 3.14 Capital Equipment Procurement Schedule - Assuming Normal Equipment Life

Item/Year	Total as of 12/83	1984	1985	1986	1987	1988	1989	1990	1991	Total 1984-1991
	(. . . . . in thousands of constant 1983 dollars . . . . .)									
Drill rigs										
# of vehicles	3	--	--	--	--	--	--	--	--	--
Cost of new vehicles	1652	--	--	--	--	--	--	--	--	--
Spare parts	441	110	110	165	165	165	165	165	165	126
Pump rigs										
# of vehicles	2	--	--	--	--	--	--	--	--	--
Cost of new vehicles	182	--	--	--	--	--	--	--	--	--
Spare parts	17	--	18	18	18	18	18	18	18	126
Heavy trucks										
# of vehicles (1)	18	--	4	12	--	--	16	--	--	32
Cost of new vehicles	1170	--	260	780	--	--	1040	--	--	2080
Spare parts	320	40	120	120	120	120	120	120	120	880
Light vehicles										
# of vehicles (2)	40	12	9	9	14	9	9	14	--	76
Cost of new vehicles	856	252	189	189	294	189	189	294	--	1596
Spare parts	288	30	70	70	70	70	70	70	70	520
Other light equip. (3)										
Value of equipment	1114	--	--	--	--	--	--	--	--	--
Spare parts	26	110	110	110	110	110	110	110	110	880
Total (000's US$)	6066	542	877	1452	777	672	1712	777	483	7292

Notes: (1) Includes the backhoe and trailer, and 3 flatbed trailers. The total number of heavy trucks is projected to decrease by one, from 18 to 17, as per Table 3.2.

(2) Includes the down-the-hole video van. The total number of light vehicles is projected to decrease by five, from 40 to 32, as per Table 3.2.

(3) Includes all generators, welders, test pumps, and logging, hydrological, geophysical, water quality analysis, radio, office, workshop, and field equipment.

costs, and capital costs. A summary of all of these costs appears in Table 3.15. Direct costs are broken down by diesel and hand-pumped wells, and by construction and recurrent (operating and maintenance) costs. Overhead costs, including indirect costs (labor and materials) and capital costs, appear as a lump sum. Also shown are the number of diesel and hand-pumped wells assumed to be constructed in each year, and the cumulative number of wells in service for each year.

The first column of Table 3.15 shows the net present value of each of the cost streams, discounted at the rate of 15%. For the purpose of calculating the per-well costs, the number of wells constructed and the cumulative number of wells in service are discounted at the same rate. The discounting of the physical number of wells has the same significance as the discounting of costs: it reflects the increased value of a well in service now over one in service in the future. In order to calculate average costs per well, the cost net present values are divided through by the net present value of the number of wells constructed and operated.

Average costs per well are affected by many factors, of which the most important are (a) direct and indirect costs, (b) the annual project production rate, and (c) the service life of the capital equipment. Assumptions concerning these factors are varied in order to calculate an indicative range of average costs. Specifically, the assumptions made were:

(1) the average well service life would be ten years;

(2) normal expected equipment life would be ten years for the heavy drill and pipe rigs; shortened life would be seven years service; and extended life would be fifteen years service;

(3) average well costs should be calculated both with and without the $6.1 million 'sunk' capital cost;

(4) a high annual production rate for the three rotary drill rigs would be 30 boreholes per year, of which 18 would become production wells (10 diesel and 8 hand-pumped);

(5) a high failure rate would be only 12 production wells per year (7 diesel and 5 hand-pumped) for the thirty boreholes;

(6) a low production rate would be 20 boreholes and 10 production wells per year (6 diesel and 4 hand-pumped).

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Table 3.15 Costs of Well Construction and Maintenance, assuming Normal Equipment Life and High Production Rates 18 Wells per Year (in thousands of constant 1983 dollars)

	Net Present Value (i = 15%)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
I. Direct Costs														
A. Construction Costs														
- Diesel Wells														
Number of wells	45	10	10	10	10	10	10	10	10					
Cost	2401	535	535	535	535	535	535	535	535					
- Hand-pump wells														
Number of wells	36	8	8	8	8	8	8	8	8					
Cost	757	169	169	169	169	169	169	169	169					
- Exploratory and Failed Wells														
Number of wells	54	12	12	12	12	12	12	12	12					
Cost	374	83	83	83	83	83	83	83	83					
-- Subtotal	3532	787	787	787	787	787	787	787	787					
B. Operating and Maintenance Costs														
- Diesel Wells														
Number of wells	227	5	15	25	35	45	55	65	75	80	80	75	65	55
Cost	2043	32	95	230	322	414	506	598	690	736	736	690	598	506
- Hand-pump wells														
Number of wells	182	4	12	20	28	36	44	52	60	64	64	60	52	46
Cost	38	1	2	9	13	16	20	23	27	29	29	27	23	21
-- Subtotal	2110	32	97	239	335	430	526	621	717	765	765	717	621	527
II. Overhead Costs														
- Indirect Costs (Labor and Materials)	1535	342	342	342	342	342	342	342	342					
- Sunk Capital Costs	6066													
- Recurring Capital Costs	4058	542	877	1452	777	672	1712	777	483					
-- Subtotal	11658	884	1219	1794	1119	1014	2054	1119	825					
III. Total Costs	17301	1704	2103	2820	2241	2231	3367	2528	2329	765	765	717	621	527

IV. Average Costs

Average Construction Cost per well, including sunk capital costs = $188,000
Average Construction Cost per well, excluding sunk capital costs = $113,000

Average Total Cost per Year of Well Service, including sunk costs = $42,000
Average Total Cost per Year of Well Service, excluding sunk costs = $27,000

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For the set of 'normal' assumptions embedded in Table 3.15 (normal equipment life and high production rates), the average costs per well are shown at the bottom of the table. The four average costs are: (1) average construction costs including sunk capital costs ($188,000), (2) average construction costs excluding sunk capital costs ($113,000), (3) average costs per year of well service, including all construction, capital, and service costs ($42,000), and (4) average costs per year of well service, including all costs except sunk capital costs ($27,000). These costs show that sunk capital costs are a very large part of total costs: <u>when sunk capital costs are excluded, total costs decrease by almost 40%</u>. In order to bring down the overall cost per well, therefore, it is important to keep the equipment procured under CGDP-I operating as long as possible.

When the assumptions concerning production rates and projected equipment life are varied, a full range of average costs can be calculated. In Table 3.16, it is seen that:

(1) average construction costs per well range from $188,000 to $307,000, and total cost per year of well service ranges from $42,000 to $66,000, depending on the assumptions. When sunk capital costs are excluded, these costs range from $113,000 to $172,000, and $27,500 to $39,600, respectively.

(2) average construction costs rise by 50% between the high and low production rate assumptions, and by only 35-40% between the high production and high failure rate assumptions. It is, therefore, economically more sensible to produce as many wells as possible, even if the success rate drops, than to drill a small number of wells.

(3) the sensitivity of costs to the production rate shows the costly impact of fuel shortages and other logistical problems. Accordingly, any steps that can be taken at a reasonable cost to minimize logistical difficulties are likely to have very high payoffs.

(4) total costs per year of well service rise by 20% between the normal and shortened capital equipment life assumptions. It is important to keep the heavy equipment operating for at least ten years. After ten years, however, the average costs per well remain about constant: this is because the recurrent costs of capital upkeep offset the lower costs derived from prolonged equipment life.

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Table 3.16 Summary of Well Construction and Operating Costs (in constant 1983 dollars)

Assumption/Type of Well	Average Construction per Well			Total Cost per Year of Well Service		
	High Production Rate	High Failure Rate	Low Production Rate	High Production Rate	High Failure Rate	Low Production Rate
I. Including All Capital Costs						
A. Normal Equipment Life						
Diesel Pumps	202,500	280,400	320,300	49,000	63,700	72,300
Hand-pumps	170,100	248,000	287,900	33,800	48,800	57,300
Average cost	188,100	266,900	307,300	42,300	57,400	66,300
B. Shortened Equipment Life						
Diesel Pumps	226,100	314,800	361,600	56,900	74,600	85,700
Hand-pumps	193,700	282,400	329,200	41,600	59,300	70,300
Average cost	211,700	301,300	348,600	50,100	68,200	79,500
C. Extended Equipment Life						
Diesel Pumps	191,200	263,600	300,100	50,500	65,300	74,200
Hand-pumps	158,800	231,200	267,700	34,900	49,800	58,500
Average cost	176,800	250,100	287,100	43,600	58,800	67,900
II. Excluding Sunk Capital Costs						
A. Normal Equipment Life						
Diesel Pumps	127,400	167,800	185,100	34,200	41,700	45,600
Hand-pumps	95,000	135,400	152,700	19,000	26,800	30,600
Average cost	113,000	154,300	172,100	27,500	35,500	39,600
B. Shortened Equipment Life						
Diesel Pumps	125,600	164,000	180,600	35,600	43,200	47,300
Hand-pumps	93,200	131,600	148,200	20,200	27,900	31,900
Average cost	111,200	150,500	167,600	28,700	36,800	41,100
C. Extended Equipment Life						
Diesel Pumps	129,100	170,300	188,100	37,000	45,400	49,900
Hand-pumps	96,700	137,900	155,700	21,400	29,900	34,200
Average cost	114,700	156,800	175,200	30,100	38,900	43,600

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(5) average construction costs per diesel well are about $32,000 (or 15%) more than for hand-pumped wells, and average costs per year of well service are about $15,000 (or 30%) more. In those locations where a diesel pump is required (i.e. where there are both sufficient water resources and sufficient demand) these higher costs would be offset by the benefits of serving a larger number of beneficiaries.

These average costs per year of well service can be used together with estimates of the number of well users (see Chapter IV) to estimate the average cost per well user.

As a final excercise in this chapter, the three cost categories -- direct, indirect, and capital costs -- were further broken down along the lines of project activities. This allows one to estimate the cost associated with each phase of work. The six types of activities are:

(1) site selection
(2) well drilling, logging, and development
(3) well testing
(4) final installation
(5) well operation and maintenance
(6) central office, warehouse, and workshop.

The complete breakdown of costs by both cost category and project activity was shown in the cost accounting matrix shown in Figure 3.1.

Table 3.17 shows the same cost accounting matrix, but now complete with the values calculated in the last three sections. With this matrix, not only can total costs per well and/or per year be calculated, a complete breakdown of costs between direct, indirect, and capital costs, and by type of activity, can be readily seen. The figures in Table 3.17 show the full cost of producing and operating wells for the middle case (high failure rate) shown in Table 3.16. This table shows that:

(1) the <u>direct cost</u> of well installation, operation and maintenance is about 27% of the total;

(2) the <u>indirect</u> cost is about 11% of the total;

(3) the annualized <u>capital cost</u> of the project, including sunk capital costs, is about 62% of the total. The annualized capital costs are calculated using the appropriate capital recovery factor (see Appendix C.)

When the total cost is divided up along the lines of the six project activities, the percentage breakdown is:

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Table 3.17 Estimated Annual Cost of the Groundwater Development Project for the Years 1984 - 1991, US$ (* — See Assumptions Below)

Activity	DIRECT COSTS					INDIRECT COSTS						CAPITAL COSTS						TOTAL COSTS	
	Labor	Materials	Fuel	Subtotal	(%) of Total	Labor	Materials	Fuel	Misc. Overhead	Subtotal	(%) of Total	Heavy Rigs	Heavy Vehicles	Light Vehicles	Light Equipment	Subtotal	(%) of Total	Total	(%) of Total
1. Site Selection (inc. hydrological, geophysical, and socioeconomic evaluation)	2292	—	11604	13896	1.60	22336	—	8705	—	31041	9.07	—	—	103031	94364	197395	9.79	242332	7.50
2. Well Drilling (inc. well drilling, setting of casing and screen, and logging)	27990	175608	83286	286884	32.96	47655	—	19231	—	66886	19.54	547000	438353	103031	27368	1115753	55.32	1469523	45.50
3. Well testing (inc. pump and water quality testing)	912	2880	12504	16296	1.87	11096	—	3482	—	14577	4.26	—	—	44156	29649	73805	3.66	104679	3.24
4. Final Installation (inc. civil works and pump installation)	3051	241884	21237	266172	30.58	30021	—	7479	—	37499	10.96	26500	109588	88313	5702	230102	11.41	533774	16.53
5. Well Operation, Maintenance and Monitoring for 10 Years	181871	31570	73670	287111	32.99	—	—	—	—	—	—	26500	—	44156	—	70656	3.50	357767	11.08
6. Central Office (inc. admin., GSO, workshop, warehouse)	—	—	—	—	—	84394	55811	30014	22037	192256	56.17	—	73059	88313	167917	329288	16.33	521544	16.15
Total of column	216116	451942	202301	870359	100.00	195501	55811	68910	22037	342259	100.00	600000	621000	471000	325000	2017000	100.00	3229618	100.00
Percent of Total Cost (%)	6.69	13.99	6.26	26.95	—	6.05	1.73	2.13	.68	10.60	—	18.58	19.23	14.58	10.06	62.45	—	100.00	—
Average Cost per Well	18010	37662	16858	72530	—	16292	4651	5743	1836	28522	—	50000	51750	39250	27083	168083	—	269135	—

Note: (*) Assuming 12 production wells per year (7 diesel and 5 handpumps), normal capital equipment life, and i=15%.

Table 3.17 Estimated Annual Cost of the Groundwater Development Project for the Years 1984 - 1991, US$ (* -- See Assumptions Below)

Activity	DIRECT COSTS					INDIRECT COSTS						CAPITAL COSTS						TOTAL COSTS	
	Labor	Materials	Fuel	Subtotal	(%) of Total	Labor	Materials	Fuel	Misc. Overhead	Subtotal	(%) of Total	Heavy Rigs	Heavy Vehicles	Light Vehicles	Light Equipment	Subtotal	(%) of Total	Total	(%) of Total
1. Site Selection (inc. hydrological, geophysical, and socioeconomic evaluation)	2292	--	11604	13896	1.60	22336	--	8705	--	31041	9.07	--	--	103031	94364	197395	9.79	242332	7.50
2. Well Drilling (inc. well drilling, setting of casing and screen, and logging)	27990	175608	83286	286884	32.96	47655	--	19231	--	66886	19.54	547000	438353	103031	27368	1115753	55.32	1469523	45.50
3. Well testing (inc. pump and water quality testing)	912	2880	12504	16296	1.87	11096	--	3482	--	14577	4.26	--	--	44156	29649	73805	3.66	104679	3.24
4. Final Installation (inc. civil works and pump installation)	3051	241884	21237	266172	30.58	30021	--	7479	--	37499	10.96	26500	109588	88313	5702	230102	11.41	533774	16.53
5. Well Operation, Maintenance and Monitoring for 10 Years	181871	31570	73670	287111	32.99	--	--	--	--	--	--	26500	--	44156	--	70656	3.50	357767	11.08
6. Central Office (inc. admin., GSD, workshop, warehouse)	--	--	--	--	--	84394	55811	30014	22037	192256	56.17	--	73059	88313	167917	329288	16.33	521544	16.15
Total of column	216116	451942	202301	870359	100.00	195501	55811	68910	22037	342259	100.00	600000	621000	471000	325000	2017000	100.00	3229618	100.00
Percent of Total Cost (%)	6.69	13.99	6.26	26.95	--	6.05	1.73	2.13	.68	10.60	--	18.58	19.23	14.58	10.06	62.45	--	100.00	--
Average Cost per Well	18010	37662	16858	72530	--	16292	4651	5743	1836	28522	--	50000	51750	39250	27083	168083	--	269135	--

Note: (*) Assuming 12 production wells per year (7 diesel and 5 handpumps), normal capital equipment life, and i=15%.

