APPRAISAL AND EVALUATION OF WATER SUPPLY AND SANITATION PROJECTS
GHANA AS A CASE STUDY

by

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SUMMARY

Existing appraisal and evaluation methodologies provide for a separate assessment of technical, financial, economic, institutional, social and environmental aspects of projects without a unifying theory to combine these aspects into a single measure of project performance. Data Envelopment Analysis is proposed as a methodology for combining project input and output factors into a single efficiency score which could be used to rank projects. The efficacy of the methodology has been demonstrated in an application to data from the water supply and sanitation sector in Ghana.

This study involved the selection of ten projects in Ghana (six in water supply and four in sanitation). Each project is a representative of large urban or small urban or large rural or small rural systems in operation in Ghana. Various technologies employed in the projects include:

(a) For water supply:
- Conventional Water Treatment Plant
- Boreholes with Motorised Pumps
- Package Water Treatment Plant
- Drilled Wells with Handpumps (2 projects)
- Hand Dug Well

(b) For sanitation:
- Conventional Sewerage
- Communal Ventilated Improved Pit Latrines for an Urban Community
- Communal Ventilated Improved Pit Latrines for Rural Communities
- Traditional Pit Latrine

Data on technical, financial, economic, institutional, social and environmental factors were collected in a 30-month fieldwork in Ghana. The fieldwork involved extensive travelling visiting urban and remote rural communities operating various systems in the sector. The data collected were analysed to provide the basic information for Data Envelopment Analysis (DEA). DEA requires input and output data for each project to be used in formulating linear programming models which are subsequently solved using a personal computer to provide an efficiency score for each project. Four different formulations were investigated and the results used to identify which projects could be classified as efficient given the Ghanaian context in which they are operated. Suggestions for the improvement of inefficient projects are made using the efficient projects as models.

In conclusion DEA is recommended as a useful tool in appraisal and evaluation of water supply and sanitation projects to be adopted in developing countries, developing banks and other aid donor agencies. Other specific recommendations are made for the water supply and sanitation sector in Ghana.

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CHAPTER ONE

GHANA IN PERSPECTIVE

1.1 INTRODUCTION

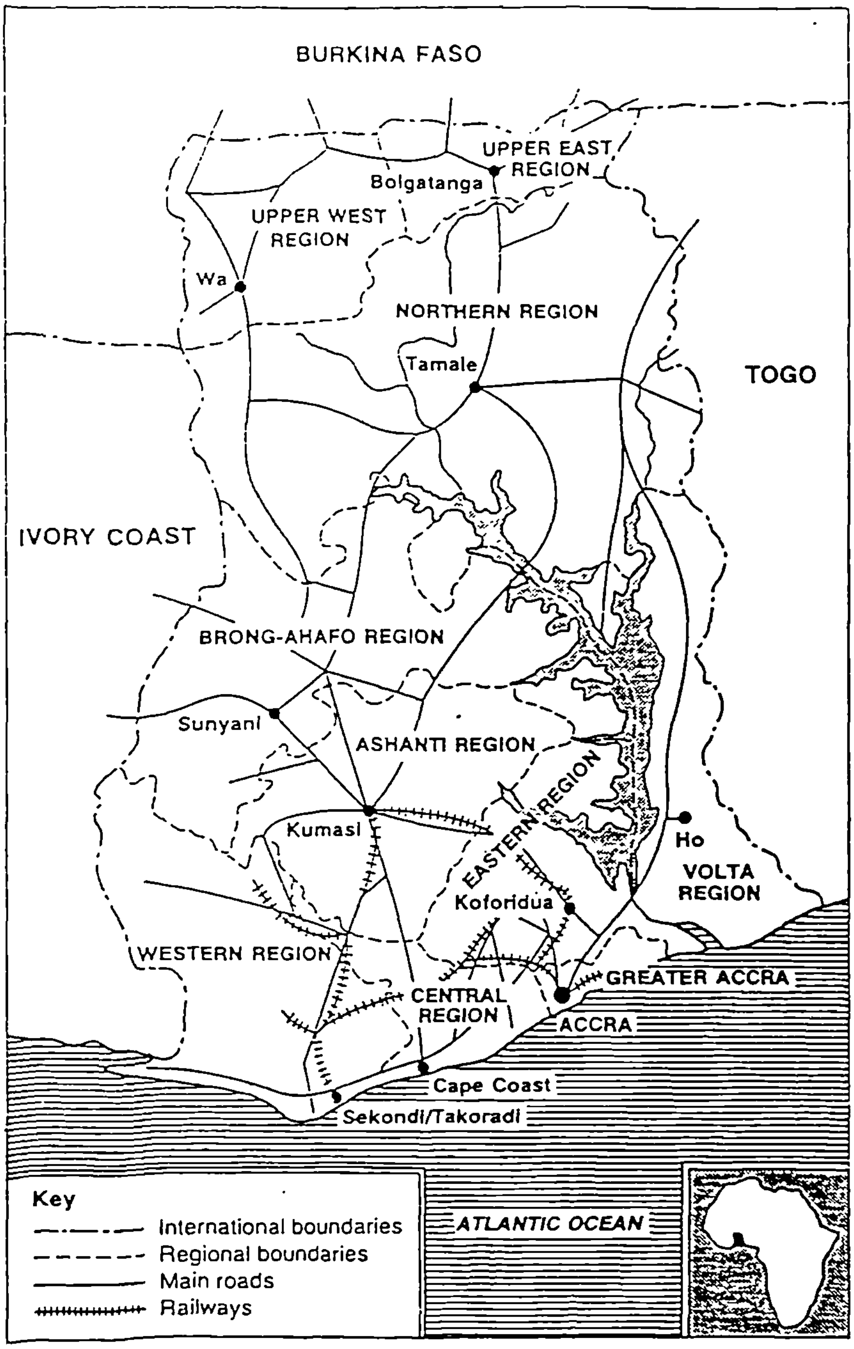
The Republic of Ghana, on the west coast of Africa, lies between latitudes 4°44'N and 11°N and longitudes 1°12'E and 3°15'W. It is bounded by Ivory Coast to the west, Republic of Togo to the east, Burkina Faso to the north and the Atlantic Ocean to the south. The Greenwich Meridian passes through the port city of Tema, 24km to the east of the capital city, Accra. The land area is approximately 238,000km^2 most of which lies below an altitude of 300m with a small area above 500m. The forest zone covers a third of the land area with the rest largely of savanna vegetation. The landscape is dominated by the Volta Lake, the largest man-made lake in the world, which covers an area of 8,500sq km and extends 650km inland.

The climate is tropical, strongly influenced by the South-West Monsoon from the South Atlantic together with the dry Harmathan winds from the Sahara to the north. Mean temperatures vary from 24-36°C in the north to 26-30°C in the south, while relative humidity ranges from 70-90 per cent along the coast to 20-55 per cent in the north. Mean annual rainfall varies from 2,250mm in the west coastal area to about 750mm in the eastern coastal area (around the capital, Accra) and 1,000mm in the north.

Administratively, Ghana is divided into ten regions which are further divided into 110 districts. The regions and their capital towns are as follows (Figure 1.1).

REGION	CAPITAL	REGION	CAPITAL
Ashanti	Kumasi	Brong-Ahafo	Sunyani
Central	Cape Coast	Western	Sekondi-Takoradi
Greater Accra	Accra	Northern	Tamale
Eastern	Koforidua	Upper East	Bolgatanta
Volta	Ho	Upper West	Wa

FIGURE 1.1: ADMINISTRATIVE MAP OF GHANA



The total population of Ghana was reckoned at 12.2 million at the last demographic census in 1984, an annual increase of 2.6 per cent from the 1970 census total of 8.56 million. The distribution in terms of community size are as below. Urban population, in Ghana, is defined as communities with population in excess of 5,000 persons.

POPULATION RANGE	NO. OF COMMUNITIES	POPULATION (MILLION) 1984
Above 5000	189	3.85
2000-5000	322	1.31
500-1999	2621	3.23
200-499	4268	1.84
100-199	4449	0.84
BELOW 100	35974	1.14
TOTAL	**47823**	**12.21**

The urban population represented 31.5 per cent in 1984 compared with 28.9 per cent in 1970. The projected total population of Ghana for 1990 is 14.24 million. (Republic of Ghana, 1987)

The political history of Ghana dates back to 1844 when the then Gold Coast became a British colony. The country was administered by a Governor as head of the Colonial Administration which operated through an appointed Government Agent working with the Native Authority headed by the traditional ruler, a system known as Indirect Rule. After several years of political agitation for self-government the British Government granted independence in 1957 to the new state of Ghana within the Commonwealth under the leadership of Dr. Kwame Nkrumah.

The Nkrumah Government at independence had a constitution which guaranteed the presence of a Governor-General appointed by the British Government. In 1960 the constitution was changed making Ghana a republic within the Commonwealth. Nkrumah's political constituents were the young men, unskilled urban workers, market women and small businessmen. The major legacies of this government are the opening of economic and social opportunities to the poor through the educational system and the creation, through the same system of highly competent professional and intellectual classes. Many policies were characterised as socialist and collectivist. Nkrumah was overthrown in a military coup in 1966.

The National Liberation Council, a military regime which was pro-West ruled the country from 1966 to 1969 and drew up the constitution for the second republic which took office after the general elections in October 1969. (Ray 1986)

The government of the Second Republic was led by Dr. K.A. Busia, who was the first Ghanaian recruited into the Colonial Administrative Service in the late 1940s. This government, though nominally non-aligned in foreign policy, seemed pro-West and continued with the policies of the National Liberation Council. The Busia Government was overthrown in a military coup in January 1972 after currency devaluation in December 1971.

The National Redemption Council led by General Archeampong an ardent admirer of Nkrumah, revalued the currency. After seven years of economic mismanagement General Archeampong was replaced by General Akuffo in July 1978. The new government was in the process of arranging for a general election when it was overthrown in June 1979 by Flight Lt. J.J. Rawlings. The top brass in the military were purged for corruption but the general elections were held to usher in the Third Republic in September 1979 under the leadership of Dr. Hilla Limman.

The Limman Administration was rather cautious in taking drastic measures in dealing with the economy. Further deterioration of the economy was inevitable and in December 1981 a second military coup led by Flight Lt. J.J. Rawlings succeeded in taking over the administration of Ghana. The government of the Provisional National Defence Council (PNDC) has taken tough, though harsh, measures to stop the decline of the Ghanaian economy (Younger, 1989).

1.2 THE ECONOMY OF GHANA

1.2.1 Historical Perspective

Ghana, as a British colony, was noted for the production of cocoa and for mining. As the leading exporter of cocoa, Ghana had 30 per cent of the world market which provided up to 60 per cent of all export earnings. Mining in Ghana, however, dates back as early as the 15th Century when Portuguese traders were dealing in gold near the mouth of Pra River. In the late 19th and 20th Centuries, European mining with modern technology was begun. Gold, manganese and diamonds were the primary minerals later bauxite also became important. The colonial government returned part of the revenues to finance development plans (Asamoah-Darko, 1980). The Guggisberg Development Plan (1920-1930) was primarily to open up the country for trade, therefore, railways, roads and a harbour were built together with some social projects including a hospital and the Prince of Wales College. Another ten year plan (1946-56) for Development and Welfare ran till 1951. The colonial government initiated yet another ten year plan for Economic and Social Development (1951-1961) but was revised in 1952 for completion by 1957. Ghana had gained independence and had £200 million locked up in long-term low interest British securities. The new government produced the second Five-Year Development Plan (1959-1964). The 1951 and 1959 plans were based on a development strategy for industrialisation formulated by W. Arthur Lewis, an eminent West Indian economist. This strategy emphasised total dependence on foreign capital for industrialisation. In other words Ghana was to continue to build up its foreign reserves in Britain to generate confidence abroad to ensure inflow of foreign capital. During the period, Ghana experienced rapid deterioration of her balance of payments position, loss of huge amounts of external reserves and failure to attract anywhere near the amount of foreign capital which Ghana counted on to assure industrial development (Fitch and Oppenheimer, 1966).

In 1961 the Second Five-Year Development Plan was publicly abandoned and the policies of the government changed to socialist-inspired planning techniques involving large government outlays for consumer and capital goods factories, stringent import controls and expanded fiscal and monetary powers. By 1966 Ghana's reserves had run down from £200 million in 1957 to £30 million in 1966 with debts of £360 million. A high percentage of the debt was contracted under the system of suppliers' credit which proved highly beneficial to lagging industries in Great Britain and West Germany. The Accra-Tema Water Supply Phase 1 was one such project financed by suppliers' credit from

West Germany. In 1965 the government of Ghana asked its main creditors to reschedule its debt and the creditors suggested the government approach the International Monetary Fund (IMF). The IMF recommended a standard stabilisation package of economic measures including termination of subsidies to state-owned enterprises and of the practice of financing new projects with suppliers' credit. The government accepted the recommendations but was overthrown before it could meet with the creditors.

The succeeding government of the National Liberation Council met twice with the creditors to reschedule the debt, devalued the currency by 43 per cent and embarked on limited privatisation of state-owned enterprises. The government of the Second Republic that followed liberalised imports causing, again, loss of reserves and accumulation of short-term debt and arrears in debt repayment. A further debt rescheduling was necessary followed by further devaluation of the currency. These measures caused the overthrow of the government in January 1972.

1.2.2 The Period of Economic Decline

Ghana, during the 1950s, was reckoned as one of the more developed countries in Sub-Saharan Africa. Per capita income was high by African standards, the educational system was the best in Africa and infrastructure and government institutions were relatively well-developed. Ghana would have been considered a middle-income country as prosperity continued into the early 1960s buoyed by high international cocoa prices. However world production of cocoa increased dramatically in the 1960s and consequently the world price fell reducing government tax revenues which depended heavily on the cocoa export tax. The large fiscal deficit was financed by printing money resulting in inflation due to excess demand and balance of payment problems. The government's response was price controls to contain inflation and import controls to stem the balance of payment problem. The results were disastrous. The economy stagnated in the late 1960s and declined steadily through the 1970s. Not only did per capita income fall but the institutions that made Ghana stand out in the 1960s, especially the schools and efficient civil service were also ruined. Living standards deteriorated so dramatically that many well educated Ghanaians left the country for employment elsewhere.

Table 1.1 compared several macroeconomic indicators for Ghana and Sub-Saharan Africa as a whole. Ghana's performance has been worse than average in a region noted for its disappointing economic development. Growth of real GDP was only 2.2 per cent per annum in the 1960s; certainly worse than 4.0 per cent for all Sub-Saharan Africa. The situation was even worse in the 1970s with zero growth for 1970-82 including a rapid decline in 1979-82 when growth rates averaged - 3.1 per cent per year. Combined with a 2.6 per cent growth rate of population, this led to a decline in per capita incomes of one-third from 1970-82. Further there was 62 per cent decline in the real minimum wage between 1970-82. Growth rates in agriculture and industry were worse than for the overall GDP indicating a shift from productive sectors into government and trading activities. In fact, in just two years, 1979/81 the share of retail and wholesale trade in GDP rose from 14 per cent to 26 per cent. The extensive system of price controls and import licensing meant that the most profitable activities in Ghana had become the pursuit of high profits by traders. Data on domestic savings and investment also suggest that the development process had been reversed in Ghana. Savings had declined from 17 per cent in 1960 to a mere 3.9 per cent of GDP in 1982. This is partially due to the real interest rates which averaged -30 per cent during 1970s. The main reason was that the government deficit rose from 2.3 per cent GDP in 1970 to 12 per cent in 1976-77 and only reduced to 7 per cent in 1980-82. Government absorption of most of the available domestic saving also reflected poor performance of investment. From a respectable 24 per cent of GDP in 1960, gross investment had fallen to 12.4 per cent in 1970 and only 3.5 per cent of GDP in 1982. Thus, it is likely that net investment was negative through much of the decade. Furthermore Ghana was losing more than physical capital. The rapid deterioration of real wages and living standards caused many of Ghana's better educated workers, teachers, doctors and civil servants to emigrate leaving Ghana with a shortage of human capital as well (World Bank, 1984a).

Table 1.1 Ghana's Relative Economic Performance, 1960-82 (per cent)

	1960-70		1970-82	
Category	Ghana	Low-income Sub-Saharan Africa	Ghana	Low-income Sub-Saharan Africa
Growth of GDP	2.2	4.0	0.0	1.8
Agriculture	n.a.	n.a.	0.0	1.6
Industry	n.a.	n.a.	-2.4	2.3
Manufacturing	n.a.	n.a.	-4.9	2.3
Services	n.a.	n.a.	1.5	4.3
Growth of per capita food production	0.3	1.0	-2.9	-1.2
Growth of consumption and investment				
Public consumption	7.2	4.6	3.3	5.0
Private consumption	1.7	3.6	-1.3	3.0
Gross domestic investment	-3.1	5.2	-4.9	2.6
Average annual inflation	7.5	2.6	34.9	10.8
Growth in merchandise trade accounts				
Exports	0.1	6.0	-5.3	-2.6
Imports	-1.5	6.2	-4.5	0.0
	1972		1982	
Government budget (percentage of GDP)				
Expenditure	19.5	22.2	10.1	16.6
Current Revenue	15.1	17.0	8.9	10.0

n.a. = not available

Source: World Bank (1984a).

Inflation averaged 34.9 per cent per year from 1970-82 with a peak of 123 per cent per year in 1982, compared to 10.8 per cent in the rest of Sub-Saharan Africa. This was fuelled largely by the need to print money to finance growing government deficit which again led to the lowering of real interest rates and to a highly over-valued exchange rate which was held fixed for almost a decade. Government imposed a variety of price controls in an attempt to suppress inflation. This led to relative prices that did not reflect scarcity values of commodities. Rationing of many goods and foreign exchange caused black markets and smuggling to flourish.

In the years immediately after independence, Ghana's exports equalled 28 per cent of the GDP compared with 21 per cent in all of Sub-Saharan Africa. But the constant dollar value of exports remained stagnant in the 1960s and declined at a rate of 5.3 per cent per year in the 1970s to the point where in 1982, exports equalled only 3.3 per cent of GDP. Discouraged by the deterioration in the economy, political instability and poor policy performance, aid donors gradually reduced their support; access to official capital inflows proved difficult and private flows had been rare. Thus, foreign exchange for imports has been restricted to export earnings. As a result, imports have followed exports down and were also only 3 per cent of GDP by 1982. Further, petroleum accounted for 50 per cent of imports and only 30 per cent were for intermediate and capital goods (World Bank, 1983a). The lack of spare parts was such that in 1982 an estimated 70 per cent of the transport fleet in Ghana was out of commission. Exchange rate policy largely accounted for the collapse of foreign trade. Taking 1973 as a base year the cedi was over-valued by 250 per cent in 1978. Although the government devalued the nominal exchange rate by 58 per cent in that same year it did little to stem the appreciation of the real rate. The World Bank estimated that by 1982 the exchange rate was over-valued by 816 per cent. Such drastic over-valuation obviously offered no incentive to export anything that could be consumed locally. Exporters began to smuggle goods such as cocoa at the black market exchange rate which ranged from 250 to 350 per cent of the official exchange rate in the 1970s and soared to 4,000 per cent of the official rate in 1982 (Younger, 1989, op. cit.). This greatly reduced the flow of foreign exchange through official channels.

Imports, however, became extraordinarily cheap. Ghanaians found it cheaper to buy imported food than to grow it domestically. Demand for imports at the official exchange rate far outstripped available foreign exchange and the government was forced to control all imports strictly. Thus, in the 1970s the government put into place a system of import licensing, price controls and administrative allocation. As the exchange rate became increasingly over-valued only very small amounts of imports were possible and those imports that were allowed were usually not goods with high scarcity values such as spare parts. This contributed to the economy's poor performance overall.

Cocoa has always been Ghana's most important export accounting for 60 to 70 per cent of all export in the 1970s. The decline in cocoa production therefore explains much of the decline in export revenues. From a peak of 538,000 tons in 1965, production gradually declined to 394,000 metric tons in 1976, then dropped sharply to a mere 179,000 metric tons in 1983. The main reason for the drop in production was the steep drop in the real producer price paid to farmers. The over-valuation of the currency throughout the period made it difficult for the Ghana Cocoa Marketing Board which receives its revenues in foreign exchange, to pay high cedi price to farmers. Secondly, the marketing costs were high. The World Bank estimated that the Ghana Cocoa Marketing Board really needs only half of its staff of 100,000. Finally, the government had steadily increased the tax on cocoa exports by holding down the producer prices. Thus, in 1965, the producers received 68 per cent of the revenues from cocoa but received only 26 per cent in 1979. In addition, the government's financial difficulties and the general foreign exchange constraint meant that extension services were no longer provided. Thus, by 1982, Ghana's cocoa production had fallen to 70 kg/ha, compared with 111 kg/ha in all Sub-Saharan Africa (World Bank, 1983a, op. cit.). Agricultural production of non export food crops fared a little better, however the per capita food production fell at an average of 2.9 per cent per year from 1970-82.

In the early 1970s timber production was Ghana's second major export after cocoa contributing an average of 11 per cent of the country's export earnings (Ghana Commercial Bank *Quarterly Economic Review*, January-March 1985). However from a peak volume of 1.3 million m^3 earning $130 million in 1973 timber exports ebbed drastically to a minimum production of 100,303 m^3 earning $12 million in 1982. Part of the reason was a ban imposed on the exportation of 14 primary hardwood species in log form in 1979. These species were to be processed before export to yield value added revenue and to provide employment. Again, high inflationary trends, low exchange rates, the effects of the fuel crisis and low commodity prices gave no incentives to timber export. General deterioration of infrastructure, especially ports and railway also contributed to the decline in exports. Mining also suffered a decline and production in 1983 was at the lowest level, about 50 per cent, of early 1970s level.

The fiscal performance of Ghana's public sector has been poor and there was no access to private credit from either domestic or foreign sources. Government deficits were financed by borrowing from the banking system. Overall, the government's share of domestic credit rose from 49 per cent in 1970 to 86 per cent in 1982 crowding out private borrowers and causing severe inflation. Tax revenue from exports fell substantially during this period although government had maintained a high tax on cocoa. Reduction in imports also reduced the tax base for import tariffs leading to a decline in tariff revenues. Further, with the over-valuation of the cedi and since taxes are levied on the cedi value of imports and exports, the tax base is again reduced. Thus while the cedi prices of domestic goods and services purchased by the government were inflating rapidly the cedi prices of the import and export were not, causing lower tax revenues and leading to increased deficits.

In addition to losses in taxes on international transactions, revenues also declined as formal markets in the economy collapsed. Both smuggling and black market transactions are non-taxable and both increased significantly during the period. Finally significant delays in the actual collection of taxes, combined with rapid inflation also reduced the real values of revenues when they were finally collected. Faced with substantial decline in revenues, the government was forced to reduce expenditures. Thus, at the same time that government deficits were causing persistent inflation, the real value of government expenditure was actually falling due to even greater declines in revenues.

Development expenditures typically 4 to 6 per cent of GDP in the early 1970s fell to 1.5 per cent of the GDP in 1982. Two areas severely affected included education and health. Expenditure on education averaged 3.4 per cent of GDP during the 1970s (compared with 5.2 per cent in all Sub-Saharan Africa) and fell to only 1 per cent of GDP in 1983 (World Bank, 1985). Government expenditure on health declined from 1.4 per cent of GDP in 1975/76 to 0.78 per cent in 1979/80 and 0.32 per cent in 1983.

Civil service employment grew at 14 per cent per annum between 1975 and 1982 although the bureaucracy was already considered over-staffed and reduction in revenues forced down real wages. Thus, while the real minimum wage for unskilled civil servants fell to only 32 per cent of its 1977 value in 1983 for a senior civil servant 1983 wages were about 15 per cent of 1977 wages. Salary reductions caused a flight of skilled labour from the civil service. For example, the Ghana Water and Sewerage Corporation (GWSC) had 90 engineers in 1979 but only 20 remained in 1984. The education ministry lost 10,000 staff including 13 per cent of all teachers.

In conclusion, Ghana's economy declined in the 1970s due to large government deficits financed with rapid monetary growth, an over-valued exchange rate, widespread price controls with consequent rationing of many goods, low producer prices for agriculture and over-staffing of government and public agencies.

1.2.3 The Economic Recovery Programme

As the economy collapsed so did the government. Flight Lt. Jerry Rawlings took power in a military coup d'etat on the last day of 1981 and formed the government of the Provisional National Defence Council (PNDC). An attempt was made to stabilise the economy. The government increased tax collection efforts and established severe expenditure controls. However the rapid decline in output and general deterioration of the economy over 10-15 years meant that fiscal austerity was not enough. The government opened negotiations with the IMF and the World Bank and announced a stabilisation and structural adjustment programme as the Economic Recovery Programme Phase 1 1983-1986 (ERP 1).

The objectives of the ERP1 (Younger, 1989, op. cit.):

(a) to 'get the prices right' by devaluing the exchange rate, increasing interest rates and decontrolling internal prices.

(b) to reduce the fiscal deficit sufficiently to eliminate the need for printing money to cover it, thus reducing inflation; and

(c) to liberalize the economy, including the foreign sector by encouraging markets to function freely.

Ewusie (1987) grouped measures under ERP1 under price interventions, budgetary reforms and institutional restructuring:

(a) Policy Framework (Prices)
- (i) exchange rate adjustment with price and trade liberalization.
- (ii) increasing the role of market mechanisms with relaxations or elimination of price controls and output levies.
- (iii) reduction of subsidies (commonly on food, agricultural input, energy).
- (iv) upward adjustment of the cost of capital and maintenance of positive real interest rates to reflect the opportunity cost of capital.

(b) Public Expenditure Management
- (i) reduction of government deficits through
  - (a) increasing public revenues and improving the buoyancy of the tax system,
  - (b) improvement on the performance of public enterprises,
  - (c) rationalisation of staffing in the public sector.
- (ii) increased effectiveness of public investment and medium-term planning through:
  - (a) more support for recurrent expenditure, leading to better capacity utilization of existing industries,
  - (b) increased public allocations to agriculture with strict privatisation of investment projects,

(c) raising of public enterprise charges and reduction of subsidised services,
(d) improved management systems and controls,
(e) introduction of new charges e.g. user charges for water, veterinary services etc.

(c) Institutional Restructuring
(i) rationalization of parastatals, particularly Marketing Boards, involving manpower reduction and a reduced set of functions,
(ii) increased competition in the provision of services with privatisation of inputs supply,
(iii) reduction or elimination of Area Development Programmes and concentration on building-up the Ministry of Agriculture,
(iv) selective decentralisation of the operation of Government institutions,
(v) substantial technical assistance to Government institutions.

In the first year of the ERP1 most of the policies were directed towards macroeconomic stabilisation. This was partly because the government could not afford much investment expenditure. The most important price adjustment was in the exchange rate. By October 1983 the cedi had been devalued by more than 1,000 per cent. Government also raised charges for its services significantly; for example, urban water rates rose 150 per cent. Deposit interest rates were raised from 8 per cent to 11 per cent and loan rates from 14 per cent to 19 per cent, though both remained well below the rate of inflation. Prices for most commodities were decontrolled and government held fiscal deficit within the limits established by the IMF and the World Bank.

Recovery in the first year of the programme was much slower than expected if not disappointing. First, the impact of the drought was more severe than had originally been estimated. Its effects on agricultural production and exports were aggravated by the accompanying bush fires that destroyed food in the field as well as in storage. The ensuing food shortage was exacerbated by the return from Nigeria, in early 1983, of an estimated 660,000 to one million Ghanaian citizens. Second, the deterioration in both physical and human infrastructures was far more serious than had initially been realised. Also power cuts made necessary by the precariously low water level at the Hydroelectric Power Station at Akosombo, which resulted from three years of drought, implied that four out of six generators had to be shut down, necessitating the complete closure of the Valco Aluminium smelting works at Tema and resulting in substantial loss of foreign exchange to the country. Agricultural output, which accounts for roughly half of GDP fell by 7.2 per cent while overall GDP declined by 4.6 per cent. At the same time, due to the food shortages, the food component of the consumer price index rose 145 per cent in 1983 pulling the overall inflation up to 123 per cent. Cocoa production declined by 11.8 per cent in 1983 to a record low of 158 million tons.

Net capital inflows were one-third of the initial ERP projections. To some extent this reflected delays in disbursement of aid but large shortfalls in official oil credits and suppliers' credit to importers cut the available foreign exchange significantly. This forced a reduction in imports with significant adverse effects on the economy. Government revenues which depend heavily on import taxes declined slightly in real terms rather than increasing as the ERP had projected. This forced large expenditure cuts including 43 per cent reduction in badly needed capital expenditure. As a result, much of the ERPs rehabilitation work-maintenance expenditures on infrastructure such as roads, ports and railway was left unfunded. Many exporters who had had very favourable relative price changes in 1983, especially minerals and timber were hampered in responding to these price changes due to lack of spare parts and to poorly functioning railways and ports. As a result non-cocoa exports were $86 million below the ERP's expectations in 1983. At the November 1983 donor's conference emphasis was shifted to removing the bottlenecks in infrastructure and it was decided that two-thirds of government's foreign exchange expenditure over the next two years would be spent on ports, railways and roads (Ewusie, 1987, op. cit.).

Shortage of investment for rehabilitation affected both public and private sectors and generally depressed the level of economic activity. Capacity utilization rates in manufacturing were less than 20 per cent in 1980-84 due largely to lack of imported inputs and spare parts. Import of crude oil, an important energy source for transport and industry, declined by 62 per cent because of the decline in oil credits and an accident at Ghana's oil refinery; and electricity production from the Volta dam fell 48 per cent in 1983 because of the low water levels of the lake. By all accounts 1983 was a very difficult year but the government made the politically risky decision to stick with the ERP and held the budget deficit to 2.5 per cent of the GDP by making large cuts in expenditures. In short the government stuck to its guns in the face of extreme adversity. This determination and the return to normal rainfall in 1984 represent the turning point in the success of the ERP. By maintaining the programme under economically and politically difficult circumstances, the government gained credibility with the IMF, the World Bank and bilateral donors who had shunned Ghana throughout the 1970s. As a consequence gross official development assistance rose 78 per cent in 1984 (Republic of Ghana, 1985) as donors began to recognise that the ERP was a serious effort worth their support. As early as 1984, the World Bank had come to believe in the government's commitment and had recommended the ERP to other donors. For example, the introduction to a 1984 World Bank progress report on the ERP states:-

> In sum, in less than two years, the government has wrought a major transformation in the overall economic environment.... A severe drought, an unanticipated foreign exchange crisis, and the resultant high inflation have greatly complicated the management of this period of transition.... Taking account of all these difficulties, it is to say the least, highly praiseworthy, that so much has been achieved thus far.....it would indeed be tragic if this experiment were allowed to fail for lack of adequate external support and Ghana's economy were permitted to slip back down the dreary slope of decline. (World Bank 1984b)

Ghana's stabilisation policies continued along the same lines in 1984-86. Thus the cedi was devalued from 30 per dollar in October 1983 to 50 per dollar in October 1985, to 60 per dollar in October 1985 and to 90 per dollar in January 1986. Finally, in late 1986, the government adopted an auction system so that the exchange rate, which is determined on a weekly basis by market forces, is more or less at equilibrium level.

Fiscal policy remained tight with the deficit held to 2 per cent of the GDP in 1984 and 1985 and the government borrowing from the central bank held to 0.6 per cent of the GDP (World Bank 1986). By July

1985 only eight items were subject to statutory price controls and administered prices continued to be adjusted upwards in real terms, the most important being an 88 per cent increase in the producer price of cocoa in May 1985. With a return to normal rains spurring sharp agricultural growth, a fortunate increase in world prices and the increase in foreign aid commitments, import flows could increase and the government could begin its rehabilitation programs for several key sectors of the economy. Pay-offs were both immediate, since certain production bottlenecks were alleviated, and long-term, as the stage was set for structural adjustments whose benefits would come in the future. Real GDP growth was 8.6 per cent in 1984, 5.1 per cent in 1985 and growth for 1986 was estimated at 5.3 per cent.

The agricultural sector which grew by 9.3 per cent led the 1984 growth. Solid growth persisted in 1985 and was more diversified. In 1986 most indicators of production show a rise beyond their 1982 levels but not up to their 1981 levels. The performance of other macroeconomy indicators in 1984 and 1985 was encouraging. Inflation fell to 40 per cent in 1984 and 10 per cent in 1985 mainly due to falling food prices. However inflation increased in 1986 to 25 per cent mainly as a result of considerable depreciation of the cedi. The constant dollar value of merchandise export rose by 29 per cent in 1984, 12 per cent in 1985 and 26 per cent in 1986 allowing Ghana to fund a larger share of its increased imports from its own resources. Furthermore the export recovery had been broad based with every major export commodity showing increases in volume. Cocoa bean production which was 159,000 metric tons in 1983 rose to 219,100 metric tons in 1986. Diamond exports rose from 425,000 carats in 1983 to 556,000 in 1986. Timber exports more than tripled from 103,000 m^3 in 1983 to 329,000 m^3 in 1986 and manganese exports doubled in two years from 127,000 tons in 1983 to 263,441 in 1985.

Government expenditure grew steadily as a proportion of GDP. Overall expenditure grew from a low of 8.0 per cent of GDP in 1983 to 12.3 per cent in 1985 and development expenditure from 0.7 per cent of GDP in 1983 to 2.0 per cent in 1985. All this was accomplished without increasing the fiscal deficit. Tax revenues increased partly because of better enforcement of tax laws but largely because of the effect of successive devaluations on trade tax revenues. The devaluations increased the cedi value of exports and imports considerably, thereby increasing the tax base. The devaluations also allowed the government to increase the producer price of cocoa which encouraged more export. The cocoa export duty was also reinstated. Also, increased flow of exports and foreign loans allowed an increased flow of imports, again increasing the tax base for tariff duties. In 1986 the economy recorded its first budget surplus after 15 years of persistent deficits (Ewusie, op. cit.).

Based on wide macroeconomic measures, the ERP1 appeared to be succeeding. The economy had experienced three years of solid growth that had not been fuelled by a large fiscal expansion. In fact the government's fiscal and monetary policies have been tight, helping to reduce inflation and restore local and international confidence in the Ghanaian economy. Government workers are back in their offices and services such as telephones, water supply and roads are very much improved. However two major problems which deserve mention are liquidity and over-staffing.

With the dramatic change in the exchange rate in 1983, firms that imported inputs found that their costs had risen sharply. To continue operations, the firms had to borrow much more money (in cedis) to finance their imports. However in many cases banks doubted the firms' ability to repay loans and were reluctant to provide them. In more general terms, the great changes in relative prices meant that some firms that had been profitable under controlled prices might not be so in freer markets, while other firms would actually be more profitable. The banks needed to distinguish insolvent firms - those that would not make a profit even if they received a loan - from illiquid ones - those that would make a profit if they could get the necessary letters of credit. Making these assessments reliably is difficult in a rapidly changing economic environment. The result was that many firms did not get loans which reduced the flow of imports and constrained the pace of the recovery. Further, lack of confidence in the banks has been demonstrated by the high proportion of monetary assets people are prepared to hold as cash outside the banks despite substantial increases in real interest rates on bank deposits. To some extent, the reluctance of depositors to shift out of currency into deposits reflects the continued uncertainty surrounding the government's financial policy, however, the government has also used records of banks deposits as a means of checking income for tax purposes thus people with income to hide tend not to deposit it in a bank. Thus far, the large inflow of foreign capital to Ghana has been sufficient to compensate for the banking system's inability to generate significant domestic finance. Ghana's financial system remains very under-developed, a problem that needs attention to avoid serious credit constraints that could hinder the country's long-term development prospects.

The problem of over-staffing presents the government with an important policy dilemma: on one hand the stabilization requires tight control of government expenditures; on the other hand, restoration of the efficiency of the civil service requires higher real wages to retain relatively skilled civil servants. Laying-off workers in the civil service and the parastatal sector has been a very difficult option to pursue politically. Until the civil service employment has been reduced to a reasonable level salaries will remain low. The government must continue to balance employment, salaries and the fiscal deficit. After 1986 the stage was set for the formulation of a Structural Adjustment Programme for 1987-89. This is a medium-term Economic Recovery Programme (ERP2).

The major macroeconomic objectives of ERP2 are as follows (Ghana Commercial Bank, *Quarterly Economic Review*, Jan-March, 1986):

(i) GDP growth of about 5 per cent per annum implying an increase of at least 1.5 per cent per annum in per capita income.

(ii) the inflation rate declining from about 20 per cent to below 15 per cent by 1989.

(iii) a revenue growth based upon a reformed tax structure and significant administrative changes that will increase the revenue to GDP ratio from 10 per cent in 1985 to about 14 per cent in 1989.

(iv) total expenditure increasing from 15 to about 22 per cent of GDP by 1989 entailing a recurrent expenditure share of about 11 per cent throughout and an increase in the share of development expenditure from about 5 per cent to about 11 per cent by 1989 with the distribution of these expenditures being based on a recently completed assessment of public expenditure priorities in the recurrent areas and of a 'core' three-year public investment programme.

(v) the investment ratio increases from 10 to about 17 per cent of GDP with the share of domestic savings rising from about 5 to about 10 per cent of GDP by 1989 and foreign saving averaging about 7 per cent over the period.

(vi) significant export growth aimed at increasing the export/GDP ratio from about 10 to about 19 per cent of GDP, while the import/GDP ratio increases from about 15 to about 25 per cent of GDP.

(vii) the overall deficit/GDP ratio (including projects financed by external aid) rises from 5 per cent to about 8 per cent in 1987 and through the period with foreign financing rising from 4 to about 7 per cent while the domestic financing remains at 1 per cent throughout the period.

(viii)an increase in the M2/GDP ratio through deepening of the financial sector from about 12 per cent to about 20 per cent in 1989.

With these objectives, the government hopes to increase living standards by about 2.0 per cent per annum. This would involve a complete restructuring of many sectors of the economy. The state enterprises sector in particular would need to be restructured during the planning period. The health and education sectors would need massive rehabilitation to support the growth in living standards.

The 1987 Budget Statement embodied the main elements of the Structural Adjustment Programme (SAP) which relate to:

(a) Trade and payment reforms - these encompass an expanded role for market determined exchange rate; further strengthening of export incentives through specification of export documentation, removal of tax elements from exporter's costs and increased retentions for non-traditional exports; and simplifications of taxation and protection structure.

(b) Cocoa sector policies - these aim at further real increase in returns to farmers; reduction in procurement and marketing costs; and streamlining of extension services, adaptive research, disease control, farm inputs and farm credit.

(c) Public expenditure policies - these will focus on increased provisions for operation and maintenance of existing investment; implementation of Public Investment Programme; resource mobilisation; and cost recovery for public services.

(d) State Enterprises reform - these are aimed at giving commercial orientation to these enterprises so that they operate without subsidies, and contribute to government revenue and development, strengthening their management through retraining, remunerative salaries, security of tenure and autonomy of managers; rationalising their structure through mergers, divestiture and liquidations; and ensuring their long-term economic and financial viability through expansion of their capital base.

(e) Public sector management - institutional and administrative capabilities will be strengthened through maintaining at least real remuneration in the public service, mobilisation of skills, retraining programmes and policy co-ordination.

(f) Social policies - realising that the prolonged economic decline had hit hardest the small-scale farming households in the drought-prone northern areas, the urban informal sector, children under five and pregnant and lactating women, policies and programmes will be instituted to provide more adequate public services, nutritional support for target groups, expanded resource flows into primary health care, education, rural water supply and literacy programmes.

A three year rolling Public Investment Programme (PIP) as an integral part of SAP, has been designed to improve planning and control in order to ensure efficient allocation of scarce resources and expeditious implementation of investment projects.

Review of economic performance in 1987 (PNDC Budget Statement and Economic Policy, 1988) indicated that GNP grew at 4.5 per cent instead of targeted 5 per cent. This implies a per capita growth rate of 1.9 per cent. Inflation was expected to decline from 25 per cent in 1986 to 15 per cent in 1987. Partly as a result of rising food prices following shortfalls in food production and partly due to rising import prices the rate of inflation in 1987 was nearly 40 per cent. Gross domestic investment rose from 9.6 per cent of GDP in 1986 to 13.1 per cent in 1987. The foreign exchange auction market operated throughout 1987 causing further devaluation of the cedi. A further step in the direction of liberalising the determination of the discount rate on Treasury Bills was the introduction of the Treasury Bill tender system in October 1987. In November 1987 the first Discount House in the country was established to broaden the base of the money market. Several rehabilitation projects were initiated or continued, including roads, ports, telecommunications and water supply projects, within the context of the Public Investment Programme.

Review of economic performance in 1988 (PNDC Budget Statement 1989) indicates that the GDP grew by a little over 6 per cent. This means over the year per capita income grew by about 3.3 per cent. The 1988 budget recorded a surplus which meant that for the third consecutive year Government has refrained from using the banking system to finance its expenditures and by reducing its indebtedness to the banking system the Government has been able to channel more resources to the banks to lend for productive uses. Poor harvests experienced in 1987 led to sharp increases in food prices which persisted into the first half of 1988. Thus, in spite of the more favourable weather conditions in 1988, when the year is taken as a whole, price increases were higher than originally projected. Inflation however dropped from 40 per cent in 1987 to 25 per cent in 1988.

The drop in cocoa prices has been particularly disturbing. The world price dropped from $2300 per tonne in July 1987 to $1,800 in July 1988. The price collapse meant a loss in cocoa export earning of about $100 million in 1988 alone. By March 1989 the world price of cocoa had fallen to $850 per tonne.

The 1989 Budget statement projected GDP growth rate of 5.5 per cent and established an economic policy framework in support of the continuing Structural Adjustment Programme (SAP) with two main objectives.

(i) to continue to make major advances in production through the growth and improved use of domestic resources while upgrading the technological base, particularly of the small scale enterprise sector; and

(ii) to distribute the gains in production through improved employment opportunities and higher remuneration for most productive members of the Ghanaian society, while improving the access of all Ghanaians to key social services in health education and housing.

In this context, the thrust of the 1989 Budget is to:

(a) Continue the prudent fiscal management of the economy.

(b) Improve the efficiency and equity of the tax system by widening the tax net and reducing direct tax rates, while increasing overall revenues through improved tax collections and selected increase in excises.

(c) Improve the effectiveness of the public expenditure policy programme through continuing policy reforms in the areas of the structure and level of the development budget, employment growth in the private sector, including small scale enterprises, wages policy, divestiture policy and policies in the key sectors of health, education and housing and activities under the Programme of Actions to Mitigate the Social Cost of Adjustment (PAMSCAD).