		Direct and Indirect Costs	Total Costs
(1)	site selection -	1.1%	7.5%
(2)	well drilling and logging -	23.7%	45.5%
(3)	well testing -	1.3%	3.2%
(4)	final installations -	22.0%	16.5%
(5)	operation and maintenance -	23.7%	11.1%
(6)	central office overhead -	28.2%	16.2%

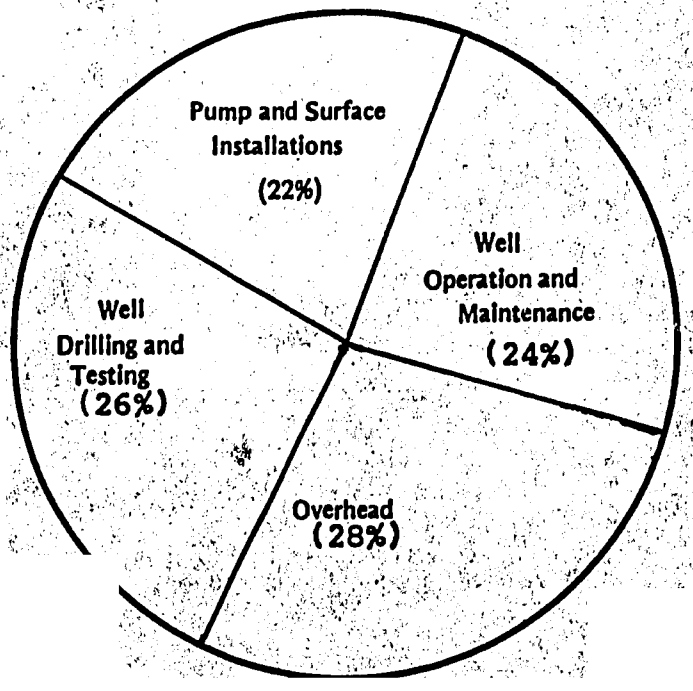
The up-front costs of well planning, drilling, and construction represent about 89% of the total cost of each well. The operating, maintenance, and monitoring costs, which are calculated as a a ten- year obligation, are only about 11% of the total cost. Although well maintenance represents a small part the budget, effective maintenance is essential to the success of the project.

A graphic summary of these basic findings appears in Figure 3.3. The second graph shows the high (62%) component of capital costs. The graph underscores a previous conclusion: namely, that if the capital procurements under CGDP-I are considered as sunk costs, which they effectively are, then the continuation of the comprehensive groundwater project is very cost effective. The marginal, or future cost of continuing the project would be much lower than the historic cost.

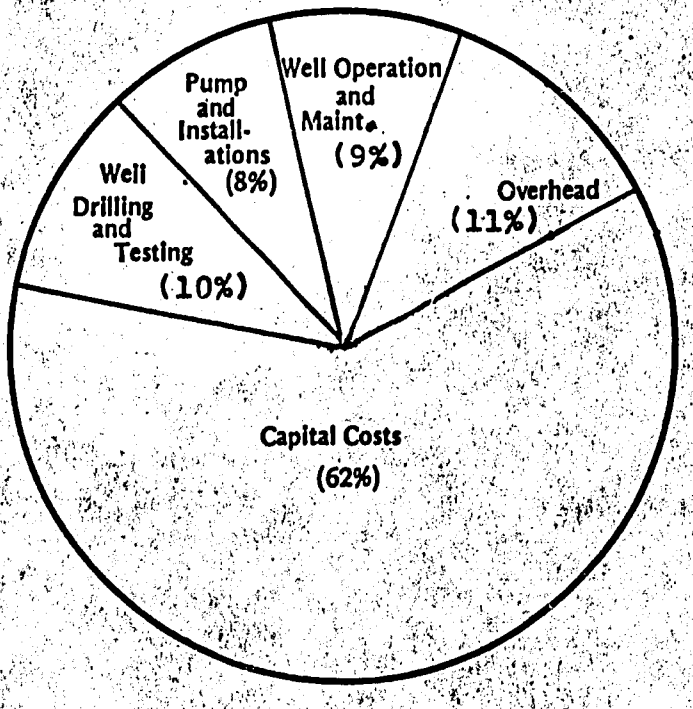
Figure 3.3

CONSTRUCTION AND OPERATION COSTS. PER WELL (*)

A. Direct and Indirect Costs Only



B. Direct, Indirect, and Capital Costs



(*) ASSUMING 1.15%, NORMAL EQUIPMENT LIFE, AND WELL OPERATION FOR 10 YEARS

IV. Benefit Analysis

4.1 Overview

In this section, the benefits of the groundwater project to the people of the Bay and Central Rangeland Regions are discussed. These benefits cannot, however, be quantified. Water-related benefits are difficult to quantify even in situations where much data is available on the end users, usage rates, willingness to pay, local health conditions, and local livestock production. In the case of this project, given the almost complete lack of quantitative data in any of these five areas, to try now to quantify benefits would be, at best, misleading.

The goal, therefore, of this chapter is to pull together most of the information that has been gathered to date that relates to the measurement of project benefits. This information can be used as a basis for future surveys, projections, and evaluations, if any, of the project's costs and benefits.

The main emphasis of this chapter is on two primary aspects of project benefits. These are (i) the average number of project beneficiaries, broken down into human and livestock populations and into the Bay and Central Range regions; and (ii) the qualitative types of benefits to be expected in each area. As only one well had been completed in the Bay region by the end of 1983, and none in the Central Rangelands, little specific information on the user populations of actual wells is available. Instead, the focus of this chapter is on estimating average user populations based on all available village surveys and census counts.

This chapter contains four more sections. Section 4.2 discusses the planning criteria used by CGDP and WDA for selecting wellsites, and section 4.3 discusses the nature of benefits expected for each area. The last two sections, Sections 4.4 and 4.5, give profiles of the two project areas, with an emphasis on population and livestock data, and discusses the projected impact of the CGDP program on each area. The nature and magnitude of expected benefits in each area is discussed.

4.2 Well-Drilling Site Selection Criteria

The criteria for selecting well sites is roughly the same in both project areas. The first set of criteria, which is based on local need, is:

(i) Present water sources are inadequate to meet

national standards, which are 15-20 liters per day per person and 20 liters per day per family livestock unit, or the quality of present water sources is below designated health standards.

(2) Present water sources are located at a distance of more than five kilometers for people, or more than thirty kilometers for livestock.

(3) Any village with a population exceeding 1,000.

(4) A transhumant community which is forced to migrate away from its homestead for several months out of the year due to water shortages. This criteria is particularly relevant if it can be shown that "sustainable increases in crop and livestock production" would be possible with improved water supplies.

(5) Identified arable or grazing lands that are under-utilized due to a lack of water resources.

These criteria are then subject to three others before any drilling is done. These are:

(6) The hydrogeological suitability of the site, as analyzed by the project hydrogeologists.

(7) The village interest in having a well, and its ability to contribute to the maintenance of the well, as identified through the TVAPP series of village meetings.

(8) Site approval by the WDA, National Range Agency, and/or by local government officials.

This site selection procedure has been jointly carried out by the CGDP and Bay Region Agricultural Development projects in the Bay Region, and the CGDP and National Range Agency in the Central Rangelands.

Drilling conditions are more difficult in the Central Rangelands than in the Bay Region, for several reasons: (a) the drillings sites are further apart, (b) the number of exploratory wells is, and will continue to be, proportionately higher, (c) the average drilling depth -- if the first few wells can be considered a good indication -- is likely to be greater, (d) communications between the well sites and Mogadishu are more difficult, and (e) the availability of local support services is less. For all of these reasons, it can be expected that fewer wells will be drilled there than in the Bay Region. It is not possible at this time to estimate <u>how many</u> wells will be drilled in each region by the end of the project, but it should be kept

in mind that there will inevitably be a greater number in the Bay Region.

4.3 Water Supply Benefits

The type of benefits attributable to the improvement of water supplies fall into the following categories:

(1) improved access to year-round high quality supplies, at existing use levels;

(2) increased quantity of water available;

(3) improved level of public health, which decreases cost of basic health care;

(4) reliability of water supplies in times of drought, which decreases both hardship and the cost of drought relief;

(5) increases in the quantity and quality of human resources available for productive economic activities, especially in agriculture. Improvement can come about through both better health and through the reduced time and effort required to draw water for household use;

(6) reduced livestock losses, and increased production potentials;

(7) stabilization of agro-pastoralist and sedentary populations, with corresponding increases in agricultural production;

(8) the ability of the government to provide increased social services, such as education and health, to more stable communities.

Some of these benefits belong to the general category of social benefits, especially those pertaining to improved health, while others are more directly related to the level of economic productivity and the possibility of increased income. The two categories of benefits are not, however, separate: improved health can be valued in part, for example, by showing its direct impact on the ability of an individual or household to earn an income. And conversely, the impact of improved water on livestock production can lead to improved nutrition and family living condition. Both economic and social project benefits can be somewhat seasonal, depending on how such water characteristics as <u>quality</u>, <u>quantity</u>, <u>accessibility</u>, <u>reliability</u>, and <u>price</u> vary over the course of the year. The seasonality of both water use and benefits will be discussed below.

Health-related benefits are a primary justification for CGDP. Health benefits are attributable to both improved water quality and increased quantities of water consumed. In all areas of Somalia, water related infective diseases are the major cause of sickness and a significant cause of mortality, and the Bay Region and Central Rangelands are no exception. Water suppplied by this project, which would come from aquifers sufficiently deep to have very low biological content, should significantly improve local water quality. (Water quality analyses have, to date, corroborated this point.) Proper design and construction practices are being followed to protect the sources from external contamination. Also, the new supplies will hopefully remove the need for villagers to use less clean waters.

The primary economic benefits that are attributable to CGDP in both project areas will be to livestock production. This is especially true in the Central Rangelands, where the livestock population far outnumbers the human population. But again, no attempt is made here to quantify future gains in livestock production attributable to the project. Even in more accessible and fully documented areas, the effect of improved and more disperse water supplies on livestock health, off-take, and grazing lands is always difficult to separate out from the influence of other concurrent social and economic changes. In the Central Rangelands, there isn't any baseline data available that could be used as the basis for any projections whatsoever.

This paper does not assume that CGDP will undertake a data collection effort that would allow, at some future date, a thorough calculation of project benefits. Such an undertaking would be expensive, and it is not clear what purpose it would serve at this point in the project's implementation. At present, it is planned that both biological and chemical aspects of water quality will be monitored as part of the CGDP program. Similarly, some aspects of user health will be monitored as part of other ongoing projects, such as the USAID Primary Health Care project in the Bay Region. However, no systematic monitoring of either health benefits or livestock production is currently planned or budgetted for in CGDP.

4.4 The Bay Region

4.4.1 Introduction

The Bay region is one of Somalia's most important agricultural areas. It contains areas that offer good agricultural land and year-round access to water which are also among the country's most densely populated rural areas. The 1975 census shows a total population of 393,153, and the Ministry of Planning has estimated the 1980 population to be 450,986, reflecting a yearly growth rate of 2.8%.

The primary agricultural area of the Bay region is the crescent-shaped area that arcs across the upper half of the region (see Figure 4.1). Farmers in the Bay region are dryland farmers, as neither of Somalia's two main rivers, the Juba and Shabelli, flow sufficiently close to provide the opportunity for irrigation. Since yearly rainfalls are highly variable, and marginal at best, the agricultural production of the region varies tremendously from year to year. It is common for Bay region farmers to try to store enough grain to cover their needs for up to three years in order to ensure their survival in periods of drought.

All families in the Bay region own a certain amount of livestock, ranging from a few household animals for agricultural families to large herds of cattle, camels, sheep, and goats. Those families who rely as much as or more on raising livestock as on agriculture are properly called agro-pastoralists, and those families entirely dependent on livestock are nomadic. Although it is impossible to give an accurate breakdown of the three kinds of families in the Bay region, there are probably more agro-pastoralist than agricultural families, and more agricultural than nomadic families.

The traditional water sources for most inhabitants of the Bay region are uars, which are man-made water storage ponds; wadis, which are transient streams; and shallow wells. The uars are the most important and common type of water supply, and are designed to retain water for as long as possible into the dry seasons. But when they dry up, as most do at least once if not twice a year, villagers must seek out water at the nearest available site, which, often, involves a round trip of up to one or two days. It is common for entire villages to uproot and move nearer to a dry season water point if the round trip is longer than six or eight hours. Even if an entire village does not uproot, the young men will lead most of the family livestock away to other less dry regions, such as the Lower Shabelli and Lower Juba.