PAMSCAD is a government effort to mitigate some of the inevitable social costs associated with Structural Adjustment Programmes. The 1987 Budget Statement identified these vulnerable groups within the society whose already dismal living conditions were likely to worsen and made provision for expanded resource flows to support such groups as small scale farming households, people operating in the urban informal sector, rural and urban poor, children under the age of five and pregnant and lactating women. In addition programmes to redeploy excess labour within the civil service and state enterprises have been started.

The 1988 Budget Statement formally set up the PAMSCAD Secretariat to co-ordinate actions by government and foreign donors to assist any identifiable vulnerable group. Three programmes have been initiated to create 40,000 new jobs since the labour redeployment exercise is expected to worsen the unemployment situation, at least, in the short-run.

(i) Programme of Public Works consisting of:
   (a) Food for work in the Northern Region.
   (b) Priority Public Works Project.
   (c) Labour intensive feeder roads project.

   These projects were expected to create 15,000 additional jobs.

(ii) A Credit Scheme for small scale farmers, small scale enterprises and rural poor. It is expected to generate 10,000 jobs each year.

(iii) A Programme for Rehabilitation, Improvement and Repairs of Secondary Schools which is expected to create 4,000 jobs for skilled and unskilled workers.

Other actions taken in 1988 include work on the National Hand Dug Well programme, the Decentralised Community Initiative Project and the Non-formal Education Programme. Criteria have been established for communities to benefit from grants under the above programmes.

The 1989 Budget Statement includes further action on Decentralised Community Initiative Projects; specifically, funds were provided for Community junior secondary school workshops, ventilated improved pit latrines, health centres and hand dug wells. Further a revolving credit scheme was established for redeployed workers in agriculture. Other activities benefiting from increased allocation of funds include organised income-generating womens' groups, the supply of essential drugs in support of primary health care, the programme for nutrition rehabilitation for 15,000 malnourished children and the mass non-formal education programme.

An agreement has been signed between the World Food Programme and the government of Ghana to provide grant for bulk purchase of food for schools and to provide food rations for workers on Priority Public Works Programmes (West Africa, 24-30 July 1989).

1.2.4 <u>Concessionary Loans and Future Prospects</u>

In 1983 the Donor's Consultative Group on Ghana which meets in Paris (Paris Club) was reconstituted after a decade of inactivity. With the implementation of the Economic Recovery Programme and the determination shown by the government of Ghana to stick to the programme under very difficult economic and political conditions, the World Bank urged members and observers of the group to provide external support for Ghana's economy. Official aid commitments rose from $190 million in 1983 to $477 million in 1985 (Ewusie, 1987, op. cit.). In fact annual commitments in 1984-86 averaged $434 million as compared to $198 million during 1980-83. As the economy responded favourably to the injection of new aid the Paris Group were encouraged to make further commitments to the Economic Recovery Programme. In 1987 the government of Ghana made a request of $575 million at the meeting but received aid commitment pledges amounting to $818.6 million (Ewusie, 1987, op. cit.). Aid commitments at the meeting in March 1989 are believed to have topped $900 million, in addition, Ghana's IMF drawings have now been placed on the Enhanced Structural Adjustment Facility (ESAF) category making it possible to spread repayments over 10 years with a 5-year grace period and an interest rate of 0.5 per cent per annum as opposed to the Structural Adjustment Facility (SAF) term which call for repayment over

5 years with a two-year grace period and an interest rate of 7.4 per cent per annum.

Ghana's total debt which in January 1989 stood at $2.4 billion showed a 83.6 per cent of concessional loans. Indeed about 87 per cent are owed to official foreign national institutions, the World Bank, African Development Bank and the International Monetary Fund and only 9 per cent represent short-term commercial bank loans. Ghana's credit rating in the donor community has improved appreciably and is expected to attract further concessionary loans in the future.

1.3 STATUS OF WATER SUPPLY AND SANITATION SECTOR

1.3.1 Water Supply

Smith (1969) provided a historical sketch on water supply development in Ghana. Before 1844 individual trading and mining companies, missionaries and small communities depended on wells, streams, ponds, dug-outs constructed in beds of streams and tanks which collected rain water from roofs of individual houses and public buildings. As population concentrations developed due to trade and employment dry season supplies no longer met the increased demand. After severe droughts in 1894/95 and 1903/04 the Public Works Department assumed responsibility for the provision of permanent water supplies for major towns. Piped water schemes were completed for Accra in 1914 and for Sekondi in 1917. The Guggisberg Plan 1920-29 spent £630,000 during the period on water supply development. Permanent works for Winneba and Cape Coast were completed in 1923 and 1928 respectively. Further the Geological Survey Department initiated investigation for new sources in the northern regions in 1920 which resulted in the establishment of a water supply division within the Department to provide small local supplies. By 1942 it had completed 252 dams, ponds and wells.

In 1944 a Department of Rural Water Development was established to provide water supplies to populations up to 10,000 persons with hydrological and hydro-geological support from the Geological Survey Department. The Public Works Department concentrated on urban supplies. Drilling operations by the Department of Rural Water Department was later supplemented by contract drilling placed with private drilling companies while the Public Work Department also started making use of consultants in investigations and design of new schemes and extensions to existing ones in an attempt to contain the flood of requests due to the changing political scene in the early 1950s. The 1951-1960 Development Plan spent an amount of £6.4 million on water supply development. Further the Urban Water Supplies Unit of the Public Works Department and the Department of Rural Water Development were merged into a new organisation, the Water Supply Division under the Ministry of Works and Housing in 1958.

Annan (1969) stated that the government of Ghana, confronted with the problem of providing good drinking water for economic and social advancement of Ghana signed an agreement in 1959 with the World Health Organisation (WHO) to send a team of experts to appraise water supply and sewerage development taking into consideration the following factors:

(i) technical aspects of long-range planning.

(ii) possibility of constituting either a national or local institution charged with full authority for providing water and sewerage services to all communities.

(iii) the methods of financing the services.

In their report the WHO team mentioned that on the grounds of health, industrial requirements and normal growth of population, the existing facilities for water supply and sewerage were grossly inadequate and that a rapid expansion of these services was urgently needed in the interest of economic and social progress. It also advised that an autonomous authority would be more efficient in providing these services than the Water Supplies Division under the Central Government. The government of Ghana, acting on the advice of the WHO created the Ghana Water and Sewerage Corporation by an Act of Parliament, Act 310, effective from September 1966. Under the Act of Incorporation the Ghana Water and Sewerage Corporation was charged with:

(a) The provision, distribution and conservation of the supply of water in Ghana for public, domestic and industrial purposes; and

(b) The establishment, operation and control of sewerage systems of such purposes.

It was also expressly stated that the Corporation shall cause its affairs to be managed in accordance with the practices observed in public utility enterprises and in particular shall cause its functions under the Act to be carried out so as to ensure that taking one year with another, its revenues are equal to or greater than its outgoings. This implied that water supply and sewerage services must be provided as a viable self-supporting enterprise.

The water resources of Ghana provide the raw material for the operation of the water supply enterprise. The assessment of the water resources potential in Ghana is based on hydrological and meteorological information collected over the years. The responsibility for measurement, collection, storage and dissemination of hydrological data devolves on the Hydrological Division of the state-owned Architectural and Engineering Services Corporation (AESC). Research and special studies are carried out by the Water Resources Research Institute operating under the Council for Industrial and Scientific Research. The collection and dissemination of meteorological data is the responsibility of the Meteorological Department. Rain gauge stations have been monitored since the 1930s, however, monitoring of hydrological stations only started in the 1950s. Hydrological and meteorological data up to 1967/68 were published in a series of Hydrological Year Books. Records after 1967/68 are available in the files of the AESC. The effects of the economic decline in the 1970s caused a deterioration in hydrometric activities due to difficulties in obtaining finance, equipment and spare parts to keep flow meters and recorders operating. Groundwater monitoring is not well developed; basic level observation facilities are lacking. However, information on some 1,500 boreholes drilled in the 1950s and early 1960s is available in the Drilling Section of the Ghana Water and Sewerage Corporation. Further, data obtained from the 3,000 wells drilled in southern Ghana and 2,500 wells drilled in the Upper Regions are also available.

In general, water supply development in Ghana is influenced by an abundance of surface water and low occurrence of ground water. Water supply to main population centres is based on surface water sources while the large number of scattered rural population benefit from groundwater sources.

Ghana is divided into ten drainage basins as shown in Figure 1.2. River flows are highly seasonal and vary widely from year to year. Flow regulation and water conservation facilities are necessary to guarantee the availability of water during periods of drought. The Volta River with its tributaries the Black and White Volta form the largest drainage complex equivalent to two-thirds the surface area of Ghana. The Volta Lake formed as a result of a dam on the Lower Volta River at Akosombo is an important resource for transportation, electricity generation, fishing and for water supply to various communities along its 650 km length. Table 1.2 presents the catchment areas and estimated yields of each drainage basin. Total annual run-off from all rivers is 2657 m^3/s. The Water Resources Sector Studies carried out in the 1970s showed that the potentially available surface water resources exceed the identifiable needs of the country (Nathan Consortium, 1970b). All major population centres are within 40 km of a major river which, therefore, serves as its source of water supply.

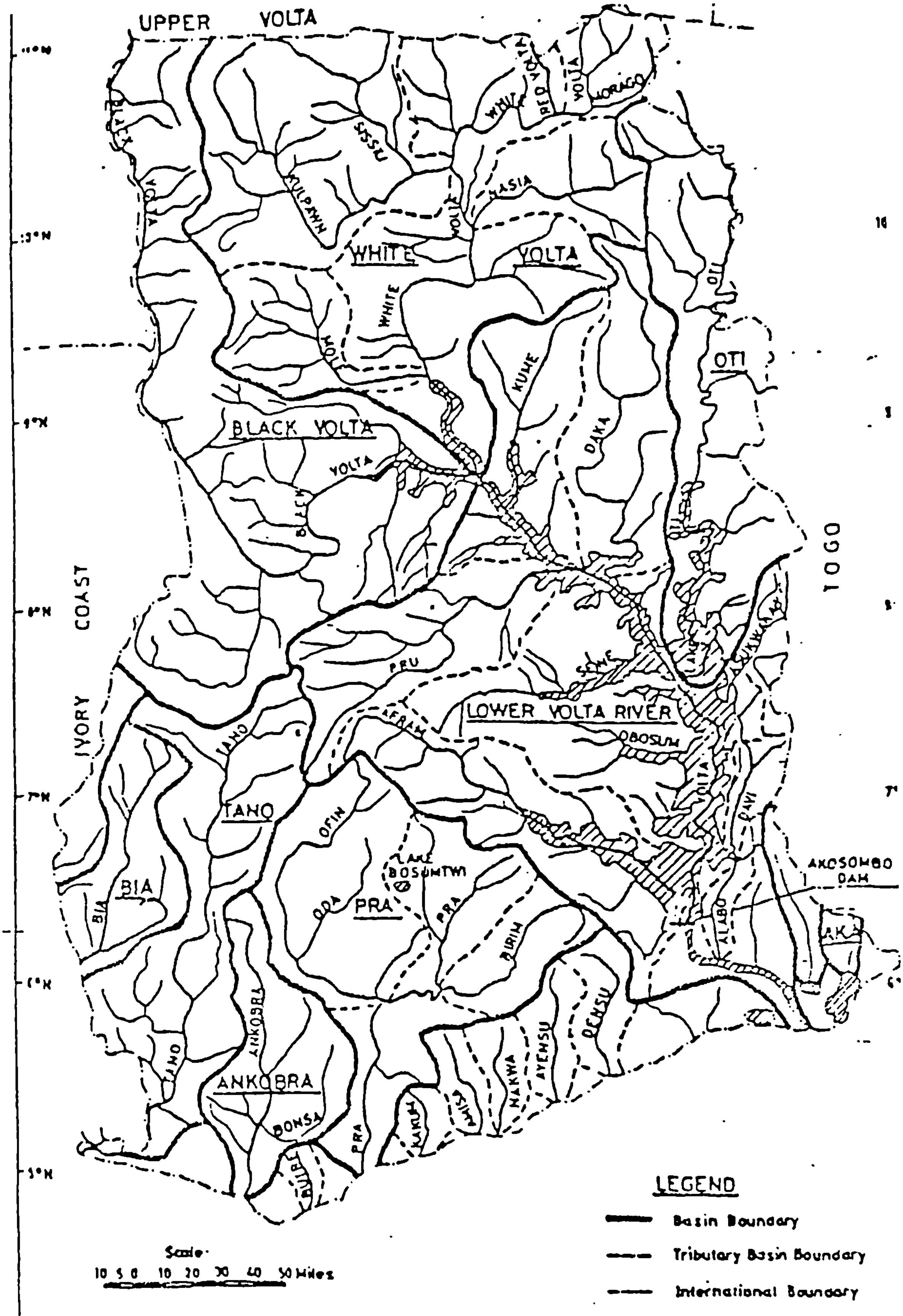


FIGURE 1.2: RIVER BASINS OF GHANA

Table 1.2 Summary of River Basin Surface Water Resources

Basin	Drainage Area in Ghana	Run-off (in cu.m/sec) Mean Annual[1]	Maximum Month[1]	Minimum Month[1]	Total Mean Annual[2]
White Volta	45,800	119	1,215	1	270
Black Volta	35,100	57	623	2	243
Oti	16,200	111	850	2	501
Lower Volta	68,600	140	2,890	2	1,088
Pra	23,200	240	1,090	16	240
Ankobra	8,500	121	470	15	121
Tano	14,900	74	524	2	74
Bia	6,500	42	474	2	42
Coastal Drainage	15,600	62	708	5	62
Tozia/Aka	3,600	16	1,800	1	16
TOTAL	**238,000**	**982**			**2,657**

1 Run-off values are for flows from within basins in Ghana and exclude flows entering from upstream.

2 Includes flows to basins from outside Ghana and upstream drainage areas.

(Source: GWSC, 1985.)

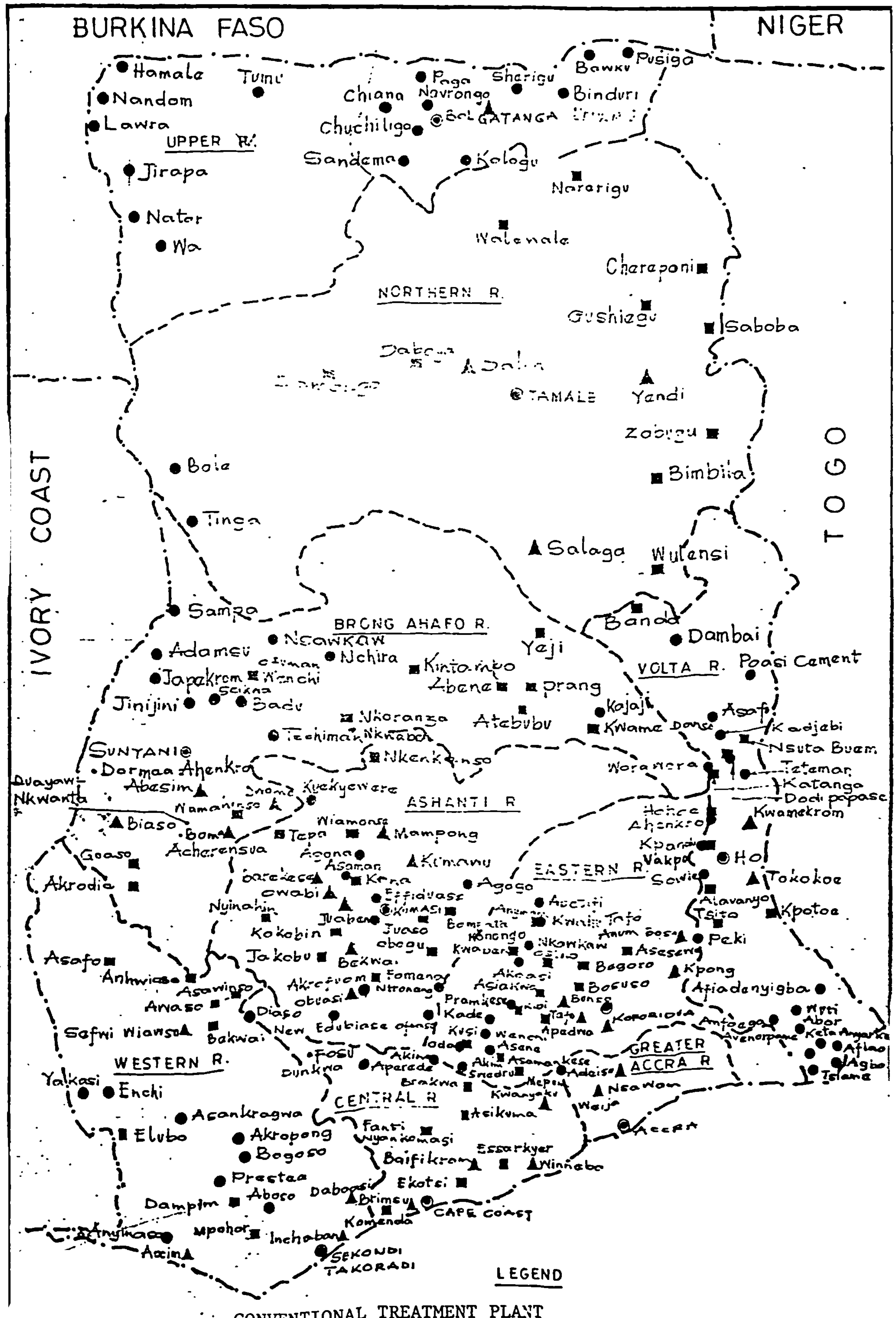
In general, Ghana is underlain by rocks with a low groundwater yield. This is due to the absence of primary permeability in the crystalline rocks of igneous and metamorphic origin of the Precambrian age. These rocks have, however, acquired secondary permeability by weathering, jointing and faulting processes. Central and Northern Ghana represent a very deep bowl shaped sedimentary basin filled with sandstones, mudstones and shales several thousands of metres thick. This basin has the poorest groundwater yield.

Groundwater quality as indicated by chemical and bacteriological constituents, is generally within acceptable limits except for certain areas in southern Ghana where the pH is low and the water tends to be aggressive. Iron and manganese in rock formations and pump parts do get dissolved leaving high residual iron and manganese concentrations in solution. High iron and manganese levels turn groundwater brownish on exposure to the atmosphere, stains laundry, discolours certain foodstuff during cooking e.g. Cassava and plantain and also imparts a bitter taste to the water. Aggressive ground waters may be responsible for up to two-thirds of hand pump breakdowns. For surface water, natural river pollution result mainly from erosion due to high intensity rainfall. Large volumes of suspended matter cause high turbidity levels in surface water. Further, with large forest cover, the decomposing vegetation in the undergrowth impart colour to surface water. Most catchment areas have large settlements and are extensively farmed. Disposal of human and animal waste in a haphazard manner impairs surface water quality. The main source of industrial pollution is from various mining operations (gold, diamonds, manganese, bauxite); manufacturing industries contribute only minimal amounts of pollutants. Currently industrial pollution is not a major problem in Ghana but the situation is being monitored by the Environmental Protection Council. The government announced in the 1989 Budget Statement a mandatory requirement of Environmental Impact Assessment of all major projects before being allowed to proceed. The statement specifically mentioned mining, metal processing and textile industries as likely to create water pollution problems.

Water related diseases are of a major concern in Ghana, particularly the high incidence of dysentery, diarrhoeas, typhoid, guinea-worm and bilharziasis. The Ministry of Health (1970) observed that wherever treated pipe-borne water is provided there is a virtual elimination of guinea-worm infection and bilharziasis. However dysentery, diarrhoeas and typhoid are prevalent in all towns and villages irrespective of existence of treated pipe-borne water supply. That the provision of good drinking water made comparatively less impact on dysentery, diarrhoea and typhoid only confirmed transmission by other feacal-oral routes such as ingestion of food contaminated with faecal matter containing pathogenic organisms. Ghana is currently cooperating with the WHO and Global-2000, a non-governmental organisation to eradicate guinea-worm infection.

Water supply coverage in Ghana is estimated at 60 per cent of the total population. This is made up of 93 per cent coverage or the urban population and 43 per cent coverage of the rural population. The policy of the GWSC is to provide all communities of population exceeding 2000 with piped-systems based on either groundwater or surface water. At

FIGURE 1.3: G.W.S.C. EXISTING (1989) WATER SUPPLY SYSTEMS



▲ CONVENTIONAL TREATMENT PLANT

■ PACKAGE TREATMENT PLANT

● BOREHOLE SCHEME

present there are 194 pipe-borne water supply systems (Figure 1.3), of which 103, including all the larger urban systems, are based on surface water and 91 supplies based on groundwater. Of the surface water systems 69 systems use package treatment plants, 25 systems are of medium capacity conventional treatment plants (that is, they consist of pumping units up to 150HP) and 9 systems are of high capacity conventional treatment plants (pumping units exceeding 150HP). The total capacity of all piped systems is about 523,000 m^3/d. 71 per cent of this total is in the three largest city systems, Accra-Tema, Kumasi and Sekondi-Takoradi, which together serve some 14 per cent of Ghana's population.

For populations less than 2000 GWSC policy is determined by the population size. Table 1.3 summarises the approach to water supply improvement to this population category.

Table 1.3 Water Supply Improvement to Population Category

Population	No. of Communities	Method of Improvement
<100	36,000	Small improvements to local sources, rainwater harvesting, spring protection
100-500	9,400	Hand dug wells with handpumps
500-2000	2,600	Drilled wells with handpumps

(Source: GWSC (1985).)

Water supply to populations under 100 has not been tackled by GWSC. Any improvements have been by the communities themselves. For populations between 100-500 GWSC has launched a programme to provide 10,000 wells within 1986-1990 with support from multilateral, bilateral and non-governmental organisations. For population between 500-2000 two large drilling programmes have been completed. The Canadian International Development Agency (CIDA) in co-operation with GWSC drilled 2500 wells fitted with handpumps in the Upper Regions and the government of the Federal Republic of Germany financed the drilling of 3000 wells fitted with handpumps by contract in southern Ghana. Other drilling programmes are being undertaken by the government of Japan, UNICEF and World Vision International (a non-governmental organisation) and the Catholic Church.

Water supply development in Ghana has been financed by:

(a) Government budgetary allocation which provides local and foreign components of project costs that are completely locally funded. GWSC's share of total government development budget has averaged 5.6 per cent, with a high of 8.9 per cent in 1979/80 and a low of 3.7 per cent in 1980/81 (CIDA, Report 2, 1985).

(b) Counterpart funds: these are the local currency contributions of government of Ghana for foreign-funded projects. It is government policy to give priority to foreign-assisted projects in the allocation of development funds.

(c) Loans and grants from various donors principal among these are the World Bank, African Development Bank, UNDP, governments of Canada, France, United Kingdom, West Germany, Italy, Denmark and India.

(d) Contributions from various foreign non-governmental organisations including the Catholic Church, World Vision International, and Water Aid.

GWSC by its Act of Incorporation is authorised to establish tariffs with the approval of government. Revenue collected from tariffs has always fallen short of expenditures for operations and maintenance. Therefore GWSC has not been able to achieve financial self-sufficiency and must go to the government each year for operating subsidies to cover operating deficit. Between 1975 and 1983 recurrent expenditure increased eleven times while revenue increased by five times. The proportion of expenditure financed from revenues declined from a high of 90 per cent in 1975/76 to a low of 34 per cent in 1980/81. Recent government actions under the Economic Recovery Programme have allowed GWSC to increase its tariffs progressively over a period to achieve recovery of operations and maintenance cost. In March 1986 the government approved a 300 per cent tariff increase and, further, allowed

25 per cent upward tariff revision each year from January 1987. It is expected that GWSC financial position will improve markedly.

1.3.2 Sanitation

As an organised service, sanitation may have been introduced into Ghana during the latter part of the colonial era, possibly in the 1930s with the establishment of the health services. The Health Department was responsible for the development of sanitation services. Public Health Boards were established in main urban centres while institutions of local government were responsible for sanitation services in small towns and villages. Sanitation as a sub-sector of health was always starved of resources because the priorities of the sector were in the provision of hospitals and drugs.

Presently responsibility for the sanitation sub-sector is fragmented. Sanitation systems, other than sewerage, are the responsibility of institutions of local government, the latest is the District Assemblies established in 1988. Responsibility for the provision of technical staff for the District Assemblies lies with the Ministry of Health. Ministry of Local Government being the supervisory ministry for District Assemblies periodically seeks assistance from central government for equipment and special projects (e.g. the rural ventilated improved pit latrine project). Responsibility for sewerage was vested in the GWSC but to date it operates only the Central Accra Sewerage System. Several small sewage plants dotted around Ghana are operated by the institutions that installed them. There is no national or central co-ordinating and policy formulating body in the sub-sector for the role GWSC plays in the water sub-sector. The result is that provision of sanitation services lags behind water services.

It is estimated that 27 per cent of the population of Ghana is served by one type of sanitation or another. This is made up of 58 per cent coverage of the urban population and 15 per cent coverage of the rural population. Urban sanitation systems include:

(a) *Sewerage*: There are only two urban areas with fully developed sewerage systems constructed as part of the infrastructure of purpose-built townships of Tema and Akosombo. In the Accra-Tema

Water Supply area there are 18 local sewerage systems serving various institutions and housing estates. In other urban areas with piped water supply similar schemes serve isolated high class developments. Central Accra Sewerage System, operated by GWSC, is meant to be the first phase of a Master Plan to sewer the entire city of Accra.

(b) *Other Sanitation Systems*: High-income housing would be served by water closet and septic tanks. Middle income housing have bucket latrines. Low income housing have, to a very limited extent, bucket latrine but most of the population use public latrines or practise open defecation in drains, in the bush and on the beaches. Public latrines are based on the bucket latrine and the aqua privy. Recently the ventilated improved pit (VIP) latrine has been introduced both as a public and a private latrine.

In rural Ghana the traditional pit latrine is the most widely used public latrine system but most of the population practise open defecation. The bucket latrine system serving some households has failed for lack of sanitary labourers. Some middle and high income housing use the water closet and septic tank with water carried into the privy room. Recently the VIP latrine has been introduced. The UNDP and the District Assemblies are promoting public VIP latrine through community self-help.

1.3.3 Strategy for Development

The GWSC has prepared a Five Year Rehabilitation and Development Plan for the water sub-sector. This is expected to cost $300 million (1985). The programme includes rehabilitation and capacity expansion of existing work together with completion of on-going projects. The UNDP commissioned a study on Rural Water Supply and Sanitation Strategy and another on Rural Water and Sanitation Programme based on appropriate technology. Cost of total coverage of the rural population was estimated at $500 million (UNDP, 1987). The Public Investment Programme prepared for Economic Recovery Programme includes selected projects from the Five Year Plan and an Accelerated Latrine Construction Project. These documents were made available to the Water and Sanitation Donor Conference in September 1987. Various donor commitments were announced.

However, the main indication of the level of assistance to be expected from donors was the announcement by the World Bank and five bilateral donors to provide $125 million over the next seven years (West Africa, 23-29 January, 1989) which is woefully inadequate.

In general, the expected impact of the Economic Recovery Programme on the Water Supply and Sanitation Sector has been summarised in Table 1.4.

Table 1.4 Expected Impact of the ERP on the Water Supply and Sanitation Sector

Structural Component	Desired Result	Consequence for the Water and Sanitation Sector
Removal of controls on agricultural prices.	Production incentive. Bigger outputs and sales.	Higher incomes in rural areas. Higher consumer aspirations for water and sanitation. Better cost recovery. Higher potential to operate and maintain locally.
Exchange rate reform.	Fostering of import substitution. Potential export increase.	Possible local manufacture of some components. Incentive to use local technology and inputs. Increase in costs of essential imports e.g. chemicals, spares etc.
Freeing interest rates.	Saving incentive. Increases the opportunity cost of capital and thereby the discount rate.	Accumulation and possible mobilization of savings as source of investment. Increases the annualised cost of projects. Applies stricter economic test.
Relaxation of utility price controls.	Financial viability and stimulus to self-financing.	User charges to reflect cost of provision. More cost recovery. Greater use of water meters, leakage detection and efficient revenue collection.
Restrictions on government expenditure.	Control of inflation.	Greater requirement for self-help in construction, operation and maintenance. Government role as facilitator rather than operator in small schemes.
Institutional reform.	Improvement of productive performance.	Increased productivity. Demanning of public corporation (GWSC). Some privatisation of functions. Decentralisation of some functions e.g. maintenance.

Source: Akosa and Barker, 1989.

CHAPTER TWO

STATEMENT OF THE PROBLEM

In 1985 WHO *Review of Mid-Decade Progress* cited various constraints in their order of seriousness as reported globally as follows:

1. Funding limitations.
2. Inadequate cost recovery.
3. Lack of trained professional personnel.
4. Inadequate operation and maintenance.
5. Lack of trained sub-professional personnel.

13. Import restrictions.
14. Non-involvement of community.
15. Lack of government policy.
16. Inappropriate technology.
17. Lack of planning and design criteria.

These constraints characterise the unimpressive performance of the Water Supply and Sanitation Sector in developing countries including Ghana.

The Water Supply and Sanitation Sector in Ghana was considered as part of the Social Sector. This meant that development funds flowed from government sources. Recurrent expenditures are partly covered by unrealistically low tariffs approved by government and partly from subsidies provided by the annual government Recurrent Budget. Indeed Annan (1969, op. cit.) stated that the Water Supplies Division was not committed to the realisation of budgeted income as its expenditures were in no way connected with the revenue it was able to make. By the formation of the GWSC in 1966 an attempt was made in the water supply sub-sector to change the situation by charging the new organisation with the responsibility of ensuring that it does not run into deficit on its operations from year to year. The sanitation sub-sector however has remained firmly in the Social Sector probably as the activity with the lowest priority ranking.

2.1 WATER SUPPLY SUB-SECTOR

The GWSC inherited the assets and liabilities of a civil service organisation whose procedures were unsuitable for a commercial undertaking. The staff had little or no commercial training. Management consultants, Public Administration Service of Chicago, were hired to transform GWSC into a commercially-oriented organisation. Meanwhile the bulk of the population in the service area were supplied through stand-pipes. Rate collection from stand-pipes could not be conveniently enforced with disconnection of supply. Indeed problems of revenue collection included:

(i) Large numbers of customers on flat rate which encouraged wastage of water and therefore loss of revenue.

(ii) Disconnected customers had access to public stand-pipes and other private supplies.

(iii) Political pressure brought to bear on the GWSC in cases of disconnection of bulk supplies to local council areas and to government institutions.

GWSC, although charged with breaking even on operations, has experienced a serious lack of political will on the part of various governments to approve adequate tariffs. Water rates instituted in 1959 when revenue collection was not a serious aim of government, went through 45 per cent currency devaluation in 1967 with its attendant increase in general price levels until a revision was granted in 1969. The new government that took office in 1971 reviewed the 1969 water rates and reduced the tariff for certain categories of consumers. In 1974 the World Bank made tariff increase a condition for granting of its credit for the Accra-Tema Water Supply Second Stage (World Bank, 1974). As a result 50 per cent increase in tariff was approved in August 1974. The next increase of 100 per cent in tariff was in 1977. However the increases in 1974 and 1977 only kept the tariff abreast with inflation (World Bank, 1983b). GWSC delayed submission of tariff proposals to government until May 1979 and the government deferred approval until February 1981. This delay devastated GWSC internal cash generation.

The increases had already become totally inadequate at the time of approval. The next request for tariff increase was submitted in 1982 and was finally approved in February 1984 by which time GWSC was already heavily in debt. Government subsidies failed to keep pace with rising costs. The government itself was in arrears on payment of water bills for various government institutions around the country. Clearly, the government support that GWSC badly needs to carry on with its assignment has been absent.

It is estimated that when GWSC was created, September 1966, 28 per cent of the total population benefited from pipe-borne water supplies. By September 1969 the percentage was 30 per cent and by the end of 1970 coverage was approximately 35 per cent. The increase in coverage over the period was politically motivated. The government of the National Liberation Council had selected the water supply sub-sector improvement as its legacy to Ghanaians and had provided generous development budgetary allocation in 1968/69 for the purpose. Most borehole water supplies and package plant installations were constructed as part of that programme. Population of the communities was the only criterion for selection and level of service was by public stand-pipes. No serious revenue generation studies were conducted and to date most of these installations have less than 10 per cent house connections or yard taps. Again additional burden had been imposed on GWSC by political administrators. During the construction of the 2500 wells programme in the Upper Regions and 3000 wells in southern Ghana, the beneficiary communities had been informed by the politicians that no tariffs will be paid. Indeed for the 2500 wells programme no tariffs were imposed during 1973-85. Sudden imposition of tariff without proper education continues to adversely affect revenue collection.

The issue of adequate tariff to balance operation cost has been addressed under the Economic Recovery Programme. Since March 1986 GWSC has been allowed annual increases in tariff without waiting for government approval. The government of Ghana is expected to give legal backing to the authorisation for tariff increases as a condition for the disbursement of African Development Bank (ADB) loan to finance the third phase of Accra-Tema Water Supply Project (ADB, 1988). With the increases in tariff, recovery of operation and maintenance cost will be achieved nationally through cross-subsidisation of rural supplies with revenues collected from commercial, industrial, house and yard connections in the city and other urban areas. The next problem will be how to proceed to full cost recovery which should be the ultimate goal.

GWSC currently receives approximately 5.6 per cent of the government Annual Development Budget. The foreign exchange component has largely been obtained from loans and grants from international financial institutions, donor countries or through direct project funding via bilateral aid agreements with various countries. The inadequacy of funding is deduced from the fact that GWSC, during its 20 years of existence, was able to increase coverage from 28 per cent to 60 per cent, an increase of only 1.6 per cent per annum. Even with this modest increase regular supplies can probably be guaranteed to only about 40 per cent of the population. During the 1970s a considerable number of projects were commenced by GWSC. Majority of these projects are currently in various stages of implementation. Some have been in progress for over 10 years. The economic decline of the 1970s deprived GWSC of the necessary development funds to complete these projects. Funding for these projects together with rehabilitation and capacity expansion are being sought under the Five Year Development Programme. However judging from the level of funding promised by the donor agencies it is unlikely most of these projects can be completed in the foreseeable future.

GWSC operates 194 pipe-borne water supply systems and some 6000 hand pump supplies. Cities and large urban areas are supplied with water from high or medium capacity conventional treatment plants. In addition, there are 69 Package Water Treatment Plants, which are essentially pressurised conventional treatment plants serving smaller urban areas. All these conventional treatment plants involve rapid sand filters which require chemical pre-treatment prior to filtration. It is not surprising therefore that chemical importation is estimated at 22 per cent of the total operating cost of GWSC. In a country where foreign exchange is scarce, slow sand filtration should be exploited wherever possible and rapid sand filters used only when raw water quality suggest these as the only form of treatment to provide the final water quality required. It is also true that rapid sand filters require more imported equipment and spares than slow sand filters. Ghana was an active participant in the WHO International Reference Centre (IRC) programme for research into slow sand filtration during the laboratory phase of the project (Kerkhoven, 1979). At the pilot plant stage GWSC was to provide space at one of its head works and funds to support the studies. This did not materialise and the research work ceased. In recent years only casual attention has been given to the slow sand filtration i.e. mentioned as possible alternative to future extension of Accra-Tema Water Treatment Plants, at both Weija and Kpong.

The precipitous economic decline in the 1970s caused severe deterioration of plant and equipment in most of the GWSC water production centres. Shortage of foreign exchange and inadequate financial support from the government meant failure to maintain equipment, shortage of spares and fuel. The result was frequent supply outages forcing consumers back to traditional sources, with its attendant risks in the spread of water-related diseases.

In water distribution, earlier decisions to provide all communities with population exceeding 2000 with pipe borne systems entailed large investment in pipes which have been grossly under-utilised for over 20 years. For some of these communities the alternative distribution system of small size pipes designed for a network of stand pipes only, drilled wells with hand pumps or hand dug wells with hand pumps should be fully investigated in the future. A related problem is the institutional framework for the operation and maintenance of rural water schemes. GWSC, as a centralised organisation, has been quite efficient in the operation and maintenance of city and urban water supply systems. This is partly because with diminishing resources, priority attention had been given to those systems that yielded the bulk of the revenue. Rural water supplies therefore suffered. However with the water supply to the 36000 communities with population less than 100 persons still to be tackled and the initiation of the hand dug well programme for communities of 100-500 persons, the problem of devolution of responsibility for operation and maintenance to the communities should be addressed. Further, maintenance responsibility for the 2500 wells in the Upper Regions still rests with GWSC and CIDA. The strategy for evolving the community-based maintenance system is still being worked out. Meanwhile the queues are getting longer at the hand pumps and additional wells will be required soon. The case for the 3000 wells in southern Ghana is rather more difficult to tackle. The water quality problems will have to be solved first and then the community based maintenance system can be attempted. GWSC has to draw the line between the water supply systems that it can efficiently operate and maintain from a centralised organisation and those that should have community based maintenance systems with technical support from GWSC. District and regional organisations of GWSC will then be restructured according to the new division in responsibilities between GWSC and the communities.

One of the major problems facing GWSC is staffing. In the early years GWSC, assisted by the management consultants PAS, secured a government approval for very attractive conditions of service for staff and also evolved and implemented an impressive staff training programme. GWSC was thus able to attract very high calibre staff for the professional areas of engineering, commercial operations and financial management. Indeed in the late 1960s and early 1970s GWSC was the highest employer of engineers in Ghana. As conditions deteriorated in Ghana as well as in the GWSC there was a mass exodus of these professionals out of GWSC. Of the 90 engineers GWSC employed in 1979 only 20 remained in 1984. Of the total number of employees of approximately 7000, just 9 per cent was classified as senior staff i.e. management, technical and administrative professionals and trade supervisors. It is estimated that 2000 staff in the lower ranks are redundant and should be retrenched in accordance with the Economic Recovery Programme redeployment of staff exercise. GWSC will require funds to pay severance costs to these 2000 employees and at the same time create better conditions of service to attract staff at the professional level.

2.2 SANITATION SUB-SECTOR

Responsibility for sewerage is vested in GWSC and that for non-sewered sanitation vested in the 110 district assemblies. With the problems that GWSC has experienced in water supply it is not surprising that GWSC has done very little in sewerage promotion. The central Accra sewerage system had been constructed to solve the sewage disposal problems of the central business district and the adjacent low income housing area. After the construction of the sewers, GWSC expected the consumers to provide the house facilities and then pay for the connection to the system. The private financing required has discouraged prospective customers from connecting up. GWSC has prepared a programme and is seeking donor financing to implement connection with repayment by instalments. In the meantime GWSC subsidises the operation and maintenance of the system. With the unpleasant experience from the central Accra sewerage GWSC has not shown any interest in taking over other sewerage works in Ghana. It is believed that most of these institutional sewage plants, based principally on the trickling filter, do not function well or are in a serious state of disrepair. To encourage GWSC to take over these plants the present operating institutions will have to rehabilitate these works. In any case it is unlikely that sewerage systems will be provided on a scale that will make any major impact on sanitation in Ghana for the foreseeable future. However GWSC will need to effectively solve the beach pollution caused by raw sewage from the Central Accra Sewerage project. Responsibility for sullage disposal where this does not form part of sewage, is not well defined. Households are expected to make appropriate arrangements for disposal but where this is not done district assemblies are the agencies to institute sanctions. However it is advocated that the agency introducing the water into the community should be made responsible for ensuring the proper disposal of waste water. Sanctions can be imposed by disconnection of water supply.

Since widespread implementation of sewerage programmes is deemed premature, non-sewered sanitation assumes major importance in both urban and rural areas. It is estimated that 27 per cent of the total population is served by one form of sanitation or another. These sanitation systems include, among others, evil smelling traditional pit latrines and the discredited bucket latrine system. Possibly only about 10 per cent of the population is served with an acceptable sanitation system. Responsibility for the provision of satisfactory sanitation services for the 90 per cent of the population in need rests with district assemblies without any established central support of the type GWSC provides for the water supply sub-sector. District assemblies have other responsibilities including the provision of schools, roads, markets and other environmental sanitation facilities. It is unlikely that excreta disposal will rank high in their priorities. Further, to initiate any meaningful sanitation programme projects will have to be prepared to the standard that will attract the necessary financing from outside the district i.e. central government or donor agencies. District assemblies lack the necessary staff; none of them have any professional staff except the Accra, Kumasi and Sekondi-Takoradi Metropolitan Assemblies. Some district assemblies are even unaware of the necessary professional input required in solving sanitation problems. Information sources for sanitation improvement need to be provided to all district assemblies.

Problems of social acceptance of latrine programmes across the country need to be examined. In the highly dispersed populations of the Northern and Upper Regions people have traditionally defecated in their farms. In a particular study by CIDA in Upper Region it was found that except for urban areas people did not perceive the need for every person to defecate at one spot. Indeed defecating in the farm is considered necessary for soil improvement. CIDA (1985, Report 5) concluded that latrines were unnecessary at this stage, however, people should be educated to take a hoe with them to provide soil cover after defecation. Communal latrines could be provided in the urban areas of such communities. Widespread use of traditional pit latrines in Southern Ghana suggest that people do not object to such facilities. However provision of communal facilities should be considered as a preliminary solution to precede the provision of private latrines. In coastal areas in Ghana privacy is not a major consideration as people defecate on the beach. There are instances where communal latrines have been ignored while defecation continues on the beach. To change people's attitudes will take persistent community education. District assemblies may require social analysis of the problem before embarking on appropriate solutions. With the introduction of pay-as-you-use latrines in certain urban areas it has been shown that people are willing to pay for neat and odourless latrines. District assemblies will have to explore these areas for additional revenue for latrine programmes.

2.3 STATUS OF PROJECT APPRAISAL AND EVALUATION IN GHANA

2.3.1 Project Appraisal

The earliest work in formal project appraisal was in connection with the Accra-Tema Water Supply and Sewerage Project. The World Bank sent a mission of engineers and financial analysts to appraise some components of Accra-Tema Water Supply Phase 1 and Central Accra Sewerage, Phase 1 in 1969. Appraisal focused mainly on technical, financial and economic aspects of the project. Financial projections were based on sewer connection rate of 300 per annum (World Bank, 1969). With hindsight it is clear that inclusion of social analysis in the appraisal would have indicated that the assumed rate of connection was unachievable. The World Bank followed up with Accra-Tema Water Supply Stage 2 which was appraised in 1974. Environmental cost, due to improved housing for the villagers resettled as a result of the formation of the Weija lake, was included in project costs. However cost of inundated land and health cost due to the spread of bilharziasis were not considered. Further, the environmental cost of sullage disposal was not considered.