4.4.2 Bay Region Village Profiles

Two sets of interviews concerning water sources and usage have been conducted in selected Bay villages in the past two

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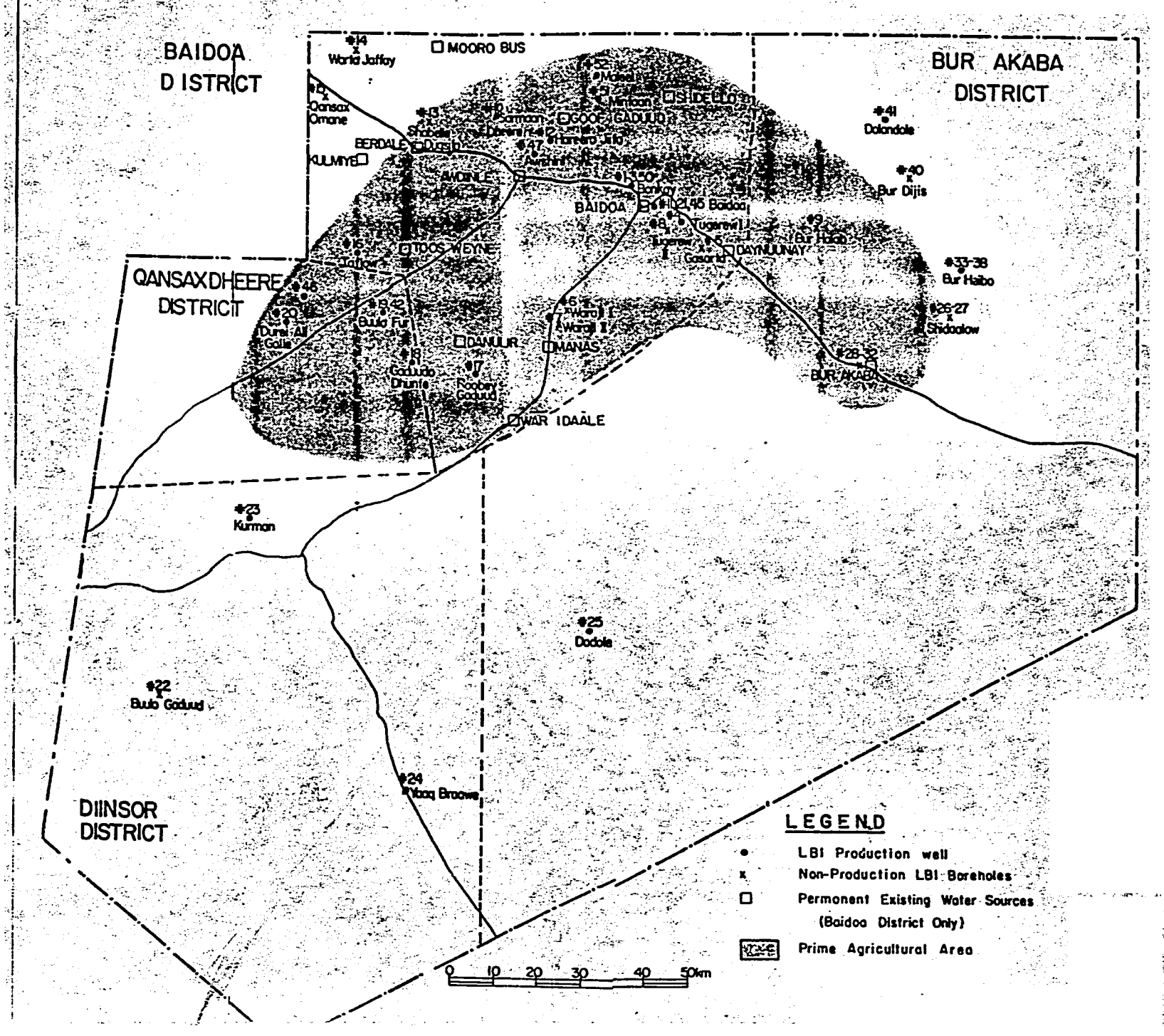
Fig. 4-1

BAY REGION



years. The first was supervised by Dr. Paula Roark, sociologist of the CGDP project (see Table 4.1), and the second by Dr. Tony Glascock, anthropologist on the Bay Region Agricultural Development Project (see Table 4.2). Data collection under the BRADP projoect is ongoing, so the results summarized here are preliminary and confined to only part of the Bay Region study area.

A. Village Organization: Residential units in the Bay region are organized into hamlets (buulos), villages (tuulos), and 'counties' (beels). In principle, the structure and organization of these units follows a simple hierarchical pattern, but in practice there are many variations depending on local demographic, historical, and political factors. In terms of this project, several key characteristics of this local administrative structure are generally agreed upon:

(1) all villages, whether tuulos or buulos, are found to have local water sources for at least half of the year. During these wet periods, most villages are settled and stationary, and almost all of the village livestock grazes and is watered locally.

(2) almost all villages were found to have a 'water committee' or similar organized means to manage the village water source(s). These committees are well-suited to organize village assistance for the construction and operation CGDP wells.

(3) tuulos are relatively close together, and one well can easily be in close proximity to several tuulos, or even beels. At one well site northwest of Baidoa, it was found that the target area of the well, narrowly defined as being the area enclosed by a five kilometer radius, crosscut the boundaries of two beels, seven tuulos, and at least twelve buulos.

(4) during the dry season, very few villages retain a local water supply. Often, the majority of inhabitants has to leave the village: some family members will typically lead the family livestock to other regions, such as Lower Shabelli, and other members will simply move closer to permanent water points within the Bay region.

Several conclusions can be drawn from these points.

First, during the two dry seasons, people and livestock from an area much larger than the immediate tuulo or beel will come to use a well. The inhabitants of the Bay region are already very mobile.

Second, during the two wet seasons, the users of the same

Table 4.1 Summary of Roark Survey Data on Bay Region Water Points

	"Village"	Wet Season Round Trip (hours)	Dry Season Round Trip (hours)	Dry Season Distance (km)
1	Sarman Dheere	.5	6	12
2	Hareero Jiifo	1.5	6	12
3	Shabelle Dugsilo	.5	8	16
4	Harta Jaffay	.5	4	7
5	Buulo Hawo	.5	8	16
6	Bootis	.5	3-6	12
7	Robay Gaduud	.5	3-6	5
8	Gaduudo Dhunte	1	6	12
9	Buulo Fur	.5	1.5	3
10	Durei Ali Galle	.5	5	9
11	Buulo Gaduud	1	3	5
12	Kurman	1	trucked	11+
13	Dodole	.2	.2	.5
14	Shiidalow	.5	.5	1

Note: (*) Numbers of water points in the tuulo area.

Table 4.2 Existing Water Sources and Distances: Summary of Glascock Survey Data, 1983

(#)		Village	Zone (Beel)	# Heads of Household	# Water Points	When Dry (1)	Fallback source, distance, and if water is free	
A.	1	Taflow	Berdaale	65	1	J only	Berdaale	6 hrs RT, free
	2	Kadhikooy	"	72	3	H & J	Berdaale	6 hrs RT, free
								Toosweyne is closer, but high user fees
	3	War Garasle	"	42	1	H & J	Berdaale	12 hrs RT, free
								Toosweyne is closer, but high user fees
	4	Kulmiye	"	59	7	- two are year-round	Year-round water supply	
							Water not sold to neighbors	
B.	5	Kariib	Toosweyne	43	1	H & J	Berdaale	6 hrs RT, free
								Toosweyne is closer, but high user fees
	6	Buula Hawa	"	62	2	H & J	Toosweyne, for water for themselves	
							Berdaale for watering animals	
	7	Buulo Amin	"	53	1	H & J	Toosweyne, for water for themselves	
							Berdaale for animals, 1-day RT	
	8	Fool Fayle	"	36	3	H & J	WDA well — used by all	
					1	WDA well	neighboring buulos	
C.	9	Idaale	Idaale	101	1	EEC uar w/ pump	Only went dry twice since 1970	
							Then went to Maanas, 8 hr RT	
	10	Nuurow Mursal	"	68	6	J only	Maanas	2-day RT, free
							Berdaale	3-day RT, free
	11	Gomor	"	52	5	J only	Danuur	4 hr RT, free
							Maanas	2-day RT, free
	12	Buulo Mareer	"	61	3	H & J	Idaale	6 hr RT, EEC uar
							Danuur	8 hr RT, free
							Maanas	2-day RT, free
D.	13	Sugi Yare	Dhayaal	48	1	H & J	Goof Gaduud	2 hr RT, WDA well
	14	War Xuseen	"	71	2	H & J	Goof Gaduud	6 hr RT, WDA well
	15	Habiirow	"	24	1	J only	Mooro Bus	8 hr RT, free
	16	War Yaroy	"	84	1	H & J	Mooro Bus	10 hr RT, free
E.	17	Buulo Jannay	Mintaan	49	1	H & J	Shidello	6 hr RT, WDA well
							Also, trucks come and sell water	
	18	Buulo Burudow	"	27	5	J always	Goof Gaduud	
						H usually	Shidello	2-day RT, WDA well
	19	Dhuugsooy	"	33	3	J only	Awdinly	WDA well
							Goof Gaduud	WDA well
							Baidoa	12 hr RT, free
	20	Buulo Muudoow	"	36	3	J always	Egeegow	8 hr RT
						H usually	Goof Gaduud	WDA well

(continued...)

Table 4.2 (continued...)

	Village	Zone (Beel)	# Heads of Household	# Water Points	When Dry	Fallback source, distance, and if water is free
F. 21	Iska-goonweyn	Haween	45	1	J only	Baidoa spring, free
22	Garwegal	"	42	1	J only	Gelden hand-dug well, fetiir (2)
23	Goof Cadey	"	19	1	J only	Baidoa Both are 2-3 days away:
						Shidello they usually go and stay
24	Dorih	"	9	1	H & J	Manawir hand-dug well, fetiir (2)
G. 25	Gareeri	Caliyow	n/a	1	J only	Baidoa 1-day RT, free
	Xasaneedin	Muumin				Manaas 1-day RT, free
26	Dhuboy	"	107	n/a	J only	Baidoa 2-day RT, free
						Awdinly by camel, WDA well
27	Abdurug	"	n/a	1	J only	Baidoa by camel, free
H. 28	Nuunay Bare	Daynuunay	57	4	J only	Daynuunay WDA well
29	Garas Gemaan	"	29	Uses a lake in the escarpment		Lake, 2 hr RT, dries up occasionally
						Baidoa 6 hr RT, free
30	Leket	"	18	2	H & J	Deelab (a lake in the escarpment) 10 hr RT
						Lahaley (a sandy streambed) 14 hr RT
						Daynuunay 10 hr RT (but no grazing land)
I. 31	Moode Moode	Moode Moode	77	2	J always H usually	Daynuunay 3 hr RT, WDA well
32	Shimbire	"	63	4	H & J	Lahaley 6 hr RT, sandy streambed, free
33	Buulo Suuban	"	20	5	J only	Daynuunay 4 hr RT, WDA well
J. 34	War Iisha	War Iisha	18	1	- EEC uar	EEC uar rarely dries up
				3	- village uars	If it does, then go to Baidoa
35	Mugdille	"	38	2	H & J	Daynuunay 6 hr RT, WDA well
36	Lawbuul	"	59	2	H & J	Daynuunay 2 hr RT, WDA well
37	Mado Weyne	"	31	2	H & J	Stream from Baidoa spring, 1 hr RT

Note: (*) The letters in the left column refer to locations on the map, Figure 4.2.
(1) J refers to the longer dry season, Jilaal, from June to September/October, and H refers to the shorter dry season, Hagai, from December to April.
(2) Fetiir refers to one who has the right to use the water from the uar or well. This right is earned by helping to maintain the condition of the uar or well.

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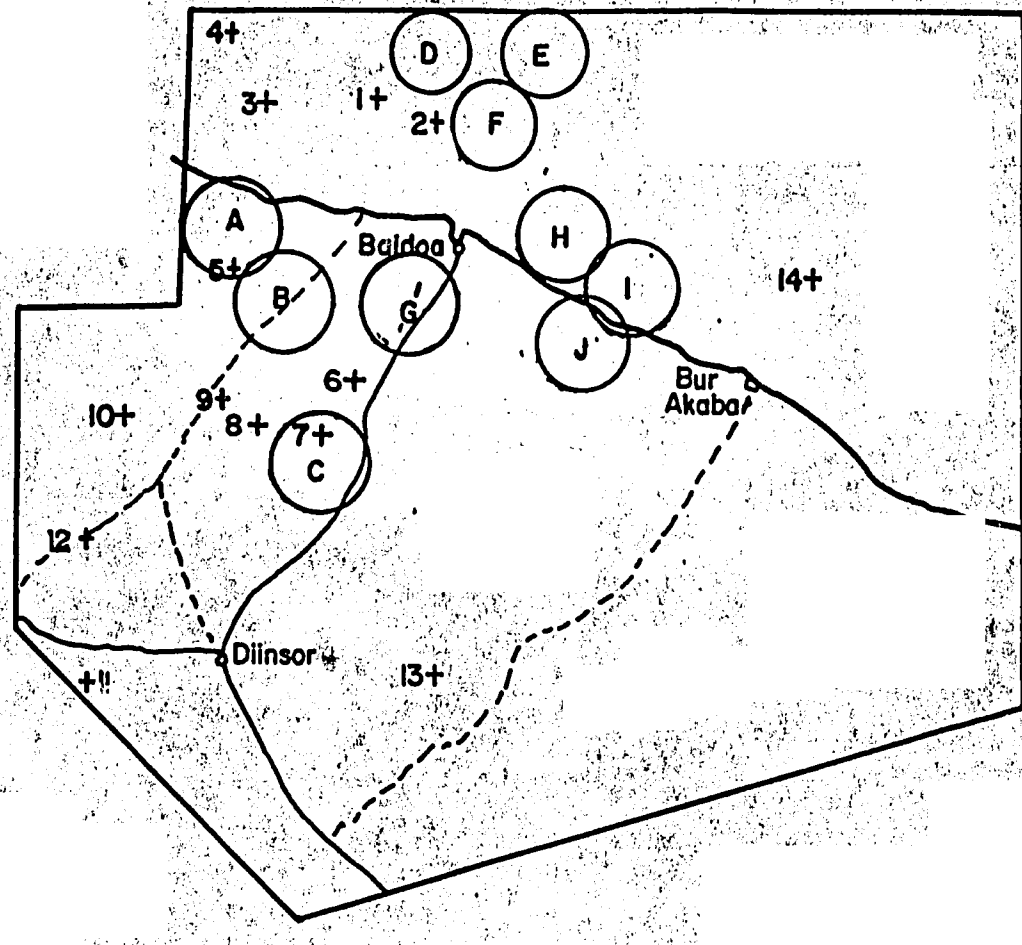
Fig 4.2

BAY REGION

"VILLAGE" SURVEY SITES



The numbers are villages surveyed by Roark.

The letters are beels surveyed by Glascock.

See Tables 4.1 and 4.2

well will be limited to, at most, local residents. Since all villages have wet season water points, none will travel to a more distant well site. Depending on the pricing of well water, even local inhabitants will probably not use the well water during the wet seasons, opting instead to use their free, traditional sources. (There is more discussion of user fees and their impact on demand in the next chapter.)

Third, there is no real difference between buulos and tuulos in terms of choosing well sites, even though most tuulos have more inhabitants than buulos. Most villages of both types have established water committees, and are, a priori (but subject to the TVAPP review process), equally able to cooperate with WDA in the operation of a new well. Both buulos and tuulos have already been chosen as sites for CGDP-I boreholes.

B. Village Population: Dr. Roark estimates that the population of a given tuulo area (which includes the tuulo village and the surrounding buulos) can vary between 1,000 and 5,000 people, that the population of a tuulo village can vary between 100 and 1,000 people, and that the population of a buulo usually varies from a few families to several dozen. These estimates are supported by the surveys conducted by Dr. Glascock: his surveys, which don't distinguish between tuulo and buulo villages, show populations ranging from between 9 and 107 households. A total of 37 villages were surveyed, and the average size was between 45 and 50 households per village (see Table 4.2). Assuming an average household size of six, this suggests average village populations of 250-300 people, with a range of 50 to over 600.

As shown above, the difference between village types is not important for the purpose of assessing water benefits. Also, the dry season users of a well will come from the larger tuulo and beel areas, not from single villages. The population of the larger areas served by a well in the dry season -- which may include members of several beels -- can easily exceed 1,000 families, or 5-10,000 people.

C. Livestock: The number of livestock in the Bay Region, and the averge herd per family, is even more difficult to estimate than village populations. There are no available livestock censuses, systematic surveys, or samplings of villages: the only data consists of scattered local estimates. Many enumerators are skeptical of the reliability of livestock estimates made by villagers themselves, and for various reasons. Some villagers, it is felt, will naturally exagerrate the average number of animals per family, while others will under-report the real number of animals for fear of government taxation. The problem of generalizing any livestock counts is further complicated by the differences between agricultural and

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agro-pastoralist families.

The BRADP surveys now being carried out include questions concerning livestock. The answers given show that reported livestock ownership varies dramatically between villages, and even between villages located in the same beel. They also show that fewer animals are owned by families living in the better agricultural areas than by families in the more marginal areas. On average, the number of cattle owned per family exceeds the number of sheep and goats, which in turn exceeds the number of camels. The range of herd sizes is about 2-40 for cattle, with a mean of about 5-15; 0-50 sheep and goats, with an average, for those families who own them, of about 20-30; and 2-20 camels (although some nomadic herders own far more), with a mean of 3-6. Translated into family livestock units, as defined by the FAO, the average family herd in the Bay region might be from 10 to 15 units, with a range from 5 to 50. A few of these animals are typically 'household livestock', which stays with and provides milk for the household for most or all of the year. The larger part of the herd is usually less stationary, and will be taken to graze outside of the Bay region during the driest times of the year.

These very rough estimates of human and livestock populations can now be put into the context of CGDP.

4.4.3 Well Water Usage in the Bay Region

The marked seasonality of well water usage was described above. In the two wet seasons, well water usage will drop off virtually to zero, due to plentiful uar supplies, while in the two dry seasons, the user population could rise to well over 5,000 people and their associated livestock. This, in fact, has been the experience of other WDA wells in the area. Given the very small number of existing permanent water sources in the entire region, and the relatively high population density, it is foreseen that the dry season demand will continue to exceed the capacity of the existing WDA wells and the new CDGP wells. In the dry season, then, pumping times may be the limiting factor on the number of beneficiaries.

Assuming that a CGDP diesel pump is operated twelve to fourteen hours a day, and pumps at the rate of twelve cubic meters per hour, the daily capacity will be about 150,000 liters. Assuming an average per capita consumption of 15 liters per day, and an average consumption per livestock unit of 20 liters per day, this amount is sufficient for almost 5,000 people and 4,000 animals per day. This corresponds to the annual average population of two to four tuulo areas, together with a household herd of about 5 livestock units per family -- which is a reasonable estimate of the numbers of dry season well users.

In the dry seasons, only the 'household' livestock will be using local well water, the rest having left the Bay Region altogether. In the wet seasons, all livestock will have returned to the area, but will be mainly consuming water from uars. During the months between these two extremes, it can be assumed that the number of animals drinking well water will be higher than in the height of either the dry or wet seasons. It is possible, over time, that livestock consumption during the dry seasons will rise if more animals remain in the Bay region due to the increased availability of local water.

Between the dry season months of peak demand and the wet season months of little or no demand, there will be several months of moderate demand. During the average year it is estimated that there will be 3-4 months of peak demand, 4-5 months of moderate demand, and 3-4 months of little or no demand. This can translated into pumping times: peak demand is the equivalent of the pump running at capacity, or 12-14 hours per day; moderate demand is 4-6 hours per day; and low demand means the pumps are turned off. The year-round average pumping time would then be about 6 hours per day, or about 70,000 liters per day. The figure of 6 hours per day, it may be recalled, was the figure used in the previous chapter for calculating the cost of pump operation and maintenance.

In conclusion, this estimate of average daily water consumption, per well, gives an indication of the average number of well users. Using the same daily consumption requirements as above, the year-round average number of beneficiaries would be about 1,500-2,500 people, and an equal number of animals (measured as livestock units).

4.4.4 Water Benefits in the Bay Region

The long-term benefits attributable to the CGDP project in the Bay region will be:

A. Health benefits, as described in section 4.2. Water consumption surveys in the Bay Region have shown that per capita water consumption drops from an average of 12-15 liters per day in the wet seasons to as low as 3-5 liters per day in the dry season. This amount of water is far below an amount necessary for proper hygiene. Improved supplies will benefit health through both increased quantity as well as the increased quality of water. The number of beneficiaries will average about 1,500-2,500 people, or about 300-400 families, per well.

It has been suggested that a broad coordination of the CGDP project with the USAID Primary Health Care project, the Somali Women's Democratic Organization (SWDO), the Women's Educational Service (WES) Family Life Centers, and the upcoming UNICEF involvement in health and welfare outreach

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programs, will compound the benefits to be derived from the improvement of local water supplies.

B. Economic benefits from increasing the availability of human resources by reducing the time and effort required to draw water. The 12-village survey conducted by Dr. Roark shows that the average round-trip time required to get water for household use increases from 1-2 hours per day to 5-8 hours per day (see Table 4.1). At distances greater than this, it was found that villages usually move away altogether to locations closer to dry season water supplies. The information gathered by the BRADP suggests even longer average dry season travel times: trips of 6-10 hours are not uncommon (see Table 4.2).

It is the women who are usually burdened with carrying water, and an easing of this time-consuming chore will allow many women to engage in alternative activities. Again, the coordination of the CGDP project with other ongoing projects that emphasize income generating projects and gardening (such as those of WES and UNICEF) will increase the ability of the women to make productive use of this time, and would compound the benefits.

C. Economic benefits gained through the stabilization of communities. Year-round water supplies sufficient for both people and livestock will allow many tuulos to remain intact through the dry seasons. This will allow increased agricultural production in marginal areas of the Bay Region, especially if combined with extension efforts to introduce dry season crops and drought-resistant seed stocks. The wider availability of water for livestock will also have beneficial effects on the ecology of the dry season grazing areas. (The need to sedentarize the population is widely apparent in Somalia.) It may also reduce the flow of rural families to the urban areas, which increases as much as 25%-50% during the dry seasons. Finally, from a sociological point of view, the agro-pastoral way of life found in the Bay Region is well-suited to the needs of both the male and female members of the family. The forced migration of the whole family away from the agricultural homestead during harsh dry seasons is disruptive.

D. Economic benefits gained through the possibility of increased livestock production. The immediate benefit of new CGDP wells to the livestock sector would be to improve the quality of water drunk by an average of 2,500-3,000 animals per well. Also, more animals would be able to remain in the Bay Region during the dry seasons. Both of these factors would tend to reduce animal losses. In the longer term, there is the possibility of improved range management. These benefits would not become apparent for several years, however, which is the time required for the construction of a sufficient number of wells to allow changes in fundamental grazing patterns and practices.

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4.5 The Central Rangelands

4.5.1 Introduction

The Central Rangelands are a sharp contrast to the Bay Region: it is a nomadic area, sparsely settled, dry, and with very little agricultural land. The wells to be constructed in this region are meant to encourage livestock production more than to serve villages. The Central Rangelands have more livestock per family than any other part of Somalia, partly because of the relatively productive rangelands, and partly because there is a greater preponderance of the smaller animals -- sheep and goats as opposed to cattle and camels -- than in areas further north. Over-grazing is a common problem throughout the region, and improved range management is required to make the grazing land more productive. The siting of wells is one tool for achieving improved range management.

The area of the Central Rangelands is three times that of the Bay Region, and consists of three regions. These are the Hiraan, Galgaduud, and Mudug regions (see Figure 4.3), with populations at the last census (1975) of 185,533, 220,872, and 269,464, respectively. The total 1975 population of 675,869 was projected to increase at a rate of 3% per year to 786,414 by 1980. At least 75% of the population is nomadic, and another 15% consists of sedentary pastoralists. The remainder is urban-oriented.

There is no complete and up-to-date estimate of the livestock population in the area, but estimates range from 1,100,000 to over 2,000,000 animals. The actual population will vary from year to year depending on the rain patterns and the resulting large-scale population and livestock movements through vast areas of Somalia and the Ogaden. It is estimated that 30-40% of the animal population was lost in the 1973-75 drought.

The drilling program for the Central Rangelands was still, at the end of 1983, in its early stages. Drilling had taken place at only a few sites in the Hiraan Region, and additional sites had been selected only in certain areas in the Mudug Region. Much less detailed socioeconomic data is available for the Central Rangelands than for the Bay Region.

4.5.2 Well-Site Profiles

The basic socioeconomic unit of this area is the degan, which is the area inhabited by a given nomadic group and the area of year-round residence for at least some members of that group. (Others will take their animals to more distant grazing lands.) A degan may be some 1,000-1,500 km2 in size, and each one will have at least one year-

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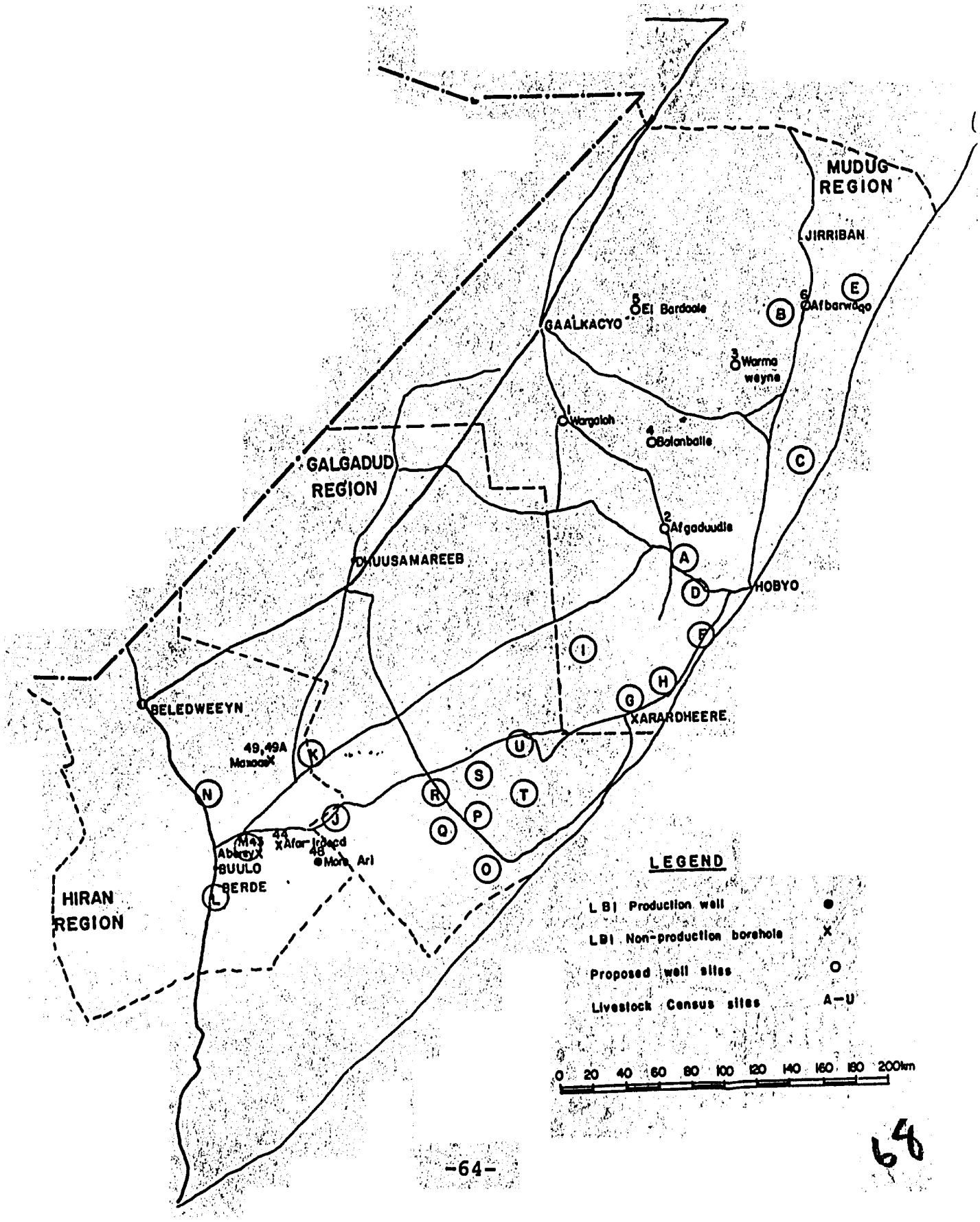
Fig. 4·3

CENTRAL RANGELANDS



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round water-hole, however small. The social cohesion found within a degan may or may not extend beyond its limits, however, which means that some neighboring degans do and others do not cooperate over such issues as water and grazing rights. Obviously, the relations between degans will affect the use and impact of any proposed well, both in situations where that well is sited completely within one degan or where it falls on the boundary between two or more.

The only available survey data on degans in the Central Rangelands is that of a 'non-formal' herding survey being conducted by the World Bank-financed Central Range Project. This survey is still ongoing, and includes only a small sampling of degans throughout the region (see Table 4.3 for details).

The survey results show that a degan may have less than 100 to well over a thousand livestock owners, where a livestock owner is assumed to be roughly equivalent to a head of household. This implies that degans may have populations ranging from a few hundred to over 5,000 people. In terms of livestock, an average family may have from 20 to over 200 animals (measured as livestock units), with roughly ten times the number of goats and sheep than cattle and camels. The average family owns nearly 300 goats and sheep, about 25 camels, and 14 cattle. The number of animals per family is surprisingly high, and shows how important the Central Rangeland is as a livestock-producing area.

Since the Central Range Project survey is not yet complete, it should be considered to be more accurate on average livestock holdings per livestock owner than on the total number of livestock or families per degan.