The African Development Bank (ADB) also sends missions to appraise its portion of the Accra-Tema Water Supply Project. The latest mission appraised the Phase 3 rehabilitation project (ADB, 1988, op. cit.).

CIDA prepares Project Appraisal Memoranda for each project on the basis of which Project Review Committee may approve a project. Other bilateral agencies and the United Nations Agencies engaged in the sector also conduct appraisal on their various projects. In these appraisal sessions GWSC may or may not participate. It seems only reasonable that since these projects will finally be managed by GWSC they should conduct an independent appraisal of all donor funded projects and formally issue appraisal reports. It is possible to constitute a team of GWSC personnel and local consultants to carry out the appraisal.

Appraisal of projects funded wholly by GWSC have been limited to technical appraisal. A team of GWSC personnel working in areas affected by the project concerned will check the prepared project for soundness of the engineering and for realistic cost estimates. A technical appraisal report will be issued. The scope of the appraisal is rather limited and should be broadened to include other aspects of appraisal. With the introduction of the rolling three year Public Investment Programme, economic and cost-effectiveness criteria have been set for projects requiring government support and GWSC projects will have to meet these criteria.

To date no formal appraisal is carried out on sanitation projects. Projects have been initiated on an ad hoc basis without any formal planning. Project preparation is not an established activity in the sanitation sub-sector. It is expected that, in future, project development in sanitation will include appraisal.

2.3.2 Project Evaluation

The World Bank, African Development Bank and the United Nations Agencies have issued Project Completion Reports but have not conducted ex poste evaluation of their projects. The agency for the government of Federal Republic of Germany, KfW, issued a very detailed ten-volume final report on the 3000 wells project; a limited evaluation was later conducted to provide the basis for decision making on proposals for the development of community-based maintenance system.

CIDA issued a final report on the technical aspects of the 2500 wells programme and followed up with a very comprehensive 18 month evaluation of the project by an independent consultancy firm who issued a five-volume report in 1986. Acting on the findings of the evaluation CIDA has continued with the community education component, provided spares and vehicles for the maintenance programme and initiated a pilot-programme for community-based maintenance programme.

GWSC has lately instituted the issue of project completion reports but none was available for inspection. No evaluation of completed projects have been conducted to check on project performance.

In the sanitation sub-sector project completion reports and formal evaluation should be included in project development as a matter of policy.

2.4 POSING THE HYPOTHESIS

In the foregoing, the problems militating against making reasonable progress in the water supply and sanitation sector have been highlighted. It is clear that there is the need to improve project development especially in the sanitation sub-sector. In particular the scope of project appraisal should be broadened and effective appraisal conducted by local institutions on all projects regardless of whether they are funded by donors or from local sources. In connection with project evaluation the issue of project completion reports should be mandatory for all projects. Wherever possible ex poste evaluation should be conducted. It is being hypothesised that timely delivery of effective and sustainable water supply and sanitation services in Ghana is achievable through an appraisal and evaluative framework that gives due consideration to technical, financial, economic, institutional, social and environmental factors.

2.5 THE OBJECTIVE OF THE THESIS

The objective of this thesis is to provide a new approach to appraisal and evaluation of projects in the water supply and sanitation sector through efficiency measurement based on Data Envelopment Analysis.

CHAPTER THREE

LITERATURE SURVEY

3.1 PROJECT APPRAISAL

According to Baum (1982) project appraisal provides a comprehensive review of aspects of the project and lays a foundation for implementing the project and evaluating it when completed. Appraisal covers the technical, financial, economic, institutional, social and environmental aspects of the proposed water supply and/or sanitation project. Indeed during project planning and design a mechanism of internal project appraisal guides the project planner in the selection of the best project alternatives to be presented to the approving authority. Project appraisal is usually performed by an independent unit not directly involved in the project feasibility study or by an external aid agency sponsoring the project with those who formulated or prepared the project in attendance.

3.1.1 Technical Aspects

Technical appraisal of projects seeks to ensure that projects are designed, appropriately engineered and follow appropriate standards. The technical alternatives considered, the solution proposed and the expected results are completely reviewed. Specifically, technical appraisal of a project is concerned with questions of physical scale, layout, location of facilities, what technology is to be used (including types of equipment and process), the need and degree of involvement of consultants in the implementation, operation and maintenance, whether realistic implementation schedule has been proposed and the likelihood of achieving project targets (Puri and Lamson-Scribner, 1976).

In water supply technical appraisal will be concerned with how the project fits into the long-term master plan, whether physical components are adequate for the planned period and whether long-term appropriate decisions with regard to such aspects as the protection of the watershed have been considered. Since master plans cover a minimum of 20 years potential sources to meet the long-term demand should be identified together with the location of future treatment plants, service reservoirs and principal transmission pipelines. Arrangement for land acquisition will be considered to ensure that future development are not delayed. The components of the proposed water supply project including dams, intake structure, treatment plant transmission mains, service reservoirs and distribution systems will be checked against the approved design criteria to ensure that sound engineering principles have been applied and adequate capacities provided. Optimisation studies carried out on various pumping capacities and size of transmission mains will be verified. Wherever possible technical appraisal of water supply should ensure that economy of scale has been considered in the choice of components. The level of service as determined by the mix of standpipes, yard connections and house connections coupled with the effect on sanitation should be thoroughly reviewed. Long-term data gathering and field investigation activities should be considered to ensure that future planning will be undertaken with a reasonable data base. Appraisal of technical aspects of rural water supply is discussed by ODA (1984). Okun and Ernst (1987), Cairncross and Feachem (1983), Cairncross and Feachem (1978) and Fair *et al* (1968) provide a comprehensive background to technical requirements and available technology in water supply.

In sanitation a wide range of technical options are available following a major research work at the World Bank, the results of which are presented in a series of publications under the general title of 'Appropriate Technology for Water Supply and Sanitation'. Kalbermatten *et al.* (1982), stated that previously the standard solution for the sanitary disposal of human waste was sewerage, the technology of which was designed to maximise the user convenience rather than health benefit. To achieve such standards of convenience in developing countries is, at once, inappropriate and unnecessary. At present the first priority of excreta disposal programmes in developing countries must be human health, that is, the reduction and eventual elimination of the transmission of excreta related diseases. This health objective can be fully achieved by non-conventional sanitation methods that are much cheaper than sewerage and are appropriate to the conditions in developing countries. These sanitation technologies can be designed to meet the health requirements at a cost affordable to the users and reflecting community preferences and customs of personal hygiene.

Sanitation programmes should provide a sequence of upgraded systems, the stages of which are implemented as the socio-economic conditions in the community improve. The range of technologies include improved pit latrines, pour flush latrine, composting latrine, aqua privies and septic tanks for use as individually operated units. These require little or no investment in facilities outside the individual sites. Community sanitation systems, that is, systems requiring off-site facilities and a permanent organised structure with full time employees to operate properly include vault latrine, communal sanitation facilities and sewerage. Technical details of sanitation systems are available in Wagner and Lanoix (1958), Pacey (1977), Feachem *et al.* (1977) and Kalbermatten *et al.* (1980). The process of selection of appropriate technology in sanitation begins with identification of all technological alternatives available for a good sanitation service. Within that set of possibilities there are usually some technologies that can be readily excluded for technical, health or social reasons. For example, a composting latrine would be socially inappropriate for a people who have strong cultural objections to the sight and handling of excreta; some technologies require institutional support that is infeasible in a given social environment. The level of water supply service exerts considerable influence on the selection process. Hand carried supplies from a water point may restrict feasible technologies to those not requiring water, that is, various variations of pit latrines such as VIP latrines and the compost latrine. The pour flush may be used where anal cleansing already requires carrying water into the latrine. However, all systems can be converted into a water seal unit when the water supply situation improves. With yard connection pour flush and vault latrines can be used but not cistern flush toilet; when the sullage generation exceeds 50 lcpd sewered pour flush toilets are feasible. However, other factors, such as bulky anal cleansing materials, soil conditions, housing conditions and consumer preference may also influence the selection process. With house connections cistern flush toilets with solid interceptor tanks and small bore sewers, conventional sewerage and septic tank with soakaway are technically feasible. Sewered pour flush toilets are also feasible. Where alternative disposal facilities can be provided for sullage all other alternatives not requiring house connections are still feasible. In all cases such factors as access and population should be considered.

Kalbermatten *et al.* (1982), op. cit., provides an algorithm for selection of sanitation technology.

Technical appraisal of projects should also review methods of construction. Generally water supply and sanitation projects provide opportunities where labour-intensive methods can be substituted for capital intensive methods; for example trenching for pipelines, hand dug well or bored wells instead of drilled wells and earthworks for various sanitation technologies. Labour intensive projects require a high degree of organisational and supervisory skills to make the labour force productive but they can be executed by self-help with technical assistance from supporting institutions to reduce costs.

A critical part of technical appraisal is a review of the cost estimates together with the engineering and other data on which they are based to determine whether they are accurate within an acceptable margin and whether allowances for physical and price contingencies during implementation are adequate. Operation and maintenance costs should be reviewed together with availability of all necessary inputs. Procurement arrangements should be reviewed to make sure they are adequate.

3.1.2 <u>Financial Aspects</u>

The main objectives of financial appraisal include:

(i) Financial viability of the project.
(ii) Financial viability of the parent government agency.
(iii) Cost recovery.
(iv) Tariff structure and rate.

<u>Financial viability of the project</u>

The capital and recurrent costs of the project will be calculated on an annual basis with due allowances for physical and price contigencies. These figures will be checked during technical appraisal to ensure their accuracy. The government agency promoting the project is usually involved with implementing other projects as well as operating existing system(s). Thus given all the other activities that the agency has to undertake an appraisal of the agency has to be undertaken to ensure that funds meant for the project are not diverted for other purposes. Sometimes it is necessary to separate the accounts of the parent government agency and the proposed project to ensure proper control of project funds. The project's financial requirements are broken down into local and foreign currency components. It is usual for developing countries to finance the local currency requirements and to seek external aid to finance the foreign currency component. Most aid agencies place a limit on the proportion of the project cost that they are prepared to finance and this proportion may vary with the recipient country and the type of project. The terms and conditions under which financing may be granted vary widely; sometimes the external aid agency may insist on another aid agency being agreeable to co-finance the project. There will have to be certain guarantees provided from governmental sources of adequate long-term budgetary allocations to the project. Porter (1983) lists the major sources of funds for water and sanitation projects as follows.

National and local budgets (grants/loans)
Bilateral aid (grants/loans)
International lending institutions (loans)
National lending institutions (loans)
Capital contributions (cash from beneficiaries)
Local funding (bonds and contributions in kind)
Internal cash flow (surplus cash generated)

In order to ensure that the project will proceed smoothly and not suffer from lack of funds the cash flow statement for the project will be prepared. This statement will be critically reviewed during financial appraisal and any additional information required will be sought where necessary. The cash flow statement will cover the implementation period and the operations period. In addition, the cash flow statement for the entire operations of the government agency will be prepared from at least three historical years together with projections for at least the duration of the project. The statement should provide information on all sources of funds which may include internally generated funds, customer deposits, domestic loans and grants and external loans. Items for application of funds include project investment debt servicing, working capital, changes in inventory. Again this statement is reviewed critically to ensure that all figures are reasonable. If the revenue position is adequate the financial rate of return of the project and the operations of the government agency should be computed. The National Association of Accountants (1961) provides comprehensive cash flow analysis for managerial control which should prove useful in the analysis of the above statements.

Financial viability of parent government agency

The financial viability of the government agency will have to be verified to ensure that it can meet its financial obligations including debt servicing to the external aid agencies. The agency should be expected to generate sufficient funds from operations to provide adequate working capital, to earn a reasonable return on fixed assets and to make satisfactory contributions to its future capital requirements. The agency's balance sheet and incomes statement should be prepared for three historical years and projected for the life of the project (NAA, 1967; Grover *et al.*, 1988). Various accounting ratios are calculated, (ODA, 1988), and compared with ratios considered acceptable for water supply and sanitation agencies. Generally water supply and sanitation agencies show poor financial performances especially in the rural areas. However external aid agencies are now laying more emphasis on social and basic health requirements of rural communities and therefore are less strict with financial criteria. This flexible attitude should be particularly beneficial to rural sanitation schemes which have received low priority in the past and which even now, more than water supply, have difficulty demonstrating viability.

Cost recovery

Recovery of costs of public sector investments from the users or beneficiaries is an important issue in project selection. Failure to recover the costs from the users through charges creates a class of users who, in effect, receive subsidy from the rest of society while it deprives the project promoter of resources that could be used to extend the service to additional users. Cost recovery systems should ensure economic efficiency. Ray (1976) states that prices derived from the efficiency objective are designed to create maximum economic benefit. Significant departures from efficiency prices should be made only after due consideration of the losses that may accrue to the economy as a consequence. However, methods of recovering project costs should promote a more equitable distribution of income within the society and, also, should enable the government to capture part or all of the increased revenue for funding future investment. The ideal cost recovery, according to Baum and Tolbert (1985) is the one that secures maximum economic benefit from the project taking account of its impact on distribution of income and revenue.

The cost recovery issue is rendered more complex in that water supply has the inherent characteristics of a private good, that is, non-payers may be excluded from the benefits and the good is rival in consumption. Together rivalry and excludability mean that market or efficiency prices can be charged i.e. a market can function. However, interference with market prices may be justified on the argument that water is a merit good and because of the external benefits of its consumption it is too important to be left to market provision.

In the case of sanitation the existence of important externalities associated with its provision and use promotes the view that market pricing may be inappropriate. Moreover because of the externalities and the non-excludability of the benefits from non-payers a market based system of payments may be both difficult and undesirable to implement. In each case cost recovery is achieved through means other than pure market prices.

A final complication is that both water supply and sanitation may well be decreasing cost industries due to the presence of economies of scale. It is well known that efficient pricing at Long Run Marginal Cost will produce losses in these circumstances. In this case cost recovery may require two part-tariffs, including the standing charge element which is designed to recover the loss.

<u>Tariff structure and rate</u>

Water supply and sanitation agencies have traditionally either charged low rates or no rates at all. In rural areas consumers are presumed to be too poor as not to be able to afford tariffs. Current thinking is that every consumer of the services should be made to pay some amount no matter how small. McGarry (1983) noted that governments are increasingly calling for a minimum local contribution, in rural areas, towards construction costs, usually in the range of 10 per cent to 15 per cent which represents the magnitude of contributions that can be made in kind. There is also a growing trend towards making rural communities responsible for operations and maintenance of the facilities once completed or at least providing funds for these purposes. This is important both as a means of easing the fiscal burden on the central government and thereby making it possible to expand rural services more rapidly and also to secure community support and active participation. In general the central government will have to determine the cost recovery policy which should indicate the percentage of total costs to be collected from users. Tariffs may be designed to recover:

(a) Operation and Maintenance costs (O & M costs)
(b) O & M cost plus financing cost.
(c) O & M cost plus financing cost plus depreciation.
(d) O & M cost plus financing cost plus depreciation plus rate of return on fixed assets.

Whatever the target to be met the tariff structure and rate should have the following characteristics (Porter, 1983 op. cit.).

(i) *Fairness*: a tariff system should have a reasonable impact on the users; it should not be too high as to exclude the poor from at least the minimum level of service. Similar types of consumers should pay on the same basis.

(ii) *Simplicity*: a tariff system should be simple to operate, to administer and should be easily understood by the consumers who should also be made to appreciate the relationship between the charge and the service provided.

(iii) *Adequacy*: whatever target has been set the charges should be designed to enable sufficient revenue to be collected to meet the target.

(iv) *Enforceability*: sanctions such as disconnection of water supply should be applied for non-payment of charges. Sanitation charges may be added onto the water bill to facilitate collection.

A variety of methods have been used in charging for water supply and sanitation services:

(a) Charges based on property values: this system is administratively simple since no separate billing and revenue collection is required. However it lacks flexibility and the operating agency is not likely to get its fair share of a single rate for several services. It also fails on the grounds of fairness.

(b) Flat rate: this system is administratively simple and could be used to recover fixed or overhead costs. However there is no relationship between charges and use; there are, also, no particular features which assist enforcement.

(c) Charges based on property characteristic: number of people living in the dwelling or number of plumbing fixtures are used to assess charges. It is a refinement of the flat rate but it has high administrative cost to keep property characteristics up to date. There is also no strong correlation between property features and demand for water and sanitation services.

(d) Unit rate charges (metering): this system is fair and can ensure economic pricing and adequate revenue but it is costly to install and operate.

Methods (a), (b) and (c) fail to connect charges to consumption, an essential ingredient of economically efficient pricing. Method (d) has the merit that it can be implemented to reflect marginal cost of provision of water supply and sanitation services. This is the key requirement of efficient pricing and has its foundations in Paretian Welfare Economics (Baumol, 1972; Graaf, 1957).

<u>Operational marginal cost pricing</u>

Saunders and Warford (1976) provided the rationale behind the use of marginal cost pricing as the optimum economic price for public goods and services. Investments in water supply and sewerage are lumpy by nature, that is, because of the usual long planning horizon, water supply and sewerage systems may be constructed with idle capacity that is utilized as demand builds up. In these circumstances there is the need for an operational marginal cost pricing technique. The Average Incremental Cost (AIC) has been devised for the determination of the average tariff rate based on marginal cost pricing (Saunders, *et al.*, 1977).

$$AIC_t = \frac{\sum_{t+1}^{T} \frac{C_t + O_t}{(1 + r)^{t-1}}}{\sum_{t=1}^{T} \frac{P_t}{(1 + r)^{t-1}}}$$

where AIC_t = per capita Average Incremental Cost in year t

C_t = Capital Cost in year t

O_t = Operation and Maintenance Cost in year t

P_t = Population served in year t.

r = the Opportunity Cost of capital

T = the life of the facility

In practice, it is often easier to calculate AIC on the basis of a volume measure (for example m^3) rather than by persons served. These volumetric costs can be transformed into per capita cost using per capita demand figures. The Average Incremental Cost implicitly takes the population served or the volume measure as a proxy for project benefits.

While it is theoretically correct to charge economic price on all consumption consideration of ability to pay might dictate otherwise. It is quite common to have an increasing block rate structure whereby the initial quantity of water sufficient to provide for basic needs is made available at a low subsidised rate. This is often referred to as the life-line block (Warford and Julius, 1979). The consumption above this level is charged at higher rates; two or three additional consumption blocks are charged at increasing unit rates. Thus it is not unusual for domestic, commercial, institutional and industrial consumers to be charged at differing rates.

3.1.3 <u>Economic Aspects</u>

Economic analysis in project work is all pervading. Questions on the identification of the project, project formulation in terms of plant size, supporting services, location, beneficiaries and pricing of output are partly answered through economic analysis. If it is limited to the appraisal stage then it can only serve as a final check on the overall soundness of the project proposal.

Benefit cost analysis is used to establish the attractiveness of a project for investment or to choose the best of several alternative mutually exclusive projects. The principle is to maximise the net social benefit or the net present value with and without the project.

Net Present Value = Present Value of Social Benefits - Present Value of Social Costs

$$NPV = PVB - PVC \tag{1}$$

$$PVB = \sum_{t=1}^{T} \frac{B_t}{(1 + r)^t} \tag{2}$$

$$PVC = \sum_{t=1}^{T} \frac{C_t}{(1 + r)^t} \tag{3}$$

where B_t = Social Benefit in year t including all externalities

C_t = Social Costs in year t including all externalities

r = Discount rate

T = Life of the project

Water supply and sanitation belong to that category of social projects where the benefits are not marketed and are invariably non-tradeable internationally. Improved public health is generally considered as the major benefit of improved water supply and sanitation. These health benefits are often exceedingly difficult to express in monetary terms. It is possible to say that safe water supply and sanitary disposal of excreta will reduce the incidence of, for example, diarrhoea. This will reduce the number of days lost through illness and that these days could, in theory, be valued. However the chain of causation is indirect, the assumption necessarily arbitrary and the benefit-cost, according to Porter and Walsh (1978), then becomes an exercise in the imagination which can be both misleading and lacking in credibility. Various attempts have been made to estimate benefits from water supply and sanitation projects. Some of these attempts are presented below.

<u>Benefits</u>

(i) *Health benefits*: these have been estimated by using the cost of medication and loss of productivity in time of illness. The problems with this approach include:

(a) Full understanding of mechanism of disease transmission and classification of diseases into water-borne, water washed, water-based and water related types when identifying the likely sources of benefits from water supply and sanitation projects (White *et al.*, 1972).

(b) Costs can be easily measured in a predominantly cash economy but less easily measured in subsistence economy or where medical sources are free.

(c) Massive unemployment, under-employment and seasonability of employment in a developing economy.

(d) Data shortages.

(e) Indirect effects of one member of the family falling ill on the activities of the other.

(ii) *Benefits from Increased Water Quantity and Time Savings in Water Supply*: Cairncross (1987) showed that, in general, as water source gets closer and journey time decreases, water consumption tends to increase but a plateau is reached when the return journey takes less than half an hour which is equivalent to a distance of one kilometre from home to source. Only when water is supplied in the house, or the yard, does consumption increase further probably by a factor of three or more. The most significant benefits occur when old water sources which are further away than one kilometre are replaced thus promoting increased water consumption.

Still more important benefit is the savings in time and effort spent in water collection. Churchill (1987) provides a methodology for assessing the value of time saved.

(iii) *Willingness to pay*: this is determined by finding out the maximum sum which a user of water supply or sanitation facility is willing to pay rather than go without its use (usually determined by proxy, namely, the revenue charges for the use of water supply or sanitation services). The total welfare changes associated with the project, measured by willingness to pay, is given by the extent to which the sum of the payment by those who feel better off exceeds (or falls short) of the sum demanded by those who feel worse off. Problems with this method include

(a) Demand for health care and potable water supply increases as education and income increase so that a better educated and higher income individual who may need a given project less is willing and able to pay more for it.

(b) The method assumes that individuals are most qualified to judge what is best for themselves.

(c) Answers are likely to be unreliable to the hypothetical question regarding what people are willing to pay. Recent methodological improvement using the Contingent Valuation Surveys report on reliable responses (Whittington *et al.*, 1987).

(d) The existing income distribution within the community is assumed to remain constant.

Other methods to assign economic value to improved health include (Saunders and Warford, 1976 op. cit):

(a) The economic worth method.

(b) Net output method.

(c) Use of government health improvement programmes to derive implicit value of human life and health.

(d) Insurance premiums.

(e) Construction of a general index which reflects changes in the standard of health in the area.

(f) Comparison of changes in disease rates associated with each alternative supply or sanitation facilities with costs.

(g) Health state method.

Least-cost Technique

In general there is no satisfactory method of comparing project alternatives with unquantifiable benefits such as exist with water supply and sanitation projects. Only in the case of mutually exclusive alternatives with identical benefits can a cost minimisation rule or least-cost analysis be applied. Even here, Yepes (1982) cautions that least-cost solutions tell us nothing about the justification of the project since the technique only provides that the net present value will be the highest but would not guarantee that the benefits would exceed the costs. Alternative water supply and sanitation systems provide a wide range of benefit levels. Kalbermatten *et al.* (1982) op. cit. stated that the convenience to users offered by an indoor toilet with sewer connection is hard to match with a pit privy. Many benefits exist in the mind of the user and varying qualities of service result in varying benefit levels. For this reason least-cost comparison will not provide sufficient information to select among sanitation alternatives. Nonetheless, if properly applied it will provide an objective common denominator that reflects the trade-off in cost corresponding to different service standards. Once comparable cost data have been developed the consumers or their community representatives can make their own determination of how much they are willing to pay to obtain various standards of service.

Many sub-projects in water supply and sanitation have been analysed by the least-cost technique e.g. the selection of gravity or pumping system to deliver a given flow, the selection between two different water treatment processes to deliver same amount of water of similar quality and the selection of the optimal sequence of several schemes to meet a growing and future demand of water supply and sanitation services. Further, the least-cost technique can be adjusted to compare alternative solutions that involve the use of equipment with different useful lives or pipeline and pumping projects designed to deliver different water flows; in these cases the common procedure is to select a given time or design capacity horizon which is a common multiple of all alternatives considered and to include within this time frame or design capacity as many stages as required to be commissioned at specific points in time to ensure that the benefits of all sub-projects over the extended time frame are the same. Future stages, needed replacements and/or operation and maintenance are then costed and discounted to provide the present value of all costs. The alternative with the lowest present value is then selected.

Also, in Bottleneck Analysis (Grover, 1983) of existing water supply and sewerage systems the problem is to determine which components of the system should have their capacities augmented and when these capacity extensions should be built. More often only some components will require additional capacity. Exactly how much the expanded capacity should be is determined by least-cost techniques.

Churchill (1987) op. cit., provides a comprehensive framework for selection of rural water supply schemes based on capital cost, labour cost, cost of the source, size of the village, the density of the population and the value of time of those hauling water. Costs are compared at the point of consumption for yard taps and hand pump. A major conclusion is that man/woman is an inefficient carrier of water and that there is under-investment in water systems in many countries because there seems to be a lot of scope for reducing costs by concentrating on minimising haul distances and wait times. However, whether this is to be done through investment in piped distribution systems or improvement in the spacing and the number of point sources (hand pumps, stand pipes) will depend on the specifics of each situation.

Economic Costing

The primary intent of economic costing is to develop a price tag for a good or service that represents the opportunity costs to the national economy of producing that good or service (Little and Mirrlees, 1974; Squire and Tak, 1975).

In connection with water supply and sanitation projects Kalbermatten *et al.* (1982) op. cit., stated three principles:

(i) All costs to the economy regardless of who incurs them should be included. Often in comparing publicly provided goods and services, such as water or sanitation, the cost borne by the household is ignored. All the costs attributable to a given alternative whether borne by the household, the utility, the national government or other entities should be included.

(ii) Each cost must be properly evaluated: this principle concerns the prices that should be used to value costs. Unit prices should reflect the factor endowment of that country. Thus a country with abundant labour will have relatively inexpensive labour costs because labour's alternative production possibilities are limited. Similarly a country with scarce water resources will have expensive water costs in the economic sense regardless of the regulated price charged to the consumer. Since governments have diverse goals which may be only indirectly related to economic objectives, market prices do not reflect true opportunity costs to the national economy also known as shadow prices.

(iii) In economic costing incremental rather than historical costs should be used. This principle rests upon the idea that sunk costs should be disregarded in making decisions about future investments. Analysis of real resource costs of a given technology must value components at their actual replacement cost rather than at their historical costs.

Shadow prices are obtained by multiplying market prices by conversion factors which reflect all distortion in the economy including transfer payments (taxes, duties, subsidies and dealer's profit), labour and the price of foreign exchange. In the economic costing of water supply and sanitation technologies four conversion factors are encountered. These are:

(a) The unskilled labour wage conversion factor.
(b) The foreign exchange conversion factor.
(c) The opportunity cost of capital.
(d) Land and other government subsidised inputs.

(a) *Unskilled labour:* Many governments enact minimum wage legislation. The normal effect of this is that unskilled labour is economically over-valued, that is, the financial wage of an unskilled labourer is higher than he would have received in the absence of the minimum wage legislation. If the economy has a large pool of unemployed labourers, the unskilled labour wage conversion factor would be close to zero because there is almost no cost to the national economy that results from unemployment of such people. If, however, a country has a few unemployed unskilled labour then the conversion factor would be 1.0 since the financial wage fully reflects economic value. Generally the conversion factor for unskilled labour in developing countries in the range of 0.5 to 1.0. However when other factors are considered in addition to opportunity cost of labour the shadow wage conversion factor may exceed 1.0 (UNIDO, 1972).

(b) *Foreign Exchange:* Many governments do not permit the free movement of the exchange rate of foreign currency for the national currency in the international money market. Sometimes this results in the currency being over-valued. The foreign exchange conversion factor is the ratio of the shadow exchange rate (what the currency would be worth in a freely trading international market) to the official exchange rate fixed by the government. This conversion factor is greater than 1.0 whenever the local currency is over-valued or import restrictions are high.

(c) *Opportunity cost of capital:* This is defined as the marginal productivity of additional investment in its best alternative use. In many developing countries capital is a scarce commodity and therefore has a high opportunity cost. The opportunity cost of capital is expressed as a percentage and it is usually in the range 8 - 15 per cent.

(d) *Land and other government subsidised inputs:* Land in certain developing countries is owned by the government. A government owned utility may acquire land at little or no cost. The economic cost however should be calculated at the price it would earn if it had been sold to a farmer or an industry. Scott *et al.* (1976) stated that the need to make a detailed valuation of land for project appraisal will generally arise when a major change in land use structure and practise is contemplated.

Mechanics of the Least-Cost Technique

The least cost technique minimises the cost function:

$$\sum_{t=1}^{T} \frac{C_t}{(1 + r)^t}$$

where C_t = cost in year t

r = discount rate

T = life of the project

For each of the mutually exclusive projects in water supply and sanitation, the various cost items occurring in any particular year, t, are valued at the prevailing market prices. These cost items include capital costs, replacement costs and recurrent cost. Each cost item is broken up into tradeable and untradeable items. The tradeable items are those imported or exported and import substitutes. These should be expressed in terms of border prices, that is, cost including freight (CIF) or free-on-board (FOB). Using the domestic currency as the unit of account, the border prices are converted into the domestic currency using the official exchange rate and then multiplied by the foreign exchange conversion factor. The untradeable items are further broken down into unskilled labour, foreign exchange, land and other local inputs. Conversion factors are applied to obtain shadow prices from the market prices. All costs valued at shadow prices are added up to provide the cost in year t. The discount rate is selected to reflect the opportunity cost of capital. The costs are discounted to give the value of the cost function. The alternative with the least value of the cost function is duly selected. The choice of the discount rate is important since the least cost solution may change depending upon the choice of discount rate. A low discount rate will favour high capital investment projects while a higher discount rate will favour projects in which the major proportion of costs are incurred in the future.

Sensitivity Analysis

In least cost analysis cost forecasts are made into the future. Errors are inevitable especially as time increases. It is necessary to determine how stable decisions are with respect to possible changes in the variables of the least-cost technique such as capital costs, replacement cost, recurrent cost, discount rate and life of the project. This operation is known as sensitivity analysis. In sensitivity analysis one variable, say, the discount rate is changed while others are kept constant. The changes in the net present value are observed. In the case of the discount rate there is a tendency for the choice between two projects to change from one to the other as the discount rate is raised from a low figure to a high figure. The point where both projects become equally attractive is referred to as the cross-over discount rate. Sensitivity of project selection to changes in other variables can be similarly determined. Majumdar (1985) explains the method of sensitivity analysis. For more rigorous treatment of the subject see Bruce (1981).

Optimal Capacity Expansion

An important application of the least cost technique is the selection of optimal staging and capacity of water supply and sewerage works. The method requires various cost functions for pipelines, water treatment plants, storage tanks, sewerage treatment plant (secondary), pumping stations which are available or can be developed from historical data. Detailed presentation of the method is provided by Yepes (1982) op. cit.

3.1.4 Institutional Aspects

Successful project development in water supply and sanitation requires institutional and legal framework that allocates authority and responsibility from the national level to the community level. Whether national or community-based, urban or rural, single or multisectoral, the institutions must have clear divisions of responsibilities avoiding gaps or overlaps in responsibilities. Institutional building in water supply and sanitation involve:

(i) A sector strategy supported by government.

(ii) Stable, autonomous institutions.

(iii) Manpower development.

(iv) Local organisations.

(v) Technical support services.

(i) *Sector strategy supported by government:* The water supply and sanitation sector has been accorded low priority by most governments in developing countries in the past. The need to evolve a strategy for sector development is crucial. Government commitment and steady support on a long term basis is essential to avoid the destructive 'stop and go' approach in the sector project development. Government support must be shown by clear objectives, policies and reliable allocation of staff and funds. Kalbermatten *et al.* (1980) op. cit. suggest a hierarchy of institutional responsibility from national to the local level and underscore the need for long term government support for the sector.

(ii) *Stable, autonomous institutions:* One of the fundamental decisions to be made in organising the water supply and sanitation sector is whether the sector should be independent or combined with other social sectors such as health. There are advantages and disadvantages in both solutions. In urban areas there is usually an established organisation that is responsible for municipal water supply and waste disposal; in large cities it is usually a completely autonomous institution. In small towns the responsible institution is frequently a department of the municipality or part of a multisectoral agency. Rural areas may be accommodated by a ministry with other responsibilities. However, in some developing countries a single national organisation may be charged with responsibility for the sector. Whatever the organisational arrangements, there should be a national policy and planning body followed by national state or municipal and district or local operating agencies. Baum and Tolbert (1985) op. cit. stated that stability has to be a prerequisite for institutions to improve their operations. Continuity in management is crucial and political interference or change in management with change in political leadership should be avoided. Autonomy in day to day management should be guaranteed within the overall framework of objectives, policies and targets of operational performance agreed with the government. Tariff policies, particularly, should be clearly spelt out to avoid delays in implementing increases when due.

(iii) *Manpower development:* A key area in institution building is the ability to attract and retain competent staff by offering good salaries and related benefits to minimise staff turnover; and the provision of training programmes to increase staff capabilities. Typically public institutions are often unable to provide staff compensation equal to that prevailing in the private sector. Trained staff leave the public service after a relatively short period of employment. Such training still provides an overall economic benefit to the country but it follows that, for the public institutions, training programmes should be continuous to ensure the availability of qualified personnel and to minimise disruption due to staff departure. Career opportunities should be clearly defined through a programme of staff development and promotion.

(iv) *Local organisations:* The importance of local organisations in the provision of water supply and sanitation services cannot be overemphasised. Water and sanitation committees formed at the local level should be involved through self help in all aspects of water supply and sanitation. As Briscoe and de Ferranti (1988) noted it is the local people themselves, not those trying to help them who have the most important role (in water supply and sanitation). The community itself must be the primary decision maker, the primary investor, the primary maintainer, the primary organiser and the primary overseer.

(v) *Technical support services:* There is the need to provide an efficient well-staffed and well-managed agency for technical support that, for small communities, will:

(a) plan programmes, provide guidelines and design assistance, monitor on-going programmes, evaluate completed projects and ensure that lessons learned are reflected in new designs.
(b) maintain close liaison among design, operation and maintenance activities;
(c) establish clear criteria for selection of materials and equipment;
(d) actively promote programmes and assist communities in their implementation;
(e) be sufficiently decentralised to assist communities effectively.

3.1.5 Design of Service Delivery Systems to Achieve Success in Water Supply and Sanitation Projects

Achievements of success in projects depends on the attainment of the proper mix of software and hardware for the particular project. Software may consist of community education and participation, human resources development and institutional development; hardware may include pumps, pipes and latrines. Software and hardware should complement one another to make project success a reality in the field (WHO/SEARO, 1985).

Feachem *et al.* (1978) identified three different models for the administration of projects.

Model 1

Table 3.1 Direct Administration or Centralised Model.

Activity	Central Authority	Branch Office (District or Region)	Community
Establish priorities	Decide project selection criteria	Modify selection criteria to suit local conditions	
Plan	Obtain information, allocate resources to regions	Interpret government priorities, select projects	Pay rates individually
Fund	Collect revenue disburse central grants and donor funds	Collect water rates, prepare project memoranda	
Implement	Provide central technical advisory unit, purchase materials	Employ labour and organise construction	
Maintain	Provide maintenance funds	Employ maintenance staff	

This administration not only builds water supply and sanitation facilities but also has the responsibility of keeping them going. This is best achieved by a specialised water and sanitation authority. The authority will have maximum ability to decide on priorities and to gear its programme to whatever economic or political strategy the government favours. Planning is simplified because the administration controls all projects and is able to build up information about the current state of water supply and sanitation affairs to enable it to take rational decisions. Raising revenue is difficult especially from public standpipes but the central authority will be in a position to raise revenue externally from central government and foreign donors. Indeed, foreign donors have favoured the establishment of central authorities to feel relatively sure that funds will be spent as intended. This system allows no community participation. People pay their rates and expect services rendered. Direct administration is expensive and seems to work well for water supply and sanitation to large towns. However when it comes to a scatter of small systems throughout the countryside the cost of effective direct administration may be daunting (Feachem *et al.*, 1978, op. cit.). This is the case both in relation to construction and to maintenance. Planning, in this model, should allow some measure of public debate. This could be organised on the lines suggested by Faludi (1973), that is, stimulating the community by inviting a cross-section of the public to debate the plans in public.

Model 2

Table 3.2 The Self Help or Community-based Model

Activity	Central Authority	Branch Office* (District or Region)	Community
Establish priority	Allow priority for self-help		Choose 'felt need'
Plan	Prepare project plans incrementally	Encourage and examine applications from communities for assistance	Establish local organisation (to participate in planning
Fund	Disburse central grants and donor funds	Collect self-help contributions, prepare project memoranda	Raise funds and make labour available
Implement	Provide central technical advisory unit, purchase materials	Provide technical supervision	Contribute labour under supervision or hire local contractor
Maintain	Provide maintenance funds	Employ maintenance staff	Provide occasional labour or services of a volunteer, alert branch office when necessary

* A well-staffed and well-supported branch office is absolutely essential to this model.

In this model communities choose their felt needs and establish their local organisations to interact with the branch office and planners to plan incrementally, that is, improvements acceptable and affordable to the communities. WHO/SEARO (1985) present a framework consisting of six steps, each step with its objectives and an algorithm for achieving the objectives.

Objectives of Step 1: To establish and use objective criteria to determine priority communities to be served first; and
To recruit and train project facilitators to assist in the community education and participation process.

Objectives of Step 2: To overcome any conceptual gap that may exist between people and planners as a result of their different perceptions of community needs.
To determine the relevance of actions for water supply and sanitation in relation to overall community needs, and
To promote in the community a favourable decision on the priority of water supply and sanitation activities in relation to other development needs.

Objective of Step 3: For planners, facilitators and people to work together to develop a project design which incorporates the proper mix of hardware and software to meet the identified community needs.

Objective of Step 4: To develop a consensus and commitment within the community regarding the planned project.

Objective of Step 5: To implement the planned project as agreed with the community.

Objective of Step 6: To follow up after the completion of the construction of facilities in order to ensure that support is available when necessary from existing programme support networks.

For the self help model to function effectively there should be a decentralisation system of administration. Rondinelli and Cheema (1983) identified the different forms of decentralisation as deconcentration, delegation to semi-autonomous or parastatal agencies, devolution to local governments or local organisations and transfer of functions from public to non-government institutions. WHO (1986) notes that central authority should extend its structures through deconcentration, as far as cost or logistics permit in order to become as close as possible to the communities it serves. Devolution means that authority and responsibility are given by the central authority to the local organisation. Community-based competence is developed through devolution of authority and responsibilities to the communities supported by strong deconcentrated units.

Model 3

Feachem *et al.* (1978, op. cit), provided a third model called the compromise model which is tailored to the needs of the particular country, in their case, Lesotho. In the compromise model the objective is to seek the virtues of the centralised and the community-based models given the particular circumstances of a given country and to integrate these virtues in the compromise model. In countries where there is no tradition of community participation or self-help model 2 cannot be expected to be effective. Communities will require time to build up capacity for self-help if this is considered necessary. Indeed, for the compromise model the level of community participation will have to be negotiated with the community.

In Ghana the centralised model has been employed to a large extent in water supply and sanitation projects. Reasonable success has been achieved in large urban communities but results elsewhere have been poor. The inability of the centralised authority to effectively reach small communities may be due to lack of resources and logistic bottlenecks. On the other hand there is a capacity for pure self-help where communities on their own provide small amenities for themselves. However this capacity is severely limited by the resources available. In the large urban areas where the centralised model seems to work this should be retained. For the other communities, the central authority will have to engage in a negotiated partnership with the communities for the delivery of water supply and sanitation services.

3.1.6 Social Aspects

Baum and Tolbert (1985), op. cit. stated that the purpose of social analysis is to consider the suitability of the proposed design to the project population and to suggest ways to improve the 'fit' between the two and to fashion strategies for project implementation that can be expected both to win and hold people's support and to achieve project goals by stimulating changes in social attitude and behaviour. In most communities water supply projects seem widely accepted as desirable, however acceptance of sanitation programmes has been difficult. It must be emphasised that planning and implementing both programmes together has a better chance of success, sometimes the only chance of success.

In designing water supply and sanitation projects social surveys must be carried out to reveal community preference. Elmendorf and Buckles (1980) mentioned that abundance and proximity are the principal factors associated with water supply while the most objectionable factors are cost and crowded water collection points. Most households desire greater accessibility through the installation of more taps at shorter distances. Again in water supply most people believe that the water quality is good if the water looks clean; by implication colour, taste and smell are important water quality criteria.

Kalbermatten *et al.* (1980), op. cit., stated that in sanitation an aesthetically attractive facility for excreta disposal with shining porcelain seat and brightly painted cement floor is preferred over cheaper, less attractive alternatives. Most people preferred sitting to squatting. Sharing of same latrine with some family members and outsiders is a social and cultural issue which must be reviewed during social feasibility analysis (Perrett, 1983). Continuous promotion of sanitation programmes is critical because even where initial acceptance is high without at least periodic promotion new families are unlikely to take the initiative to install a latrine.

Incentives: Communities can be made to accept sanitation easily together with water supply or a health clinic. In most communities the concern for improved water supply does exist but lack of economic resources, lack of leadership and lack of technical know-how are given as reasons for not implementing ideas. Elmendorf and Buckles (1980) op. cit stated that people, especially in the rural areas, are generally willing to provide time in work rather than pay more than a small amount. Communities value unity and progress more than time and money spent on community projects; social pressure, possible loss of goodwill and deterioration of solidarity are key factors motivating people to undertake community projects.

Project Design: Montgomery (1974) defined three important contributions of social science to project design. These include:

(a) Selection of technology.

(b) Means of diffusion of technology.

(c) Motivation for adoption of technology.

(a) Selection of technology

The important considerations in the selection of technology should be that it is technically efficient, cost efficient, can be understood by users, fulfils user's needs and expectation, is affordable and can be maintained by the user.

(b) Means of diffusion of technology

Channels and systems should be available for responsive administration, promotion of activities including health education, efficient delivery of service, instruction in operation, training in maintenance, effective delegation of authority and periodic monitoring.