The dry and wet season populations of a degan are different, for both humans and animals. The population of most degans goes down in the dry seasons, as some families leave the area to find water elsewhere. Also, the population becomes more concentrated around the fewer number of dry season water points.

There is too little data available on both the locations of future well-sites and on the size of local populations to allow any useful estimates of the number of well users, per well, in the Central Rangelands. Neither is there much prior information to go by: only one potential production well has been drilled to date, and no actual pumping experience has been gained. The issue of whether neighboring degans will cooperate or not in the use of a new CGDP well is also completely uncertain. At this time, it can only be suggested that in the dry seasons -- the time of peak demand -- one well could serve the dry season populations of from one to three degans. As in the case

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Table 4.3 Non-Formal Livestock Census in the Central Rangelands, 1983

REGION/ District/ Degan (1)	# of Live-Stock Owners Interviewed(2)	Average Number of Animals per Owner				Average # Livestock Units (3)
		Camels	Goats	Sheep	Cattle	
MUDUG—						
Hobyo:						
A. Wisil	600	19.9	142.6	101.1	9.8	65.1
B. Afbarwaqo	321	10.3	170.1	244.1	2.8	67.4
C. Dhinoda	180	22.6	301.3	330.4	20.2	127.4
D. Gawan	600	12.9	262.2	107.1	10.5	72.8
E. Garacad	130	23.9	408.4	555.4	56.7	207.1
F. Ceel Huur	300	1.7	79.9	79.5	8.3	30.4
Haradhere:						
G. Haradhere	240	4.9	92.8	93.6	3.7	33.1
H. Deegan	90	7.5	48.3	12.6	4.2	21.2
I. Dumaye	570	29.2	281.1	79.3	20.7	102.3
HIRAAN—						
Bulo Berti:						
J. Muqokori	406	94.3	249.3	33.9	9.9	163.2
K. Maxaas	510	62.6	271.9	29.8	6.1	122.1
L. Mukhtar	94	24.8	100.4	9.7	7.9	52.7
M. Aborey	170	42.7	165.6	6.2	1.9	76.8
N. Halgan	1028	23.3	177.5	33.4	19.2	74.7
GALGADUUD—						
El Der:						
O. Masagaweyn	430	33.2	184.8	205.6	31.9	122.2
P. Nooleye	330	13.3	114.9	138.5	23.2	71.5
Q. Galad	300	17.9	78.7	247.3	23.4	86.5
Ceel Buur:						
R. Diri	240	12.2	103.5	25.5	5.7	37.1
S. Ja'ar	229	7.8	236.9	15.7	2.6	43.9
T. Bergan	10	13.3	10.2	39.1	3.5	26.3
U. Gal/Hareeri	80	4.7	43.8	20.3	3.6	17.5
Average Livestock per Owner		26.6	189.5	103.9	14.3	84.2

Notes: (1) Letters refer to map in Chapter IV, Figure 4.2.
(2) Livestock owners were interviewed at the main watering points in the degan over a 1-3 week period. Not all owners could be interviewed, and it is not known how close to 100% the actual number is. For degans with an (*), the number is felt to be within 10-15% of the total number of livestock owners within the degan.
(3) Camels are 1.25 units, goats and sheep .125, and cattle 1.0 units.

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of the Bay Region, it is likely that in the dry seasons, the wells will run at capacity. A diesel pump run for 12-14 hours per day can pump 150,000 liters per day. Assuming 10 lts/day per person and 20 lts/day per livestock unit, this is sufficient water for up to 250 families and 7,000 animals, which is less than the average population of a single degan.

4.5.3 Water Benefits in the Central Rangelands

The long-term benefits attributable to the CGDP project in the Central Rangelands would be:

A. Health benefits, as described in section 4.2. Both the quantity and quality of water available to Central Rangeland nomadic families would increase significantly. Due to the relatively low population density in the area compared to the Bay Region, the number of human beneficiaries would be correspondingly lower. On the basis of a year-round average, it is expected that some 50-250 families would benefit from each well. (This estimate is based on a peak demand of 250 families and associated livestock, per well.)

B. Economic benefits gained through increased livestock production. As there will be far greater numbers of animals than people using the Central Rangeland wells, the potential livestock production benefits could exceed the health benefits. These production benefits would be generated by at least four distinct mechanisms: (1) improved water quality, (2) improved water security in times of drought, (3) improved range ecology due to animals being able to feed in areas currently lacking water resources, and (4) improved range ecology due to an increased number of dry season water points and the correspondingly greater dispersion of herds.

C. Social benefits gained through the stabilization of communities. Increased year-round water supplies would allow greater numbers of animals and people to remain sedantary throughout year. Although the economic impact of this, in and of itself, is not clear (since, for example, dry season agriculture is not possible in most of the Central Rangelands, even for sedentary families), the stabilization of rural populations is in line with long-term government objectives. A more stable population is necessary before other government services, such as education and health, can be made readily available to the degan populations.

V. User Charges

User charges are levied on all water provided through government channels in Somalia. Water is provided as a utility good, not as a social service, and user charges are levied to help defray the cost of providing that good. The current nation-wide price for water is SS 10 per cubic meter, or one shilling per 100 liters.

The uniform national price for water is based on the average delivery costs of several urban water systems, such as Mogadishu and Hargeisa. It is not based on either marginal delivery costs or on an analysis of user willingness to pay. Nevertheless, the current national uniform price is used in this study as a benchmark for analyzing the financing of CGDP wells.

Even in rural areas, the idea of user charges is not new. Water fees are charged at all WDA wells and EEC uars, as well as at some 'private' water points. Traditionally, all the households with rights to draw water at the village uar or well would 'pay' for that right by helping to maintain the source from year to year. People from outside the village, especially those desiring to water large herds of animals, are usually required to pay money.

The imposition of user charges has strong economic justification: not only does it help meet expenses, it also reduces the overall level of government subsidies, encourages water conservation, and encourages livestock owners to sell non-productive animals in order to help pay their watering fees. Economics can help determine the optimal rates to be paid by users, but social and political considerations must also be taken into account. This section will analyze the question of what user fees will cover the cost of operating, and, if possible, of constructing wells.

An optimal user fee is that which recovers all operation and maintenance costs, as well as the complete cost of the initial investment. In other words, the optimal user fee equals the full cost of delivering the water. Table 5.1 shows the water delivery cost, and it shows optimal user fees depending on the extent of cost recovery that is desired. These costs are for diesel pumps, since no user fees are planned to be collected at hand-pumped wells.

In order to recover the cost of well operation and maintenance, fees of between 5 and 8 shillings/m3 would have to be charged, as shown in the bottom line of the first section of Table 5.1: this is slightly more than half of the current government fee. Even at relatively low levels of demand, generated revenues (at 10 SS/m3) would more than pay for well operating expenses.

Table 5.1 Calculation of User Fees based on Water Consumption, Pump Life and Cost Recovery

	--Payback Period 5 Years-- Average Daily Consumption 70 m3 (1)	35 m3 (2)	--Payback Period 10 Years-- Average Daily Consumption 70 m3 (1)	35 m3 (2)
Annual Operating Cost (3)	5656	4546	5656	4546
Annualized Maintenance Cost	1215	1215	1215	1215
Subtotal I (US$)	6871	5761	6871	5761
(SS)	119418	100126	119418	100126
Required User Fee (SS/m3) to Recover Subtotal I	5	8	5	8
Annualized Value of Direct Costs (4)	13413	13413	7520	7520
Subtotal II (US$)	20284	19174	14391	13281
(SS)	352544	333252	250110	230818
Required User Fee (SS/m3) to Recover Subtotal II	14	26	10	18
Annualized Value of Indirect Costs (5)	4391	4391	2462	2462
Subtotal III (US$)	24676	23566	16852	15742
(SS)	428865	409573	292896	273604
Required User Fee (SS/m3) to Recover Subtotal III	17	32	11	21
Annualized Capital Recovery Cost (6)	25885	25885	14511	14511
Subtotal IV (US$)	50561	49451	31364	30254
(SS)	878745	859454	545102	525810
Required User Fee (SS/m3) to Recover Subtotal IV	34	67	21	41

Notes: (1) + (2) Corresponds with average daily pumping times of 6 and 3 hours, respectively.
(3) See operating and maintenance costs in Table 3.8.
(4) Equals direct costs for diesel wells (Table 3.10) * capital recovery factor.
(5) Equals indirect costs per well * capital recovery factor.
(6) Equals capital costs per well * capital recovery factor.
Assumptions (5) and (6) based on a high production rate, i.e. 18 production wells constructed per year.

In order to recover the direct cost of constructing diesel wells, which averages $54,000 per diesel well (see Table 3.10), the government fee of 10 SS/m3 would have to be almost doubled. The actual required fee varies, as shown in Table 5.1, from 10 SS/m3, assuming a long payback period and high average daily consumption, to 26 SS/m3, assuming a shorter payback period and more modest average daily consumption. The current government water tariff is not sufficient, at estimated levels of demand, to pay the government back within ten years for all of its direct costs in constructing and operating diesel wells.

Subtotal III in Table 5.1 shows the user fee necessary for the government to recover both its direct and indirect costs. The range of fees, depending on actual average pumping times and payback periods, is from 11 to 32 SS/m3. The government price would have to be doubled to recover these costs in five years (assuming high demand) or in ten years (assuming low demand).

Subtotal IV shows the fee required to recover the full costs, including capital costs, of constructing wells. order to achieve full cost recovery, assuming the same volume of pumped water as before, fees of 25-65 SS/m3 would have to be charged.

This financial approach to user fees does not make any assumptions concerning user willingness to pay or the seasonal sensitivity of demand to price. In fact, very little is known of the demand curve for water in the Bay and Central Rangelands. Spot observations of the fees charged at selected water points in the Bay Region are known, but research has not yet been done on household expenditures on water over time. (User fees charged in 1982 ranged from .5 to 2 SS per camel, .25 to .5 SS per cow, and .1 to .25 SS per sheep or goat. These prices are comparable to the government price of 10 SS/m3. See the CGDP Exploration Report, 1983, pg. 6-48.)

Before actual revenue projections can be made for CGDP wells, more study of user willingness to pay is required.

A family who uses well water from three to seven months a year would be required to pay from 100 to 300 SS per year. The higher cost is roughly equivalent to half the value of a goat, which does not seem an unreasonably high price for a family to pay for clean water. To a poor family, however, the form of this required payment may be equally as important to its willingness to pay as its total cost. Current government policy is to charge users on a unit basis, ie. at each time water is withdrawn. An alternative to this would be to collect fees on a lump-sum basis, such as for periods varying

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from one month to one year. Lump-sum payments could have several possible advantages:

(1) Ease of administration, since the number of cash transactions would be greatly reduced and the need of monitering water use would be much less;

(2) Reduced seasonality of demand, since users would not resort so quickly to traditional sources if the use of well water was already paid for;

(3) Increased health benefits, since during the wet seasons, more clean well water would be used than contaminated surface water;

(4) Closer parallels with traditional village administration of water rights: culturally, lump-sum payments are closer than unit fees to the traditional 'fetiir' notion of earning one's right to use a water source. 'Fetiir' refers to those who have helped maintain the condition of the village uar or well. Although a person or family usually becomes fetiir by working, one can also become fetiir by purchasing the right. This type of seasonal cash payment, which can range from one to several hundred shillings per year, is identical to the idea of establishing lump-sum payments for the right of drawing water at WDA wells. The importance of this notion is that partial responsibility for well maintenance could be more easily assumed by the village water committee if it was understood that it had a year-round interest in the well, not just a seasonal need.

(5) The possibility of generating increased revenues; it is possible that lump-sum payments at WDA wells could generate more revenue than unit charges, although this could not be verified unless either demand surveys or actual experiments were carried out. The reasoning is simple: experience has shown that villagers will go to great lengths, such as walking two or more hours to an alternative source, to avoid purchasing water. It is psychologically easier to make a single, necessary investment of SS 300 than to make 300 daily investments of one shilling each.

The idea of lump-sum user financing of WDA wells is suggested here as an alternative to unit fees. At least three real problems can be foreseen, however. These are (a) the problem of pump reliability, and what to do in the case of (inevitable) breakdowns and water shortages; (b) the ability of villagers to make a

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relatively large, single lump-sum payment; and (c) the difficulty of linking the size of each family's lump-sum payment with its livestock holdings. The first problem would require WDA to gain credibility in the area of pump maintenance, and the second could lead to the possibility of accepting in-kind payment, such as of livestock or labor. Neither of these problems is insurmountable. The third problem would require flexibility in the calculation of lump-sum fees, since the number of livestock kept locally by each family varies month by month. One approach would be to treat the lump-sum payment as a credit against which incremental water use is debited, as opposed to treating the payment as the right to draw an unlimited amount of water in a fixed period of time.

The most important conclusion of this chapter is that given the projected level of demand at the CGDP wells, the current government water fee of 10 SS/m3 is sufficient to repay (i) all diesel well operation and maintenance costs, and (ii) only half, or slightly more than half, of the direct cost of constructing each well. A user fee of 20 SS/m3 would repay the government for both its direct and indirect costs. The capital cost of the CGDP program cannot be recovered, however, unless the price for water could be raised from 10 to about 50 SS/m3 without a subsequent decrease in demand.

This chapter's second conclusion is that alternative means of payment may increase the ease of administering and maintaining rural wells, increase total government revenues, and increase total water use and hence total benefits derived from the use of clean water.

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VI. Conclusions

This report has generated a wealth of data concerning the costs of drilling wells in Somalia, the type of benefits to be gained, and the scale of user fees required to finance program costs. The principal conclusions, and the use to which they can be put, are summarized here.

6.1 Costs

The full cost of drilling wells was calculated in Chapter III (see Table 3.16). The cost of constructing an average well, including "sunk" capital costs (defined as the $6.1 million of capital equipment procured under CGDP-I), is about $200,000-$280,000, and the average cost of providing one year of well service, including all costs, is about $45,000-$60,000. When "sunk" capital costs are excluded, these costs decrease to only $120,000-$160,000, and $30,000-$35,000, respectively. These costs are for what is defined as an 'average well' -- whose assumed average depth, diameter, type of pump, and period of use, are all based on the past experience of CGDP.

Of the total cost of an average well, more than 60% is the capital cost of the heavy equipment and tools used by the project, and less than 40% is the cost of the materials, labor, fuel, and overhead required by each well. The finding that capital costs are such a large part of total costs is important in several respects:

(1) The <u>marginal cost</u> of constructing each additional well, once the capital equipment has been procured, is a small part of the total.

(2) <u>Any attempt to cut costs should focus first and foremost on the procurement of capital equipment</u>. Any given reduction in capital costs -- say, 10% -- would lead to much greater cost savings than an equivalent reduction in direct costs or overhead. It is not the purpose of this report to judge where, if at all, capital expenditures have been excessive under CGDP-I: rather, this report enables project planners and evaluators to see the high incidence of capital costs, to weigh the impact of specific changes or savings, and to compare the procurements of this project with that of other well-drilling programs.

(3) <u>The program costs are very sensitive to the the expected life of the capital equipment</u>, since longer equipment life means that the capital equipment costs can be spread out over a greater

number of years and over a greater number of wells. If the drill rigs are only used for seven, as opposed to ten years, the average cost per year of well service would rise by 20%.

(4) Maintaining a high annual well production rate is essential to keeping per well costs at an acceptable level. This is because annual fixed costs, including both capital costs and overhead, together account for 70% of program costs. A 44% reduction in the assumed well completion rate, from 18 to 10 wells per year, would increase total costs per year of well service by almost 60%. A higher drilling rate reduces average costs, even if the rate of well failures increases.

(5) Since the cost of capital equipment is such a large part of program costs, the original choice of technology is an extremely important determinant of costs. The costs for CGDP have been estimated for a period of ten years, which is the projected lifespan of the three rotary drill rigs. The CGDP is, essentially, locked in to the use of the rotary drill rig technology. Planners of future similar groundwater projects should be able to compare the costs shown here with those of other technological alternatives in order to choose the most appropriate technology for achieving the desired results at the lowest overall cost.

The cost analysis contained in Chapter III can be used by the government and its donor agencies to evaluate the cost effectiveness of the project, to compare with the costs and performance of other similar projects, and to foreceast future groundwater aid requirements. It can be used to compare the cost of developing of groundwater resources with that of alternative supplies. Also, it can be used by the WDA to plan its yearly budget and to evaluate the potential cost savings to be gained by altering any of the various program components. Finally, WDA can use this analysis, as is discussed below, in the calculation of appropriate user fees.

6.2 Benefits

The data used in the evaluation of project benefits is less detailed than for costs, and the results are much more tentative. An effort was not made to quantify benefits, but rather to estimate the number and type of project beneficiaries, and to describe the type and relative importance of the water-related benefits.

In both project areas, water demand will be quite seasonal, due to (a) the ready availability of surface

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water in the wet seasons (involving shorter carrying distances, for many people, than the well), and (b) the fact that traditional water sources are free of charge. In the dry season, however, the wells will enable significant improvements in water availability and water quality. By averaging out projected demand throughout the year, estimates were made of the annual average number of people and animals using wells in the Bay Region and Central Rangelands, and of the required pumping times.

In the Bay Region, it is estimated that the average annual number of beneficiaries per well would be about 1,500-2,500 people, together with an equal number of family livestock (measured as livestock units). This is equivalent to an average user population, per well, of about 300-400 families and their household livestock.

The provision of clean year-round water in the Bay Region will generate important public health benefits in the form of reduced incidence of water-related diseases. It will also free up significant labor resources, especially of women, currently devoted to drawing water. Other kinds of project-generated benefits will be (a) agricultural production benefits gained by sedantarizing populations that currently migrate away from their home villages during the dry seasons, (b) livestock production benefits attributable to increased water availability and improvements in water quality, for livestock, and (c) the potential for improved range management and grazing patterns that would lead to more productive grazing areas.

In the Central Rangelands, it is more difficult to estimate the number of future project beneficiaries because of the paucity of data on the population, livestock, and water requirements of the specific areas (called degans) under consideration. However, it can be assumed that during the harsh dry seasons, one well will serve the residents of from one to three degans, and that most wells will operate at or near to capacity. Dry season demand is likely to be the equivalent of about 250 families and their associated livestock, up to a total of 7,000 livestock units. Wet season demand will probably drop off to almost nothing, as in the Bay Region. Any estimates of an annual average number of beneficiaries would be conjecture, but would fall somewhere between these two extremes.

In the Central Rangelands, where the human population is much smaller than the animal population, the health benefits, if quantifiable, would probably be of lower magnitude than benefits to the livestock sector.

Although an economic cost/benefit analysis should ideally be able to compare the rates of return on investments in different regions, it is not now possible to compare the

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economic return on CGDP investments in the two different project areas. There is not yet any significant quantitative basis upon which total costs and total generated benefits in the Bay Region and the Central Rangelands can be compared.

6.3 User Fees

The current government water tariff, which is 10 SS per m3, is sufficient -- at the projected levels of demand -- to pay the government back for all of its operting and maintenance costs, and slightly more than half of its direct costs incurred in constructing diesel wells. The direct costs are those costs such as labor, fuel, and materials (pumps, well casing, cement, etc.) that are used in the construction of each well. A tariff of 20 SS/m3 could generate enough revenue to recover both project direct and indirect costs. Even this higher tariff would not, however, generate enough revenues to even approach those required to recover the capital cost of the project.

It is recommended that the government explore the possibility of collecting periodic lump-sum payments from well-users, as opposed to unit payments. It is possible that lump sum payments would (a) increase the volume of water consumed, especially during the wet seasons, with a corresponding increase in health benefits, (b) increase total revenues, (c) simplify the administration of the revenue-collecting body, and (d) correspond more closely with the traditional manner with which villages organize and administer water resources, thereby improving village participation and sense of responsibility.

6.4 The Future of the Comprehensive Groundwater Development Project

It is found that (1) if 18 production wells per year are constructed, (2) if the project's capital equipment is well-maintained, and (3) if sufficient attention is paid to the collection of water fees, then the CGDP program can become partially self-supporting. The direct costs and overhead could become almost entirely user-financed, and only the capital costs would require either government subsidy or foreign assistance.

<u>Each of these three conditions, however, would be very difficult for the WDA to achieve on its own.</u> The CGDP program is currently being assisted by a team of a dozen expatriate groundwater experts, all of whom are helping

WDA achieve the target construction rate of 18 production wells per year. It is not likely that WDA would be able to sustain this rate without the continuation of such technical assistance.

In particular, it is not likely that WDA mechanics would, working along, be able to keep the sophisticated drill and pump rigs in proper working condition. Without the continued services of an expatriate mechanic, it is widely believed that this equipment would not attain a working life-span of ten years, which is the lifespan assumed in the cost analysis. Of course, the earlier and longer the periods of equipment breakdown, the higher will be the average per well costs, the lower the production rate, and the lower the accrued benefits.

It is also likely that continued assistance to WDA hydrogeologists will be required in order to obtain the high ratio of production wells to exploratory wells that was assumed in the cost analysis. Finally, as more CGDP wells become operational, WDA may require assistance in strengthening its Operating Division, which would be charged with operating, maintaining, and collecting revenues from the new wells.

In conclusion, the future of the CGDP will probably rely upon two kinds of foreign assistance:

(1) <u>assistance in the procurement of capital equipment</u>. To date, about $6 million has been spent on the procurement of capital equipment, and it is projected that $7.3 million more will be required between 1985 and 1991 to keep the program operating at current levels (see Table 3.14). It is not foreseen that this cost, all of which would be a foreign exchange cost to the Somali government, will be recoverable through well-user fees. Unless the Somali government appears willing to devote general revenues to the procurement of well-drilling capital equipment, foreign aid will be required to keep the groundwater project going. The projected capital needs are modest, however -- slightly more than $1 million per year through 1991.

(2) <u>technical assistance</u>. There is no doubt that ongoing technical assistance will be required for the CGDP program to operate successfully and cost-effectively. It is not the purpose of this paper recommend the necessary technical assistance program, although three areas of need were mentioned above.

This paper has calculated the basic costs of the project's well-drilling activities, taken initial steps towards

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estimating project benefits, and established financial targets for the user-financing of well construction costs. It is hoped that these results will assist the government of Somalia and interested donor agencies, including USAID, in planning the upcoming years of the Comprehensive Groundwater Development Project.

APPENDICES

A. CGDP and Related Procurements

- A.1 Summary of all CGDP Project Procurements
- A.2 Commodity Procurements (PIOC's) for CGDP-I
- A.3 Commodity Procurements (PIOC's) for the Bay Region Agricultural Project and the Central Rangeland Development Project, which were purchased for CGDP-I
- A.4 LBI Contractor Fund for Equipment, Materials, and Supplies

B. Approximate Diesel Fuel Costs for Diesel Engine and Helical Rotor Pumps

C. Capital Recovery Factors

D. Capital Equipment Procurement Schedules, Assuming Normal, Shortened, and Extended Equipment Life

E. Costs of Well Construction and Maintenance under Varying Production Rates and Equipment Lifespans

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Table A.1 Summary of all Comprehensive Groundwater Development Project Procurements, as of December 1983

Procured through	'000 US$
1. CGDP-I Project (USAID #104) (*)	5850
2. Bay Region Agricultural Development Project (USAID #113)	1430
3. Central Rangelands Development Project (USAID #108)	1005
4. LBI Contractor Fund	272
Total (000's US$) --	8557

Note: Amount shown is the estimated total cost, not the amount allocated by USAID, which is slightly higher.

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Table A.2 Commodity Procurements (PIOC's) for CGDP I, in Chronological Order (US$)

PIOC # --	Date	Item(s)	FOB Price (US Dollars)	CIF Price (US Dollars)
1. (#90045)	4/80	Spare parts for Failing Co. drill rigs	59800	66100
		Spare parts for Koechering Co. Speedstar drill rigs	46900	52900
		Total --	106700	119000
2. (#90047)	6/80	3 geophysical vehicles (GM Suburbans), logging equipment, and spare tires	n/a	239360
3. (#90048)	6/80	Expatriate staff household furnishings	n/a	250800
4. (#90049)	6/80	7 GM pickups	68990	\\
		1 GM pickup crewcab	11510	175270
		4 GM Suburban passenger vehicles	45820	//
		Additional spare parts (est. @ 15%)	n/a	33120
		Total --	---	208390
5. (#00001)	6/80	3 TH60 Ingersoll-Rand rotary drill rigs, with standard accessories, bits, drill pipe, stabilizers and 150 55-gal. drums of drill foam	n/a	1651580
6. (#00002)	6/80	Spare parts for Failing Co. drill rigs	201450	222200
7. (#00003)	6/80	Expatriate staff household appliances	n/a	117140
8. (#10001)	2/81	4 GM Crewcab pickups	74010	85510
		1 GM Suburban	n/a	17830
		2 GMC flatbed trucks C7D064	//	109490
		2 GMC fuel tankers C7D042	215140	105940
		1 GMC water tanker C7D042	\\	60390
		PVC well casing and screen:		
		14,763' of 8" casing	43850	68950
		2,622' of 8" screen	22060	34700
		Misc. fittings, solvents	n/a	8750
		Wyoming Bentonite drilling clay	17420	50320
		30 tires and tubes	2460	2880
		Expatriate household supplies and appliances	5610	7160
		Total (est.) --	---	551920
		Total (USAID alloc.) --	---	618970
9. (#00007)	2/81	1 water and 1 gas trailer (Gen. Engine Co.)	8370	14900
		2 GM/Isuzu diesel generators	31180	49290
		2 Airstream trailers and accesories	56640	93620
		Office furnishings	25800	33900
		Total --	121990	191710
10. (#10007)	12/81	10 Ingersoll Rand 15" tricone bits	39250	49860
11. (#10011)	2/82	Field equipment, tents, utensils	n/a	27270

PIOC # --	Date	Item(s)	FOB Price (US	CIF Price Dollars)
12. (#10015)	3/82	Spare parts for TH60 drill rigs	17865	24640
13. (#10018)	5/82	HACH portable water quality lab	n/a	3270
14. (#10019)	5/82	Equipment for water quality analysis lab	n/a	16130
15. (#10024)	6/82	1 Gestetner mimeograph machine	1740	
		Office supplies	740	
		Welding equipment, generator, gas, and gas bottles	14100	
		Total --	16580	22320*
16. (#20007)	7/82	I. Spares for TH60 drill rigs	68700	
		II. Spares for TH60 mud pumps	22680	
		III. Spares for TH60 IH diesel engine	17360	
		IV. Spares for TH60 Detroit Diesel engine	14900	
		V. Spares for 5 GMC trucks	12140	
		VI. Spares for GMC tanker assemblies	1780	
		VII. Spares for GMC-Cat diesel engines	25740	
		VIII. Additional equipment/tools		
		Drill tools	43380	
		GM/Isuzu generator	21490	
		Mech. tools, supplies, pumps	63620	
		IX. 2 Chevrolet S-10 light pickups	15180	
		A. Tools for Detroit Diesel Engines	3400	
		B. Parts for logging units	3680	
		C. Spares for GM/Isuzu generators	920	
		D. Hydraulic spares for TH60 drill rigs	16650	
		E. Test equipment for logging units	13850	
		F. Hydrogeological equipment	26050	
		G. Water Quality lab test equipment	14300	
		H. Mobile and base station radio equipment	24290	
		I. Test pumps, starters, and generator	59230	
		Total (est.) --	469340	750944*
		Total (USAID alloc.) --	---	1031000
17. (#20009)	9/82	Diesel generator, compressor, battery charger, etc.	6910	7650*
		Tools, dies, hoses, belts	12480	17240
		Drill press, steam cleaning equipment	3610	5110
		Total --	23000	30000
18. (#20014)	10/82	Special petroleum lubricants	n/a	35000
19. (20015)	11/82	Spare transmissions, batteries, tires	19750	28630
20. (#20018)	12/82	Field equipment, metal beds, tents	n/a	15000
21. (#20022)	12/82	2 GMC Pickups	26940	
		1 GMC Suburban	14300	
		5 GMC Blazers	66200	
		6 GMC Crewcabs	96980	
		1 GMC Pickup with tool compartments	16160	
		1 GMC Mechanics service truck C7D042	42680	

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PIOC # --	Date	Item(s)	FOB Price (US Dollars)	CIF Price
		Vehicle spare parts, batteries, winches	9420	
		3 16' flatbed trailers	14670	
		7 campers	41520	
		Total (est.) --	328870	493305*
		Total (USAID alloc.) --	---	515000
22. (#90136)	1/83	Replacement engine for GM/Isuzu generator	n/a	3200*
23. (#20024)		Procurement cancelled		
24. (#90140)	7/83	3 Navidyne satellite navigators and accessories	18500	20000*
25. (#10039)	7/83	100 tons cement	6910	14950
26. (#20034)	8/83	A. Spares for TH60 drill rigs	9500	
		B. Spares for TH60 Detroit Diesel engines	2750	
		C. Spares for GM trucks	16900	
		D. Spares for GM transmissions	1350	
		E. Vehicle workshop tools, equipment	28150	
		F. Spares for cement pump	50	
		G. Tools for TH60 drill rigs	6000	
		H. Field camping equipment	9850	
		I. Spares for logging units	21800	
		J. Hydrogeological equipment	13300	
		K. Water quality lab equipment	1700	
		L. Cable tool drill rig equipment	30300	
		M. Submersible test pumps	22000	
		N. Support equipment		
		Backhoe and backhoe trailer	37000	
		Down-the-hole video van	45000	
		Total (est.) --	245650	393040*
		Total (USAID alloc.) --	---	429250
27. (#00066)	8/83	Civil works pipe fittings (for 10 wells)	n/a	28100
28. (#30017)	9/83	Procurement cancelled		
29. (#30016)	9/83	Mobile and base station radio equipment		
30. (#00072)	9/83	Vehicle lubricants and special fluids		
31. (#00073)	10/83	2 Windmills, pumps, and pipe fittings		
32. (#30020)	12/83	Civil works construction materials and fittings		
Total (estimated) --			---	6023029
Total (USAID allocation) --			---	6428040

Notes: Only PIOC's 1-7 and 12 were closed as of Dec. 12, 1983. Although some of the later prices are actual prices, many are the estimated (pre-bid) prices. Those prices marked with an asterisk (*) are either estimated as a residual of individual PIOC's, or are the total USAID allocations based on pre-bid estimates.