(c) Motivation for adoption of technology

The community should be involved in project initiation, choice of level of service, location of facilities, scheduling of labour-intensive/self help activities, training in maintenance, decision on frequency for and mechanism for fee collection and enforcement of sanctions for unsatisfactory fee payment.

3.1.7 Environment Aspects

Water supply and sanitation projects show significant effects on the general environment. Various studies quoted by Saunders and other (1976), op. cit., indicate that provision of water supply and sanitation reduce a number of communicable diseases. Esrev *et al.* (1985) provided data on types of water supply and sanitation intervention and their corresponding reduction in diarrhoea morbidity. Indeed, improvement in public health constitutes the ultimate benefit of water supply and sanitation projects. For a project area, data should be gathered on mortality and morbidity rates, incidence of various water-borne, water washed, water based and water related diseases. From this base line data continuous monitoring after the completion of the project should indicate improvements in public health.

In water supply projects, surface water sources have to be protected from contamination through human activity in the catchment area. Lack of proper sanitation, use of chemical pesticides and fertilizer and erosion from poor agricultural practices adversely affect water sources. Watershed management techniques should be reviewed (Grover, 1983, op. cit.). Dams and other control structures provide low flow augmentation for use downstream but could affect the incidence of malaria, schistosomiasis and onchocerciasis. Flood control measures due to control structures should be reviewed. Effect of drought should be assessed using past experience. In the dry season, the incidence of certain diseases increase, for example, the African trypanosomiasis, as a result of people and tsetse fly congregating around muddy holes. Excessive withdrawal of groundwater could result in permanent fall in the water table which might increase land subsidence and also adversely affect the local vegetation. In water treatment, disposal of backwash water and sludge should be well conceived. Distribution of water involves effective management of pipe bursts and leaks which create pools of water increasing the incidence of malaria. Improved aesthetic design of structures should be encouraged especially as Griffiths and Klein (1983) mentioned the environmental impact of the water tower dominating the skyline.

In sanitation land pollution results from indiscriminate defecation and cause pollution of surface water sources increasing the incidence of a wide range of diseases during the rainy season. Use of pit latrines should not pollute groundwater sources. Inadequate collection and disposal of sullage and treated effluent could increase the incidence of Bancroftian filamasis, however, proper use of sullage and treatment effluent in household gardens could improve family income. Sludge from sewage treatment plants and pit latrines should be adequately disposed of through agricultural use, burial or drying and incineration where effects on air pollution should be monitored. Effect of effluent discharges on the ecosystem of receiving waters should be monitored.

3.2 PROJECT EVALUATION

3.2.1 Definition and Scope of Evaluation

Evaluation is the term used when a study is made during or after a project has been implemented to assess what lessons are to be learned and the extent to which the objectives of the project have been attained. Clarifying further the usage of terminology in project work, Hagebroek (1983) stated

> 'In AID (United States Agency for International Development) we distinguish evaluation from appraisal on time-wise basis. We use the term 'appraisal' to connote those preparatory and pre-investment assessment we made prior to funding a project or programme or adopting a policy or procedure. The term "evaluation" is reserved for assessment undertaken after a project, programme or other type of foreign assistance activity has been funded either during the implementation period or on ex-post basis.'

Evaluation, therefore, takes place as an on-going process often as part of monitoring and evaluation to ensure effective project execution by identifying and dealing with problems and issues that arise while the project is being implemented. In contrast, as Baum and Tolbert (1985), op. cit., pointed out, *ex-post* evaluation looks more broadly at the probable impact of the completed project in relation to the original expectations. It takes place at a later date when investment costs are firmly known, some benefits may already have been captured and earlier estimates of results can be updated although operating costs and benefits still lie in the future. This thesis is concerned with *ex-post* evaluation of water supply and sanitation projects.

3.2.2 Functions of Evaluation

Two functions of *ex-post* evaluation are identifiable. First, the learning function which is served by ascertaining the reasons for a project's apparent success or failure in order to pinpoint the features that deserve replication in future projects and to identify the pitfalls to be avoided. Second, the accountability function which is served by informing managers and those to whom they are responsible how far and how effectively individual projects are achieving the desired results.

Ex-post evaluation has the benefit of hindsight or to be exact partial hindsight and, thus, from that vantage point it will almost certainly disclose ways in which activities could have been better carried out. But if the process is to function well and serve its intended purpose it must be made clear to all concerned that mistakes are not being uncovered to point the finger of blame. The objective is to learn from them so that they are not repeated. Discussing the evaluation of water supply and sanitation projects WHO (1983) stated that evaluation does not in itself improve anything; it should not be just a listing of problems and their possible causes but should also include recommendations of the following types:

(i) action needed to get non-functioning facility into operation; to improve a facility; and to improve the utilization of a facility.

(ii) complementary activities that need to be initiated or re-emphasised for benefits to materialise or increase.

(iii) modifications needed for future projects.

(iv) actions needed to ensure that lessons learned are conveyed to other programmes and other agencies.

3.2.3 Methodology

Two methods employed to conduct evaluation are:

(i) *the cross-section method:* as with appraisal the ideal methodology for evaluation is a comparison of the 'with' to the 'without' the project situation. In practical terms this means choosing 'experimental' areas which have received the investment to be evaluated and comparing them to 'control' areas which have not received the investment but which in all respects are as similar as possible to the experimental areas. Thus the control area will have been subject to all the other changes affecting the region. Identifying suitable control areas in practice is often difficult.

(ii) *the longitudinal method:* a baseline survey conducted 'before' the investment is made is compared to an 'after' study of the same area carried out some years after the completion of the project. Critics of this method point to the existence of extraneous changes over time which will be difficult to isolate and remove from the 'after' survey results. This method poses particular difficulty in requiring that estimates be made of what would have been the trends without the investment.

3.2.4 Choice of Evaluators and Timing of Evaluation

Evaluation needs to be objective and should be based on wide experience so that the best people are those not directly involved or responsible for the planning and implementation of the project concerned. Independence of mind, judgement and experience are qualities to look for. However, the basic requirements are an enquiring, sceptical and challenging mind; the ability to think systematically and rigorously; openness to new ideas and sensitivity to the complexities and constraints of organisation. Naturally an evaluation by an expert of high repute lends weight to the results. WHO (1983) suggested that the person(s) should be familiar with the project or similar projects but should not be so closely involved as the outcome might be biased. ODA (1983) found that the most desirable teams comprised a combination of their own staff and hired academics or consultants. USAID also used combined teams of their staff, consultants and academics. Baum and Tolbert (1985), op. cit., mentioned that in the World Bank, one or two years after completion of disbursement, Bank operational staff, who were directly involved with preparation and implementation of the project, review the project by preparing a project completion report. This first stage of a two part process ensures both comprehensiveness and the participation of Bank operational staff. The second stage is assigned to the Operations Evaluation Department which reports separately to the President of the World Bank and the Bank's Executive Directors.

3.2.5 Work Programme

Normally a set of Terms of Reference will be drafted for the evaluation study. Thereafter the steps in an evaluation are likely to entail establishing the facts, processing the information, making judgements and lastly drawing conclusions and making recommendations to guide future action. The ODA has suggested the following stages for the evaluation process.

(i) *Definition of Objectives and the Project Plan:* What were the objectives of the project? (Quantifiable objectives can be readily evaluated but qualitative objectives can only be verified by observing the direction of trends.) Who were the intended beneficiaries? What were the main intended inputs and outputs? What assumptions underlay the project analysis? What was the implementation plan? What alternative methods of achieving the aims were considered?

(ii) *Analysis of Implementation:* This stage involves an analysis of what happened to the project and any problems that arose. Were inputs provided as planned? Were schedules kept to? Have outputs been achieved as expected? Have supporting ancillary services been adequate? What were the problems causing delay in implementation and what were the consequences of delay? Was the management of the project adequate? What were the strengths and weaknesses of the project implementation?

(iii) *The Project Achievement and Comparison of Objectives*: The comparison of what was actually achieved to that intended should be in terms of rate of return, total cost, output levels, completion dates and effect on target groups. This will involve the following questions: Did the project achieve its main objectives? Did the project objectives change during the life of the project? Were there unanticipated results of the project either beneficial or harmful? What were the most important factors explaining success or failure? Can an analysis of the costs and benefits be undertaken? Who were the main beneficiaries? Were there any alternative ways of achieving the desired output that might have been more cost effective.

(iv) *Reporting and Recommendation of Follow-up:* What are the key lessons to emerge from the project? What were the factors favourable or adverse which made for the relative success or failure of the project? Is new light thrown on particular areas or new problem areas revealed? How do findings compare with previous evaluations in the same field? What are the recommendations arising directly from this project for future similar projects or for the continued operation of this project?

3.2.6 Feedback

Evaluations are of little value if there is no mechanism operating to channel their conclusions back to project planners and administrators handling similar projects. Indeed Cairncross *et al.* (1980) stated that the two main purposes of *ex-post* evaluation are first to provide feedback to the project itself and second, to provide feedback to the planning process. Feedback may be a report to a committee or in the form of circulated memoranda and guidance notes. Most external aid agencies make available their evaluation reports to interested members of the public and to the governments of those countries within which the evaluation projects are located. Wiener (1983) indicated that the World Bank makes available all reports to all members of the Bank's evaluation 'audience' - member governments, management and staff.

3.2.7 WHO Minimum Evaluation Procedure

The WHO (1983), op. cit., proposed a relatively cheap, simple and quick method of evaluating water supply and sanitation projects. The basis of the evaluation procedure is that the benefits expected from water supply and sanitation projects cannot be fully realised unless the facilities are functioning in the correct way and there is full utilization of the facilities by the beneficiaries. The proposed procedure recognises three stage evaluations: they are functioning, utilisation and impact. Evaluation may focus on one or more of the three stages. There is little value in evaluating a particular stage unless the objectives of the previous stage have been largely achieved. Impact evaluation is generally more complex and costly to plan and carry out than functioning and utilisation of facilities. The proposed procedure excluded impact evaluation, however, some useful comments on impact evaluation have been made.

Procedure for Evaluation

The sequence of steps in the minimum evaluation procedure are: decision to evaluate; selection of persons responsible for the evaluation; desk study of project documents; field visit to plan the evaluation; selection of focus of the evaluation; collection of data; assessment of data; preparation of recommendations; review of the report; follow-up action.

Focus of Evaluation

Information obtained from the desk study of project documents should help define the focus of the evaluation. Where the initial field visit showed several problems with functioning of facilities there is no point in carrying out an evaluation of utilisation or impact. Within a project that consists of a number of individual water schemes functional aspects might be emphasised on schemes with functional problems; utilisation aspects on schemes which function well but have utilisation problems and for schemes with both satisfactory functioning and utilisation a special impact study could be carried out.

Evaluation of Functioning

Four indicators of the functioning of water supply facilities are described as:

(i) Water quantity
(ii) Water quality
(iii) Reliability of water supply
(iv) Convenience of water points.

(i) *Water quantity:* The design criteria specify consumption in litres per capita daily (lcpd) of 20-40 for standpipes; 40-80 for yard connection; 50-150 for house connection. Consideration should be given to shifts from standpost supply to yard connection to house connection. Allowance in consumption for livestock and seasonal variation in demand should be investigated. Data requirements include human and livestock populations, present consumption, water losses, present production, hours of supply, days of supply, trend in production, capacity of supply, peak supply capacity, seasonal variation in capacity and demand, bottlenecks in the system. For handpump schemes data required are maximum hourly capacity, population expected to be served by one pump and whether the wells dry up in the dry season. The data collected is assessed. Any discrepancies should be explained and possible action taken. Some actions to increase water availability include decrease in water losses through leak detection and repair programming, improved tap maintenance, educational programme and augmentation of limiting components in the system. Actions to increase water use include promotional campaign, change in pricing policy, construction of additional water points, promotion of yard and house connection and extension of distribution system.

(ii) *Water quality*: The target should be to deliver safe water which implies no bacteriological pollution, acceptable chemical properties, colour, taste and odour. Data for analysis are obtainable water quality surveys and sanitary surveillance. Reference should be made to the WHO Guidelines for Drinking Water Quality for guidance on water quality assessment. However if the source is surface water without treatment then it is likely the water is faecally contaminated; water from a protected groundwater source is uncontaminated. Tests for faecal pollution should be carried out on water sources and on water from taps. If chlorine residual exists there is no need for bacteriological tests. Samples from household storage should be tested. Observation of household practices in the use of water is recommended. Data collected should be assessed and possible courses of action proposed. Action may include installation of a slow sand filter. High levels of fluoride and nitrate might cause abandonment of source. Hygiene education might be required to modify undesirable household practices.

(iii) *Reliability of Water Supply*: Although it is assumed at the planning stage that supply will be continuous throughout the year this is hardly the case. Alternative source in use during breakdowns should be noted. Data should be collected on the frequency and duration of outages in the supply of water. Note that outages can be complete or partial, that is, either portions of the system such as treatment is not functioning or portions of the water points are not functioning. Low reliability is due mainly to poor maintenance, poor design, poor construction or a combination of these. Poor maintenance is remedied through adequate finance, good programme and trained staff. Poor design might be due to inappropriate technology dependent on inadequate supply of scarce fuel. Poor construction might be due to lack of supervision and poor workmanship.

(iv) *Convenience of Water Points:* Design criteria should indicate maximum distance from households to the water points. Where there is marked seasonality it is possible for traditional sources to be closer in wet season than the new supply. Traditional wet weather sources and distances from the houses to the source should be determined. The data collected will be assessed; if the proportion of households located further from waterpoints than the specified distance is excessive or if the households are foresaking the new supply in favour of traditional sources more conveniently located, then more water points should be provided.

Indicators of Functioning of Sanitation Facilities

For sanitation three indicators of functioning are identified as:

(i) Proportion of households that have improved latrines.
(ii) Sanitation hygiene.
(iii) Sanitation reliability.

(i) *Proportion of households that have improved latrine:* The proportion of households with sanitation facilities will be obtained through a house-to-house survey. After assessing the data reasons should be assigned to the current coverage and action should be recommended as appropriate. For example, promotional activities and workshops should be organised to motivate more families to build latrines. Certain families who cannot afford current designs should be assisted to simplify design or cheaper designs should be provided.

(ii) *Sanitation hygiene:* Unhygienic latrines deter people from using them. The aim must be to curtail insect breeding, smell and fouling through appropriate design. Condition of the latrine should be assessed through physical inspection. Other factors such as the presence of lid on the latrine and water in the water seal must be noted. Possible actions to be taken include improved design, promotion and hygiene education.

(iii) *Sanitation reliability:* Failures due to inappropriate design, construction or maintenance can deter people from participation in latrine programmes and should be kept to a minimum. For each type of latrine the criteria for proper functioning should be identified. For example, a VIP latrine should have a vent pipe with mosquito screen intact. House to house surveys should provide data on failures in reliability. Possible causes of failure include poor design, poor construction, poor operation and maintenance and poor back-up services. Appropriate action on the above causes should be recommended.

Hygiene Education

Hygiene education in support of water supply and sanitation projects is best carried out in local languages by local people who are trusted and who have similar ethnicity, class, life style to the project beneficiaries. Hygiene education should be organised within the context of the primary health care programme with women as the principal target group. Four indicators of the functioning of hygiene education are:

(i) Understanding the language of the message.
(ii) Understanding the content of the message.
(iii) Access to messages.
(iv) Face to face contact with project staff and other educators.

The language and the message should both be readily understood. Sample of audience should be tested with some of the hygiene education messages. If more than 10 per cent do not show understanding, then the messages should be redesigned to incorporate indigenous concepts of purity, pollution and cleanliness.

Access to messages will depend upon the media employed, which media include, cinema, radio, television, newspapers, posters and pamphlets. A high degree of access of the target audience to the particular media used is required. Assessment of the population access to the media used should indicate whether media should be retained or an alternative sought.

It is suggested that project staff in face to face contact with project beneficiaries can reinforce the messages of the media. A survey should find out how much over a specified period of, say, one month when project staff have been in direct contact with beneficiaries. Possible actions to be taken will include organisation of a workshop to extend the knowledge of project staff, and encourage more contact with the project beneficiaries.

Evaluation of Utilisation

In water supply two indicators of utilisation are:

(i) Proportion of household using facilities.

(ii) Volume of water used and for what purpose.

(i) *Proportion of household using facilities:* Everyone within the supply area should be encouraged to use the facility throughout the year unless they have a private source of water. Data should be obtained about who are the users and non-users of the facility. Distances from the household to the water point should be measured and non-users should be asked for their reasons for non-use of facility. Data will be collected through household surveys and physical observation at the water points. Action to be recommended will depend on the reasons given for non-use of the facility.

(ii) *Volume of water used and for what purpose:* Water supply facilities are normally designed to cater for all domestic needs such as drinking, cooking, washing of food, utensils, clothes and personal washing. Water for domestic animals and possibly for watering gardens are allowed for in the estimates of water demand. Data will have to be obtained on the total daily water use per capita for different levels of service and the allocation of water used for various purposes. Information should be obtained through observation and interviews at the water points and households. At the same time information about daily and seasonal alternative water use should be obtained. Data will be assessed by comparison with design criteria. If water use is below the design criteria promotional and educational programmes will be required. Alternatively, design criteria should be revised to avoid over-design. If water use is too high, design criteria should be revised to avoid water shortages in future designs. If wastage is detected then there should be educational campaigns to stop wastage or water saving plumbing fixtures must be installed or a progressive tariff policy with metering could be introduced.

Indicator of Utilisation of Sanitation Facilities

The indicator of utilisation of sanitation facilities is the proportion of the people using the facilities. The target is to get as many household members as possible of all households to use the facilities. Particular attention should be given to toddlers and young children who may require special arrangements. Since observation of latrines to determine usage is regarded in most societies as an invasion of privacy, a combination of subtle interviewing with signs of usage should be used. Reasons for non-use should be obtained as well. Information is also needed on the use of latrine by younger children, at what age they start using the latrine and where they defecate before that age. Data should be assessed on the basis that expected benefits will not materialise if a large proportion of household members do not use the sanitation facilities. Various possible actions can be taken for non-use. For example, where women are not to use the same latrine as men in the household, separate latrines should be built for women. Designs should be modified for children or alternatively separate facilities could be provided. Adults could be educated on washing hands after defecation. Where latrines are inconveniently located location should be changed or additional latrines built.

Indicators of Utilisation of Hygiene Education

Three indicators are suggested for the utilisation of hygiene education. Behaviour in respect of the indicators in the project area may be compared either with baseline study or with behaviour in a comparison area. The indicators are:

(i) Water storage habits.
(ii) Handwashing after defecation.
(iii) Knowledge of oral rehydration.

Data on all indicators will be obtained through interviews and observation, in the project area of households with facilities and households without facilities. Where there are no changes in behaviour the education techniques need to be altered. Primary health care workers should teach mothers oral rehydration method of treating diarrhoea.

Evaluation of Impact

The purpose of impact evaluation studies, according to WHO (1983), op. cit., could be:

(i) To establish if an investment in water supply sanitation and/or hygiene education has resulted in improved health and/or economic status among those served by the facilities.
(ii) To establish the relative impact of investment in water supply versus sanitation versus hygiene education.
(iii) To establish the relative impact of alternative levels of service.
(iv) To establish economic rates of return for investment in water supply, sanitation and hygiene education to be compared with rates of return for alternative investment.

It has been shown in a number of evaluation studies that if water supply and sanitation facilities function well and are properly used, there are reductions in disease morbidity, in particular, diarrhoeal diseases among children.

Conclusions of various impact studies are presented below. Saunders and Warford (1976), op. cit., reviewed 28 impact studies and concluded that the incidence of certain diseases are related to the quality and quantity of water supply and sanitation facilities available to users. However, it was not possible to determine from the studies made how much health improvements can be expected from a specific water supply and sanitation investment in a specific area.

Hughes (1981) concluded after reviewing 43 published studies that morbidity reductions of 20 per cent or more are usually statistically significant and frequently observed.

McJunkin (1982) reviewed 200 publications and concluded that:

(i) There are health impacts where safe water is readily available in adequate quantities.

(ii) The present state-of-the-art of epidemological forecasting makes it difficult, if not impossible, to predict with accuracy the incremental health status improvements that might be expected from incremental improvements in water supply and sanitation.

(iii) Evaluation of health impacts usually require major investment in time and skilled manpower and should be limited to research projects with adequate resources.

Briscoe *et al.* (1986) indicated that the literature is replete with examples of Health Impact Evaluation of water supply and sanitation projects that have been undertaken under conditions in which satisfactory evaluation could not satisfy the three criteria of being useful, sensible and feasible; useful, that is, the benefits outweigh the cost; sensible, that is, it is reasonable to assume that measurable health impacts exist; and feasible, that is, the necessary scientific and other resources are available. The case-control method of Health Impact Evaluation is outlined. This method proceeds backwards from effect to cause by comparing the incidence of water supply and sanitation among two groups of people - those with diarrhoea and those without it. The advantages of the method are listed as smaller sample sizes, better reliability of information, evaluation initiated only after proven functioning and utilisation of facilities and that the method is quick and easy to compare with other methods.

3.3 LOGICAL FRAMEWORK APPROACH

The logical framework approach (LFA) is a system of project planning defined by Cracknell and Rednall (1986) as a set of interlocking concepts which can be used together in a dynamic fashion to develop a well designed, objectively-described and evaluable project. LFA expresses the cause-effect linkage between the various levels of project objectives and sets out the means of achieving them. LFA has two distinctive elements, namely the hierarchy of objectives and the matrix of four rows and four columns for presenting an analysis of the means and ends which go to form a project.

The hierarchy of objectives are expressed as Inputs, Outputs, Purpose or Immediate Objectives, and Goal or Wider Objectives (Sectoral or National). The elements of the hierarchy are considered necessary for effective identification, appraisal, monitoring and evaluation of projects. Inputs are not objectives *per se* but they are the various activities and resources which are necessary to achieve the outputs of the project. It includes what materials/equipment or services are to be provided, at what cost and over what period. Outputs specify the kinds of output, quantities of output, and the time limits for achieving each output. Outputs, indeed, are quantified, time bound targets which should be realised in order to achieve the purposes or immediate objectives of the project. The purposes or immediate objectives are the intended immediate effects on the project area or the target group. They include the expected benefits (or disbenefit) and the distribution of such benefits; any improvements or changes expected from the project are specified. The goal or wider objectives of the projects are the wider sectoral or national objectives which the project will help to attain. These objectives are the overall reasons for implementing the project.

The matrix can be presented as a narrative but it is normally shown as a table. The typical matrix is presented in Table 3.3. Numerous variants exist. For example, in some organisations a row of 'Activities' is introduced to link Inputs and Outputs but the 'Goal' level is omitted. Other organisations introduce an additional row in between 'Purpose' and 'Goal' levels to make room for intermediate objectives.

Table 3.3 **The Logical Framework Matrix**

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Goal: Overall reason for the project; desired end towards which efforts are directed.	What are the quantitative ways of measuring, or qualitative ways of judging whether the goal has been achieved.	What sources of information exist or can be provided cost-effectively.	Assumptions and specific events which are beyond project control but influencing achievement of the goal.
Purposes: Achievements expected if the project is completed successfully and on time.	What are the quantitative measures (including the realised internal rate of return) by which achievement and distribution of effects and benefits can be judged?	What sources of information exist or can be provided cost-effectively? Does provision for collection need to be made under Inputs-Outputs.	What are the factors not within the control of the project, which, if not present, are liable to restrict progress from Outputs to achievement of Purposes.
Outputs: Results, products or installations expected from good management of the project inputs.	Inventory of what has been produced or installed and when.	Sources of data, data collection methods and data analysis to assess whether outputs were accomplished.	What external factors must be realised to obtain planned Outputs.
Inputs: Activities and resources used to produce the outputs.	List of resource inputs and activities necessary to produce outputs.	Sources of data, data collection methods, and data analysis to quantify inputs.	What decisions or actions outside project control are necessary for inception of project.

(Source: Cracknell and Rednall, 1986.)

The first column of the matrix shows the hierarchy of project objectives. The logic of this column is that if resource inputs are provided on time and certain activities take place then project outputs will be realised; if the outputs are realised, then the project purpose will be achieved; if the project purpose is achieved, this contributes to the overall goal. In order to construct the matrix the goal of the project is determined, then the purpose is derived. The expected project output to achieve the purpose is determined and then the required project inputs to achieve output are determined.

The fourth column is the next to be tackled starting at the bottom by examining whether there are any assumptions to be made in the form of events outside the direct control of the project which must also take place to guarantee successful realisation of project outputs. Similar assumptions are made as outputs and purpose are considered and also for purpose and goal. In this way assumptions on every level of objectives are obtained and their importance together with their probability of occurrence are evaluated. Assumptions which are very important for the success of the project and have a low probability are considered crucial requiring close monitoring. Indeed, if an assumption is evaluated as improbable it becomes a so-called 'killer assumption' necessitating a redesign of the project.

The second column establishes the objectively verifiable indicators by which the degree of success of the project will be measured. Good indicators specify three dimensions: quality, quantity and time.

Finally, the third column provides the description of the sources and means for verifying indicators. When no information is available for a particular indicator then a cost-effective method of collecting the information should be found or else another indicator easier to verify should be substituted. Some project planners construct the matrix as they work through the project, others prefer to complete the matrix on completion of project planning to reveal any gaps in their thinking. Still others have used the Logical Framework as a background to what is called 'Brainstorming' by a group of people with experience and relevant skills to thrash out the nature of the problem and out of that process the project begins not evolve. In organisations using LFA the matrix is one of the documents presented to the approval authority. However, the matrix is expected to be revised as the project progresses and monitoring and evaluation reveal changing project circumstances. The matrix is used to computerise and store information on the hierarchy of objectives together with successive monitoring and evaluation reports. Lessons learned on *ex post* evaluation are also stored. Cracknell and Rednall, op. cit. recognise the limitations of the LFA methodology and state that, in itself, it gives no guidance on many essential aspects of project appraisal and design. Indeed it does not supplant, for example, cost benefit analysis or technical, financial or institutional appraisal. However it provides a consistent and logical framework within which different disciplines can be brought to bear on a project, seeing the project as more than a package of inputs and outputs.

Logical Evaluation Framework

LFA used in project design provides a basis for evaluation planning. Through clear definition of project objectives, verifiable indices (to measure achievement of objectives) and project assumptions (risks) *ex post* evaluation can be planned to provide meaningful and reliable conclusions. LFA stipulates baseline data requirement which should be collected during the feasibility study surveys. Early planning of evaluation through the LFA ensures that the baseline data and the *ex post* evaluation data are comparable. The Logical Evaluation Framework based on the LFA permits separate evaluation of project efficiency, effectiveness and impact. Evaluation of project efficiency, according to McGarry and Tam (1986), is primarily concerned with how outputs were achieved given project inputs and activities. The amount and quality of outputs are compared with the resources and means mobilised. Efficiency evaluation deals with management issues, for example, whether or not the resources were supplied at the appropriate levels, on time and whether they were well managed. Project effectiveness evaluation looks at the achievement of project purposes. In the case of water supply and sanitation projects an evaluation is made of whether facilities are functioning and if they are being well utilised. It may also comment on achievement of project output and project goal. Impact evaluation, however, is mainly concerned with project goal. It pertains to the effect of the project on the recipient population, the development of the sector and the country as a whole. Impacts will be both positive and negative, foreseen and unforeseen.

McGarry and Tam (1986), op. cit., outlined the logical evaluation framework specifically for impact evaluations involving economic, health, social, environmental, developmental, technical and political impacts. The scope of the evaluation is determined by the impacts considered relevant. An example of a typical evaluation of rural water supply and sanitation project concerning specifically social, economic and organisational impacts is outlined.

CHAPTER FOUR

THEORETICAL FRAMEWORK: DATA ENVELOPMENT ANALYSIS

4.1 OVERVIEW

Performance evaluation of public sector organisations which employ multiple inputs to produce multiple outputs have been tackled by various researchers (Charnes *et al.*, 1981). In general when the profit motive is absent and the criteria for desirability are not so obvious it is common to use reference groups for goal setting and performance evaluation. Thus citizens and managers evaluate their public agencies in relative terms, looking for improvement over time and making comparisons with similar public agencies. Difficulties with comparative approaches involve lack of any acceptable aggregate performance measures, problems with combining multiple performance measures and further problems with relating performance measures to utilisation of multiple inputs. A major problem stems from the multi-dimensionality of measures which cannot be valued through market prices and therefore remain non-commensurable. Lewin and Morey (1981) suggested that it would be desirable to have a procedure capable of:

1. Deriving a single summary measure of the relative efficiencies of a set of decision making units (DMUs), such as local governments, in terms of their utilization of input to produce outputs.

2. Handling non-commensurate multiple outputs and input factors.

3. Not being dependent on a set of *a priori* weights or prices.

4. Handling qualitative factors such as 'sensitivity to public needs' in addition to quantitative factors.

5. Be theory-based, transparent and reproducible.

6. Be equitable and defensible.

The Data Envelopment Analysis (DEA) technique has all the desirable features mentioned above. DEA is a procedure that has been designed specifically to measure relative efficiency in situations where there are multiple inputs and outputs and there is no obvious objective way of aggregating either inputs or outputs into a meaningful index for productive efficiency. Further the DEA procedure is designed for evaluating the relative efficiency of the public sector DMUs performing similar missions and for which actual measures of input factor and outputs (performance indicators) are available. DEA is based upon the economic notion of Pareto Optimality. Charnes *et al.* (1981), op. cit., stated the Pareto efficiency conditions as follows:

1. *Output Orientation:* A DMU is not efficient if it is possible to augment any output without increasing any input or without decreasing any other output.

2. *Input Orientation:* A DMU is not efficient if it is possible to decrease any input without augmenting any other input or without decreasing any output.

A DMU will be characterised as efficient, if and only if, neither (1) nor (2) obtains. (For further explanation on Pareto Optimality see Baumol (1972), op. cit., and Call and Holahan (1983).)

DEA has been applied in such diverse fields as education (Bessent *et al.*, 1982), electricity production (Fare and Primond, 1984), criminal justice (Lewin *et al.*) recreation (Rhodes, 1982), health care (Sherman, 1984) and Real Property Maintenance Activities (Bowlin, 1987). In this thesis DEA is applied to Water Supply and Sanitation Projects in a developing country, Ghana. Inputs into water supply and sanitation projects are characterised by technical, financial, economic, institutional, social and environmental factors while output factors include reliability, utilization and convenience. These factors are largely non-commensurate and cannot be aggregated in any objective manner. To date assessment of inputs at project appraisal rely on both quantitative and qualitative indicators to forecast outputs which are themselves expressed in both quantitative and qualitative terms. A limited scope of project appraisal would assess quantitatively the least cost of investment in water supply and/or sanitation project to produce some health benefit assessed qualitatively. Accepting the least cost option does not indicate whether the costs are higher or lower than the benefit because costs and benefits are non-commensurate. Further in project evaluation assessment of, say, project outputs measured by reliability and user convenience *vis-a-vis* project inputs such as social involvement and technical factors cannot provide a single objective answer. Attempts to improve objective assessment have employed a matrix of weights which is fraught with arbitrariness. DEA deals with these problems to provide a single objective measure of project efficiency assessed relative to the best practice in the sector.

4.2 FORMULATION OF THE DATA ENVELOPMENT ANALYSIS METHOD

The Data Envelopment Analysis technique was developed by Charnes, Cooper and Rhodes (1978) based on a concept of efficiency originally proposed by Farrell (1957). The usual output/input ratio measure of efficiency is formulated in terms of a fractional mathematical programming model. The relative technical efficiency of any DMU is calculated by forming the ratio of a weighted sum of outputs to a weighted sum of inputs where the weights for both outputs and inputs are to be selected in a manner that calculates the Pareto efficiency of the particular DMU. The DEA methodology solves the resulting non-linear fractional mathematical programming problem for each DMU.

Output weights U_1, U_2,......U_S (one for each output) and

Input weights V_1, V_2,......V_M (one for each input) are selected so that the weights are non-negative and also so that the ratio of the weighted outputs to the weighted inputs for the DMU in question is maximised subject to the constraint that the ratios of weighted outputs to weighted inputs for each DMU is equal to or less than 1.0. Thus there are S plus M variables and N constraints, where N is the total number of DMUs being compared. The formulation is as follows (Lewin and Morey, 1981, op. cit.).

The Objective Function

$$\text{Maximise} \quad \frac{\sum_{r=1}^{S} U_r Y_{rj_0}}{\sum_{i=1}^{M} V_i X_{ij_0}} \qquad [1]$$

subject to the constraints

$$\frac{\sum_{r=1}^{S} U_r Y_{rj}}{\sum_{i=1}^{M} V_i X_{ij}} \leq 1 \quad j = 1,2....j_0....N$$

$U_r \geq 0; \quad r = 1, 2.....S$

$V_i \geq 0; \quad i = 1, 2.....M$

where Y_{rj} = observed amount of r^{th} output for the j^{th} DMU

$(r = 1, 2,.....S; \; j = 1, 2.....j_0.....N)$

and X_{ij} = observed amount of i^{th} input for the j^{th} DMU

$(i = 1, 2,.....M; \; j = 1, 2.....j_0.....N)$

In some formulations the variables U_r, V_i are required to be strictly positive. However Silkman (1986) stated that it is unlikely that such cases will be encountered in applications and the strict positivity requirement complicates the analysis without providing real benefit. Consequently, it is ignored.

The fractional mathematical programme formulated in [1] is non-linear and non-convex but can be transformed into either one of two linear programmes which can be solved using the Simplex method.

The problem is to find a set of weights U and V to maximise the efficiency of DMU in question subject to the constraint that no other DMU has an efficiency ratio exceeding unity using the same set of weights. The solution method ensures that efficiency scores lie between 0 and 1 with a fully efficient DMU having a score of 1.

The first formulation is as follows:

$$\text{Maximise} \quad \sum_{r=1}^{S} U_r Y_{rj_0} \qquad [2]$$

subject to

$$- \sum_{r=1}^{S} U_r Y_{rj} + \sum_{i=1}^{M} V_i X_{ij} \geq 0 \quad (j = 1, 2 \ldots j_0 \ldots N)$$

$$\sum_{i=1}^{M} V_i X_{ij_0} = 1$$

$$U_r \geq 0 \; ; \quad r = 1, 2 \ldots S$$

$$V_i \geq - \; ; \quad i = 1, 2 \ldots M$$

The above formulation constrains the weighted sum of the inputs to be unity and maximizes the outputs that can be obtained.

The second formulation constrains the sum of the weighted output at unity and minimizes the inputs needed. Its formulation is as follows.

$$\text{Minimise} \quad \sum_{i=1}^{M} V'_i X_{i,j_0} \qquad [3]$$

subject to

$$0 \leq - \sum_{r=1}^{S} U'_r Y_{r,j} + \sum_{i=1}^{M} V'_i X_{ij} \quad (j = 1, 2 \ldots j_0 \ldots N)$$

$$\sum_{r=1}^{S} U'_r Y_{r,j_0} = 1$$

$$U'_r \geq 0 \; ; \quad r = 1, 2 \ldots S$$

$$V'_i \geq 0 \; ; \quad i = 1, 2 \ldots M$$

The optimal value of [2] is the efficiency score of the DMU in question and should lie between 0 and 1. The optimal value is 1 if, and only if, the DMU is efficient.

The optimal value of [3] is the inverse of the optimal value of [2]. The optimal value of [3] is 1 if, and only if, the DMU in question is efficient.

The Dual of the DEA Linear Programme (Silkman, 1986, op. cit.)

In the theory of linear programming, every linear programme has a companion linear programme which is called its dual. The dual problem which uses a completely different set of variables has its own set of constraints and its own objective function expressed in terms of those variables. There are formal rules for the construction of the dual problem and there are standard ways of interpreting the values of the dual variables. Moreover linear programming theory teaches that when the simplex method is applied to any linear programme, not only do we obtain its optimal solution, we also obtain the optimal solution to the dual problem. Thus, with no additional computational effort whenever we solve the problem (DEA), we also solve its dual; that is, we obtain the values of the dual variables that optimize the dual objective function while satisfying all the dual constraints.

The formulation, representing the linear programming dual of [2] is as follows:

$$\text{Minimise } [Q_0] \qquad [4]$$

subject to

$$\sum_{j=1}^{N} P_j Y_{rj} \geq Y_{r,j_0} \qquad r = 1, 2.....S$$

$$-\sum_{j=1}^{N} P_j X_{ij} + Q_0 X_{ij_0} \geq 0 \qquad i = 1, 2.....M$$

$$P_j \geq 0 \qquad j = 1, 2.....j_0....N$$

Q_0 is unrestricted in sign

subscript 0 refers to the DMU in question i.e. j_0^{th} unit

where Y_{rj} = observed amount of r^{th} output for the j^{th} DMU

and X_{ij} = observed amount of i^{th} input for the j^{th} DMU

Q_0 = decision variable for the DMU in question i.e. j_0^{th} unit

P_j = dual variables

Thus there are N+1 variables made up of one P variable for each of the N DMUs and one Q variable. Also there are r plus i constraints (number of outputs plus number of inputs). The j_0^{th} DMU is Pareto efficient if and only if the optimal value of $Q_0 = 1$. Further the reference set for the j_0^{th} DMU is that subset of DMUs ($j = 1, 2....j_0....N$) for which $P_j > 0$ in the optimal solution.

Similarly, the formulation representing the linear programming dual of [3] is:

Maximize $[Q_0']$ [5]

subject to

$$\sum_{j=1}^{N} P_j' X_{ij} \geq X_{ij_0} \qquad i = 1, 2.....M$$

$$-\sum_{j=1}^{N} P_j' Y_{rj} + Q_0' Y_{rj_0} \geq 0 \qquad r = 1, 2.....S$$

$$P_j' \geq 0; \qquad j = 1, 2.....j_0.....N$$

Q_0 is unrestricted in sign

subscript 0 refers to the DMU in question i.e. j_0^{th} unit

where Y_{rj} = observed amount of r^{th} output for the j^{th} DMU

and X_{ij} = observed amount of i^{th} input for the j^{th} DMU

Q_0' = decision variable for DMU in question j_0^{th} unit)

P_j' = dual variables

The j_0^{th} DMU is efficient if and only if the optimal value of $Q_0' = 1$. The optimal value of Q_0 is equal to the inverse of the optimal value of Q_0'.

4.3 A GRAPHICAL APPROACH TO DEA

4.3.1 Single Output and Multiple Inputs

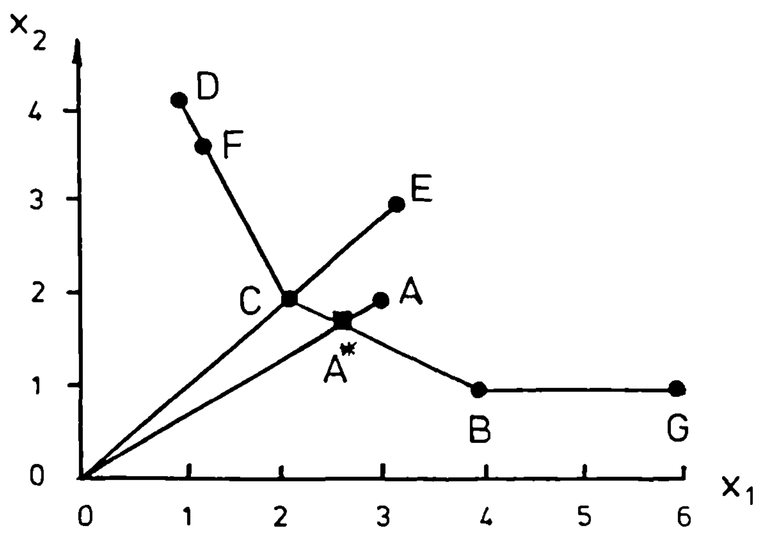


Figure 4.1: Single Output and Multiple Inputs

Source: Barrow and Wagstaff (1989)

In this example there are seven DMUs all producing a single output Y with two input (X_1, X_2). It is assumed that all seven authorities produce one unit of output. (This assumption is not critical since we can express each input level as input per unit output, that is, to divide each input level at a given DMU by the output level of that DMU. This has the effect of normalising the input levels of the DMUs and of making it possible to compare the normalised input levels across DMUs.) The inputs of the DMUs are A(3, 2), B(4, 1), C(2, 2), D(1, 4), E(3, 3), F(1.25, 3.5), G(6, 1).

The DMUs are plotted on the graph Figure 4.1 using the inputs X_1, X_2. In principle any DMU that is lower than and to the left of another DMU is more efficient than that DMU because it is producing the same unit of output but is using lower levels of both inputs. It follows that we may view the origin as the ultimate goal towards which all DMUs strive as they attempt to become more efficient. Measuring the technical efficiency of a DMU requires an estimate of the location of the efficient unit isoquant. This efficient unit isoquant is obtained by picking adjacent pairs of DMUs and joining them with a line segment. If the line segment has a non-positive slope and none of the other DMUs lies between it and the origin the chosen DMUs are declared efficient. Otherwise they are not. The line segments linking all the efficient DMUs trace out the efficient isoquant. This isoquant envelops all the inefficient DMUs hence the term 'data envelopment analysis'.

Points at the kinks (such as B and C) represent real DMUs. Points between the kinks represent hypothetical DMUs formed by taking weighted averages of the input levels of the DMUs at the ends of that segment. DMU F is obtained by taking three-quarters of D's input levels and a quarter of C's input level. DMU A is inefficient and therefore a line joining A to the origin crosses the isoquant at point A* which lies between B and C. DMUs B and C are termed the reference set of DMU A. Point A* refers to a hypothetical DMU formed by a weighted average input of the DMUs in the reference set and it is efficient because it lies on the efficiency frontier. The technical efficiency of DMU A is measured as OA*/OA. The DMU E is inefficient but has only one DMU in its reference set i.e. DMU C. This is because DMUs C and E employ inputs in the same ratio but E employs more of each input to produce the same output. DMU G is technically efficient but it employs more of input X_1 than DMU B does. DMU G is said to have 'slack' in its usage of input X_1.

To compute the efficiency of DMU A we restate the linear programming model in [4].

Technical Efficiency = Min $[Q_0]$

subject to

$$\sum_{j=1}^{N} P_j Y_{rj} \geq Y_{rj_0} \quad ; \qquad r = 1.....S \text{ (output)} \qquad [6]$$

$$-\sum_{j=1}^{N} P_j X_{ij} + Q_0 X_{ij} \geq 0 \quad ; \qquad i = 1. ...M \text{ (inputs)} \qquad [7]$$

Apply [6] to DMU A and the reference set DMUs B and C we have

$$P_B(1) + P_C(1) = 1 \qquad \text{(output)} \qquad [8]$$

Apply [7] to DMU A and the reference set DMUs B and C we have

$$4P_B + 2P_C = 3Q_A \qquad \text{(input } X_1\text{)} \qquad [9]$$

and $$P_B + 2P_C = 2Q_A \qquad \text{(input } X_2\text{)} \qquad [10]$$

Solving [8], [9] and [10] we have

$$P_B = {}^2/7; \quad P_C = {}^5/7; \quad Q_A = {}^6/7.$$

Therefore DMU A has efficiency score of $^6/7$ and the hypothetical DMU A* is formed by taking 5/7 of DMU C and 2/7 of DMU B.

In the case of DMU G it is DMU B which acts as the reference DMU. Therefore considering input X_1

$$4P_B \leq 6Q_G \qquad [11]$$

and considering input X_2

$$1P_B = 1Q_G \qquad [12]$$

and for output

$$P_B = 1 \qquad [13]$$

From [12] and [13]

$P_B = 1$ and $Q_G = 1$; therefore DMU G is efficient.

From [11] DMU G has two surplus units of input X_1.

To check the computation of Technical Efficiency of DMU A we restate the fractional programming model [1].

$$\text{Technical Efficiency} = \text{Max} \frac{\sum_{r=1}^{S} U_r Y_{rj_0}}{\sum_{i=1}^{M} V_i X_{ij_0}} \qquad [14]$$

Subject to

$$\frac{\sum_{r=1}^{S} U_r Y_{rj}}{\sum_{i=1}^{M} V_i X_{rj}} \leq 1 \qquad [15]$$

Apply [15] to DMU B.

$$\frac{1U}{4V_i + 1V_2} = 1 \qquad [16]$$

Apply [15] to DMU C.

$$\frac{1U}{2V_1 + 2V_2} = 1 \qquad [17]$$

From [16] and [17] $V_2 = 2V_1$.

Substituting in [16]

$$\frac{U}{V_1} = 6$$

$$\text{Efficiency of DMU A} = \frac{1U}{3V_1 + 2V_2} = \frac{1U}{7V_1} = \frac{6}{7} \qquad [18]$$

From [16], [17], [18]

$U = 1; \; V_1 = {}^1/6; \; V_2 = {}^1/3.$

4.3.2 Single Input and Multiple Output

In Figure 4.2 there are five DMUs (A, B, C, D and E) all producing output Y_1 and Y_2 with a single input X. The output mixes of the DMUs differ and are as follows:

A(2,3), B(5,1), C(3,3), D(1,4) and E(2,2).

Inefficient DMUs are separated from efficient DMUs by joining adjacent pairs of DMUs with a line segment. If the line segment has a non-positive slope and none of the other DMUs lies to the north-east of it, the chosen DMUs are declared efficient. Otherwise they are not. DMUs C and D are efficient but DMU A is inefficient. The envelope of efficient DMUs constitute a production possibility frontier or the efficiency frontier which serves as a benchmark against which the inefficient DMUs are compared. The hypothetical DMU A* is formed by taking weighted averages of efficient DMUs C and D and is therefore also efficient. However DMU A uses the same input as A* but produces less outputs. The efficiency of DMU A is measured as OA/OA*.

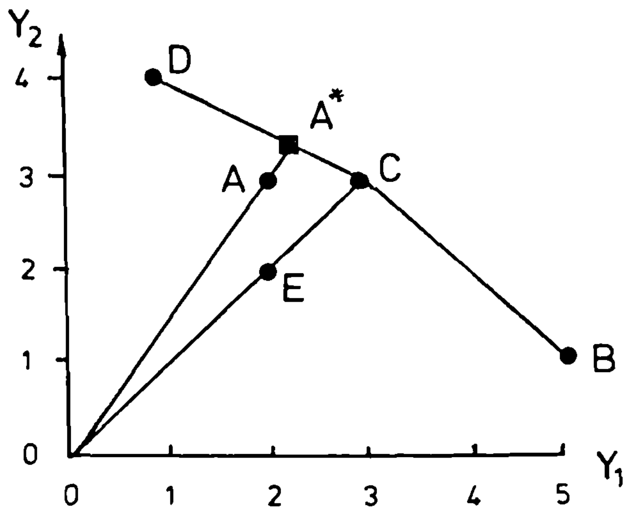


Figure 4.2: Single Input and Multiple Outputs

Source: Barrow and Wagstaff,(1989)

Let the weights required to create DMU A* be P_C and P_D for DMUs C and D respectively, and Q_A be the efficiency of DMU A. To compute the efficiency of DMU A we restate the linear programming model in [4].

Technical Efficiency = Min $[Q_0]$
subject to

$$\sum_{j=1}^{N} P_j Y_{rj} \geq Y_{rj_0} ; \qquad r = 1.....S \text{ (output)}$$

$$-\sum_{j=1}^{M} P_j X_{ij} + Q_0 X_{ij_0} \geq 0; \quad i = 1....M \text{ (input)}$$

The reference set for DMU A are DMUs C and D.
Therefore for output Y_1

$$3P_C + 1P_D = 2 \qquad [19]$$

For output Y_2

$$3P_C + 4P_D = 3 \qquad [20]$$

For input

$$P_C + P_D = Q_A \qquad [21]$$

From [19], [20] and [21]

$P_C = {}^5/9; \quad P_D = {}^1/3; \quad Q_A = {}^8/9.$

To verify the technical efficiency of DMU A restate the fractional programming model [1].

$$\text{Technical Efficiency} = \text{Max} \frac{\sum_{r=1}^{S} U_r Y_{rj_0}}{\sum_{i=1}^{M} V_i X_{ij_0}}$$

subject to

$$\frac{\sum_{r=1}^{S} U_r Y_{rj}}{\sum_{i=1}^{M} V_i X_{rj}} \leq 1$$

For DMU C

$$\frac{3U_1 + 3U_2}{1V} = 1 \qquad [22]$$

For DMU D

$$\frac{1U_1 + 4U_2}{1V} = 1 \qquad [23]$$

From [22] and [23]

$$\frac{U_1}{V} = \frac{1}{9} \quad \text{since } U_2 = 2U_1$$

Efficiency of DMU A

$$\frac{2U_1 + 3U_2}{1V} = \frac{8U_1}{V} = \frac{8}{9} \qquad [24]$$

There U_1 = $^1/9$; U_2 = $^2/9$; Efficiency = $^8/9$ as above.

4.3.3 Multiple inputs and multiple outputs

This condition cannot be represented graphically. The linear programming models have to be formulated in the usual manner and solved by the simplex method using either main frame computer systems or software adapted for microcomputers. Silkman (1986) op. cit., estimated that in most practical situations these linear programmes will be small with no more than ten decision variables and a few hundred constraints. Personal computers have the capacity to solve such problems.

4.4 LIMITATIONS OF DEA

1. DEA requires all inputs and outputs to be specified and measured. Failure to include a valid input or output will bias the results against efficient users of the input or efficient producers of the output. Inclusion of an invalid input or output causes some DMUs to be rated as more efficient than they really area. Thus DEA must be properly structured.

2. DEA assumes that each unit of a given input or output is identical to all other units of the same type. Thus, on the input side, skilled personnel are considered to have same level of skill although in practice one may be more experienced and better trained than another. On the output side a unit of water utilization in a rural water project may have greater health consequences than a unit of utilization in a large urban area. However the problem is inherent in the data base and not in the technique.

3. The basic form of DEA assumes constant return to scale. That is proportional changes in all input levels result in changes of equal proportion in output levels. This is an important assumption since it allows all DMUs to be scaled and compared to a unit isoquant. The same frontier or production surface is thus applicable to all DMUs. However recent research (Byrnes *et al.*,

1984) indicates that DEA can be used to detect and measure scale effects.

4. The input and output weights produced by DEA cannot be interpreted as values in the economic sense even though they seem to share the same mathematical representation. In fact, the optimal weights for a given DMU often include zeros when no-one would argue that the corresponding entities are valueless. However, this is not so much a shortcoming of the procedure as it is a note of caution on interpretation of the results. DEA does not purport to ascertain unit values of inputs and outputs, only to measure relative efficiency.

5. Specification of the number of inputs and outputs is tempered by the number of DMUs or observations. A rule of thumb for maintaining an adequate number of degrees of freedom when using DEA is to obtain at least two DMUs for each input or output measure. This heuristic is the result of empirical testing by Charnes, Cooper and others. Note, for instance, that an insufficient number of DMUs for the variables being used would tend to rate all DMUs efficient simply because of inadequate number of degrees of freedom. Thanassoulis *et al.* (1987) suggest ways to reduce the number of inputs and outputs to improve the discriminatory power of the method.

CHAPTER FIVE

METHODOLOGY

5.1 SELECTION OF PROJECTS

In order to conduct an in-depth analysis of the water supply and sanitation sector it was deemed appropriate to select ten projects to reflect the sizes of communities or groups of communities served and also the technologies employed in the sector. The policy of GWSC, based on the assessment of water resources, both surface water and ground water, has been to provide water supply to four broad population groups by means technologies deemed appropriate to each group. Projects in sanitation were selected to reflect the same population groups. The ten projects selected included six water supply projects and four sanitation projects; the ratio also, by coincidence, reflected the level of activities in the sub-sectors.

5.1.1 Water Supply Sub-sector

1. *Large Urban*

In Ghana populations in large urban areas, i.e. population in excess of 40,000 persons are supplied from surface water sources with conventional water treatment plant using rapid gravity filters. The project selected is the Accra-Tema Water Supply Phases 1 and 2. It involves GWSC and Donor Financing; by far the largest water supply undertaking in Ghana.

2. *Small Urban*

Populations between 2000-40,000 are served from either ground water or surface water sources. A sample of 20 ground water supplies were selected out of 91 existing supplies for study. Water supplies based on surface water sources employ package water treatment plants which are conventional treatment plants with pressure filters. 20 units out of the existing 69 units were selected for study. All supplies have piped distribution systems.

3. Large Rural

Population between 500-2000 are served by drilled wells with hand pumps. The two projects selected reflected two distinct geographical locations with different water resources endowments; the dry, Upper Region and the wet southern Ghana. Further the technical approach adopted by the donor agencies were quite different. The projects selected are the 2500 wells by CIDA in the Upper Regions and the 3000 wells by the government of the Federal Republic of Germany in southern Ghana.

4. Small Rural

Populations between 100-500 are served with hand-dug wells with hand pump. The project selected is a community-based project aided by a foreign non-governmental organisation.

5.1.2 Sanitation Sub-Sector

1. Large Urban

The project selected is the Central Accra Sewerage System which serves commercial and industrial concerns together with high, middle and low income housing.

2. Small Urban

The bucket latrine system has been discredited as demeaning and inhuman to those employed to operate it. The project selected replaces the communal bucket latrines with the Kumasi-type Ventilated Improved Pit Latrine designed as a communal unit and implemented by the Kumasi Metropolitan Assembly and the communities.

3. Large Rural

The project selected was a government of Ghana/Communities Partnership Project to build the communal type Kumasi-type Ventilated Improved Pit Latrines in communities that met the specified conditions.

4. Small Rural

Most rural communities provide the traditional pit latrines as the first organised sanitation system. The project selected, the traditional pit latrine, will continue for a long time to serve most rural communities.

5.2 DATA COLLECTION

For each of the ten projects selected data collection was organised under the following sub-headings: Technical factors, Financial factors, Economic factors, Institutional factors, Social factors and Environmental factors.

5.2.1 Technical Factors

(a) Technology

(i) Water Production

1. Selection: the selection of the technology for water production is assessed as to its suitability for producing final water of acceptable standard from the available raw water and for its appropriateness for the environment in which it is located and operated.

2. As designed: the design of the water production system is studied and all components recorded. All available drawings are inspected and checked for soundness of engineering and adequate ratings and capacities.

3. As built: physical components as constructed are checked against designs so that disparities between design and as built component can be investigated. Quality of construction is assessed and defects are noted.

(ii) Water Distribution

1. Selection: the type of water distribution whether pipe-borne or non pipe-borne is noted together with the level of service provided.

2. As designed: all available drawings are studied and capacities of pumps, reservoirs, pipe sizes, pipe materials and lengths as designed are recorded.

3. As built: details of water distribution system as built are compared with the design and any discrepancies investigated.

Types of hand pumps installed, depths of wells and distribution in the communities are also noted.

(iii) Sanitation Collection System

1. Selection: the process of technology selection was traced through the appraisal of consultancy reports on sewerage. Pit latrines represent on-site collection selected as alternatives to other technologies, for example, the bucket latrine.

2. As designed: designs of sewers were studied and all drawings inspected. Sizes of sewers, slopes, lengths, materials, pump capacities and manhole designs were noted. Designs of the ventilated pit latrines and traditional pit latrines were also noted.

3. As built: the collection system as constructed was compared with the designs where available. Quality of construction was noted.

(iv) Sanitation Treatment and Disposal System

1. Selection: technology for the final disposal of sewage was studied and recorded. Arrangements for disposal of sludge from pit latrines were observed and recorded.

2. As designed: any available design and drawings were inspected.

3. As built: construction of disposal facilities for sewerage and sludge were inspected and recorded.

Objectively verifiable indicators are pump ratings and plant capacities in m^3/day.

(b) Operations

(i) Plans available for operation including operators manuals, manufacturer's instructions, and other planned operator periodic routines are studied and assessed for efficacy and appropriateness.

(ii) Actual operational records and observed practice are checked against plans and discrepancies investigated.

(iii) An attempt is made to assess requirements for effective operations.

Objectively verifiable indicator employed is the level of attainment of planned operational levels.

(c) Maintenance

(i) Plans available for preventive maintenance, breakdown maintenance and emergencies are studied and assessed for efficacy and appropriateness.

(ii) Actual maintenance records and observed practice are checked against plans and discrepancies investigated.

(ii) Attempt is made to assess requirements for effective maintenance.

Objectively verifiable indicator used is the level of attainment of planned maintenance levels.

(d) Types of Faults

Faults on various system components were studied but records were taken on faults causing breakdown of the entire water supply or sanitation system. In particular the following aspects of faults were noted.

(i) Timing of faults - times of occurrence of faults.

(ii) Time of repair - time taken on repairs in days or months.

(iii) Frequency - number of faults occurring within one month.

(e) Quality

(i) Water quality parameters were measured for both raw water and final water. Where there are historical records these are studied and any significant changes taking place over time is noted.

(ii) For sewage various quality parameters were measured. In other sanitation projects the sludge was either in contact with fresh excreta or was less than 12 months old and therefore declared unsafe.

All quality parameters were measured in their traditional units.

(f) Quantity

(i) Quantities of water produced daily over a period of three years was recorded. A limited household survey was conducted to provide information on quantities and sources of water reaching the household whether from improved sources or from traditional sources.

(ii) Quantities of sewage pumped daily over a three year period was recorded. In other sanitation projects the rate of sludge accumulation and rate of de-sludging pits (where applicable) were recorded.

5.2.2 Financial Factors

(a) Cost

(i) Capital cost: for each project total capital cost was obtained together with the division into foreign cost and local cost components.

(ii) Operations costs: the operations costs was obtained from the accounting records. Where records were not available the cost is estimated with the assistance of the plant operators and accounting staff.

(iii) Maintenance cost: this was obtained from the accounting records. Where records were not available the cost is estimated with the assistance of maintenance personnel and accounting staff.

(iv) Design life: GWSC maintains a record of life of assets for depreciation purposes. Lives of some equipment were obtained from consultant reports. Lives of various pit latrines were obtained from experience of users and designers.

(v) Replacement cost: where current prices are available these will be taken as replacement cost else historical cost are escalated with inflation index. Any existing plans for replacement of components of the various water and sanitation systems are noted.

(b) Income

(i) Tariff: various tariffs in use on the projects are noted. Where historical records are available previous tariffs were also obtained.

(ii) Collection/billing: information on billing in water supply and sewerage operated by GWSC were available together with collection. For sanitation project there was no billing but data on collection for pay-as-you-use latrines in Kumasi were available. Other modes of collection include a head tax or fund raising activities.

(iii) Government finance: the level of government financing on each project was recorded.

(iv) Local council finance: the level of local council (district assembly) financing, where applicable, is recorded.

(v) Donor financing: in donor aided projects external financing is recorded and differentiated into grants and loans.

(vi) Community finance: some projects are wholly or partially financed by the communities. The level of community finance on such projects is noted.

(c) Ability to Pay

The ability of the members of a community to contribute to cost recovery is measured by the income levels in the community. The legislated minimum wage is noted.

(d) Willingness to Pay

In communities with water supply and sanitation services, willingness to pay is taken as the level of actual payment of various contributions required for the project. Where there are prices other than official tariff levels such as charges by water vendors, these are also noted.

5.2.3 Economic Factors

(a) Cost

(i) Capital cost: the information is the same as collected under Financial Factors.

(ii) Operation cost: the information is the same as collected under Financial Factors.

(iii) Maintenance cost: the information is the same as collected under Financial Factors.

(iv) Design life: the information is the same as collected under Financial Factors.

(v) Replacement cost: the information is the same as collected under Financial Factors.

(b) Benefit

(i) Revenue: on projects with established tariff; revenue is used as a surrogate for benefit.

(ii) Least cost solution: information should be sought on whether least cost analysis was conducted in the selection of the project and whether the project as implemented is the least cost solution.

(c) Shadow Prices

(i) Foreign exchange rate: the foreign exchange rates of the cedi to the dollar were recorded from 1967 to 1988 and the shadow price of foreign exchange obtained from the offices of the World Bank and the Institute of Statistical, Social and Economic Research, University of Ghana as the Auction Rate/Foreign Exchange Bureau Rate.

(ii) Wages: the minimum wage rates wQ;Q obtained for as many years as possible. The shadow wage rate was obtained from the offices of the World Bank, Accra and the Institute of Statistical, Social and Economic Research, Ghana.

(iii) Land: the price of land rental was obtained from the Economic Unit of the Ministry of Agriculture, Accra. Outright sale of land is not a common transaction. Most land is held on leasehold.

(d) Interest Rate

(i) Bank rate: interest rates prevailing on various transactions at the banks were recorded. This included the Bank Discount Rate and Savings Interest Rate.

(ii) Interest rates for projects: banks interest rates on various projects including agricultural sector, export sector, construction projects were obtained. In addition the interest rate used by the Public Investment Programme at the Ministry of Finance and Economic Planning, Ghana was also obtained.

(iii) Inflation indices: these were obtained from the Consumer Price Index.

5.2.4 Institutional Factors

(a) Construction

The institutional arrangement for project construction was recorded as by contract, by force account, by self help or by various combinations of these arrangements.

(b) Operation and Maintenance

The institutional arrangement for operation and maintenance was recorded as by contract, by community self help or by full-time employed personnel. With the full-time employed personnel numbers of personnel required for the various skills, numbers of unskilled labour and supervisor personnel are recorded.

(c) Logistic

Information on the logistic support required on the various projects are recorded especially for fuel, chemicals and other supplies for water supply projects. In sanitation projects the main logistic problem was with availability of de-sludging trucks for pit emptying.

(d) Training

Training programmes available on all projects were recorded. This includes on-the-job training and formal training in appropriate institutions. An assessment of training requirement on projects without training programmes or with inadequate training programme was made. Further, aid programmes for training institutions in the sector were noted.

(e) Legal Responsibility/Declared Aims

Various institutions have legal responsibilities in the sector. Information on the legal roles of these institutions is obtained especially with GWSC and District Assemblies. As far as possible the declared aims of external aid donor agencies participating in particular projects is ascertained.

5.2.5 <u>Social Factors</u>

(a) Taste and Odour

Information on taste and odour problems on the projects are obtained especially their influence on social acceptability are assessed.

(b) Distance Travelled

Distance travelled to traditional sources are obtained. Also range of distances walked from households to facilities (hand pumps, stand-pipes, latrines) are measured.

(c) Queuing Period

On the projects where queues develop information is obtained on range of queuing periods.

(d) Types of Water Collecting Containers

Range of sizes of water collecting containers are measured.

(e) Anal Cleansing

On sanitation projects the types of anal cleansing materials are obtained.

(f) Children

In the provision of water supply and sanitation facilities any special consideration is for children's facilities should be noted.

(g) Community Involvement in Project

Community involvement in the project is assessed under the following sub-headings.

(i) Request: evidence of community request for the project is noted.

(ii) Level of service/coverage: community's involvement in decisions on level of service and coverage should be recorded.

(iii) Dialogue: the existence of dialogue as communication between project planner and communities is recorded.

(iv) Commitment: evidence of community's commitment to the project before implementation is noted.

(v) Appropriate technology: community involvement in the selection of technology appropriate or not, should be noted.

(vi) Willingness to pay: survey of community's willingness to pay or demonstration of willingness to pay is recorded.

(vii) Cost recovery: community's involvement in decision on cost recovery and subsequent contribution to cost recovery is noted.

(viii)Ability to pay: community's demonstrated ability to pay project contributions or tariffs is recorded.

(ix) Decision making: the extent of community involvement in decision making on all aspects of the project is noted.

(x) Responsibility: the extent of community sharing in the responsibility for the delivery of the service is ascertained.

(h) Population Factors

General population factors including age structure, education, male/female ratio, religion and population density together with community population sizes are obtained.

(i) Alternative Facilities

The existence of alternative facilities other than those provided under the project are observed and recorded.

5.2.6 Environmental Factors

(a) Beach Pollution

The problem of pollution of the beach by sewage pumped from the central Accra pumping station was observed together with the dilution effect due to the tides. Plans for elimination of the pollution as proposed by the consultants and the efforts of GWSC to obtain financing were discussed and recorded.

(b) Sludge Disposal from K-VIP Latrines

Information on sludge disposal practices on the urban and rural K-VIP latrines were obtained and the extent of the pollution problem was assessed.

(c) Sullage Disposal

Sullage disposal facilities on all water supply projects were ascertained and where these were absent the cost of providing minimum facilities to avert pollution and mosquito breeding were obtained.

5.3 DATA UTILIZATION

5.3.1 Description of Projects

Data collected on each of the ten projects were used to provide detailed descriptions of the projects. This is intended to provide a sectoral overview of the technologies employed, financial arrangements and the scale of projects under investigation. A background to the types of delivery systems employed, especially the relative roles of GWSC, District Assemblies and the communities in the sector has been provided.

5.3.2 Data Analysis

The data collected was analysed to provide representative values for all quantitative measures and descriptive evaluation of qualitative data as a basis for developing the input and output factors required in the application of DEA.

5.3.3 Application of DEA

To formulate the linear programming model requires the identification of the relevant input and output factors and the availability of numerical measures for the factors identified.

Input Factors

The success or failure of delivery of water and sanitation services is determined by technical, financial, economic, institutional, social and environmental factors. Each of these broad groups of factors will be represented by a single factor selected to reflect the desired attribute that enhances the chances of success of the delivery system.

(a) Technical Input Factor

After consideration of many possible representative measures it was decided that the foreign exchange component of capital cost is the best single factor reflecting technical complexity and the dependency of the project on a very scarce resource. The technical input factor was measured by the fraction of the foreign cost component of the capital cost of the project.

(b) Financial Input Factor

Cost recovery on water supply and sanitation projects is a major consideration in the assessment of project performance. It is generally believed that the higher the level of cost recovery from the community the higher the chances of project success due to the lesser dependence on external financing. Cost recovery is defined here as the ratio of the actual annual revenue collection to the annual full cost of delivery of the service. Full cost is calculated as the annualised cost of capital, operation and maintenance cost at the discount rate of 15 per cent and with 20 year life. The deficit on full cost is therefore the fraction of full cost not covered by revenue. The financial input factor is therefore calculated as the deficit on full cost. Projects on which the community bears all costs, the financial input factor is zero. On the other hand project on which the community contributes nothing and no tariffs are instituted the financial input factor is unity.

(c) Economic Input Factor

This factor is calculated as the resource economic cost for the delivery of the service. The capital cost together with the operation and maintenance costs are disaggregated into foreign cost component, unskilled labour cost and other local costs. The foreign cost and unskilled labour costs are multiplied by the appropriate shadow price conversion factors. The conversion ratio for foreign exchange is the ratio of the foreign exchange rate at the Foreign Exchange Bureau and the foreign exchange rate at the Foreign Exchange Auction. For this study the ratio is 1.5. The conversion factor for unskilled labour is the ratio of the agricultural wage to the legislated minimum wage. For this study the ratio was calculated as 2.0. The annualised economic cost for each project was calculated at 15 per cent discount rate and 20 year life. From the annualised cost the cost per person per annum was derived for each project. For water projects an assumed per capita water consumption of 40 l/day was used in the calculation. For sanitation projects the annualised cost was calculated as above and the utilization population or the design population, depending on which is greater, is used to derive the cost per person per annum. The economic input factor as calculated was used in the formulation of the linear programming model.

(d) Institutional Input Factor

The institutional input factor represents the level of skilled manpower employed full-time to operate and maintain the water supply or sanitation project. Casual workers employed by the community are excluded. The number of skilled manpower employed is obtained for the population served. The number so obtained is increased proportionately to provide the equivalent number of skilled personnel for an assumed population of a million people. The institutional input factor is, therefore, the number of skilled personnel employed per a million population.

(e) Social Input Factor

This factor measures the level of community involvement in the project. This was obtained by the answers to the following questions. Answers should be Yes or No. The Yes answer scored zero while No answer scored 1.

(i) Did the community make a request for the project?
(ii) Was the community involved in determining level of service or coverage?
(iii) Is there established dialogue between project planners and community?
(iv) Is there any evidence of community commitment to the project?
(v) Was the community involved in the selection of appropriate technology?
(vi) Did the community demonstrate willingness to pay towards project cost?
(vii) Was the community involved in discussions on cost recovery?
(viii)Does the community possess the ability to pay towards project costs.
(ix) Was the community involved in decision making generally on the project?
(x) Is the community sharing in the responsibility of providing the service?

A high level of community involvement gives a low score and a low level of community involvement gives a high score. The assumption is that a high level of community involvement increases the chances of project success.

(f) Environmental Input Factor

This factor measures the cost of eliminating or reducing the acceptable levels any environmental problems associated with the project. For the water supply projects the environmental problem considered was sullage disposal. Cost per person of effective disposal of sullage is the Environmental Input Factor for water supply. For sanitation projects the environmental problem was associated with sludge disposal in the case of the K-VIP latrines and with final disposal of sewage in the case of the Central Accra Sewerage project. Sludge disposal on-site requires the provision of sludge drying area and subsequent incineration of the dry sludge. Off-site sludge disposal requires the provision of trenching grounds for burial of sludge. In the case of sewerage the failure of the sewage outfall caused deposition of sewage on the beach with very serious pollution problems. Facilities for the treatment of sewage and final disposal of the effluent have been designed awaiting implementation. The cost of providing these facilities for sanitation constitutes the Environmental Input Factor measured as cost per person served.

Output Factors

Project outputs were determined as reliability, utilization and convenience. These are the outputs obtainable from water supply and sanitation projects through the application of the Minimum Evaluation Procedure. This procedure, as mentioned in Chapter Three, evaluates projects at three levels. Project Functioning, Project Utilization and Health Impact. For the purposes of this study project output is limited to Project Functioning and Utilization in the expectation that health benefits will be captured by ensuring that projects are reliable and the services provided are convenient to the user and that services are, in fact, utilized.

(a) Reliability Output Factor

Reliability is measured by the fraction of the time when the facility is operational. In water supply projects operational problems, such as power outages, shortages of fuel, chemicals and spare parts, cause unavailability of water supply. Reliability for water supply projects is measured as the fraction of the time when the service is available to the user. In sanitation the operation and maintenance problems that cause partial or total unavailability of the service are peculiar to the system in use.

(i) In the case of the traditional pit latrine the structure is assumed to be sound and the likelihood of pit caving in is not considered. The unavailability of some squatting positions is mainly due to creation of unsightly conditions through improper use. Reliability is measured as the fraction of squatting positions available at any moment.

(ii) The Rural K-VIP latrine has no permanent attendant and is cleaned only periodically by volunteers. Unsightly conditions persist for long periods rendering some compartments unavailable. Reliability is measured by the fraction of compartments available for use.

(iii) The Urban K-VIP latrine has regular attendants who clean up unsightly conditions as soon as they are reported by users. However early filling of some pits may cause the temporary close-down of some compartments. Pit emptying operations cause temporary unavailability of some compartments. Reliability is measured as the fraction of compartments available for use.

(iv) The Central Accra Sewerage system requires periodic flushing and removal of blockage that cause disruption of normal operation of the system. Reliability is measured as the fraction of the time when the system is fully operational.

(b) Utilization Output Factor

Utilization in water supply project is measured as the fraction of daily water use from the improved source. In the Accra-Tema Water Supply Project where no alternative sources exist in the supply area utilization is measured by the population coverage. In sanitation projects, utilization is measured by the fraction of population using the facility i.e. the observed number of users to the population that should be served. In the case of the Central Accra Sewerage utilization was measured as the ratio of the number of connections to the potential number of connections.

(c) Convenience Output Factor

Convenience on all the projects was measured as the population density in the service area.

All input and output factors calculated as above are summarised in the Table 5.1 below.

Table 5.1

Input and Output Factors

Project		Input Factors X_1	X_2	X_3	X_4	X_5	X_6	Output Factors Y_1	Y_2	Y_3
Accra-Tema	A	X_{1A}	X_{2A}	X_{3A}	X_{4A}	X_{5A}	X_{6A}	Y_{1A}	Y_{2A}	Y_{3A}
Borehold	B	X_{1B}	X_{2B}	X_{3B}	X_{4B}	X_{5B}	X_{6B}	Y_{1B}	Y_{2B}	Y_{3B}
Package Plant	C	X_{1C}	X_{2C}	X_{3C}	X_{4C}	X_{5C}	X_{6C}	Y_{1C}	Y_{2C}	Y_{3C}
2500 Wells	D	X_{1D}	X_{2D}	X_{3D}	X_{4D}	X_{5D}	X_{6D}	Y_{1D}	Y_{2D}	Y_{3D}
3000 Wells	E	X_{1E}	X_{2E}	X_{3E}	X_{4E}	X_{5E}	X_{6E}	Y_{1E}	Y_{2E}	Y_{3E}
Hand Dug Well	F	X_{1F}	X_{2F}	X_{3F}	X_{4F}	X_{5F}	X_{6F}	Y_{1F}	Y_{2F}	Y_{3F}
Cen. Accra Sew	G	X_{1G}	X_{2G}	X_{3G}	X_{4G}	X_{5G}	X_{6G}	Y_{1G}	Y_{2G}	Y_{3G}
Urban K-VIP	H	X_{1H}	X_{2H}	X_{3H}	X_{4H}	X_{5H}	X_{6H}	Y_{1H}	Y_{2H}	Y_{3H}
Rural K-VIP	I	X_{1I}	X_{2I}	X_{3I}	X_{4I}	X_{5I}	X_{6I}	Y_{1I}	Y_{2I}	Y_{3I}
Trad. Pit Lat.	J	X_{1J}	X_{2J}	X_{3J}	X_{4J}	X_{5J}	X_{6J}	Y_{1J}	Y_{2J}	Y_{3J}

X_1 - Technical Input Factor
X_2 - Financial Input Factor
X_3 - Economic Input Factor
X_4 - Institutional Input Factor
X_5 - Social Input Factor
X_6 - *Environmental Input Factor*
Y_1 - Reliability Output Factor
Y_2 - Utilization Output Factor
Y_3 - Convenience Output Factor

Projects are denoted by subscripts A, B, C, D, E, F, G, H, I, J, as follows:

Accra-Tema Water Supply	A	Hand Dug Well	F
Borehold Water Supply	B	Central Accra Sewerage	G
Package Plant Water Supply	C	Urban K-VIP Latrine	H
2500 Drilled Well Water Supply	D	Rural K-VIP Latrine	I
3000 Drilled Well Water Supply	E	Traditional Pit Latrine	J

For example,

X_{1A} - represents Technical Input Factor for Accra-Tema Water Supply.

X_{3E} - represents Economic Input Factor for 3000 Drilled Wells Water Supply.

X_{6J} - represents Environmental Input Factor for Traditional Pit Latrine.

Y_{1D} - represents Reliability Output Factor for 2500 Drilled Wells Water Supply.

Y_{2G} - represents Utilization Output Factor for Central Accra Sewerage.

Y_{3I} - represents Convenience Output Factor for Rural K-VIP Latrine.

To formulate the linear programming model we define the weights:

U_1 - Reliability Output Factor

U_2 - Utilization Output Factor

U_3 - Convenience Output Factor

V_1 - Technical Input Factor

V_2 - Financial Input Factor

V_3 - Economic Input Factor

V_4 - Institutional Input Factor

V_5 - Social Input Factor

V_6 - Environmental Input Factor

Efficiency of Accra-Tema Water Supply $= \frac{\text{Output}}{\text{Input}}$

$$= \frac{U_1Y_{1A} + U_2Y_{2A} + U_3Y_{3A}}{V_1X_{1A} + V_2X_{2A} + V_3X_{3A} + V_3X_{3A} + V_4X_{4A} + V_5X_{5A} + V_6\ X_{6A}}$$

If we constrain input to equal 1 (unity) we can maximise output, that is:

Maximise $U_1Y_{1A} + U_2Y_{2A} + U_3Y_{3A}$

subject to the constraint

$$V_1X_{1A} + V_2X_{2A} + V_3X_{3A} + V_4X_{4A} + V_5X_{5A} + X_6X_{6A} = 1$$

But the weights are selected such that the efficiencies of all 10 projects are less than or equal to 1 (unity), which gives 10 constraints, one for each project.

1. Accra Tema Water Supply

$$\frac{U_1Y_{1A} + U_2Y_{2A} + U_3Y_{3A}}{V_1X_{1A} + V_2X_{2A} + V_3X_{3A} + V_4X_{4A} + V_5X_{5A} + V_6X_{6A}} \leq 1$$

$$\therefore\ U_1Y_{1A} + U_2Y_{2A} + U_3Y_{3A} \leq V_1X_{1A} + V_2X_{2A} + V_3X_{3A} + V_4X_{4A} + V_5X_{5A} + V_6X_{6A}$$

$$\therefore\ -U_1Y_{1A}-U_2Y_{2A}-U_3Y_{3A}+V_1X_{1A}+V_2X_{2A}+V_3X_{3A}-V_4X_{4A}+V_5X_{5A}+V_6X_{6A} \geq 0$$

2. Borehole Water Supply

$$\frac{U_1Y_{1B} + U_2Y_{2B} + U_3Y_{3B}}{V_1X_{1B} + V_2X_{2B} + V_3X_{3B} + V_4X_{4B} + V_5X_{5B} + V_6X_{6B}} \leq 1$$

$\therefore U_1Y_{1B} + U_2Y_{2B} + U_3Y_{3B} \leq V_1X_{1B} + V_2X_{2B} + V_3X_{3B} + V_4X_{4B} + V_5X_{5B} + V_6X_{6B}$

$\therefore -U_1Y_{1B}-U_2Y_{2B}-U_3Y_{3B}+V_1X_{1B}+V_2X_{2B}+V_3X_{3B}+V_4X_{4B}+V_5X_{5B}+V_6X_{6B} \geq 0$

Similarly:

3. Package Plant Water Supply

$$-U_1Y_{1C}-U_2Y_{2C}-U_3Y_{3C}+V_1X_{1C}+V_2X_{2C}+V_3X_{3C}+V_4X_{4C}+V_5X_{5C}+V_6X_{6C} \geq 0$$

4. 2500 Drilled Wells Water Supply

$$-U_1Y_{1D}-U_2Y_{2D}-U_3Y_{3D}+V_1X_{1D}+V_2X_{2D}+V_3X_{3D}+V_4X_{4D}+V_5X_{5D}+V_6X_{6D} \geq 0$$

5. 3000 Drilled Wells Water Supply

$$-U_1Y_{1E}-U_2Y_{2E}-U_3Y_{3E}+V_1X_{1E}+V_2X_{2E}+V_3X_{3E}+V_4X_{4E}+V_5X_{5E}+V_6X_{6E} \geq 0$$

6. Hand Dug Well Water Supply

$$-U_1Y_{1F}-U_2Y_{2F}-U_3Y_{3F}+V_1X_{1F}+V_2X_{2F}+V_3X_{3F}+V_4X_{4F}+V_5X_{5F}+V_6X_{6F} \geq 0$$

7. Central Accra Sewerage

$$-U_1Y_{1G}-U_2Y_{2G}-U_3Y_{3G}+V_1X_{1G}+V_2X_{2G}+V_3X_{3G}+V_4X_{4G}+V_5X_{5G}+V_6X_{6G} \geq 0$$

8. Urban K-VIP Latrine

$$-U_1Y_{1H}-U_2Y_{2H}-U_3Y_{3H}+V_1X_{1H}+V_2X_{2H}+V_3X_{3H}+V_4X_{4H}+V_5X_{5H}+V_6X_{6H} \geq 0$$

9. Rural K-VIP Latrine

$$-U_1Y_{1I}-U_2Y_{2I}-U_3Y_{3I}+V_1X_{1I}+V_2X_{2I}+V_3X_{3I}+V_4X_{4I}+V_5X_{5I}+V_6X_{6I} \geq 0$$

10. Traditional Pit Latrine

$$-U_1Y_{1J}-U_2Y_{2J}-U_3Y_{3J}+V_1X_{1J}+V_2X_{2J}+V_3X_{3J}+V_4X_{4J}+V_5X_{5J}+V_6X_{6J} \geq 0$$

The linear programme as formulated has 9 variables (3 outputs and 6 inputs) and 11 constraints (10 for the projects and 1 input constraint - 1 for the project whose efficiency is being measured).

Collecting all the programme parts together.

(a) Accra-Tema Water Supply

Objective Function

$$\text{Maximise } U_1Y_{1A} + U_2Y_{2A} + U_3Y_{3A} + 0V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 + 0V_6$$

subject to

$$0U_1 + 0U_2 + 0U_3 + V_1X_{1A} + V_2X_{2A} + V_3X_{3A} + V_4X_{4A} + V_5X_{5A} + V_6X_{6A} = 1$$

$$-U_1Y_{1A}-U_2Y_{2A}-U_3Y_{3A}+V_1X_{1A}+V_2X_{2A}+V_3X_{3A}+V_4X_{4A}+V_5X_{5A}+V_6X_{6A} \geq 0$$

$$-U_1Y_{1B}-U_2Y_{2B}-U_3Y_{3B}+V_1X_{1B}+V_2X_{2B}+V_3X_{3B}+V_4X_{4B}+V_5X_{5B}+V_6X_{6B} \geq 0$$

$$-U_1Y_{1C}-U_2Y_{2C}-U_3Y_{3C}+V_1X_{1C}+V_2X_{2C}+V_3X_{3C}+V_4X_{4C}+V_5X_{5C}+V_6X_{6C} \geq 0$$

$$-U_1Y_{1D}-U_2Y_{2D}-U_3Y_{3D}+V_1X_{1D}+V_2X_{2D}+V_3X_{3D}+V_4X_{4D}+V_5X_{5D}+V_6X_{6D} \geq 0$$

$$-U_1Y_{1F}-U_2Y_{2F}-U_3Y_{3F}+V_1X_{1F}+V_2X_{2F}+V_3X_{3F}+V_4X_{4F}+V_5X_{5F}+V_6X_{6F} \geq 0$$

$$-U_1Y_{1G}-U_2Y_{2G}-U_3Y_{3G}+V_1X_{1G}+V_2X_{2G}+V_3X_{3G}+V_4X_{4G}+V_5X_{5G}+V_6X_{6G} \geq 0$$

$$-U_1Y_{1H}-U_2Y_{2H}-U_3Y_{3H}+V_1X_{1H}+V_2X_{2H}+V_3X_{3H}+V_4X_{4H}+V_5X_{5H}+V_6X_{6H} \geq 0$$

$$-U_1Y_{1I}-U_2Y_{2I}-U_3Y_{3I}+V_1X_{1I}+V_2X_{2I}+V_3X_{3I}+V_4X_{4I}+V_5X_{5I}+V_6X_{6I} \geq 0$$

$$-U_1Y_{1J}-U_2Y_{2J}-U_3Y_{3J}+V_1X_{1J}+V_2X_{2J}+V_3X_{3J}+V_4X_{4J}+V_5X_{5J}+V_6X_{6J} \geq 0$$

Similarly we formulate for each project.

(b) Borehole Water Supply

Objective Function is

$$\text{Maximise } U_1Y_{1B} + U_2Y_{2B} + U_3Y_{3B} + 0V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 + 0V_6$$

subject to

$$0U_1 + 0U_2 + 0U_3 + V_1X_{1B} + V_2X_{2B} + V_3X_{3B} + V_4X_{4B} + V_5X_{5B} + V_6X_{6B} = 1$$

Plus 10 constraints above with the inequality sign.

(c) Package Plant Water Supply

Objective Function is

$$\text{Maximise } U_1Y_{1C} + U_2Y_{2C} + U_3Y_{3C} + 0V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 + 0V_6$$

subject to

$$0U_1 + 0U_2 + 0U_3 + V_1X_{1C} + V_2X_{2C} + V_3X_{3C} + V_4X_{4C} + V_5X_{5C} + V_6X_{6C} = 1$$

Plus 10 constraints above with the inequality sign.

(d) 2500 Drilled Wells Water Supply

Objective Function is

$$\text{Maximise } U_1Y_{1D} + U_2Y_{2D} + U_3Y_{3D} + 0V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 + 0V_6$$

subject to

$$0U_1 + 0U_2 + 0U_3 + V_1X_{1D} + V_2X_{2D} + V_3X_{3D} + V_4X_{4D} + V_5X_{5D} + V_6X_{6D} = 1$$

Plus 10 constraints above with the inequality sign.

(e) <u>3000 Drilled Wells Water Supply</u>

Objective Function is

$$\text{Maximise } U_1Y_{1E} + U_2Y_{2E} + U_3Y_{3E} + 0V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 + 0V_6$$

subject to

$$0U_1 + 0U_2 + 0U_3 + V_1X_{1E} + V_2X_{2E} + V_3X_{3E} + V_4X_{4E} + V_5X_{5E} + V_6X_{6E} = 1$$

Plus 10 constraints above with the inequality sign.