Table A.3 Commodity Procurements (PIOC's) for the Bay Region Agricultural Project and the Central Rangeland Development Project, which were purchased for CGDP-I

PIOC # --	Date	Item(s)	FOB Price (..US Dollars ..)	CIF Price
1. Bay - 1	8/82	Drilling bits, tri-cone and hammer	58415	
		Well casing and screen (for 20 wells)	91755	
		Drilling tools and supplies	27610	
		Deep well pumps and spares (20 diesel, 20 hand)	284470	
		GMC heavy vehicles:		
		1 knuckle crane truck	57345	
		1 fuel tanker	39865	
		2 water tankers	79735	
		2 flatbed trucks	60260	
		Seaco pump rig (with derrick and accessories)	62440	
		Total --	761895	1219032*
2. Central Range - 1	8/82	Drilling bits, tri-cone and hammer	59950	
		Well casing and screen (for 10 wells)	35110	
		Drilling tools and supplies	27380	
		Deep well pumps and spares (10 diesel, 10 hand)	142570	
		GMC heavy vehicles:		
		2 knuckle crane trucks	114690	
		2 water tankers	79730	
		1 flatbed truck	30130	
		Spare tires	3060	
		Seaco pump rig (with derrick and accessories)	62440	
		Total --	555060	888096*
3. Bay - 2	12/83	Drill bits	58860	
		Drilling mud additives	12540	
		Pump rig tools (for pump installation)	5800	
		Pump spares (for Mono pumps)	39600	
		Total (est.) --	116800	186880*
		Total (USAID alloc.) --		210000
4. Central Range - 2	12/83	Drilling mud additives	6500	\\
		Pump rig tools (for pump installation)	6600	60300
		Pump spares (for Mono pumps)	20400	//
		Civil works construction materials	n/a	55000
		Total --	---	115300
Total --			---	2469608

Note: (*) CIF value estimated on the basis of a standard 60% markup.

Table A.4 LBI Contractor Fund for Equipment, Materials, and Supplies (US$)

	FOB Value	CIF Value
1 Jeep Station Wagon	n/a	12000
Mechanics tools	40000	50500
Spare parts for GMC light vehicles	150000	190500
GMC Suburban (9 passenger)	15000	19000
Total (US$) —	—	272000

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Appendix B: Approximate Diesel Fuel Costs for Diesel Engine and Helical Rotor Pumps

The fuel cost of operating a diesel pump can be derived from the following equation:

$$C = \frac{(9.81\ hv) * 0.33 * P}{3600 * e}$$

where:

C = operating cost ($)
h = total dynamic head required (m), assumed to be equal to D, the depth of the well
v = volume of water required (m3)
e = diesel input to water output effiency ratio, assumed = 0.55
P = price of diesel ($/liter)

The equation simplifies to:

$$C = 0.001635 * D * v * P$$

The pumps used in this project pump approximately 12 m3 per hour at an average well depth of 100 meters.

Appendix C - Capital Recovery Factors

CAPITOL RECOVERY FACTORS (CRF)

i(%)	2	3	4	5	6	7	8	10	15	30
					n(years)					
2.5	.5188	.3501	.2658	.2153	.1815	.1575	.1395	.1143	.0808	.0478
5	.5378	.3672	.2820	.2310	.1970	.1728	.1547	.1295	.0963	.0651
7.5	.5569	.3845	.2986	.2472	.2130	.1888	.1707	.1457	.1133	.0847
10	.5762	.4021	.3155	.2638	.2296	.2054	.1874	.1627	.1315	.0106
12.5	.5956	.4199	.3327	.2809	.2467	.2226	.2048	.1806	.1508	.1288

Derived from $$CRF = \frac{i\,(1 + i)^n}{(1 + i)^n - 1}$$

where i = annual interest or social discount rate
n = expected life of capitol (year)

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Table D.1 Capital Equipment Procurement Schedule - Assuming Normal Equipment Life

Item/Year	Total as of 12/83	1984	1985	1986	1987	1988	1989	1990	1991	Total 1984-1991
	(. . . . . in thousands of constant 1983 dollars . . . . .)									
Drill rigs										
# of vehicles	3	--	--	--	--	--	--	--	--	--
Cost of new vehicles	1652	--	--	--	--	--	--	--	--	--
Spare parts	441	110	110	165	165	165	165	165	165	126
Pump rigs										
# of vehicles	2	--	--	--	--	--	--	--	--	--
Cost of new vehicles	182	--	--	--	--	--	--	--	--	--
Spare parts	17	--	18	18	18	18	18	18	18	126
Heavy trucks										
# of vehicles (1)	18	--	4	12	--	--	16	--	--	32
Cost of new vehicles	1170	--	260	780	--	--	1040	--	--	2080
Spare parts	320	40	120	120	120	120	120	120	120	880
Light vehicles										
# of vehicles (2)	40	12	9	9	14	9	9	14	--	76
Cost of new vehicles	856	252	189	189	294	189	189	294	--	1596
Spare parts	288	30	70	70	70	70	70	70	70	520
Other light equip. (3)										
Value of equipment	1114	--	--	--	--	--	--	--	--	--
Spare parts	26	110	110	110	110	110	110	110	110	880
Total (000's US$)	6066	542	877	1452	777	672	1712	777	483	7292

Notes: (1) Includes the backhoe and trailer, and 3 flatbed trailers. The total number of heavy trucks is projected to decrease by one, from 18 to 17, as per Table 3.2.
(2) Includes the down-the-hole video van. The total number of light vehicles is projected to decrease by five, from 40 to 32, as per Table 3.2.
(3) Includes all generators, welders, test pumps, and logging, hydrological, geophysical, water quality analysis, radio, office, workshop, and field equipment.

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Table D.2 Capital Equipment Procurement Schedule - Assuming Shortened Epuipment Life

Item/Year	Total as of 12/83	1984	1985	1986	1987	1988	Total 1984-1988
	(. . . . . in thousands of constant 1983 dollars . . . . .)						
Drill rigs							
# of vehicles	3	--	--	--	--	--	--
Cost of new vehicles	1652	--	--	--	--	--	--
Spare parts	441	110	110	165	165	165	715
Pump rigs							
# of vehicles	2	--	--	--	--	--	--
Cost of new vehicles	182	--	--	--	--	--	--
Spare parts	17	--	18	18	18	18	72
Heavy trucks							
# of vehicles (1)	18	--	4	12	--	--	16
Cost of new vehicles	1170	--	260	780	--	--	1040
Spare parts	320	40	120	120	120	120	520
Light vehicles							
# of vehicles (2)	40	12	9	9	16	8	54
Cost of new vehicles	856	252	189	189	336	168	1134
Spare parts	288	30	70	70	70	70	310
Other light equip. (3)							
Value of equipment	1114	--	--	--	--	--	--
Spare parts	26	110	110	110	110	110	550
Total (000's US$)	6066	542	877	1452	819	651	4341

Notes: (1) Includes the backhoe and trailer, and 3 flatbed trailers. The total number of heavy trucks is projected to decrease by one, from 18 to 17, as per Table 3.2.

(2) Includes the down-the-hole video van. The total number of light vehicles is projected to decrease by five, from 40 to 32, as per Table 3.2.

(3) Includes all generators, welders, test pumps, and logging, hydrological, geophysical, water quality analysis, radio, office, workshop, and field equipment.

Table D.3 Capital Equipment Procurement Schedule - Assuming Extended Equipment Life

Item/Year	Total as of 12/83	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total 1984-1996
	(. . . . . in thousands of constant 1983 dollars . . . . .)													
Drill rigs														
# of vehicles	3	--	--	--	--	--	--	--	--	--	--	--	--	--
Cost of new veh.	1652	--	--	--	--	--	--	--	--	--	--	--	--	--
Spare parts	441	110	110	165	165	165	165	165	165	165	165	165	165	1870
Pump rigs														
# of vehicles	2	--	--	--	--	--	--	--	--	--	--	--	--	--
Cost of new veh.	182	--	--	--	--	--	--	--	--	--	--	--	--	--
Spare parts	17	--	18	18	18	18	18	18	18	18	18	18	18	198
Heavy trucks														
# of vehicles (1)	18	--	4	12	--	--	16	--	--	16	--	--	--	48
Cost of new veh.	1170	--	260	780	--	--	1040	--	--	1040	--	--	--	3120
Spare parts	320	40	120	120	120	120	120	120	120	120	120	120	120	1360
Light vehicles														
# of vehicles (2)	40	12	9	9	14	9	9	14	9	9	14	9	9	126
Cost of new veh.	856	252	189	189	294	189	189	294	189	189	294	189	189	2646
Spare parts	288	30	70	70	70	70	70	70	70	70	70	70	70	800
Other equipment (3)														
Value of equip.	1114	--	--	--	--	--	--	--	--	--	--	--	--	--
Spare parts	26	110	110	110	110	110	110	110	110	110	110	110	110	1320
Total (000's US$)	6066	542	877	1452	777	672	1712	777	672	1712	777	672	672	11314

Notes:
(1) Includes the backhoe and trailer, and 3 flatbed trailers. The total number of heavy trucks is projected to decrease by one, from 18 to 17, as per Table 3.2.
(2) Includes the down-the-hole video van. The total number of light vehicles is projected to decrease by five, from 40 to 32, as per Table 3.2.
(3) Includes all generators, welders, test pumps, and logging, hydrological, geophysical, water quality analysis, radio, office, workshop, and field equipment.

Table E.1 Costs of Well Construction and Maintenance, assuming Normal Equipment Life and High Production Rates 18 Wells per Year (in thousands of constant 1983 dollars)

	Net Present Value	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
	(i = 15%)													
I. Direct Costs														
A. Construction Costs														
- Diesel Wells														
Number of wells	45	10	10	10	10	10	10	10	10					
Cost	2401	535	535	535	535	535	535	535	535					
- Hand-pump wells														
Number of wells	36	8	8	8	8	8	8	8	8					
Cost	757	169	169	169	169	169	169	169	169					
- Exploratory and Failed Wells														
Number of wells	54	12	12	12	12	12	12	12	12					
Cost	374	83	83	83	83	83	83	83	83					
-- Subtotal	3532	787	787	787	787	787	787	787	787					
B. Operating and Maintenance Costs														
- Diesel Wells														
Number of wells	227	5	15	25	35	45	55	65	75	80	80	75	65	55
Cost	2043	32	95	230	322	414	506	598	690	736	736	690	598	506
- Hand-pump wells														
Number of wells	182	4	12	20	28	36	44	52	60	64	64	60	52	46
Cost	38	1	2	9	13	16	20	23	27	29	29	27	23	21
-- Subtotal	2110	32	97	239	335	430	526	621	717	765	765	717	621	527
II. Overhead Costs														
- Indirect Costs (Labor and Materials)	1535	342	342	342	342	342	342	342	342					
- Sunk Capital Costs	6066													
- Recurring Capital Costs	4058	542	877	1452	777	672	1712	777	483					
-- Subtotal	11658	884	1219	1794	1119	1014	2054	1119	825					
III. Total Costs	17301	1704	2103	2820	2241	2231	3367	2528	2329	765	765	717	621	527

IV. Average Costs

Average Construction Cost per well, including sunk capital costs = $188,000
Average Construction Cost per well, excluding sunk capital costs = $113,000

Average Total Cost per Year of Well Service, including sunk costs = $42,000
Average Total Cost per Year of Well Service, excluding sunk costs = $27,000

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Table E.2 Costs of Well Construction and Maintenance, assuming Normal Equipment Life and High Failure Rates
12 Wells per year (in thousands of constant 1983 dollars)

	Net Present Value	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
	(i = 15%)													
I. Direct Costs														
A. Construction Costs														
- Diesel Wells														
Number of wells	31	7	7	7	7	7	7	7	7					
Cost	1681	375	375	375	375	375	375	375	375					
- Hand-pump wells														
Number of wells	22	5	5	5	5	5	5	5	5					
Cost	473	106	106	106	106	106	106	106	106					
- Exploratory and Failed Wells														
Number of wells	81	18	18	18	18	18	18	18	18					
Cost	561	125	125	125	125	125	125	125	125					
-- Subtotal	2715	605	605	605	605	605	605	605	605					
B. Operating and Maintenance Costs														
- Diesel Wells														
Number of wells	161	4	11	18	25	32	39	46	53	56	56	52	45	38
Cost	1446	25	69	166	230	294	359	423	488	515	515	478	414	350
- Hand-pump wells														
Number of wells	115	3	8	13	18	23	28	33	38	40	40	37	32	27
Cost	50	1	2	6	8	10	13	15	17	18	18	17	14	12
-- Subtotal	1495	26	71	171	238	305	371	438	505	533	533	495	428	362
II. Overhead Costs														
- Indirect Costs (Labor and Materials)	1535	342	342	342	342	342	342	342	342					
- Sunk Capital Costs	6066													
- Recurring Capital Costs	4058	542	877	1452	777	672	1712	777	483					
-- Subtotal	11658	884	1219	1794	1119	1014	2054	1119	825					
III. Total Costs	15869	1515	1895	2571	1962	1924	3031	2162	1935	533	533	495	428	362

IV. Average Costs

Average Construction Cost per well, including sunk capital costs = $267,000
Average Construction Cost per well, excluding sunk capital costs = $154,000