(f) <u>Hand Dug Well Water Supply</u>

Objective Function is

$$\text{Maximise } U_1Y_{1F} + U_2Y_{2F} + U_3Y_{3F} + 0V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 + 0V_6$$

subject to

$$0U_1 + 0U_2 + 0U_3 + V_1X_{1F} + V_2X_{2F} + V_3X_{3F} + V_4X_{4F} + V_5X_{5F} + V_6X_{6F} = 1$$

Plus 10 constraints above with the inequality sign.

(g) <u>Central Accra Sewerage</u>

Objective Function is

$$\text{Maximise } U_1Y_{1G} + U_2Y_{2G} + U_3Y_{3G} + 0V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 + 0V_6$$

subject to

$$0U_1 + 0U_2 + 0U_3 + V_1X_{1G} + V_2X_{2G} + V_3X_{3G} + V_4X_{4G} + V_5X_{5G} + V_6X_{6G} = 1$$

Plus 10 constraints above with the inequality sign.

(h) <u>Urban K-VIP Latrine</u>

Objective Function is

$$\text{Maximise } U_1Y_H + U_2Y_{2H} + U_3Y_{3H} + 0V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 + 0V_6$$

subject to

$$0U_1 + 0U_2 + 0U_3 + V_1X_{1H} + V_2X_{2H} + V_3X_{3H} + V_4X_{4H} + V_5X_{5H} + V_6X_{6H} = 1$$

Plus 10 constraints above with the inequality sign.

(i) <u>Rural K-VIP Latrine</u>

Objective Function is

$$\text{Maximise } U_1Y_I + U_2Y_{2I} + U_3Y_{3I} + 0V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 + 0V_6$$

subject to

$$0U_1 + 0U_2 + 0U_3 + V_1X_{1I} + V_2X_{2I} + V_3X_{3I} + V_4X_{4I} + V_5X_{5I} + V_6X_{6I} = 1$$

Plus 10 constraints above with the inequality sign.

(j) <u>Traditional Pit Latrine</u>

Objective Function is

$$\text{Maximise } U_1Y_J + U_2Y_{2J} + U_3Y_{3J} + 0V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 + 0V_6$$

subject to

$0U_1 + 0U_2 + 0U_3 + V_1X_{1J} + V_2X_{2J} + V_3X_{3J} + V_4X_{4J} + V_5X_{5J} + V_6X_{6J} = 1$

Plus 10 constraints above with the inequality sign.

The above formulation is the complete set of 10 programmes run for the 3 outputs 10 projects option. Other options such as 3 outputs 6 water projects/4 sanitation projects separately, 2 outputs 10 projects option and 2 outputs 6 water projects/4 sanitation projects separately can be formulated on similar lines.

1. <u>3 outputs, 6 inputs, 6 water projects</u>

Formulate each of 6 linear programmes as above but reduce the inequality constraints to 6 formed by the water projects. There will be:

9 variables (3 outputs, 6 inputs)
1 equality constraint
6 inequality constraints

2. <u>3 outputs, 6 inputs, 4 sanitation projects</u>

Formulate each of 4 linear programmes as above but reduce the inequality constraints to 4 formed by the sanitation projects. There will be:

9 variables (3 outputs, 6 inputs)
1 equality constraint
4 inequality constraints

3. <u>2 outputs (Reliability and Utilization) with 10 projects or 6 water projects or 4 sanitation projects</u>

Formulate the linear programmes as indicated above but terms in U_3 are dropped. The objective functions have two terms only in U_1 and U_2 and zero terms for V-variables. There will be:

8 variables (2 outputs, 6 inputs).

For 10 projects option, we have 1 equality constraint and 10 equality constraints.

For 6 water projects, we have 1 equality constraint and 6 inequality constraints.

For 4 sanitation projects we have 1 equality constraint and 4 inequality constraints.

The linear programming formulations obtained are solved by the Simplex Method. This is a method of solving any linear programming problem developed by G.B. Dantzig and is available in any textbook on linear programming (Vajda, 1966; Hillier and Lieberman, 1986). The method has been adapted for solution by computers and software are available. The software used in this thesis is a COPYRIGHT 1986 SGF SOFTWARE. It is a programme for solving minimisation programmes. In linear programming a maximisation programme is equivalent to minimisation of the negative of the objective function with the constraints unchanged.

The efficiency scores obtained from the solutions to the various linear programmes are used to rank the projects and to compare the relative performance of the projects.

CHAPTER SIX

DATA SOURCES AND PROBLEMS OF DATA COLLECTION

6.1 WORK PROGRAMME

Field work in connection with this thesis took place between October 1986 and December 1988. Details of the work programme followed are set out below.

1 - 22 October 1986

Preliminary attempts to define objectives and scope of the study with project supervisors - Mr. Peter Barker and Mr. R.W.A. Franceys.

23 October 1986

Meeting with Dr. Sandy Cairncross of London School of Hygiene and Tropical Medicine.

27 October 1986

Arrival in Ghana.

November 1986

Letters of introduction to the Managing Director, Ghana Water and Sewerage Corporation and to Head of Department of Civil Engineering, University of Science and Technology.

December 1986

Workshop on Accra Sanitation organised by German Technical Co-operation (GTZ), World Bank, United Nations Development Programme, UNICEF, Ghana Water and Sewerage Corporation and Accra Metropolitan Assembly.

January 1987

Arrival of personal effects from Britain and clearance from Port of Tema.

January/February 1987

Visit to African Development Bank in Abidjan, Ivory Coast.

<u>February 1987</u>

Visit to World Bank Offices in Accra.

Seminar on Project Cycle organised by Ghana Institution of Engineers, African Development Bank and World Bank.

<u>2 March 1987</u>

Meeting with Ghana Water and Sewerage Corporation Management on my Work Programme on projects under their control.

<u>March/April/May 1987</u>

Beginning of Project Visits and Data Collection: ACCRA-TEMA WATER SUPPLY PROJECT - PHASES 1 AND 2.

<u>June/July 1987</u>

CENTRAL ACCRA SEWERAGE PROJECT.

<u>July/August 1987</u>

3000 WELLS PROJECT

<u>September/October 1987</u>

URBAN K-VIP LATRINE PROJECT, KUMASI.

<u>September 1987</u>

Donor Conference on Water Supply and Sanitation.

<u>November/December/January 1987/88</u>

BOREHOLE WATER SUPPLY PROJECT.

<u>December/January/February 1987/88</u>

PACKAGE PLANT WATER SUPPLY PROJECT.

<u>January 1988</u>

Supervisory Visit - Mr. Peter Barker.

<u>March/April 1988</u>

RURAL K-VIP LATRINE PROJECT.

<u>May/June/July 1988</u>

Preliminary Visit to:

2500 WELLS PROJECT

HAND DUG WELL PROJECT

TRADITIONAL PIT LATRINE PROJECT

<u>August 1988</u>

Supervisory Visit - Mr. R.W.A. Franceys.

<u>August/September 1988</u>

Data collection from officials and files and interviews with Management at Head Office, Accra, of Ghana Water and Sewerage Corporation.

<u>October 1988</u>

2500 WELL PROJECT.

<u>November 1988</u>

HAND DUG WELL PROJECT.

TRADITIONAL PIT LATRINE PROJECT

Workshop on objective - Oriented Project Planning organised by German Technical Cooperation (GTZ) in cooperation with United Nations Development Programme and World Bank.

<u>December/January 1988/89</u>

Data collection from officials and files:

Ministry of Local Government,

Ministry of Finance and Economic Planning Statistical Service.

<u>February/March 1989</u>

Break in activities. Occasional site and office visits.

<u>4 April 1989</u>

Return to Loughborough.

6.2 MEETINGS - WORKSHOPS - SEMINARS - CONFERENCES AS DATA SOURCES

On 23 October 1986 a meeting with Dr. Sandy Cairncross, a leading researcher in the Water Supply and Sanitation sector, took place at the Ross Institute in London. Discussions centred on his experiences and, in particular, of the Ross Institute in project evaluation. Based on resources required alone, health impact evaluation cannot be undertaken in many evaluation projects. New directions in the use of time saving in quantifying benefits in water supply were discussed. Various articles published and unpublished written by him were collected and other publications of the Ross Institute purchased. The meeting was useful in helping to decide on the scope of my research work given the resources available.

Central Accra Sewerage Project was one of the subjects of discussion at the Accra Sanitation Workshop which took place in Accra, 1-5 December 1986. The workshop brought together participants from the German Agency for Technical Cooperation (GTZ), the World Bank, United Nations Development Programme, United Nations Children's Fund, Ghana Water and Sewerage Corporation, Accra Metropolitan Assembly, Cameroons and Nigeria, to engage in participatory planning for phasing out bucket latrines in Accra with the support of GTZ. The programme for phasing out bucket latrines will involve technological choices involving promotion of domestic connections to the existing sewerage system and large-scale delivery of ventilated improved pit latrines together with recommending feasible technological alternatives. The workshop also addressed delivery methods including technology delivery, financing mechanisms and cost recovery policies/mechanisms, community participation, marketing and health education for users of sanitation facilities. Other issues deliberated upon were the institutional framework for project implementation, training needs and roles of private enterprise. The workshop was useful in that it revealed what options are available for Accra Sanitation *vis-a-vis* the Central Accra Sewerage Project. It also afforded the opportunity to discuss issues with Julie Viloria of the World Bank who presented her evaluation of urban sanitation programmes in the Philippines and Dr. Michael McGarry, a leading researcher in the Water Supply and Sanitation Sector, who introduced me to Logical Framework Analysis adapted to evaluation as Logical Evaluation Framework.

The African Development Bank is a major donor in the water sub-sector particularly in connection with the Accra-Tema Water Supply Phase 2 and proposed Phase 3. A visit was arranged for early February 1987 although no replies were received from the official letters sent to the Bank. A meeting with Mr. Kometsi Khotle, Sanitary Engineer, centred on the bank's approach to project work in general and project appraisal in particular in this sector. Another meeting with Mr. P.E. Njuguna, Project Officer for Accra-Tema Water Supply, discussed the completion report for Phase 2 and the appraisal for Phase 3. Meetings were also held with Mr. M. Bonzaher, Economist and Mr. Erikson, Financial Analyst on the bank's requirements in economic and financial appraisal of projects in the water supply and sanitation sector. Finally, a meeting was arranged with Mr. P.G. Rwelamira, Economist, of the Project Evaluation Section. Discussion centred on projects evaluated and evaluation procedures. Various evaluation reports were collected. While in Abidjan a meeting was arranged with the Sector Development Team of the World Bank to discuss their programme for Ghana - contact person was Mr. Hyland of the Sector Development Team. The usefulness of the meetings at the African Development Bank is to obtain from practitioners the project appraisal and evaluation procedures.

In Accra a visit was undertaken to the offices of the World Bank to meet Dr. Raj Sharma in February 1987. The discussion was on use of shadow prices in the Ghanaian context. Some information on shadow prices for labour and foreign exchange was obtained. The request for appraisal and project completion reports on World Bank financed water supply and sanitation projects could not be honoured mainly because such documents are not given to individuals and also because they could be obtained only from the World Bank offices in Washington DC. Dr. Sharma also offered the services of their library for any further information required. The usefulness of the visit was the information on shadow prices and procedure for procurement of publications.

At the seminar on Project Cycle, Ghanaian engineers were exposed to project development through the Project Cycle. Dr. Nnamoko of the African Development Bank led the discussion on the bank's operations.

The usefulness of the seminar was to highlight project appraisal and project evaluation as important stages in the Project Cycle.

The Conference on Water and Sanitation, 23-25 September 1987, was organised by the government of Ghana in association with the United Nations Development Programme. It brought together all foreign donors (multilateral, bilateral, non-governmental) and all local institutions working in the sector. The theme of the conference was *Clean Water and Improved Sanitation will Promote Good Health and Prosperity for All by the Year 2000*. The stated objectives were as follows.

- To propose strategies which should be adopted by the government of Ghana and organisations in the sector to bring potable water and satisfactory sanitation to the Ghanaian population by the year 2000. In particular, the imbalance in the supply of potable water to urban and rural communities should be redressed.

- To examine the institutional framework within which sector activities should take place and make recommendations to strengthen institutional arrangements.

- The Conference should also look at the possibilities of production of handpump parts and appropriate sanitation installations to support efforts to bring good water and sanitation to the population hitherto unserved.

- The Conference should further examine the issue of financing and cost recovery in the sector so as to ensure a long life cycle for investments made.

- To present programmes and projects for the sector to donors to enlist their support.

Several recommendations were made and the Donor Agencies after examining the five-year (1987-1991) Development Programme outlined, commented on the unsatisfactory flow of government counterpart funds, the over-ambitious scope of the Five-year Plan and the more favourable institutional arrangements proposed. Each donor agency pledged support for particular activities.

International Development Association - $30 million for systems rehabilitation.

Caisse Centralle (French Government) - Support for 1000 drilled wells in Central Region.

Canadian International Development Agency (CIDA) - $10 million for several sector projects and local manufacture of hand pump.

UNICEF - $1.0 million per annum for small community water supply and sanitation.

KfW (German Government) - DM5.0 million for borehole rehabilitation works.

ODA (British Government) - $5.0 million for rehabilitation of Kumasi Water Works. Will consider other projects in Ashanti Region.

World Vision International (non-government organisation) - 80-100 drilled wells per annum.

German Agency for Technical Cooperation (GTZ) - Rehabilitation of projects in Eastern Region.

United Nations Development Programme (UNDP) - $2 million for three new projects.

The government of Ghana informed the conference that Water Supply and Sanitation Projects are now considered super-core (top priority) projects in respect of the Economic Recovery Programme. The conference was extremely useful in assessing new directions of the Government of Ghana and volume of aid from donor agencies.

The workshop on Objective-oriented Project Planning in November 1988 provided a first-hand application of a planning methodology similar to Logical Framework Analysis to a low-cost water supply project although not enough time was provided to complete the process. The workshop also provided a forum to discuss privately with the German Government Evaluation Team on some aspects of the 3000 wells programme especially the proposed educational input leading to community-based maintenance system.

6.3 PROJECT VISITS AS DATA SOURCES

Work programme in respect of the six projects under the management of the Ghana Water and Sewerage Corporation was submitted and a meeting held on 2 March 1987 to discuss the programme. The management agreed to provide all assistance and provide a letter of introduction to all units to be visited. Office accommodation was also provided.

6.3.1 Accra-Tema Water Supply - Phases 1 and 2

The main data centres can be classified into four groups.

(a) The Accra-Tema Metropolitan Area Manager's Offices composed of several sub-units including:

- the Area Engineer's office, dealing with all operational data.
- the Area Project Engineer's office, dealing with capital projects.
- the Consultants - TAHAL (Water Planning) of Tel Aviv and AESL of Canada.
- the Area Electrical Engineer's office - power supply etc.
- the Area Financial Controller's office with sub-divisions.
- the Area Revenue Officer for all revenue matters.
- the Area Control Room - system network centre.
- the Central Laboratory with Area Chemist.
- the Area Administrative Officer - personnel matters.
- the Area Stores and Purchasing Officer - pipes, chemicals, fuel etc.
- the Area Workshops providing supporting services.

(b) Kpong Head Works and Anciliary Works consisting of:

- Intake and Low-lift Pumping Station (raw water).
- Kpong Old Waterworks
- Kpong New Waterworks (Phase 1)
- laboratory
- transmission lines to Tema.
- Tema Booster Station.
- transmission lines to Accra.
- Accra Booster Station.

(c) Weija Head Works consisting of:

- Weija Dam and Reservoir
- Intake and Raw Water Pumping Stations
- Weija old water works.
- laboratory.
- Weija New Waterworks (Phase 2)
- transmission lines

(d) Water Distribution:

- Distribution Engineer's office
- Accra Central District
- Accra West District
- Accra North-west District
- Accra North District
- Accra East District
- Madina District
- Dansoman District
- Faults office
- Leakage Survey
- Tema Distribution Engineer's office

Letter of introduction was submitted to the Area Manager followed by general discussion on data requirements. Various reports and drawings were collected from Area Manager and Consultants for study. Introduction to all key staff at Area Manager's office was arranged. Considerable time was spent getting acquainted with physical installations through the reports and drawings. A programme was drawn up for visiting physical installations. Data from most sections in the Area Manager's office require going back into the available records, some already in the archives. Officers who may have to help to search will do this in addition to their day to day work. There is the need for lots of tact and some incentives. As time-dependent data were to be collected up to the end of 1988. This meant setting up data requirement and coming back periodically to work with staff in various sections. Most documents cannot be taken away. In very special circumstances the head of the section may grant permission or the Area Manager's consent will have to be sought for documents to be released.

Visit to physical installations started with Kpong Headworks. The Station Manager was the contact person. Tour of the various sections of the old and new treatment plants was undertaken followed by an introduction to an array of plant installation, instruction, operation and maintenance manuals with drawings. There was the need to get familiar with the inventory of equipment and their functions. A programme for detailed visit to various units and data requirements was discussed and scheduled. The programme was executed with the sectional heads of various units in attendance. This was followed up with desk study on the operational documents and files. Most data are summarised in monthly production reports and sent to the Area Engineer's office in Accra, however, data on breakdown rates and down times are not processed for individual pieces of equipment. The data exists but will require several months of collation and analysis. Power outages are minimal since supply is off the direct power lines from the hydroelectric plant at Akosombo about 20km away. From Kpong inspection tours were arranged on the transmission line corroded due to the failure of the cathodic protection devices. Replacement of sections in progress.

The next installation visited was Tema Booster Station with the 4500 m^3 reservoir plus other minor reservoirs. Records at the station are well kept by the Station Manager who has been at post for over 26 years. Good performance summaries accompany production reports to the Area Engineer's Office. Station is very well kept. Tour visit undertaken on the transmission main to Accra which is also being rehabilitated. Daily reservoir levels are communicated to the Area Control Room in Accra.

Accra Booster station was visited to get acquainted with the pumping arrangements for operating the Pressure Zoning System. Station records are well kept with daily reports sent by telephone to Area Control Room. Station house-keeping was reasonably good. Tour visits conducted to the Medium Pressure Zone Reservoir which is under repair and the High Pressure Zone Reservoir. The station has 45000 m^3 reservoir serving the Low Pressure Zone as well. Water distributed to the various pressure zones are available in the records.

Weija headworks which includes the Phase 2 works was visited on an arranged schedule with the Station Manager. The Weija Dam and the impounded reservoir had influenced raw water quality with decaying vegetation and low dissolved oxygen levels for sometime but improvements had been observed of late. There is even suggestions of possible future use of slow sand filters. Data on raw water quality obtained from the beginning of lake formation to the end of 1988 through the Plant Control Chemist. Algae and weed blooms are serious seasonal problems being tackled. Data on the operations of the two pumping stations, the new Canadian and old West German are available. Study tours were taken through the two old treatment works. The Pintsch Bamag (West German Plant) was operating during the period of visit but the Paterson-Candy Plant (British) was being rehabilitated. The main study centred on the Phase 2 Treatment Plant commissioned in 1984. Drawings, installation, operation and maintenance manuals were studied and inventory of equipment taken to cross-check with drawings. Flow measurement were checked with attendants and maintenance schedules discussed with the maintenance engineers. Problems with filter backwash resulting in loss of media were studied. By far the most persistent fault is power outages which were fully recorded. The station communicates production levels and reservoir levels to the Area Control Room daily and issues monthly production reports to the Area Engineer's office.

Water distribution section provided the base for data collection on both technical and revenue activities. Accra is divided up into seven distribution districts each with technical and revenue sections; thus the district manager could be a technical or a revenue officer. Tema distribution is a separate entity headed by an engineer. Visits were undertaken to the various districts and Tema to observe their daily routines. Unfortunately the system does not include any continuous recording flow meters or pressure gauges to ascertain system performance over time. Two non-recording gauges, located at the Accra Distribution Engineer's office had readings recorded for some time. The fault office located at the Accra Distribution Engineer's office is operated on 24-hour basis. Records of faults are available. These faults are referred to the district concerned or are attended to by an emergency gang located at the fault office. Feedback of action taken, how much time taken, and areas affected by the fault are not always forthcoming.

However, areas with inadequate supply were located, slum and squatter areas were visited to ascertain facilities available and some interviews with consumers were conducted.

5.3.2 Central Accra Sewerage Project

Data sources on this project are as follows:

Accra-Tema Metropolitan Area Manager's Office
Consultants
Sewerage Engineer's Office
Pumping Stations

The Area Manager's Office with its sub-divisions as described earlier provided data on staff strength, revenue, expenditures, and maintenance schedules. Project reports and project history were provided by the Consultants. The Sewerage Engineer's Office was the main source of data. It consisted of the Drawing Office, the Sewer Maintenance and Service Connection Section. The Drawing Office had all 'as built' drawings. Considerable time was spent getting acquainted with the system. Sewer sizes, locations, slopes, manholes and their locations, connection points for customers, pumping stations and other designs yet to be constructed. Due to the low level of activity in construction, extension works and new connection the staff in this section seemed demotivated.

The Sewer Maintenance and Service Connection Section had all the operating and maintenance manuals for sewers and manholes. The flushing programmes for the various classes of sewers were laid out and the records of activities were reasonably well kept. However, there was no Faults Office which recorded on a daily basis complaints on the system and from customers. Further there was no laboratory for checking on the sewage quality changes as new connections, especially from factories, are made. Information on quality was based on earlier measurements by consultants and especially commissioned analysis carried out by the Area Chemist using borrowed facilities from other laboratories. This is a deplorable state of affairs and could lead to admission of very undesirable effluents. However, field visits including walking in the 1000mm interceptor sewer did not reveal any corrosion in sewers.

Pumping stations provided data on physical installations and their present condition. Operating records are available but are not analysed or well kept. Reports issues monthly are sketchy and do not include maintenance activities.

There is a need for increased management attention to the Sewerage Division, above all, to address the training needs, to provide laboratory facilities and to effectively solve the beach pollution by sewage from pumping stations.

6.3.3 3000 Drilled Wells Project

Data sources on this project include the following:

Project Manager/Co-manager's Office
Kumasi Base Workshop
Handpump Testing Programme
Other Regional Workshops
Some District Workshops
Field Visits in 6 Regions
IGIP Consultant on Education Proposals
Volumes 1-10 IDC Consultants' Final Reports

A letter of introduction was presented to the Project Manager, Mr. Wolshield, who agreed to provide all assistance possible. An appointment was set up to discuss the project data requirements and proposed field visits. Maintenance reports and information on new approach to combat the corrosion problem were obtained. Information was passed on to Regional Workshop on the field visits.

Kumasi Base Workshop provided information on spare parts position and general modifications being carried out on pumps especially the development, the Ghadev Pump, which uses weights to improve the operation of India Mark II in shallow wells. Specific information was provided for wells in Ashanti Region prior to field visits. The Hand Pump Testing Programme based in the Kumasi Base Workshop provided information on types of pumps under test and their monitoring programme.

Field visits were combined with visits to regional workshops and some district workshops. In all 304 pumps were visited in 101 communities located in six regions. Visits involved locating wells, finding out whether they are operable, whether the pump is being used, water quality by inspection and interview with the consumers. Distances from households had to be assessed (mainly by pacing). Where community leaders were available they will be interviewed to find out how revenue collection is organised together with well site maintenance. Usually distances to traditional sources are assessed on information provided by the community since it proved physically impossible to visit all traditional sources.

Most of the workshops visited faced the same problems of lack of spare parts and maintenance of access roads.

Desk study of the Consultants' final reports Volume 1-10 provided invaluable information on the construction work with costs. The report on educational proposals provided information on future directions of the project.

6.3.4 Urban Kumasi-type Ventilated Improved Pit Latrines Project

Data sources for this project consist of the following:

- The office of the Executive Chairman, Kumasi Metropolitan Assembly
- The City Engineer's office, Kumasi Metropolitan Assembly
- The Cleansing Department, Kumasi Metropolitan Assembly
- Field visits to latrines
- Committees for the Defence of the Revolution
- Traditional Authority (in Amakom Area)
- Toilet Rehabilitation Committee (Adum Area)

Letter of introduction was presented to the City Engineer who then arranged a meeting with the Executive Chairman of the City Council. Discussions centred on how the project was initiated by the Executive Chairman and his personal interest in visiting project sites on Sundays. Sanitation was his top priority activity; a good example of how political support can be effectively used to prompt communities to manage their sanitation facilities. The City Engineer's Office provided information on costs, institutional arrangements in construction, contributions of the City Council and community contributions. The City

Cleansing Department provided data on the availability of cesspit emptyers and the performance of the latrines. This latrine technology was new to the Cleansing Department and there were quite genuine apprehensions expressed about the efficacy of the technology in the urban setting.

Field visits were undertaken to the six latrines constructed in the centre of the city and two others in the peri-urban areas. At each latrine level of usage was observed for three days (two working days and one day at the weekend). Queuing periods were noted and numbers of people in the catchment areas were assessed. Interviews were conducted with users on the admission charge and the acceptance of the new latrines.

Interviews were conducted with the community organisations managing the latrines; in most cases the Committees for the Defence of the Revolution were not very keen on providing details of revenues and expenditures. The Traditional Authority and the Toilet Rehabilitation Committee managing other latrines were very co-operative in providing details of revenue and expenditures. In the peri-urban areas no admission fees were charged and head taxes were raised to pay for pit de-sludging. Visits were paid to some new project sites.

6.3.5 Borehole Water Supply Project

Data sources for this project consist of the following:
The Drilling Section of the Ghana Water and Sewerage Corporation
Nine Regional offices of Ghana Water and Sewerage Corporation
District offices of Ghana Water and Sewerage Corporation
Borehole Water Supply Stations
Head Office of Ghana Water and Sewerage Corporation in particular
Director of Operations and Maintenance Statistical Office
Water Engineering Company

The Drilling Engineer's office based in Kumasi provides the main source of data on drilling operations in Ghana. The records section maintains record cards on each borehole drilled since 1955, some have cost figures but a good record of borehole logs are available. The Drilling Unit still retains the services of drilling superintendents with over 30 years experience in the field who can provide personal local knowledge of various drilling operations. Mechanisation of boreholes has been the responsibility of the Mechanical/Electrical Section of the Drilling Unit who also undertake major maintenance assignments in all regions.

Borehole Water Supply Project can be found in all regions except Greater Accra. The Regional Offices of the Ghana Water and Sewerage Corporation keep records on each station in terms of staff strength, revenue performance and on all expenditures through a system of account codes. Regional borehole servicing unit also provide data on maintenance operations at each station but records are not very well kept.

Water Engineering Company based in Accra has a contract to maintain all Pleuger submersible pumps and also keeps good records on these installations and the schedule of visits carried out.

Visits were undertaken to twenty borehole water supply stations in eight regions; there are only two borehole water supply stations in the Northern Region and none of them was visited. Visits provided first-hand data on station operations, fuel supply problems and afforded the opportunity to interview consumers on acceptability of services provided, water quality and revenue and use of traditional sources. District Offices were visited only when this proved convenient; transportation difficulties do not always allow this if borehole supplies are located away from the controlling district office. Production reports are sent monthly to the Director of Operations and Maintenance and are available at the Statistical Office.

6.3.6 Package Plant Water Supply Project

Data sources for this project consist of:

Package Plant Unit, Drilling Section of Ghana Water and Sewerage Corporation

Seven Regional Offices, Ghana Water and Sewerage Corporation

District Offices, Ghana Water and Sewerage Corporation

Package Plant Water Supply Stations

Head Office, Ghana Water and Sewerage Corporation in particular Projects Division and Statistical Office

Package Plant importation and distribution to the regions was the responsibility of the Projects Division at the Head Office of the Ghana Water and Sewage Corporation. Cost data and sizes of units at particular locations are obtainable from office files and the Drawing Office.

Package Plant water supplies are located in all regions except Greater Accra, Upper East and Upper West regions. Offices of the seven beneficiary regions provide data on staffing levels, expenditures, revenue, supply of fuel and chemicals. The Regional Maintenance Units have data on maintenance operations while the Regional Chemist provides information on the performance of the dosers. Record keeping of these activities is particularly lacking and therefore information tends to be verbal. The German Agency for Technical Co-operation (GTZ) was involved in a project rehabilitating some of the Package Plants and the staff could give an account of the state of the plant prior to rehabilitation.

Visits took place to twenty Package Plant installations in the seven regions. Operations were at different levels - some completely broken down (in one case the plant has not operated for more than six years but the staff remained at post, some functioned without any dosers, where only one doser was available it was used to dose alum, and others, especially the newly rehabilitated plants functioned perfectly. Data on revenue collection and consumer attitudes were obtained through interviews with customers and members of the Committee for the Defense of the Revolution. Queuing time and distances of standpipes from households were assessed.

The Package Plant Unit located at the Drilling Section of the Ghana Water and Sewerage Corporation was involved in installation work and has been retained to undertake major maintenance work involving re-sanding of filters, stripping and rebuilding elevated tanks. Cost data on maintenance was obtained from this unit. Monthly production reports were sent to the Statistical Office at the Head Office.

6.3.7 Rural Kumasi-type Ventilated Improved Pit Latrine Project

Data sources for this project are as follows:

Head Office of the Department of Rural Housing and Cottage Industries

Six Regional Offices of the Department of Rural Housing and Cottage Industries Communities

Department of Civil Engineering, University of Science and Technology, Kumasi

The project was formulated by the Department of Civil Engineering of the University of Science and Technology in consultation with the Ministry of Rural Development and Co-operatives. Training of trainers selected from the implementing agencies of the Ministry, that is, Department of Rural Housing and Cottage Industries and Department of Community Development, was undertaken at the University of Science and Technology. Data on postings of trainers and training of final year masonry students were obtained from the Regional Offices and Head Office of the Department of Rural Housing and Cottage Industries. Selection of villages and acceptance of payment of community deposits was done in the regions but data was poorly kept in some regions. Earlier regional information returns to Head Office was a good source of data together with movement orders for materials to the communities. Government releases of funds for the project were also obtained from the Head Office of the Department of Rural Housing and Cottage Industries.

Visits were undertaken to ten completed projects in the six beneficiary regions. In each community meetings took place with the chief or his representative, the members of the Committee for the Defense of the Revolution and Town Development Committee. After explanation of purpose of study and discussion permission was granted for observations and interviews. Two whole days were spent in each community to collect data. In most of these communities where wells for the 3000 wells existed data collection for the two projects were combined. Members of the Committee for the Defense of the Revolution were very helpful in providing information on the community contribution in kind for the project. The main concern was slow pace at which materials arrived and hence the effort required to sustain the interest of the community to get the project completed. The technology is new to the communities and operations were explained at length particularly pit de-sludging by manual method and who should undertake the task. Experience from other communities was shared with them.

6.3.8 2500 Drilled Wells Project

Data sources for this project include:

The office of the CIDA Project Manager
Two regional offices, Ghana Water and Sewerage Corporation
The Handpump Maintenance Engineer, Upper East Region
District Offices, Upper East and West, Ghana Water and Sewerage Corporation
Water Utilization Project, Upper Regions, Ghana Water and Sewerage Corporation
World Bank/UNDP Community Water and Sanitation Project, Upper Regions
Vol. 1-5 Canadian International Development Agency Evaluation Reports
Communities

Letter of introduction was received by the Regional Manager, Upper East of Ghana Water and Sewerage Corporation. The Handpump Maintenance Engineer was made the co-ordinator of the study. Consultant reports were made available. While getting acquainted with details of the projects an appointment was set up to meet the CIDA Project Manager. Data on the total CIDA involvement in the project was provided in addition to the new directions CIDA would like to follow in the future, that is, the World Bank/UNDP Community Water and Sanitation Project, funded by CIDA. The pilot phase of identification of suitable handpump for Upper Regions and Ghana was beginning in October 1988.

A meeting with the leader of the Water Utilization Project also provided data on the scope of the Health and Community Educational Programme.

Field visits were undertaken to 60 handpump communities in the Upper East Region. Transportation difficulties are so severe that the Handpump Maintenance Engineer had to assist with his Toyota Pick-up. His presence facilitated contact with the communities and made communication, together with flow of information, easier. Interviews were conducted through an interpreter, a Ghana Water and Sewerage Corporation employee, in the local language. Details on revenue payment were provided by Revenue Section. District offices maintain a card system for each pump which provided information on maintenance work and sometimes even materials used. Spare parts position was excellent. Motor cycles and other vehicle operations were limited mainly by the general fuel shortage in the region.

Similar trip was undertaken to Upper West region where 35 wells were visited. Field trips were mainly to check on any changes that had taken place since the 18-month (1984/85) Project Evaluation by a CIDA team. The five-volume report is an invaluable data source.

6.3.9 Hand-dug Well Project

Data sources for this project consist of:

- Akuapem District Administration Office
- Office of the Project Supervisor
- Water Aid Office, Accra
- Communities

The office of the political administrator of the Akuapem District is the focal point of activities of the Akuapem Rural Development Foundation. Data on communities applying to benefit from the project, the selection process and materials committed to the project are obtainable from this office. The project supervisor is secretary of the three-man selection committee and thus provides the vital link between the selection committee and the communities. The project supervisor is also the budgeting officer. His budget estimates are approved by the three-man committee and sent to Water Aid office in Accra for onward transmission to Water Aid offices in London. Equipment, stores and supplies are kept at the office of the Project Supervisor, a modest wooden structure located at Akropong, the district capital town. A Toyota four-wheel drive pick-up is the project vehicle. Field visits were undertaken to several project sites where construction is still in progress. The communities are located away from main transport routes and the access roads are just bush paths. Communities generally travel on foot and is common sight to see school children walking up to 10km to school. The communities are farmers mainly and women can be seen carrying farm produce to the villages taking turns on the rotating market days.

Having selected Timber Nkwanta as study project, the village headman and the Committee for the Defense of the Revolution were informed. At a meeting three days were selected including a non-farming day. The project supervisor was present for the first day of the study and then handed over to the members of the Committee for the Defense of the Revolution. The village water committee members were introduced indicating individual responsibilities on the committee.

The Water Aid official, Mr. Ron Bannerman, proved rather difficult to locate. He had just taken over the project and was touring other Water Aid projects in the Afram Plains and in Upper East Region. Later he was located at the head office of the Ghana Water and Sewerage Corporation where he provided data on Water Aid involvement in this and other projects.

6.3.10 Traditional Pit Latrine Project

This project was planned and constructed by the community of Esreso without any assistance from external sources. The community therefore remains the only data source.

On the first day of visit a member of the Committee for the Defense of the Revolution was contacted, who arranged for a meeting with the chairman. Discussions centred on my data requirement and the purpose of the study. The chairman intimated that the community was working on getting a Kumasi-type ventilated improved pit latrine constructed but had not been able to raise enough funds. It was mentioned that some of the data may have to be obtained discretely without the community members being informed officially. For example, depth measurement of sludge accumulation could be done at midday when most people are away from the village. Another meeting was arranged to meet the chief and the members of the Town Development Committee. The chairman of the Committee for the Defense of the Revolution led the discussion and concluded that it was possible to get assistance for their Kumasi type ventilated improved pit latrine if they co-operated with the study. Finally, permission was granted for the study. Data collection took seven days to include a non-farm day and weekend when wage earning workers are at home. Counting the number of female users had to be undertaken from a sheltered spot without the users knowing. Most women would not respond to interviews about when and how often the latrine was used. On the prompting of the members of the Committee for the Defense of the Revolution some women provided responses. Depth of sludge accumulation was measured on a quiet afternoon.

Esreso draws water from a traditional source. A single well drilled was dry. The opportunity was taken to survey for willingness to pay for water from drilled wells.

Putuagya, a village two kilometres from Esreso was also surveyed for willingness to pay for well water and for the construction of a Kumasi-type ventilated improved pit latrine.

Valuation of non-cash items in the construction of the traditional pit latrine was based on cost for alternative uses. For example, timber from the bush was valued as firewood for fuel.

6.4 GOVERNMENT INSTITUTIONS AS DATA SOURCES

Various government institutions were visited to collect data on certain aspects of the projects being studied. In connection with the Economic Recovery Programmes the Ministry of Finance and Economic Planning provided information on the Structural Adjustment Programme and the Public Investment Programme. Information on the general performance of the Ghana economy to date was made available.

The Ghana Statistical Service was an invaluable data source for socio-economic indices. Recent surveys on cost of living had not been published yet. This would have provided information in the effect of the Structural Adjustment Programme on the population. Details of the 1984 Population Census have not been fully published although available on request.

Formal meetings were arranged with the Managing Director and the Director of Development of the Ghana Water and Sewerage Corporation to ascertain the status of project appraisal and project evaluation within the context of project development.

The Ministry of Local Government being the focal point of sanitation activity provided some information on the future trends in the involvement of Utility Services Committees of the new elected District Assemblies in the sanitation sub-sector.

6.5 GENERAL PROBLEMS IN DATA COLLECTION

The projects under investigation are distributed throughout Ghana; from the Accra-Tema Water Supply and the Central Accra Sewerage located within or very close to the city of Accra to the drilled wells located in a remote village in the Upper Regions. The fieldwork, thus, called for very extensive travelling. The decline in the economy had caused major dislocations in the public transportation system. Roads could not be maintained and therefore in a deplorable state of disrepair. Vehicles plying the roads had been drastically reduced in numbers and the condition of those vehicles available left a lot to be desired. Projects had to be visited, mostly using public transport. The interminable waiting periods and the frequent vehicle breakdowns on the roads made the fieldwork unnecessarily difficult and lengthy in time requirements. The situation was not much helped when the research sponsors, the World Health Organisation, determined funding levels without much knowledge of the scope and content of the fieldwork. Even as prices soared during the fieldwork due to steep devaluations of the local currency no additional funds were made available. Further, requests for funds for photography, books, reports, photocopying and for payment of incentives to services provided by others were not attended to until the end of the fieldwork. This meant most expenditures had to be pre-financed from other sources in the hope that World Health Organisation will repay. Any future work will require proper assessment of funds required with subsequent timely release of such funds.

The areal coverage of the projects also required good means of communication with a host of personnel who needed to be contacted prior to undertaking visits. The telephone system covered a few areas and was not even reliable. Letters were useful but replies depended on someone else's priorities and may or may not arrive when posted. This meant that visits had to be undertaken in most cases in the hope that key personnel will be available on arrival. It was only fortuitous that key personnel were in fact available during most visits when prior appointments had not been fixed.

Record keeping was quite satisfactory on most projects. However records accumulated over the years are dumped in haphazard fashion in so-called archives. The very sight of these archives can put off any not-too-eager researcher. Processing of data before storage should be a critical activity but can only be undertaken when information needs are determined.

CHAPTER SEVEN

DESCRIPTION OF PROJECTS

7.1 ACCRA-TEMA WATER SUPPLY PROJECT: PHASE 1 AND PHASE 2

7.1.1 Historical Perspective

As a result of severe droughts in 1894/95 and 1903/04 the government of the Gold Coast (later Ghana) assumed responsibility for the provision of permanent water supplies for Accra and other major towns. By 1914 the earliest water supply scheme for Accra had been completed (Smith, 1969 op. cit.). This plant has since been retired but two transmission lines, 300mm pipeline completed in 1918 and 350mm pipeline completed in 1929 are still in service as secondary mains.

7.1.2 Existing Water Supplies Prior to Phase 1

The only source of water supply to Accra depended on the Weija Dam on the Densu River, 12km to the west of Accra. A conventional water treatment plant of capacity 19000m^3/d built by Paterson-Candy was completed in 1952/53 together with a 400mm pipeline. In 1959 another pipeline 525mm was also constructed from the treatment plant to Accra. In 1963 the Pintch-Bamag Plant, also a conventional water treatment plant of capacity 24000m^3/d built by a West German firm was completed. Power supply to the treatment plants was from the National Grid but four diesel alternators had been provided as standby. (These standby equipment have since been out of service.)

The raw water pumping station, located adjacent to the Weija Dam, draws water through an intake tower. Four electrically driven vertical turbine pumps each capable of pumping at 1000m^3/h and total head of 115m have been installed. On normal operations three pumps are on duty in parallel, with the fourth on standby. The design output on normal operation should be 59000m^3/d but due to bottle-neck in the pipework about 50,000m^3/d was obtained. Raw water from this station is delivered to both the Paterson Candy plant and the Pintch-Bamag plant.

At the Paterson-Candy Plant raw water is delivered into 4500m^3 tank and then flows by gravity to a dividing chamber with overflow weirs where chemicals are added. The flow is divided to 16 hopper-bottomed sedimentation tanks each of size 6.4m x 6.4m. From the sedimentation tanks the water gravitates to the filter block consisting of eight rapid gravity sand filters each of size 9.1m x 3.6m and then to the clear water wells of capacity $4500m^3$. After undergoing pH correction and chlorination the water is supplied into the distribution network of Accra.

At the Pintch-Bamag Plant raw water from the pumping station is delivered into a $4500m^3$ tank and then gravitates into a dividing chamber with two overflow weirs which divides the flow to two clariflocculators each fitted with four stirrers. From the clariflocculators the water passes to a battery of five rapid gravity sand filters and then to a $4500m^3$ clear water tank from which it is supplied by gravity to the distribution network of Accra. Modifications carried out at this plant increased the capacity from 23,600 to $31,400m^3/d$.

In 1968 heavy rainfall and widespread flooding caused over-topping at the Weija Dam which consequently was washed away. The two treatment plants had to rely on the run of the river with very low flows during the dry season causing severe cuts in treatment capacity.

Water supply to Tema depended on the Old Kpong Waterworks located 54km to the north on the Lower Volta River. These works also consist of the original Paterson-Candy Plant and the later addition, Pintch-Bamag Plant.

The raw water pumped from the Volta River is treated by passing it through clariflocculators and then through rapid gravity sand filters. There are a total of five clariflocculators - two in the Paterson-Candy plant and three in the Pintch-Bamag plant. The former are 16.75m in diameter and the latter 30.5m in diameter. There are eight filters in the Paterson-Candy plant and five in the Pintch-Bamag plant. Each filter at the Paterson-Candy plant measures 7m x 6m. The five Pintch-Bamag filters are identical to those installed at the same time, 1963, at the Weija Works. Each filter measures 6m x 9m (twin filter of each 3m x 9m). The combined capacity of the Paterson-Candy plant and the Pintch-Bamag plant is $36,300m^3/d$. Water is delivered to Tema through

525mm main which was laid in 1958/59. With the help of a booster-station 21,600m^3/d was delivered to Tema.