Average Total Cost per Year of Well Service, including sunk costs = $57,000
Average Total Cost per Year of Well Service, excluding sunk costs = $35,000

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Table E.3 Costs of Well Construction and Maintenance, assuming Normal Equipment Life and Low Production Rates
10 wells per year (in thousands of constant 1983 dollars)

	Net Present Value (i = 15%)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
I. Direct Costs														
A. Construction Costs														
- Diesel Wells														
Number of wells	27	6	6	6	6	6	6	6	6					
Cost	1440	321	321	321	321	321	321	321	321					
- Hand-pump wells														
Number of wells	18	4	4	4	4	4	4	4	4					
Cost	379	84	84	84	84	84	84	84	84					
- Exploratory and Failed Wells														
Number of wells	45	10	10	10	10	10	10	10	10					
Cost	312	70	70	70	70	70	70	70	70					
-- Subtotal	2131	475	475	475	475	475	475	475	475					
B. Operating and Maintenance Costs														
- Diesel Wells														
Number of wells	136	3	9	15	21	27	33	39	45	48	48	45	39	33
Cost	1226	19	57	138	193	248	304	359	414	442	442	414	359	304
- Hand-pump wells														
Number of wells	91	2	6	10	14	18	22	26	30	32	32	30	26	22
Cost	39	0	1	5	6	8	10	12	14	14	14	14	12	10
-- Subtotal	1265	19	58	143	200	257	314	371	428	456	456	428	371	314
II. Overhead Costs														
- Indirect Costs (Labor and Materials)	1535	342	342	342	342	342	342	342	342					
- Sunk Capital Costs	6066													
- Recurring Capital Costs	4058	542	877	1452	777	672	1712	777	483					
-- Subtotal	11658	884	1219	1794	1119	1014	2054	1119	825					
III. Total Costs	15054	1378	1752	2411	1793	1745	2842	1964	1727	456	456	428	371	314

IV. Average Costs

Average Construction Cost per well, including sunk capital costs = $307,000
Average Construction Cost per well, excluding sunk capital costs = $172,000

Average Total Cost per Year of Well Service, including sunk costs = $66,000
Average Total Cost per Year of Well Service, excluding sunk costs = $40,000

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Table E.4 Costs of Well Construction and Maintenance, assuming Shortened Equipment Life and High Production Rates -- 18 wells/year (in thousands of constant 1983 dollars)

	Net Present Value	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
	(i = 15%)										
I. Direct Costs											
A. Construction Costs											
- Diesel Wells											
Number of wells	34	10	10	10	10	10					
Cost	1793	535	535	535	535	535					
- Hand-pump wells											
Number of wells	27	8	8	8	8	8					
Cost	566	169	169	169	169	169					
- Exploratory and Failed Wells											
Number of wells	40	12	12	12	12	12					
Cost	280	83	83	83	83	83					
-- Subtotal	2639	787	787	787	787	787					
B. Operating and Maintenance Costs											
- Diesel Wells											
Number of wells	158	5	15	25	35	45	50	50	50	50	50
Cost	1407	32	95	230	322	414	460	460	460	460	460
- Hand-pump wells											
Number of wells	126	4	12	20	28	36	40	40	40	40	40
Cost	54	1	2	9	13	16	18	18	18	18	18
-- Subtotal	1460	32	97	239	335	430	478	478	478	478	478
II. Overhead Costs											
- Indirect Costs (Labor and Materials)	1146	342	342	342	342	342					
- Sunk Capital Costs	6066										
- Recurring Capital Costs	2922	542	877	1452	891	651					
-- Subtotal	10135	884	1219	1794	1233	993					
III. Total Costs	14234	1704	2103	2820	2355	2210	478	478	478	478	478

IV. Average Costs

Average Construction Cost per well, including sunk capital costs = $212,000
Average Construction Cost per well, excluding sunk capital costs = $111,000

Average Total Cost per Year of Well Service, including sunk costs = $50,000
Average Total Cost per Year of Well Service, excluding sunk costs = $29,000

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Table E.5 Costs of Well Construction and Maintenance, assuming Shortened Equipment Life and High Failure Rates -- 12 wells/year (in thousands of constant 1983 dollars)

	Net Present Value (i = 15%)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
I. Direct Costs											
A. Construction Costs											
- Diesel Wells											
Number of wells	23	7	7	7	7	7					
Cost	1255	375	375	375	375	375					
- Hand-pump wells											
Number of wells	17	5	5	5	5	5					
Cost	354	106	106	106	106	106					
- Exploratory and Failed Wells											
Number of wells	60	18	18	18	18	18					
Cost	419	125	125	125	125	125					
-- Subtotal	2028	605	605	605	605	605					
B. Operating and Maintenance Costs											
- Diesel Wells											
Number of wells	112	4	11	18	25	32	35	35	35	35	35
Cost	998	25	69	166	230	294	322	322	322	322	322
- Hand-pump wells											
Number of wells	81	3	8	13	18	23	25	25	25	25	25
Cost	34	1	2	6	8	10	11	11	11	11	11
-- Subtotal	1032	26	71	171	238	305	333	333	333	333	333
II. Overhead Costs											
- Indirect Costs (Labor and Materials)	1146	342	342	342	342	342					
- Sunk Capital Costs	6066										
- Recurring Capital Costs	2881	542	877	1452	819	651					
-- Subtotal	10094	884	1219	1794	1161	993					
III. Total Costs	13154	1515	1895	2571	2004	1903	333	333	333	333	333

IV. Average Costs

Average Construction Cost per well, including sunk capital costs = $301,000
Average Construction Cost per well, excluding sunk capital costs = $151,000

Average Total Cost per Year of Well Service, including sunk costs = $68,000
Average Total Cost per Year of Well Service, excluding sunk costs = $37,000

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Table E.6 Costs of Well Construction and Maintenance, assuming Shortened Equipment Life and Low Production Rates -- 10 wells/year (in thousands of constant 1983 dollars)

	Net Present Value (i = 15%)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
I. Direct Costs											
A. Construction Costs											
- Diesel Wells											
Number of wells	20	6	6	6	6	6					
Cost	1076	321	321	321	321	321					
- Hand-pump wells											
Number of wells	13	4	4	4	4	4					
Cost	283	84	84	84	84	84					
- Exploratory and Failed Wells											
Number of wells	34	10	10	10	10	10					
Cost	233	70	70	70	70	70					
-- Subtotal	1592	475	475	475	475	475					
B. Operating and Maintenance Costs											
- Diesel Wells											
Number of wells	95	3	9	15	21	27	30	30	30	30	30
Cost	844	19	57	138	193	248	276	276	276	276	276
- Hand-pump wells											
Number of wells	63	2	6	10	14	18	20	20	20	20	20
Cost	27	0	1	5	6	8	9	9	9	9	9
-- Subtotal	871	19	58	143	200	257	285	285	285	285	285
II. Overhead Costs											
- Indirect Costs (Labor and Materials)	1146	342	342	342	342	342					
- Sunk Capital Costs	6066										
- Recurring Capital Costs	2881	542	877	1452	819	651					
-- Subtotal	10094	884	1219	1794	1161	993					
III. Total Costs	12556	1378	1752	2411	1835	1724	285	285	285	285	285

IV. Average Costs

Average Construction Cost per well, including sunk capital costs = $349,000
Average Construction Cost per well, excluding sunk capital costs = $168,000

Average Total Cost per Year of Well Service, including sunk costs = $80,000
Average Total Cost per Year of Well Service, excluding sunk costs = $41,000

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Table E.7 Costs of Well Construction and Maintenance, assuming Extended Equipment Life and High Production Rates
18 Wells per Year (in thousands of constant 1983 dollars)

	Net Present Value	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
(i = 15%)																		
I. Direct Costs																		
A. Construction Costs																		
- Diesel Wells																		
Number of wells	54	10	10	10	10	10	10	10	10	10	10	10	10					
Cost	2900	535	535	535	535	535	535	535	535	535	535	535	535					
- Hand-pump wells																		
Number of wells	43	8	8	8	8	8	8	8	8	8	8	8	8					
Cost	915	169	169	169	169	169	169	169	169	169	169	169	169					
- Exploratory and Failed Wells																		
Number of wells	65	12	12	12	12	12	12	12	12	12	12	12	12					
Cost	452	83	83	83	83	83	83	83	83	83	83	83	83					
-- Subtotal	4267	787	787	787	787	787	787	787	787	787	787	787	787					
B. Operating and Maintenance Costs																		
- Diesel Wells																		
Number of wells	250	5	15	25	35	45	55	65	75	85	95	100	100	90	80	70	60	50
Cost	2252	32	95	230	322	414	506	598	690	782	874	920	920	828	736	644	552	460
- Hand-pump wells																		
Number of wells	200	4	12	20	28	36	44	52	60	68	76	80	80	72	64	56	48	40
Cost	87	1	2	9	13	16	20	23	27	31	34	36	36	32	29	25	22	18
-- Subtotal	2339	32	97	239	335	430	526	621	717	813	908	956	956	860	765	669	574	478
II. Overhead Costs																		
- Indirect Costs (Labor and Materials)	1854	342	342	342	342	342	342	342	342	342	342	342	342					
- Sunk Capital Costs	6066																	
- Recurring Capital Costs	5068	542	877	1452	777	672	1712	777	672	1712	777	672	672					
-- Subtotal	12988	884	1219	1794	1119	1014	2054	1119	1014	2054	1119	1014	1014					
III. Total Costs	19594	1704	2103	2820	2241	2231	3367	2528	2518	3654	2814	2757	2757	860	765	669	574	478

IV. Average Costs

Average Construction Cost per well, including sunk capital costs = $177,000
Average Construction Cost per well, excluding sunk capital costs = $115,000

Average Total Cost per Year of Well Service, including sunk costs = $44,000
Average Total Cost per Year of Well Service, excluding sunk costs = $30,000

Table E.8 Costs of Well Construction and Maintenance, assuming Extended Equipment Life and High Failure Rates
12 Wells per year (in thousands of constant 1983 dollars)

	Net Present Value	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
(i = 15%)																		
I. Direct Costs																		
A. Construction Costs																		
- Diesel Wells																		
Number of wells	38	7	7	7	7	7	7	7	7	7	7	7	7					
Cost	2030	375	375	375	375	375	375	375	375	375	375	375	375					
- Hand-pump wells																		
Number of wells	27	5	5	5	5	5	5	5	5	5	5	5	5					
Cost	572	106	106	106	106	106	106	106	106	106	106	106	106					
- Exploratory and Failed Wells																		
Number of wells	98	18	18	18	18	18	18	18	18	18	18	18	18					
Cost	678	125	125	125	125	125	125	125	125	125	125	125	125					
-- Subtotal	3280	605	605	605	605	605	605	605	605	605	605	605	605					
B. Operating and Maintenance Costs																		
- Diesel Wells																		
Number of wells	177	4	11	18	25	32	39	46	53	60	67	70	70	63	56	49	42	35
Cost	1597	25	69	166	230	294	359	423	488	552	616	644	644	580	515	451	386	322
- Hand-pump wells																		
Number of wells	127	3	8	13	18	23	28	33	38	43	48	50	50	45	40	35	30	25
Cost	55	1	2	6	8	10	13	15	17	19	22	23	23	20	18	16	14	11
-- Subtotal	1652	26	71	171	238	305	371	438	505	571	638	667	667	600	533	467	400	333
II. Overhead Costs																		
- Indirect Costs (Labor and Materials)	1854	342	342	342	342	342	342	342	342	342	342	342	342					
- Sunk Capital Costs	6066																	
- Recurring Capital Costs	5068	542	877	1452	777	672	1712	777	672	1712	777	672	672					
-- Subtotal	12988	884	1219	1794	1119	1014	2054	1119	1014	2054	1119	1014	1014					
III. Total Costs	17920	1515	1895	2571	1962	1924	3031	2162	2124	3230	2362	2286	2286	600	533	467	400	333

IV. Average Costs

Average Construction Cost per well, including sunk capital costs = $250,000
Average Construction Cost per well, excluding sunk capital costs = $157,000

Average Total Cost per Year of Well Service, including sunk costs = $59,000
Average Total Cost per Year of Well Service, excluding sunk costs = $39,000

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Table E.9 Costs of Well Construction and Maintenance, assuming Extended Equipment Life and Low Production Rates
10 Wells per year (in thousands of constant 1983 dollars)

	Net Present Value	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	(i = 15%)																	
I. Direct Costs																		
A. Construction Costs																		
- Diesel Wells																		
Number of wells	33	6	6	6	6	6	6	6	6	6	6	6	6					
Cost	1740	321	321	321	321	321	321	321	321	321	321	321	321					
- Hand-pump wells																		
Number of wells	22	4	4	4	4	4	4	4	4	4	4	4	4					
Cost	458	84	84	84	84	84	84	84	84	84	84	84	84					
- Exploratory and Failed Wells																		
Number of wells	54	10	10	10	10	10	10	10	10	10	10	10	10					
Cost	377	70	70	70	70	70	70	70	70	70	70	70	70					
-- Subtotal	2574	475	475	475	475	475	475	475	475	475	475	475	475					
B. Operating and Maintenance Costs																		
- Diesel Wells																		
Number of wells	150	3	9	15	21	27	33	39	45	51	57	60	60	54	48	42	36	30
Cost	1351	19	57	138	193	248	304	359	414	469	524	552	552	497	442	386	331	276
- Hand-pump wells																		
Number of wells	100	2	6	10	14	18	22	26	30	34	38	40	40	36	32	28	24	20
Cost	43	0	1	5	6	8	10	12	14	15	17	18	18	16	14	13	11	9
-- Subtotal	1394	19	58	143	200	257	314	371	428	485	542	570	570	513	456	399	342	285
II. Overhead Costs																		
- Indirect Costs (Labor and Materials)	1854	342	342	342	342	342	342	342	342	342	342	342	342					
- Sunk Capital Costs	6066																	
- Recurring Capital Costs	5068	542	877	1452	777	672	1712	777	672	1712	777	672	672					
-- Subtotal	12988	884	1219	1794	1119	1014	2054	1119	1014	2054	1119	1014	1014					
III. Total Costs	16957	1378	1752	2411	1793	1745	2842	1964	1916	3013	2135	2059	2059	513	456	399	342	285

IV. Average Costs

Average Construction Cost per well, including sunk capital costs = $287,000
Average Construction Cost per well, excluding sunk capital costs = $175,000

Average Total Cost per Year of Well Service, including sunk costs = $68,000
Average Total Cost per Year of Well Service, excluding sunk costs = $44,000

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