7.1.3 Accra-Tema Water Supply Project - Phase 1 (Figure 7.1)

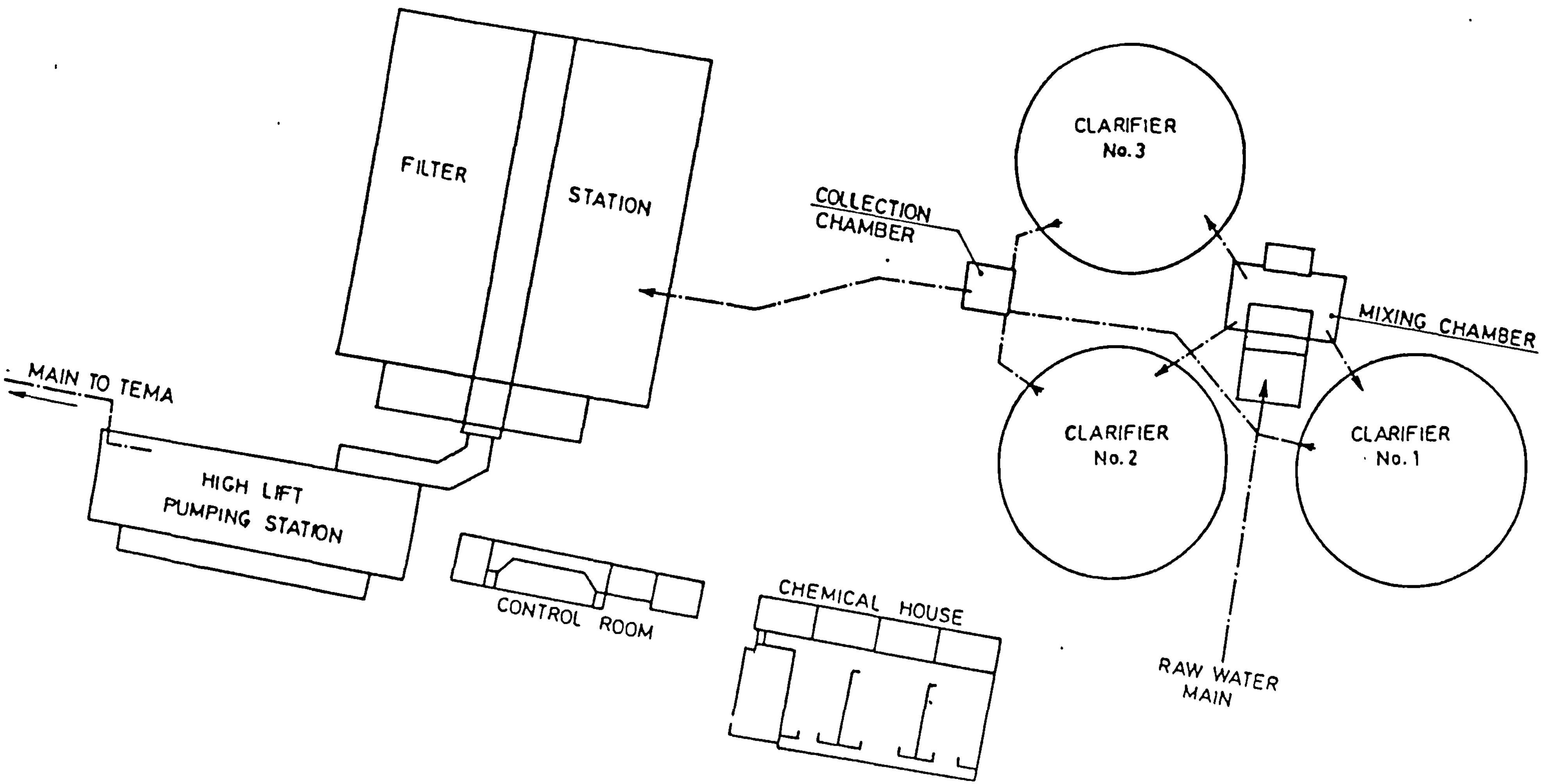
In 1963 the World Health Organisation commissioned TAHAL (Water Planning) Ltd. of Tel Aviv and Engineering Science, Inc. of Arcadia, California to draw up a Master Plan for the development of water supply and sewerage disposal schemes till the year 2000 for Accra-Tema Metropolitan Area (ATMA) (TAHAL, 1965). During the preparation of the Master Plan the then existing water supply facilities of ATMA, described above, had not been able to meet the water demand. Consequently, the government of Ghana entered into a contract with STEPRI (A German consortium of Stahlunion-Export GmBH and Phoenix-Rheinrohr-International GmBH) for the construction of a water supply system capable of supplying 180,000m^3/d to ATMA from the Volta River at Kpong. The entire works constructed under Phase 1 include the following (GWSC, 1981a).

- Intake situated on the west bank of the Volta River, some 50m north of the old intake. The structure contains two screening chambers each fitted with cleaning brushes.
- Raw water pumping station which is integral with the intake structure and houses three electrically driven vertical pumps each capable of 3358m^3/h at 25.2m head. Electrical instruments and controls are provided. Water is pumped to the existing treatment plant and through 1200mm fibre glass reinforced plastic rising main to the new treatment works 900 metres west of the intake where it enters directly into a double compartment Vortifloc mixing chamber.
- Vortifloc double compartment composed of Compartment No. 1 equipped with electrically operated paddle mixer with two paddles. When only one paddle works it operates as a mixer but with both paddles working it operates as a flash mixer. (Alum was dosed here until 1975 when it was stopped because of the improvement in raw water quality following the completion of the Volta Dam upstream of the intake.) Compartment No. 2 contains a second electrically operated paddle mixer. From Compartment No. 2 the water flows through 900mm pipes to the clariflocculators.
- Clariflocculators consist of three tanks each of 18.7m in internal diameter. The mixer for the internal core of each clarifier is

FIGURE 7.1: ACCRA TEMA WATER SUPPLY - PHASE 1

LAYOUT OF NEW TREATMENT WORKS

KPONG



capable of 3.22rpm or 4.05rpm. Each clariflocculator discharges its effluent into a peripheral channel 0.8m wide. A 900mm pipe leads from each of the peripheral channels to a collecting chamber and then through 1200mm pipes to the rapid gravity sand filters. The clariflocculators are fitted with scrapers. An automatic timer-controlled de-sludging system operates two de-sludging valves at each clariflocculator. The sludge discharges into a sump from where it is pumped by two de-sludging pumps to waste. The sludge pumps are operated by timer-triggered remote control from the Control Room. There are also two sludge recirculation pumps which return sludge to the mixing chambers preceding the clariflocculators.

- Rapid Gravity Sand Filters consist of 20 filters arranged in ten twin filters with a total filtration area of $1200m^2$. Provision has been made for additional four twin filters of total area $480m^2$ with foundations in place. The filters have the following auxiliary equipment - three wash water pumps each of capacity $1800m^3/h$. with 18m head, three air scour blowers of capacity $63m^3/min$ and two compressors.
- Chemical Dosers and Chemical House consist of facilities for storing, preparing and dosing of alum (stopped in 1975), lime, sodium carbonate and chlorine. The alum facilities consist of two storage tanks each of capacity $350m^3$ and two daily tanks each of capacity $60m^3$. There are transfer pumps from storage to daily tanks as well as two solution feed pumps. Lime facilities include two lime solution tanks fitted with mixers and two lime dosing pumps. For sodium carbonate there are two storage tanks each of capacity $350m^3$ and two daily tanks with mixers and agitating pumps. Two feed pumps are provided. The chlorination unit has storage for 20 drums of gaseous chlorine which is a three-month supply. When supply of gaseous chlorine is interrupted bleaching powder is dosed instead. Chlorinations equipment have been provided as two units for prechlorination and two units for final chlorination. Safety equipment such a neutralization chamber, exhaust fan, water spray and shower have been provided.
- High Lift Pumping Station provides for two vertical feeder pump, one on duty and one standby, working in series with three horizontal pumps also connected in series. Each vertical feeder

pump is capable of 6,620m^3/h discharge at 8m head and each horizontal pump has capacity of 6,595m^3/h discharge at a total head of 107m. There is a fourth horizontal pump on standby. The filtered water is pumped from the clear water tank to the Tema Terminal Reservoir.

- Transmission of treated water from the High Lift Pumping Station to Tema Terminal Reservoir of 45,500m^3 capacity is through 1050mm steel main bitumen coated and cement mortar lined. The length of the steel main is 54km.
- Gravity feeder main of 1050mm steel pipe conveys water from the Tema Terminal Reservoir to the Tema Township.
- Tema Booster Station with a capacity of 80,000m^3/d has three pumps connected in series on duty with one standby.
- Transmission from Tema to Accra is through an 800mm steel main externally coated with bitumen and lined with cement-mortar. This main is 22.5km long.
- Accra Terminal Reservoir of capacity 45,500m^3 and Top Water Level (TWL) of 73.15m receives water from Tema Booster Station and serves a three-fold purpose as storage reservoir for emergency needs as balancing reservoir for Tema and Accra Booster Stations and as supply reservoir for Accra Low Pressure Zone (LPZ).
- Accra Booster Station pumps water to the Accra Medium Pressure Zone (MPZ) and High Pressure Zone (HPZ). It is equipped with two units for each pressure zone (one operational one standby). Provision has been made for one additional unit for each pressure zone. The station delivers 39,000m^3/d through an 800mm steel main to the MPZ Reservoir of capacity 9000m^3 and TWL 97.54m and 9000m^3/d to the HPZ Reservoir of capacity 9000m^3 and TWL 137.15m through a 400mm steel main.
- Distribution improvements included dividing the Accra Distribution System into three zones. The Low Pressure Zone (LPZ) covers areas with ground elevation between 0-30.5m. The Medium Pressure Zone covers areas with ground elevation between 30.5-61m. The High Pressure Zone covers areas with ground elevation above 61m. Various sizes of primary, secondary and tertiary mains ranging from 800mm to 150mm were constructed (Figure 7.2).
- A booster station was constructed to increase the flow through the 525mm transmission line from Weija.

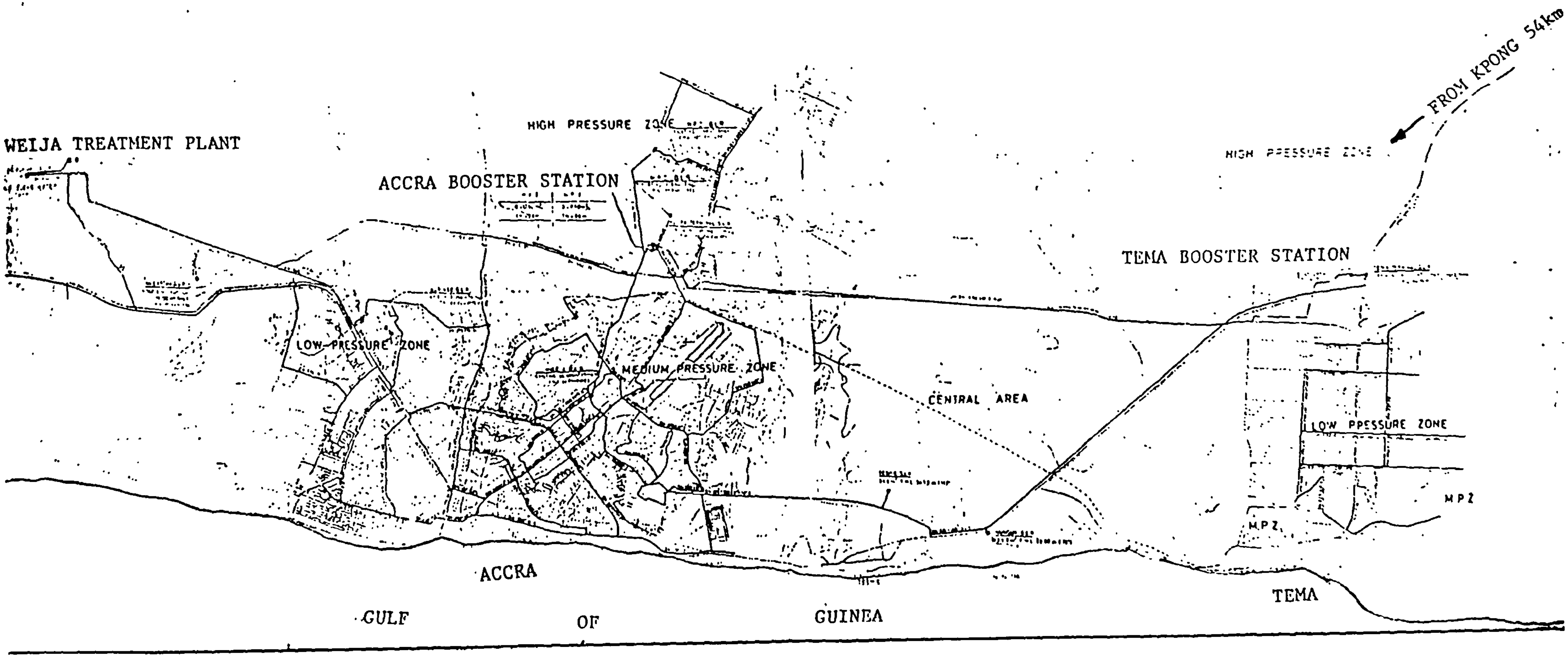


FIGURE 7.2: ACCRA-TEMA WATER SUPPLY PROJECT

- Staff housing units were provided at Kpong Waterworks, Tema Booster Station and Accra Booster Station.
- Communication equipment were provided at all stations together with a telemetering system at a Central Control Room at the headquarters of the Accra-Tema Metropolitan Area of the Ghana Water and Sewerage Corporation.
- Training facilities were provided for the engineers, chemists and technicians who were employed at all the stations in Germany. Local training was provided by German counterpart staff.

The Accra-Tema Water Supply Phase 1 Project was completed in 1966 at a cost of $34.834 million financed by suppliers credit guaranteed by the government of the Federal Republic of Germany.

7.1.4 Accra-Tema Water Supply Project - Phase 2

On the basis of studies conducted by TAHAL (Water Planning) of Tel Aviv in 1971, the Ghana Water and Sewerage Corporation entered into an agreement with the International Development Association (IDA) of the World Bank, the Canadian International Development Agency (CIDA) and the African Development Bank (ADB) in 1972 for the construction of the Accra-Tema Water Supply Project - Phase 2.

The original proposal for the Phase 2 project had to be reduced in scope because of financial restrictions.

Original Project	Implemented Project
(a) Weija New Dam	Weija New Dam
(b) Raw Water Pumping Station of Capacity 136,363.6m^3/d	Raw Water Pumping Station of Capacity 90,909.1m^3/d
(c) Raw Water Pumping Main of size 1,050mm	Raw Water Pumping Main of size 900mm
(d) Weija New Treatment Plant of Capacity 136,363.6m^3/d	Weija New Treatment Plant of Capacity 68,181.8m^3/d
(e) Transmission Mains from Weija to Accra	Transmission Mains from Weija to Accra
(f) Accra Medium Pressure Zone Reservoir	Deleted
(g) McCarthy Reservoir	Shifted to Phase 3

(h) Tema Terminal Reservoir	Deleted
(i) Tema Elevated Tanks and Booster Station	Deleted
(j) Extension to Accra and and Tema Distribution	Reduction in the Distribution Extension Programme

Various components of the project were financed by different agencies and were constructed by contractors appointed by Ghana Water and Sewerage Corporation and the financing agency. Details of the project components are as follows:

- The design of the Weija Dam established the height at 16.8m or 2.4m above the height deemed desirable for water supply in order to provide for possible future diversions for irrigation. The dam was of the rock-fill type with a clay core. Contract for the construction was awarded to an Italian construction firm in 1973 and was completed in 1978. This component was financed by the International Development Association/World Bank.
- In connection with the construction of the dam and the creation of the Weija approximately 2000 people in eight villages were affected and had to be resettled in six new villages. Construction was undertaken by local contractors and the project financed by the Ghana Water and Sewerage Corporation.
- The Raw Water Pumping Station was constructed by the dam contractor and was financed by the International Development Association.
- Raw Pumping Main was constructed by a local contractor with materials supplied by foreign suppliers. Financing was by the African Development Bank. It is expected that in future this main will be duplicated.
- Power supply to the pump house and the supply and installation of three pumps each of capacity of $34m^3$/min with head of 113m were undertaken by Canadian suppliers and contractors. Operation is two pumps in parallel and one standby giving a capacity of 68,000 m^3/d. The pumps are driven by constant speed motors with a butterfly valve to control the flow. Provision has been made for the installation of a fourth pump to extend capacity to $13,600m^3$. This component was financed by the Canadian International Development Agency.

- The Water Treatment Plant was jointly financed by the Canadian International Development Agency who was responsible for the supply and erection of all equipment by the Canadian suppliers and contractors and the African Development Bank responsible for the civil works constructed by local contractors (Figure 7.3). The treatment plant is composed of an initial spray aerator unit followed by two clarifiers. The clarifiers have the following features: a primary mixing and reaction zone where the raw water reacts with the chemicals in the presence of recirculated slurry, a second reaction chamber, a clarification zone and sludge removal scrapers and devices. The clarified water is collected in orifice type radial launders which lead to the collecting channel. The specification of the clarifiers are as follows:

Diameter	31.7m
Height	4.75m
Rates Capacity	34,100m^3/d
Maximum Capacity	45,500m^3/d
Residence time	2.33 hours

Four Rapid Gravity Sand Filters are provided each of size 10m x 9.75m with a depth of 0.76m. The under-drainage system includes a Graver Partilok strainer together with water and air scour concrete inserts. Filter inlet channels are of capacity 16,400m^3/d. Flow to each individual filter unit is controlled by a 700mm valve operated either manually or pneumatically. Each filter unit is fitted with a Venturi flow rate controller suitable for flow range of 3,300 to 110,000m^3/d. The effluent range is set either manually from individual filter control consoles or automatically from the master control room. For air scouring, three electrically driven air blowers are provided (two duty and one standby). Water for backwashing is supplied from the washwater reservoir which is filled by three vertical centrifugal pumps (two duty and one standby) drawing water from the filtered water effluent channel in the filter gallery.

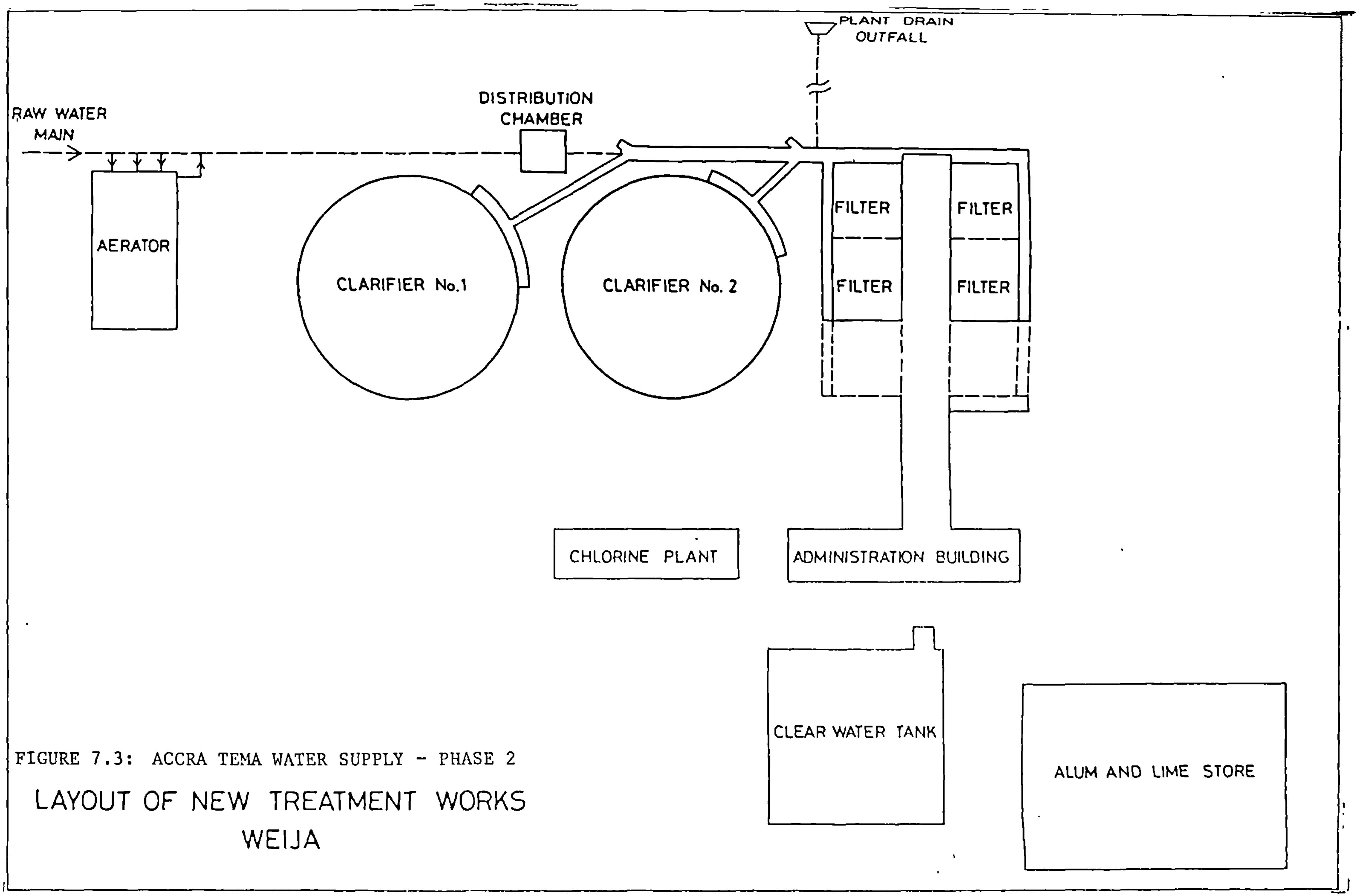


FIGURE 7.3: ACCRA TEMA WATER SUPPLY - PHASE 2

LAYOUT OF NEW TREATMENT WORKS
WEIJA

PLATE 7.1
WEIJA WATER TREATMENT PLANT

PLATE 7.2
FILTER BEDS AT KPONG

The following chemical facilities are provided for dry storage, preparations of solutions and delivery of solutions to the various points of application. For alum there is storage capacity for a six-month stock which is supplied dry in 100 lb bags. Two $60m^3$ day-tanks are provided for preparation of a 20 per cent solution. Each tank is sufficient for 24 hours operation with the other on standby. The tanks are equipped with circulation pumps to keep the solution homogeneous. Three manually set feed pumps (two duty and one standby) apply the solution at a dosage determined daily. For lime, storage capacity is provided for a three-month stock of dry form hydrated lime supplied in 50 lb bags. Three $21m^3$ day tanks for preparation of a 10 per cent suspension are provided. Each tank is sufficient for 12 hour operation and one tank is in use at a time. The tanks are fitted with stirrers to maintain the lime in suspension. Two lime injection pumps (one duty one standby apply the suspension via duplicate galvanised steel pipes. One of the steel pipes is in use at a time, allowing the other to be flushed when necessary through a special flushing connection. Dust extraction units are provided for both lime and alum facilities. For chlorination the plant is designed for a maximum dosage at 10mg/l for pre-chlorination and 2mg/l for post chlorination. The facilities provided include two rows of one ton drums with overhead crane sufficient to maintain a three month stock. Others are two scales each capable of holding two containers with a switchover system, two vacuum-operated solution chlorinators, chlorine residual detectors, recorders, alarms and chlorine solution and water supply pumps.

- Transmission mains of 900mm steel pipe and 700mm steel pipe together of 7.8km long were supplied by foreign sources through an international tender. Construction of the pipeline was by local contractors. The African Development Bank financed this component.
- Distribution mains extension for primary, secondary and tertiary pipelines of about 177km long. Supply of pipes was financed by the International Development Association but the construction undertaken by various local contractors was financed by the Ghana Water and Sewerage Corporation.

Project costs are presented below (World Bank, 1983b).

Component	Local Cost (Cedi)	Foreign Cost (US dollar)
IDA	23,823,000	10,357,000
CIDA	4,224,000	8,644,000
ADB	13,849,000	8,200,000
GWSC	25,552,000	
TOTAL	67,448,000 (US$ 24,526,545)	27,201,000
Grand Total	US$ 51,727,545	

All components of the project were substantially completed by 1984.

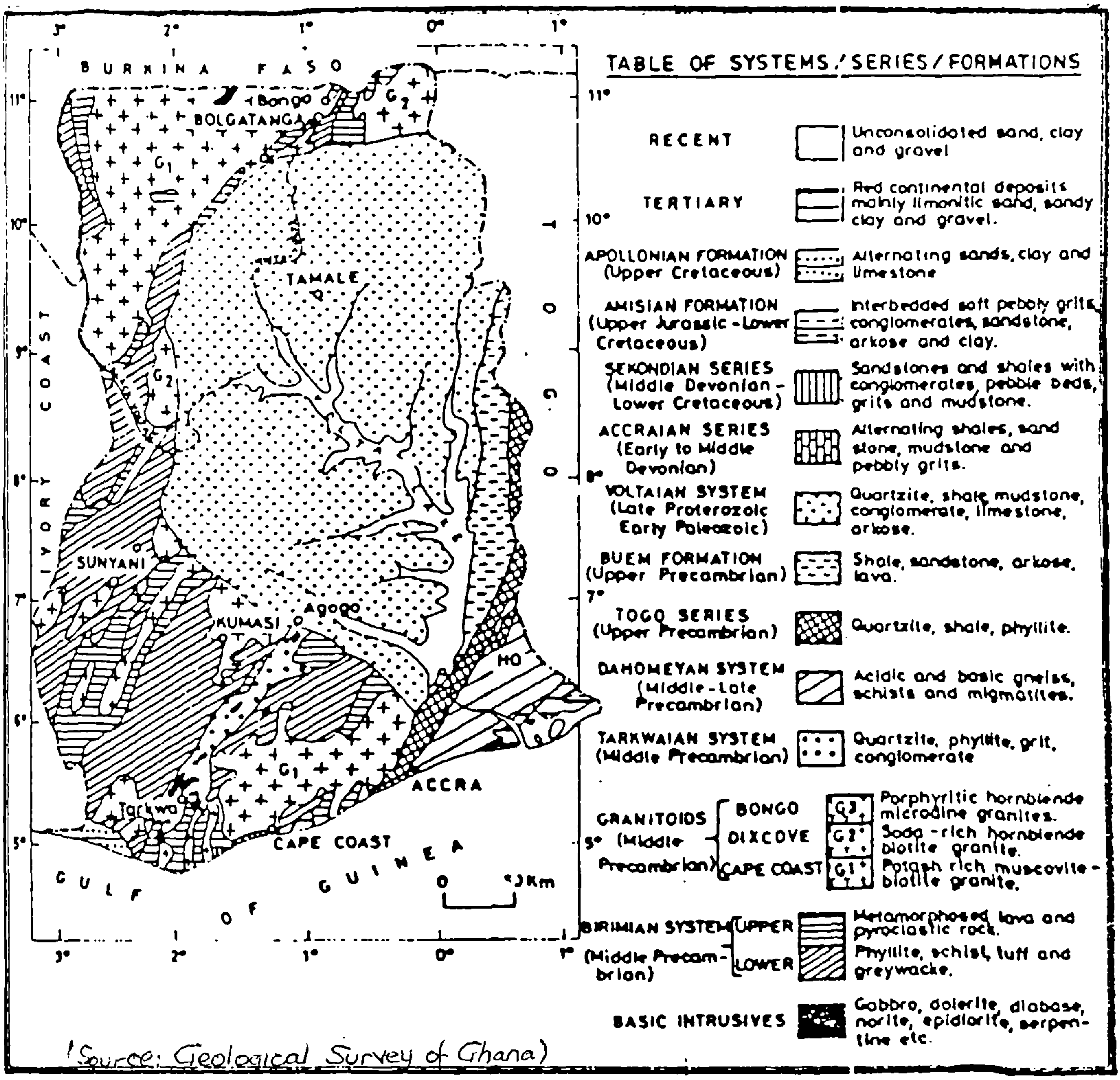
7.2 BOREHOLE WATER SUPPLY PROJECT

7.2.1 Hydrogeology of Ghana

Most of Ghana is underlain by crystalline and sedimentary rocks having little or no primary permeability. These rocks have however gained variable but low secondary permeability through jointing and fracturing. The crystalline rock area which forms 54 per cent of Ghana is composed of the following geologic formations (Nathan Consortium, 1970b) (Figure 7.4).

- Birrimian Formation is made up of metamorphosed lava, a pyroclastic rock, phyllite, schist, tuff and greywacke. It is of the middle pre-cambrian age. The Birrimian underlies about 27 per cent of the country and is the most important water-bearing formation. Boreholes sunk in this formation have average safe yield of about $19m^3/h$. Depth of weathering in general is about 25m. Borehole average depth is 60m.
- Granitic rocks consist of three distinguishable types; the porphyritic hornblende microline granites, soda-rich hornblende biotite granite and the potash-rich muscovite-biotite granite. Granite rocks are of the middle pre-cambrian age and underlie about 20 per cent of the country. This formation is less fractured and jointed than the Birrimian and hence less weathered. The average safe yield of boreholes in this formation is $11m^3/h$. Average depth of boreholes is about 48m in southern Ghana and about 36m in the less weathered drier north.

FIGURE 7.4: GEOLOGICAL MAP OF GHANA



(Source: Geological Survey of Ghana)

- Tarkwaian formation is composed of quartzite, phyllite grit and conglomerate and is of the middle pre-cambrian age. This formation underlies only two per cent of the country and is hydrogeologically similar to the Birrimian formation.
- Togo formation is made of quartzite, shale and phyllite of the upper pre-cambrian age. It is not as fractured or jointed as the Birrimian. Depth of weathering is about 14m. Average safe yield of boreholes is $9m^3/h$. The formation underlies only one per cent of the country.
- Dahomeyan formation consists of acidic and basic gneiss, shists and migmatites of the middle to lower pre-cambrian age. It underlies about four per cent of Ghana. It has a very poor groundwater potential due to the low degree of fracturing of the rock and to the very low permeability of the sandy clay to which the rock weathers.

The sedimentary rock formations underlie about 42 per cent of Ghana and is composed of the following geologic formations.

- Voltaian formation is made up of quartzite, shale, mudstone, conglomerate, limestone and arkose. It is of the Paleozoic age. The Voltaian beds are relatively flat and underformed over most of the basin. Folding and fracturing is found mainly in the eastern part of the basin however the outcrops marking the northern western and southern boundaries are also fractured. The groundwater potential is very low since secondary permeability is much less developed. Except for the periphery the basin would normally not be exploited for groundwater. However the effect of the Volta Lake that lies entirely in the Voltaian basin is yet to be investigated.
- Buem formation is composed of shale, sandstone, arkose and lava and is of the upper pre-cambrian age. It underlies three per cent of the country. It is in fault contact with the Togo formation and is fractured to a greater degree than the Togo formation. Boreholes have an average safe yield of $9m^3/h$ and thus classify the formation as having a good yield for water supply. Depth of weathering is about 5m.
- Sekondian and Accraian formations consist of sandstones, shales with conglomerate pebbles, mudstone and pebbly grit. This

formation has not been exploited for groundwater since they cover only 270 sq km much of it occupied by Accra, Cape Coast and Sekondi-Takoradi which are supplied from surface water sources.

- Eocene and Cretaceous formations are made up of marine series of shales, sandstone and limestone. Some successful boreholes of average yield of $13m^3/h$ have been drilled but saline water have been encountered towards the coast. This formation underlies about one per cent of the country.
- Tertiary and Recent deposits: tertiary deposits underlie less than one per cent of Ghana. Deposits need to be investigated but groundwater potential is expected to be low. Recent deposits such as stream alluvium and laterite cover much of Ghana and are of sufficient depth to form suitable reservoirs for water. Relatively shallow boreholes can be used for year-round water supplies.

7.2.2 Development Policy

Groundwater occurrence in Ghana is low but there is enough potential to be developed for supply to small communities. The Ghana Water and Sewerage Corporation decided that wherever possible groundwater sources will be exploited and distribution system provided for all communities with population in excess of 2000 persons. This project is concerned with those communities that have benefited under this scheme. To date 91 Borehole schemes with distribution systems are in operation through Ghana. The regional spread is as follows:

Region	No. of Communities
Ashanti	8
Brong-Ahafo	12
Central	3
Eastern	14
Greater Accra	Nil
Northern Region	2
Volta	21
Western	7
Upper East and West	24
TOTAL	91

Total population served by these schemes is 808,808 (1984) projected to 943,473 (1990).

7.2.3 Project Implementation

In the late 1950s and in the 1960s several boreholes were drilled in Ghana either on contract or by force account operated by the Drilling Section of the Ghana Water and Sewerage Corporation. Percussion drilling was employed. In the early boreholes partial casing using steel pipes in the weathered zone was the construction technique. Later all boreholes were fully lined with steel pipe slotted in the aquifer zone and given gravel packing. Boreholes drilled in the 1970s have uPVC pipe casing, again, slotted in the water bearing locations. Borehole sizes varied from 300mm to 150mm most wells being 200mm diameter. Depth of well varied with the formation but drilling was usually terminated when fresh rock is encountered. Borehole logs were well kept and records are available at the Drilling Section of the Ghana Water and Sewerage Corporation. Boreholes are pump tested to determine yield, dynamic water level, drawdown and recovery characteristics. The typical Borehole log is as follows:

Town:	Effiduase
Borehole No.:	A C 12
Static Water Level:	1.2m
Dynamic Water Level:	23.8m
Yield:	11.9m^3/h
Depth:	76m
Date Drilled:	20-1-64

Geological Log

0 - 13.1m	-	Laterite and Clay
13.1m - 21.4m	-	Sand Stone
21.4m - 61m	-	Weathered Granite
61m - 76m	-	Hard Granite

Mechanisation of boreholes depended on the safe yield. The policy had been to mechanise all boreholes with a yield in excess of 4.5m^3/h with motorised pump. Sizing of pumps depended on the size of community being served, the yield of the borehole and the hydraulics of the distribution system. A number of boreholes ranging from one to several could be mechanised for one community. However the typical project would have two boreholes.

Most of the borehole water supplies were undertaken in the late 1960s when the government decided to provide water supply to all communities above 2000. Standard designs were prepared and the communities identified. Communities that had boreholes drilled and capped were given priority. Mechanisation was by electrical submersible pumps with power supply by generator sets or from the National Grid. The West German pump manufacturers, Messrs Pleuger won the contract to supply the pumps. Generator sets were supplied by Brush of Britain. Installation and construction of generator rooms for each well were undertaken by contract or by force account by a combined team from the GWSC Drilling Section and the Regional Projects Unit. Two generator sets (one duty one standby) were installed in a generator room constructed close to the borehole. Electrical connections are made to the pump. The pump is lowered into the borehole as the rising main is connected length after length. The final position of the pump is at least 5m from the bottom of the borehole. The rising main is connected through bulk meters to the distribution system.

The typical distribution system will consist of 150mm and 100mm asbestos cement pipes constructed by force account to all sections of the community. Public standpipes are installed at vantage points within the community. In most cases the elevated tank, capacity $45m^3$ and of the pressed steel type, is installed on a 12m tower on the highest ground level in the community. Connection from the distribution to the tank is such that water is pumped into distribution and the excess of supply over demand then enters into the tank, with the result that where the demand exceeds supply as is the case with most of these installations, no water gets into the tank. It is only in a few instances that water from the boreholes is pumped into the tank first, before gravitating into the distribution system.

PLATE 7.3
BOREHOLE SCHEME WITH POWER FROM THE NATIONAL GRID

PLATE 7.4
BOREHOLE SCHEME WITH GENERATOR ROOM, ELEVATED TANK AND BOREHOLE COVERED IN CONCRETE CHAMBER

7.2.4 Water Quality

Water quality data from a sample 375 boreholes were collected and analysed by Mallari (1969) and Amuzu (1974) to provide an assessment of groundwater quality as compared with the World Health Organisation Drinking Water Standards (1971). Results of the survey are reproduced here as indicative of groundwater quality in Ghana.

- Calcium concentration showed only two per cent of samples above the maximum permissible level of 200mg/l.
- Chloride concentration was in the range 0 - 2700mg/l with only two per cent exceeding the maximum permissible level of 600mg/l.
- Iron occurs excessively in a large number of supplies with 31 per cent containing iron concentration in excess of the maximum permissible level of 1.0mg/l.
- Magnesium concentration was in excess of the maximum permissible level in only one per cent of samples.
- Sulphate concentration was observed to be in excess of the maximum permissible level in only two per cent samples where the maximum level recorded was 971mg/l.
- Total dissolved solids had only two per cent of samples in excess of the maximum permissible level of 1500mg/l as calcium carbonate.
- Total hardness showed two per cent of samples in excess of the maximum permissible level of 500mg/l as calcium carbonate.
- Nitrate concentrations were all within the maximum permissible level of 45mg/l.
- Manganese concentrations exceeded the maximum permissible level of 0.05mg/l in 17 per cent of the samples. The range of concentrations measured was 0-4.5mg/l.
- pH values fell outside the desirable range of 7.0-8.5 in 40 per cent of the samples. (It is most probable that samples outside the range were less than pH 7.0.)

The main problems with groundwater quality in Ghana are in respect of low pH values and high iron and manganese values. Iron and manganese concentrations cause incrustation in meters and in pipes and fittings. Further high iron and manganese values import a bitter taste to the water and also stains laundry. In most cases sources may be rejected for high concentrations of iron and manganese. Some attempts have been made with iron removal systems with varying degrees of success.

7.2.5 Project Costs

Capital costs for typical project to supply 22.7m^3/h.

Drilling 2 No. Boreholes	$ 20,000
2 No. Submersible Pumps	$ 8,240
4 No. Generator Sets	$ 40,000
2 No. Generator Room	$ 10,000
1 No. Elevated Tank	$ 10,000
Distribution	$ 30,000
TOTAL	$118,240
Total Cost for 91 Projects	$10,759,840

7.2.6 Operation and Maintenance

These projects are operated and maintained by the Ghana Water and Sewerage Corporation under its regional and district organisation. The typical borehole water supply scheme will be operated by a staff of three pump and engine attendants and two watchmen. Fuel supply is on monthly basis. Maintenance is by Water Engineering Company, agents of Pleuger Pump and by staff from the Ghana Water and Sewerage regional and district organisation. Water Engineering Company provides a three-monthly inspection and maintenance tour of all stations with Pleuger Pump. District and regional staff visit on request.

Annual operation and maintenance cost per project.

Operational personnel	$ 6,000
Fuel/Electricity	$ 3,000
Maintenance	$ 3,000
Transportation	$ 500
Overheads	$ 1,000
TOTAL	$ 13,500

7.2.7 Revenue Collection

Revenue collection is undertaken by the revenue section of the Ghana Water and Sewerage Corporation. Depending on the size of the community permanent revenue offices with staff are available for daily collection or staff will be sent into the community for house to house collection on specified days of the week.

7.2.8 Community Participation

In general, community participation in these projects have been very low. In a few instances Ghana Water and Sewerage Corporation has solicited the help of community leaders in revenue collection.

7.3 PACKAGE PLANT WATER SUPPLY PROJECT

7.3.1 Background

In 1968 the government of Ghana decided as a priority to provide water supplies to all communities with population in excess of 2,000 persons. Some communities were served from groundwater sources but given the rate at which the government wanted the assignment carried out, the targets could only be achieved if surface sources could be treated using treatment plants that could be constructed very fast. The management of the Ghana Water and Sewerage Corporation decided on the Package Water Treatment Plants as the appropriate units to meet the targets. Two sizes of plants $18m^3/h$ and $9m^3/h$ were imported from the British firm Paterson-Candy International. Communities to benefit from the scheme were selected. Sixty-nine plants were installed to provide water supply to a population of 345,000 (1984) projected to a population of 402,442 by 1990. Regional distribution of the Package Plant installations are as follows.

Region	No. of Plant
Ashanti	11
Brong-Ahafo	11
Central Region	7
Eastern Region	14
Greater Accra	Nil
Northern	9
Volta	9
Western	8
Upper East	Nil
Upper West	Nil

7.3.2 Development Policy

Communities with population in excess of 2,000 persons should be provided with piped systems.

7.3.3 Project Implementation

Communities were selected to benefit from the installation of one of the two sizes based on the population. In one or two instances two plants have been installed at the same location. For a typical project the initial requirement had been identification of an appropriate perennial source. Most communities are reasonably close to a surface source but a few communities are located up to eight kilometres from the source. The effect of such long distances on the subsequent operation and maintenance of the project is not difficult to imagine. Maintenance of access road, if any, or if there is no access road operators having to carry fuel to walk those distances and, of course, having a long raw water pipeline to keep clear of vegetation and to maintain.

- The source should be perennial, however, given the inadequacy of hydrological information generally and especially on small rivers selection was based on local information which in several instances proved to be inaccurate. Many sources do dry up in the dry season or else extraction of raw water is severely limited. Most intakes consisted of a weir across the stream with a side intake. In case of the source being major river with wide variation in water level, no weirs were built but deep side intake wells with connecting channels to the river were used.
- Raw water pumps have been selected based on the suction requirements at the intake. For deep wells vertical spindle or electrical submersible pump have been provided. However the standard pumps purchased with the Package Plant are two units of self priming positive displacement mono pump (one duty one standby) employing a double-helical rotor in a rubber stator. Electrical motors are provided to be driven off two generator sets powered by diesel engines (one generator on duty, one standby). The generators were sized to provide lighting for the community as well. A generator and pump house is provided together with fuel storage facilities.

The Package Plant being a pressured system is located at the highest point in the community together with the elevated tank. The raw water pumps send water straight through the plant to the elevated tank.

The Paterson-Candy International Water - Man Auto Wash Treatment Plant comprises five distinct sections of equipment including Pre-treatment Chemical Plant, Clarification Plant, Filtration Plant, Post-Treatment Chemical Plant and Treated Water Storage Tank (Paterson-Candy International, 1969) (Figure 7.5).

- Chemical building is constructed to house the chemical plant which consists of three displacement type chemical dosers and solution preparing tank for the preparation and dosing of solutions of alum soda ash and chlorine. The doser provides a means of adding the chemical solutions to a pressure main using the differential pressure created by a Venturi tube or orifice plate to impel the chemical solution into the main. The equipment consists of a flexible sac contained within a steel pressure vessel. Chemical solution mixed to the required strength is charged into the flexible sac and connected to the low pressure side of the differential pressure producing device connected at the dosing point in the pipeline. The high pressure tapping on the differential pressure device is connected to the space between the sac and the pressure vessel. Due to the difference in pressure water flows into this space thereby causing an equal quantity of chemicals to be displaced from the sac to the injection fitting at the low pressure tapping. The chemical solution flow rate is controlled and measured by a flow meter which controls and measures the water flow into the pressure vessel.
- The Clarification Plant is a vertical cylindrical tank with a conical bottom section. The raw water dosed with alum at the first injection point is brought down a pipe in the centre of the conical section of the tank and then rises through a Sludge Blanket formed as the plant is operated. The water rises to the top of the tank and leaves through a pipe connected to the top of the tank. The sludge settles out of the clarified water and settles at the bottom of the clarification tank. A small sludge collecting cone inside the clarifier is allowed to run continuously out slowly to waste to stabilise the top level of the blanket. The main de-sludging valve located at the bottom of the tank is operated from time to time to remove heavier settled material.

FIGURE 7.5: PACKAGE WATER TREATMENT PLANT

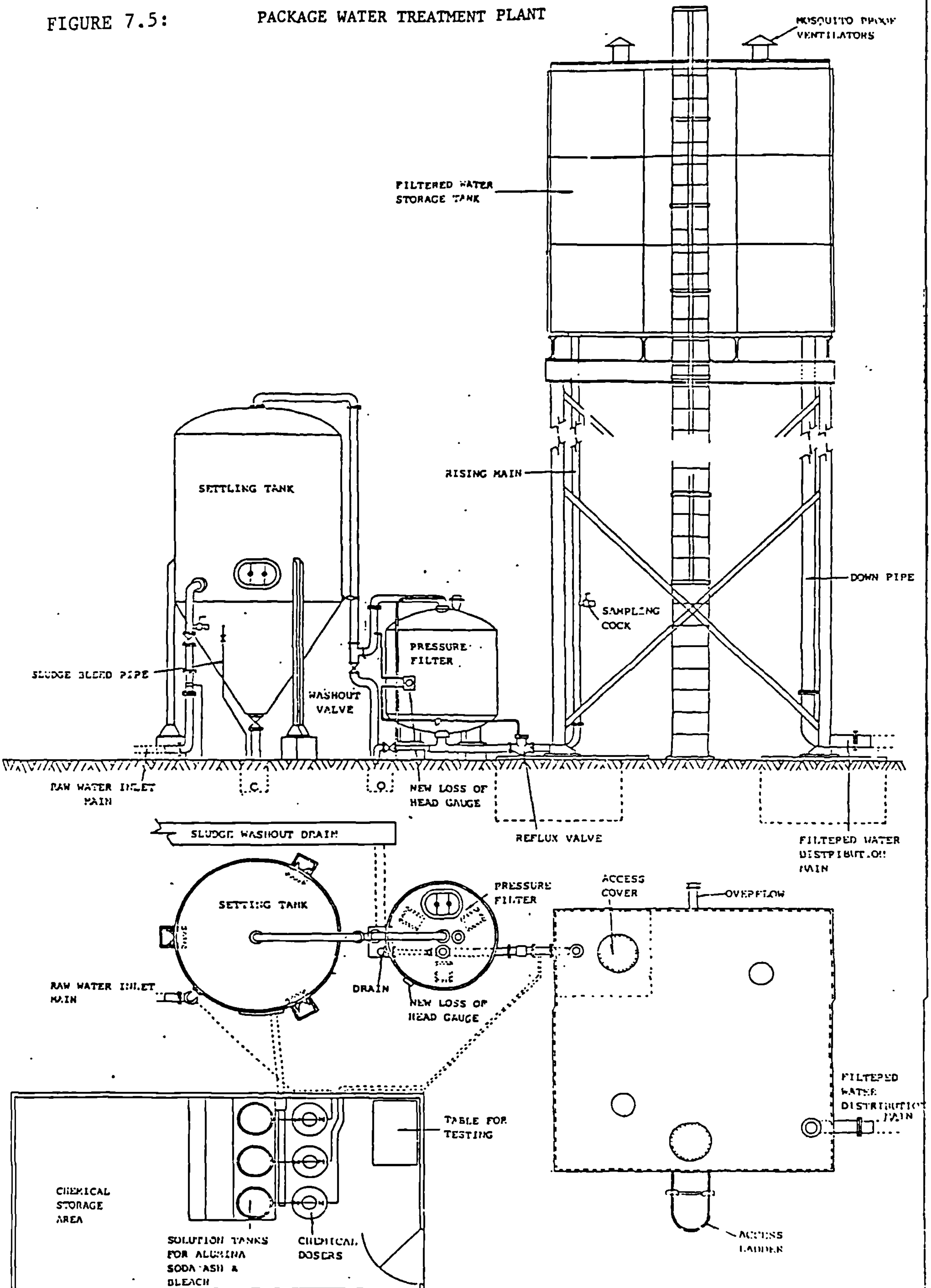


PLATE 7.5
RIVER INTAKE WITH PUMP AND GENERATOR ROOM

PLATE 7.6
PACKAGE PLANT WITH TREATMENT ROOM

- The filter is a vertical cylinder pressure type using as filter media graded filter anthracite, graded sand and pebbles supported on a steel plate floor fitted with polypropylene nozzles. Settled water from the top of the clarifying tank enters through the top of the filter and passes through the anthracite, sand, pebbles, nozzles and finally through the bottom of the filters. Solutions of soda ash and bleaching powder are injected from the chemical plant before the water rises into the elevated tank. When the filter becomes dirty the head loss device causes the inlet value automatically to close and the wash out valve opens reducing pressure in the filter and causing a quantity of water from the storage tank to flush through the filter in an upward direction and then through the wash out value to waste. This operation is performed completely automatically and requires no attention from the operator. Water from the settling tank will be flowing to waste during the washing operation.
- Elevated Storage Tank of capacity $45m^3$ and $90m^3$ are supplied with the $9.09m^3/h$ and $18.18m^3/h$ Package Plants respectively. The tank is standard pressed steel sectional cold water storage type constructed from 1.2m square standard plates. It is provided with a flat mild steel cover with ventilators and the whole is supported on a 12m steel tower which is provided with an access ladder. Within the tank steel plates form a corner compartment for storing wash water. This compartment is the first to be filled as filtered water enters the tank and overflows from it to fill the rest of the storage tank. During filter backwash the washwater tank supplies the necessary backwash water and the water level in the rest of the tank is not affected. The wash water compartment is never completely emptied as the backwash is stopped automatically before this happens.

Water distribution from the elevated tank is through 150mm and 100mm asbestos cement or uPVC pipes constructed by either force account or on contract to the various sections of the community. Public standpipes are located at vantage points. Yard taps and house connections are encouraged but less than ten per cent of the households have connected to the system.

7.3.4 Project Capital Cost

	$9.09m^3/h$ Plant	$18.18m^3/h$ Plant
2 No. Pumps	$ 6,400	$ 8,200
2 No. Generator Sets	$ 20,000	$ 34,000
Treatment Plant	$ 15,700	$ 24,800
2 No. Pump/Treatment Room	$ 10,000	$ 10,000
Elevated Storage Tank	$ 10,000	$ 18,000
Intake	$ 10,000	$ 15,000
Distribution	$ 30,000	$ 50,000
TOTAL	$ 103,100	$ 160,000
Number Installed	58	11
Total Capital Cost	$7,681,800	

7.3.5 Operation and Maintenance

These projects are operated and maintained by the Ghana Water and Sewerage Corporation under its regional and district organisation. The typical project will be operated by two pump and engine attendants, two treatment attendants and one watchman. Fuel and chemicals are supplied on a monthly basis from the regional stores. Maintenance work is undertaken by district or regional staff and occasionally by the specialised package plant staff located at the Drilling Section of the Ghana Water and Sewerage Corporation. The automatic system of backwashing has been quite problematic and has been replaced by a manual system. Chemical dosers especially perforation of the flexible sac, is another problem area which has been brought to the attention of the manufacturers.

Annual operation and maintenance costs.

	$9.09m^3/h$ Plant	$18.18m^3/h$ Plant
Operational Personnel	$ 6,000	$ 6,000
Fuel/Electricity	$ 1,500	$ 3,000
Chemicals	$ 1,200	$ 2,400
Transportation	$ 500	$ 500
Maintenance	$ 3,000	$ 4,000
Overheads	$ 1,000	$ 2,000
TOTAL	$ 10,200	$ 13,900

7.3.6 Revenue Collection

Revenue collection is undertaken by the revenue section of the Ghana Water and Sewerage Corporation. In the larger communities permanent revenue offices manned by revenue staff are open daily but in the smaller communities revenue staff are sent in for house to house collection on specified days of the week.

7.3.7 Community Participation

There is minimal community participation as Ghana Water and Sewerage Corporation is responsible for all activities. However institutions within the community have been approached to help with revenue collection and to take over some standpipes for direct sales to the community.

7.4 2500 DRILLED WELLS WATER SUPPLY PROJECT

7.4.1 Background

Prior to 1970 most of the rural population in the Upper Regions (East and West) had no access to potable water. The traditional sources mostly surface water and a few hand dug wells, were often inadequate to assure sufficient water during the dry season. This deficiency of potable water coupled with ignorance of appropriate health and sanitation practices and variable local food production created a cycle of disease and poverty. In the early 1970s the government of Ghana had given priority to the development of the Upper Regions which included the improvement in water supply. The Canadian International Development Agency agreed to undertake rural water supplies and some improvements to selected urban supplies. On 23 July 1973 a Memorandum of Understanding between the government of Ghana and Canada was signed. This project is concerned with the rural water supply involving the drilling of 2,500 wells and the installation of hand pumps (Figure 7.6). At a later stage other components such as Water Utilization Project and Maintenance Stabilization Project were also undertaken.

7.4.2 Development Policy

The Ghana Water and Sewerage Corporation had established that communities with populations between 500 and 2,000 persons shall be provided with drilled wells fitted with hand pumps.

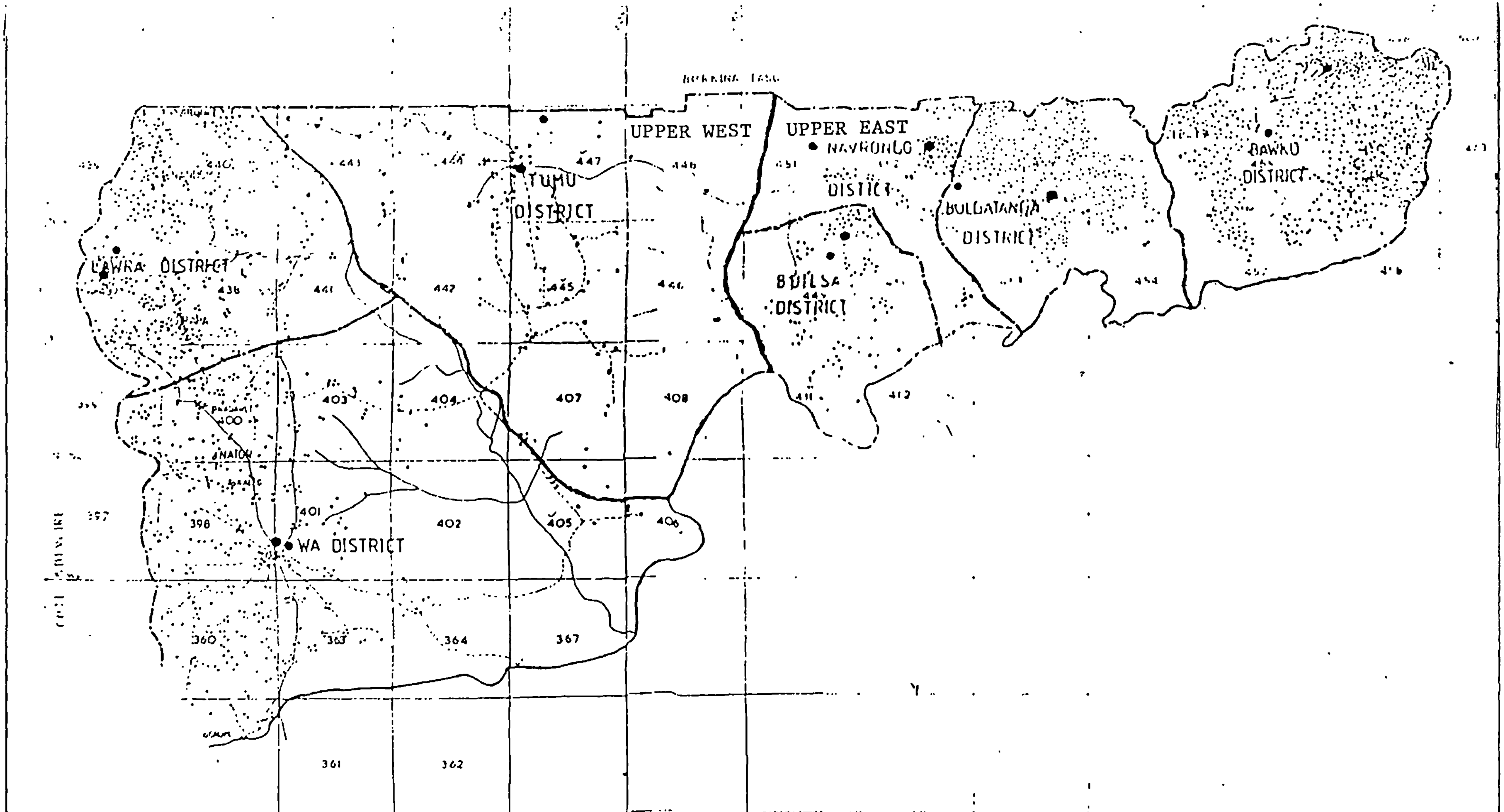


FIGURE 7.6: 2500 DRILLED WELLS PROJECT AREA

7.4.3 Project Implementation

The Upper Regions are characterised by highly dispersed settlements. The regions are underlain by mainly jointed and fractured. Weathered rocks have been recorded up to depths of 60m. The main water bearing zones are moderately to slightly coarse grained rocks and fractured quartz within the decomposed rock (CIDA, 1985, Report 1). Drilled wells were selected as appropriate technology for exploiting the groundwater sources for use by the communities.

Institutional arrangement for the project implementation was to make use of Ghana Water and Sewerage Corporation drilling crews with Canadian Advisers for the various sections of the construction organisations. Various types of advisers provided are the Resident Management Adviser, Adviser (Drilling Superintendent), Adviser (Workshop Superintendent), Adviser (Hydrogeologist), Adviser (Regional Workshop), Adviser/Trainer (Field Mechanic), Adviser/Trainer (Electronics) and Construction Superintendent. Rotary drilling rigs were employed. Phase 1 drilling programme 1973-1977 was awarded to the consultant W.L. Wardrop & Associates of Winnipeg to oversee the drilling of 1000 wells and installation of hand pump. In 1977 the Phase 2 programme started with a programme to drill 1,500 wells and to install hand pumps. This phase was completed by 1981. Together with the drilling programme a hand pump testing project had been initiated in order to select suitable hand pumps for the project. As a result of the tests, Monarch and Beatty hand pumps were selected, both manufactured in Canada. The Beatty hand pump proved unreliable and all 1,200 Beatty hand pumps, already installed, had to be replaced with another Canadian hand pump, the Moyno.

In 1978 the Water Utilization Project was initiated with a mandate to educate people in the proper use of water and in basic hygiene and sanitation. Other components of the programme were pump maintenance and community involvement in well site maintenance. Phase 1 of the Water Utilization programme has been completed but Phase 2 is still in progress.

The Upper Region Maintenance Stabilisation started in 1982 had the objectives of increasing the operational reliability of rural and urban supplies, pump replacements, provision of vehicles, equipment and spare parts. This was completed in 1986.

Population served is 900,000, that is 360 persons to a hand pump.

7.4.4 Water Quality and Well Yield

Well yields varied between 10 l/min to 600 l/min with over 60 per cent in the range 10 l/min to 50 l/min (Bannerman, 1986). Water quality analysis indicated, in general, that the water produced is safe. Values of same parameters are as follows.

pH 6.5-7.5; Total Iron < 0.4 mg/l; Nitrate < 25. mg/l; Chloride < 16 mg/l.

7.4.5 Project Capital Cost

The project involved both rural and urban components. Assessment of cost of the rural component alone has proved difficult. However, drilling project manager estimates the cost of each well drilled as $5,000.

Hand pump cost (1982) $740.

The total involvement of the Canadian International development Agency to date is 34.8 million Canadian dollars.

The government of Ghana commitment was over c100 million (c = cedi).

7.4.6 Operation and Maintenance

The project is operated and maintained by the Ghana Water and Sewerage Corporation under its regional and district organisations in the Upper East and West Regions with crucial support provided by the Canadian International Development Agency. Currently the maintenance organisation is a parallel organisation within the GWSC with its own staff and vehicles purposely for the maintenance of hand pumps and separate from the urban systems maintenance organisation.

Under the Maintenance Stabilization Programme, CIDA and GWSC jointly run the maintenance organisation headed by an Adviser (Maintenance). In January 1988 GWSC staff managed the system entirely with CIDA providing spare parts vehicles and other essential inputs. It is obvious that without the vital support from CIDA the maintenance system will collapse.

The Maintenance Organisation presently has the following staff and vehicles.

	Staff	Vehicles	No. of Hand Pumps
Head Office	4	1 Toyota Pick Up	-
Bolgatanga District	15	1 Bedford Truck 1 Toyota Pick Up 5 Motor bikes	590
Navrongo District	6	1 Toyota Pick Up 2 Motor bikes	187
Builsa District	3	2 Motor bikes	162
Bawku District	12	1 Bedford Truck 1 Toyota Pick Up 5 Motor bikes	754
Wa District	10	1 Toyota Pick Up 4 Motor bikes	447
Lawra District	8	1 Toyota Pick Up 3 Motor bikes	406
Tumu District	7	1 Toyota Pick Up 2 Motor bikes	162

Maintenance targets are as follows:

90% of all pumps operational at all times.

80% of all repairs by motorist (mechanic on motor bike).

34% of hand pump inspected per month (i.e. 100% inspection in 3 months).

Zero backlog each month (no carry over if faulty pump).

In addition targets are set for retraining pump caretakers, access road maintenance, back filling around hand pumps, construction of extended pump pads and animal troughs.

Annual Operation and Maintenance Cost is $92.06 per well.

PLATE 7.7
MOYNO PUMP INSTALLATION WITH ANIMAL WATER TROUGH

PLATE 7.8
MONARCH PUMP INSTALLATION WITH ANIMAL WATER TROUGH

7.4.7 Revenue Collection

Each hand pump is reckoned to serve 20 households scattered around the pump. A headman who may be a chief or a village elder accepts responsibility for the pump and undertakes to collect revenue from all households using the pump and pay to the Ghana Water and Sewerage Corporation. Most of the payments take place during the harvesting season.

7.4.8 Community Participation

Initial involvement of the communities in the project was minimal, particularly during Phase 1 drilling operations. Water Utilization Project was initiated in 1978 to involve the Phase 2 drilling operations. The Memorandum of Understanding governing Phase 2 (CIDA, 1985 Report 4) informed the consultant to coordinate his activities with public health, education, community and development advisers to ensure that the projects meet the needs of the local population not only with respect to provision of potable water but to achieve the broader social, economic an public health benefits. Due cognizance must be taken of the sensitivities and local customs of the rural population. The Water Utilization Project was mandated to provide hand pump maintenance, community health education and community development self-help projects.

In each pump community two persons (one male one female) have been trained to identify and report faults. Since the pumps selected for the project are not the village level operation and maintenance (VLOM) type, local repairers could not be trained. The communities have been mobilised to undertake backfilling to ensure proper drainage around pumps, maintenance of access roads to pumps, extension of the pump pad and construction of animal water troughs. Communities are currently involved with revenue collection.

The Water Utilization Project Phase 2 is currently training two persons (one male one female) in each pump community as Community Water Organisers who, in addition to consolidating community involvement as explained above, also have to teach the communities about diarrhoea diseases and the use of oral rehydration therapy.

The Canadian International Development Agency has agreed to fund a United Nation Development Programme pilot project aiming among other things at transferring maintenance responsibility to the communities through training on the use of Afridev, Volanta, Nira and Aquadev hand pumps.

7.5 3000 DRILLED WELLS WATER SUPPLY PROJECT

7.5.1 Background

The project was conceived as part of the National Five-year Development Plan 1975-1980 which aimed at increasing national coverage of safe and reliable water supplies from 38 per cent to 50 per cent with particular emphasis on rural water which had only 15 per cent coverage then. On 6 July 1976 the government of Ghana and the Federal Republic of Germany entered into a Financing Agreement. The Ghana Water and Sewerage acted on behalf of the Ministry of Finance and Economic Planning (government of Ghana) and Kreditanstalt Fuer Wiederaufbau (KfW) acted as agency for the German Ministry for Economic Cooperation (BMZ). A previous project administered by the World Health Organisation had selected communities to benefit from the project. On 14 December 1977 Consultancy Agreement was signed with International Drilling Consultants, a joint venture between IGIP of Germany, Elektrowatt of Zurich/Switzerland and AESC of Accra/Ghana. The project was to provide 3000 drilled wells equipped with hand pumps in villages between the range of 500-2000 inhabitants (one well serving about 300 persons).

7.5.2 Development Policy

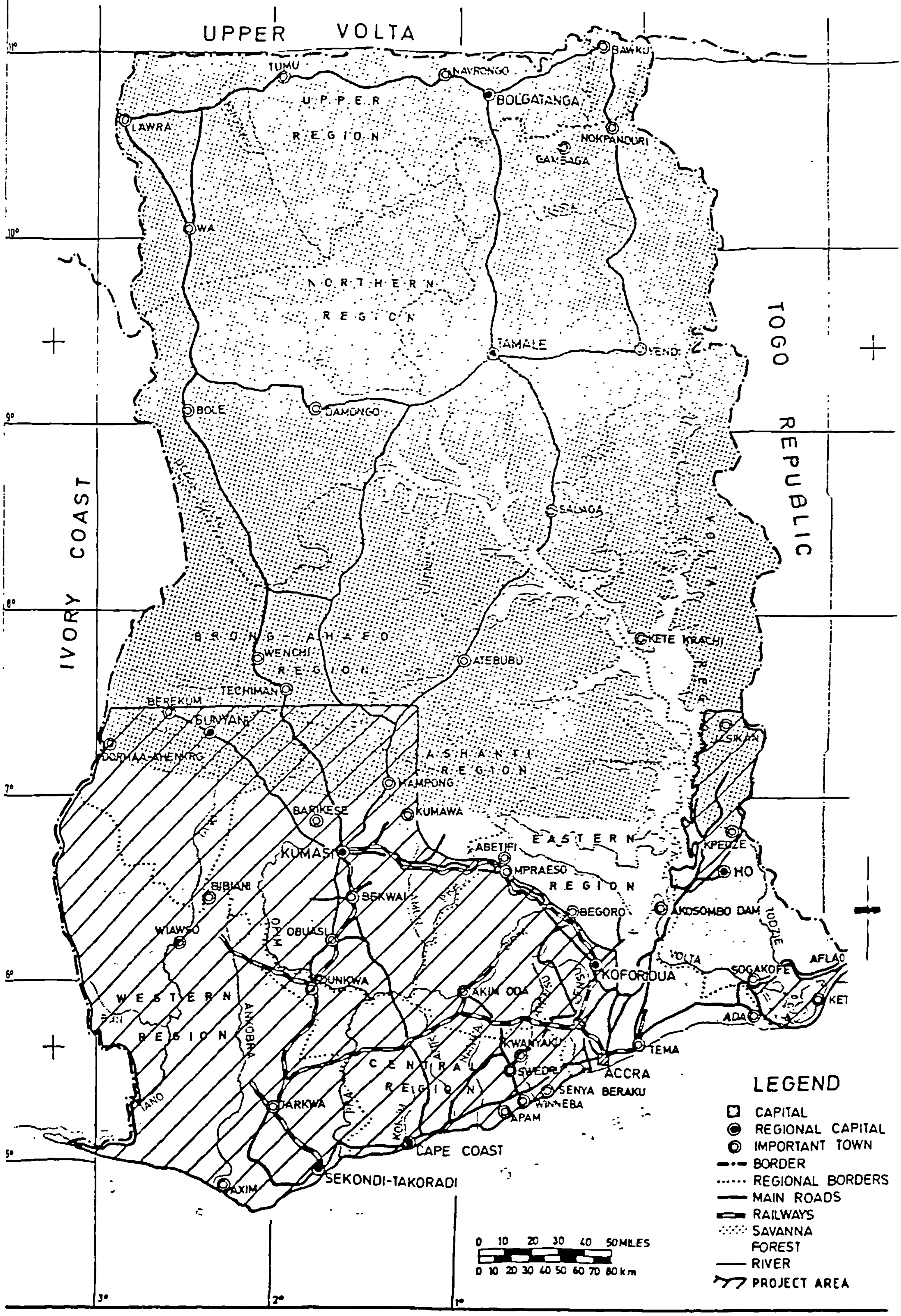
This project was part of Ghana Water and Sewerage Five Year Plan 1975-80 furthering its policy of providing water supplies to communities of between 500-2000 persons through drilled wells fitted with hand pumps.

7.5.3 Project Implementation

The project area, that is, south and central Ghana (Figure 7.7), is underlain mainly by Pre-Cambrian metamorphic rocks in association with granite complexes. The north-eastern part of the project area is underlain by thick sedimentary Voltaian Formation. In the far south, near the coast, occur several small patches of nearly flat-lying

GHANA

FIGURE 7.7: 3000 DRILLED WELLS PROJECT AREA



Devonian to recent sediments. Although fresh rock outcrops occur most of the project area is covered by a mantle of weathered rock and soil usually 15 to 80m in thickness.

Project execution was by contract drilling. In July 1980 Ghana Water and Sewerage Corporation signed the contract agreement with Prakla-Seismos of West Germany for the drilling and installation of pumps for 2000 wells - Phase 1 and drilling started in January 1981. Hand pump testing programme was carried out from July 1979 to May 1980. Eleven hand pumps were tested and the Inalsa India Mark II and the Moyno pumps were selected and purchased. In July 1982 Phase 1 drilling was completed and contract for Phase 2 involving 1000 wells was awarded. By December 1983 3000 wells had been drilled and equipped with hand pumps.

7.5.4 <u>Water Quality and Well Yield</u>

Well yield varied between 5 l/min to 200 l/min with over 60 per cent between 20 l/min and 100 l/min and an overall average yield of about 40 l/min. The design minimum permissible yield was specified at 14 l/min but wells with yield of 5 l/min were fitted with hand pumps to limit the number of dry wells (International Drilling Consultants, 1984).

This project is plagued with water quality problems stemming primarily from very low pH, low alkalinity and soft waters, 80 per cent of the wells have pH between 5 and 7. The result of this has been excessive corrosion of hand pump parts causing high iron concentration usually greater than the limiting concentration of 5 mg/l acceptable to this project. Note that the World Health Organisation maximum permissible limit is 1 mg/l. This has caused rejection of the well water on quality grounds. The aggressive well water caused frequent breakdowns of the hand pump and it has become necessary to change galvanised pump rods and pipes to stainless steel. Langenegger (1987) presents guidelines for selection of pump in aggressive water areas but mentioned that the cost of hand pumps with stainless steel parts is double that with galvanised material.

pH	Aggressivity of Water	Application of Galvanised Material
pH > 7	Negligible	Suitable
6.5 < pH < 7	Little to Medium	Limited
6 < pH < 6.5	Medium to Heavy	Not Recommended
pH < 6	Heavy	Not Recommended

From the above table serious errors seem to have been committed in the selection of pumps for the project. By December 1988 60 per cent of the installed pumps were inoperable.

7.5.5 Project Capital Cost

Total project capital cost is quoted as 63.4 million Deutsch marks and 55.9 million cedis (1978-1982).

Total Cost is $40.37 million for 3000 wells.

7.5.6 Operation and Maintenance

This project is operated and maintained by the Ghana Water and Sewerage Corporation under its regional and district organisation with vital support from the Federal Republic of Germany through kPW and IGIP Consulting Engineers. Drilling of wells took place in six regions with well distribution as follows.

Region	No. of Wells	Region	No. of Wells
Ashanti	1017	Eastern	561
Western	594	Volta	337
Central	354	Brong Ahafo	97

Maintenance of wells is organised from the following regional workshops.

Project Base Workshop based in Kumasi for Project/Ashanti
Western Regional Workshop based in Sekondi/Takoradi
Eastern Regional Workshop based in Nsawam
Central Regional Workshop based in Cape Coast
Volta Regional Workshop based in Ho

There are also ten district workshops. Expatriate staff include:

1 Maintenance Manager
5 Maintenance Supervisors

PLATE 7.9
YOUNG GIRL OPERATING A MOYNO PUMP

PLATE 7.10
WOMAN CLEANING INDIA MK 2 PUMP APRON

Ghana Water and Sewerage Staff include:

1 Co-manager, Accra
1 Principal Superintendent, Nsawam
2 Senior Superintendents, Nsawam
1 Senior Superintendent, Kumasi
4 Superintendents
1 Foreman
64 Junior Foremen/Artison (Mechanics/Driver/Rigmen, etc. for the various workshops)

Vehicles include 14 UNIMOG four-wheel drive trucks, several Yamaha motor bikes.

It is clear from the above that the Federal Republic of Germany continues to provide technical assistance and supply of vehicles, spare parts for both vehicles and hand pumps and other essential inputs. This support is vital for the long-term sustainability of the project. Further with the high breakdown rate of the hand pumps due to corrosion support is being provided for the importation and refitting of pumps with stainless steel rising main and pump rods.

Annual cost of operation and maintenance is reckoned at $70.65 per well.

7.5.7 Revenue Collection

The communities are billed according to the number of households. The responsibility then rests with the Town or Community development Committee and the Committee for the Defense of the Revolution to organise collection and payment to the Ghana Water and Sewerage Corporation.

7.5.8 Community Participation

In this project community involvement has been minimal. This stems partly from the fact that drilling and installation of pumps were undertaken by contract. However, the need for education was recognised and incorporated into the initial contract between the government of Ghana and the Federal Republic of Germany but this was not carried out and has still not been initiated. With the maintenance programme, the need for education, community mobilisation, etc. has become more apparent. Contract Amendment (Phase 3) Maintenance Unit incorporated the need for information, sensibilization and education campaign to be carried out. It was noted in the Contract Amendment (IGIP, 1988) that

- the acceptance of the wells by the users has partly suffered from decreasing quality of water (high iron content due to corrosion) and from the different taste of well water (ground water) compared to the water from streams (surface water).
- in many cases the hygienic condition with respect to the surroundings of the wells, transport, storage and use of the water have to be improved.
- the supervision and responsibility of the operation and maintenance of hand pumps have to be shifted gradually from the Expatriate staff to the Ghana institutions (villages, GWSC) in order to ensure an efficient continuation of the programme after the withdrawal of the expatriates.

The final aim of the education campaign was stated as being '....the complete or partial takeover of the maintenance costs by the users of the wells and the consumption of the water under hygienic conditions in order to improve the health of the population'.

Proposals based on the above statements have been prepared by the IGIP Consultants but the response from KfW has been luke warm. In the meantime some hand pumps have been disconnected by the GWSC for lack of payment by communities and communities have gone back to their traditional sources.

7.6 HAND-DUG WELL WATER SUPPLY PROJECT

7.6.1 Background

Hand dug wells have been a source of drinking water for communities, large and small, for a long time. However in 1982 the government of Ghana launched an action plan for the Water Decade. Among several proposals was the objective to accelerate rural water development and dug wells were an essential part of the plan to achieve that objective. Several agencies both local and foreign have been engaged in dug well construction over the years. To harmonise efforts the government of Ghana launched a five-year programme to provide 10,000 dug wells for small communities. All hand dug well programmes will be coordinated under the above programme.

7.6.2 Development Policy

The Ghana Water and Sewerage Corporation has established that communities of population below 500 persons shall be provided with water supplies from hand dug wells with hand pumps.

7.6.3 Project Implementation

Water Aid, a non-governmental organisation working in the water supply and sanitation sector in Ghana, is the voluntary effort of the British Water Industry for the Water Decade. Water Aid works with local organisations and on this project it is the Akuapem Rural Development Foundation (ARDF). This project is one of the hand dug wells completed under the Water Aid programme with ARDF.

A Memorandum of Understanding concluded between Water Aid and ARDF in 1985 seeks to construct 24 hand dug wells in the Akuapem District of Ghana. Water Aid would provide tools (for simultaneous construction of two wells), hand pumps, and cement. The communities, under the supervision of the ARDF will provide:

(a) Sand, stones and labour (sand and stones should be on-site before the project can start).
(b) Contribution of $184 (10,000 cedis in 1985) for pump maintenance before the pump is installed.
(c) Establishment of a water committee to raise funds for future maintenance.
(d) Community-based maintenance programme to be established with Afridev hand pump instead of India Mark II.

The village of Timber Nkwanta was one of the communities that applied to the ARDF to benefit from the programme. This was accepted by the three-man committee of the ARDF. The project supervisor and the village leaders selected the site and the community arranged to pile up sand and stone for the project.

PLATE 7.11
INDIA MK 2 PUMP INSTALLED ON HAND DUG WELL - NOTE HATCH ON WELL COVER

PLATE 7.12
STEEL FORMS, AIR COMPRESSOR, PROJECT VEHICLE AT A NEW WELL SITE

The Project Supervisor moved equipment to the site and agreed on a work programme with the community, that is, a three-days work in a week. The community was divided into three sections, each section did one day a week. The well was 1.2m diameter and 7.6m deep and took eight weeks to complete. The top cover incorporates a hatch which allows the use of rope and bucket when the hand pump breaks down.

Water quality is satisfactory. The well is capable of producing 13.5 l/min on normal operation.

7.6.4 Project Capital Cost

Capital cost provided includes all items provided by the community in kind costed at the prevailing prices in 1985.

Cost of hand pump	\$ 677.0
40 bags of cement	\$ 197.0
6 m^3 of stones	\$ 147.8
3 m^3 of sand	\$ 9.3
Other materials	\$ 18.0
Labour	\$ 615.9
Equipment/transport/overheads	\$ 615.0
TOTAL	\$2280.0

7.6.5 Revenue Collection

There is no tariff instituted but the community raised \$184 through a head tax of \$1.84 per adult. Fund raising activities will be organised in future.

7.6.7 Community Participation

The community is involved in every aspect of the project.

7.7 CENTRAL ACCRA SEWERAGE PROJECT

7.7.1 Background

In 1963 the World Health Organisation commissioned Tahal Consulting Engineers Ltd in association with Engineering Science Inc. to draw up a Master Plan for the development of water supply and sewage disposal schemes till the year 2000. Following the Master Plan feasibility reports were prepared for Phase 1 of the Sewerage Scheme after which detailed designs and contract documents were prepared for Phase 1 Stage 1 of the Sewerage Scheme recommended in the feasibility report. The contract documents for the Sewerage Project, Phase 1 submitted in May 1970 covered the following works.

Contract S/1 - Sewerage of Central Accra (Figure 7.8)

Contract S/2 - Extension of the 5/1 sewerage system for Accra plus extension and modifications to the existing sewerage system in Tema.

Contract S/3 - Extensions to the sewers laid under the two previous contracts.

Contract S/4 - Construction of 1.83m diameter sea outfall at Accra and Tema.

In 1969 the Ghana Water and Sewerage Corporation (GWSC) entered into agreement with the International Development Association (IDA) of the World Bank for financing of Contract S/1 of the first phase of the sewerage works (GWSC 1981b).

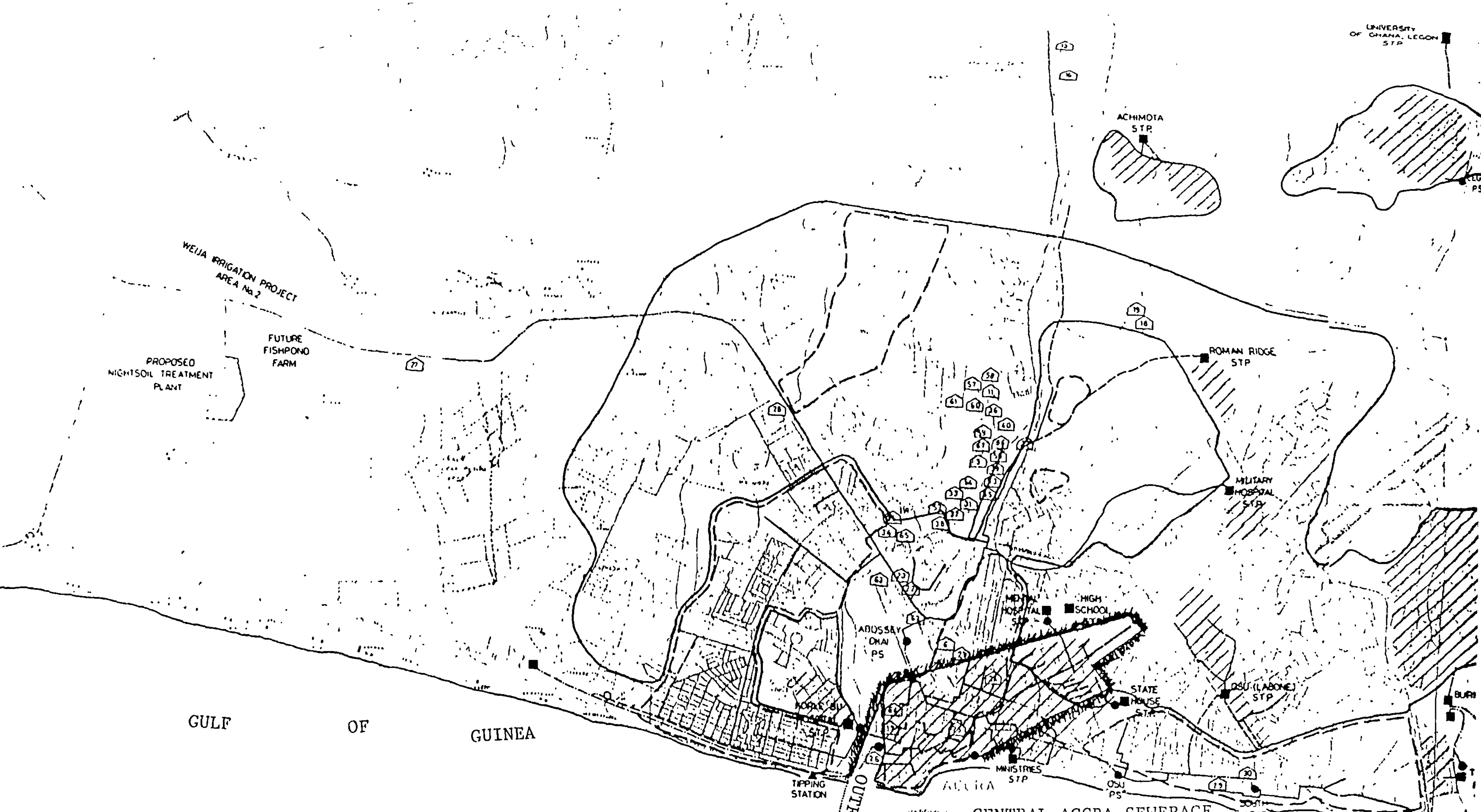
7.7.2 <u>Development Policy</u>

The Ghana Water and Sewerage Corporation under its Act of Incorporation is charged with the responsibility for the provision of sewerage services throughout Ghana.

7.7.3 <u>Project Implementation</u>

Contract for S/1 construction was awarded to Water Resources Development (International) Ltd, Israel in 1970 and work started in March 1971 with a contract period of 24 months. Delays due to the inclement weather and shortage of cement resulted in substantial completion in August 1973, about six months behind schedule. Contract for pumping and electrical equipment was awarded to Jos Hansen and Soehne of West Germany.

The project involved about 32km of 225mm to 1000mm reinforced concrete sewers manufactured locally by Pfeifer Spun Concrete Ltd and laid to cover a project area of about 750 hectares. Provision was made for 500 junctions for house-connection and for facilities for admitting



CENTRAL ACCRA SEWERAGE PROJECT AREA

LOCATION OF INDUSTRIES

APPROXIMATE BOUNDARIES OF AREAS SERVED PRINCIPALLY BY SEPTIC TANKS

AREAS SERVED PRINCIPALLY BY PAN LATRINES

SEWERED AREAS

FIGURE 7.8:

dry weather flow from open sewers to augment flow. Three pumping stations were provided including:

- Central Accra Pumping Station with two duty pumps and one stand-by providing a maximum capacity of 59000 m^3/d.
- Korley-Bu Pumping Station with one duty pump and one stand-by providing a capacity of 11400 m^3/d.
- High Street Pumping Station with one duty pump and one stand-by providing a capacity of 4500 m^3/d.

Arranging financing of the sea outfall as envisaged in contract S/4 proved difficult. Mobil Oil Company donated a 3660m long 300mm diameter submarine pipeline to the government which was cut into three equal sections to form a triple-pipe temporary outfall 1220m long for the discharge of the sewage into the sea.

7.7.4 Project Capital Cost

The capital cost of the project was $3.39 million including $1.56 million loan from the International Development Association (IDA, World Bank).

7.7.5 Operation and Maintenance

This project is operated and maintained by the Sewerage Division of the Accra-Tema Metropolitan Area of Ghana Water and Sewerage Corporation. The division is headed by an engineer with a total staff of 46 and three vehicles (two Pick-ups and Flushing Wagon). After 15 years of operation i.e. up to 1988, 395 connections have been made to the sewerage system. Flushing of sewers is based on a preventive flushing programme. The Central Accra Pumping Station is operated on three shifts for 24 hours. Duty pump is operated for 5-10 minutes every hour. Total daily pumping is 2-3 hours with occasional five hour pumping. Total pumping rate is about 2270 m^3/d. The High Street Pumping Station operates for only ten minutes a day. The Korle-Bu Pumping Station has not functioned because of a poorly constructed feeder sewer. A new sewer is yet to be constructed. Maintenance of sewers has been quite satisfactory. However maintenance work at the pumping stations has been unsatisfactory. The stand-by generator at the Central Accra Pumping Station has been inoperable since 1984. Ventilation equipment in the wet pit area has broken down and two large comminutors have severely corroded and are out of service. The harsh corrosive environment has affected various lighting fittings and even mild steel bars in the reinforced concrete. Improvement in maintenance level is urgently required.

Annual Operation and Maintenance Cost is $150,400.

7.7.6 Environmental Effects

Coastal protection works carried out after the installation of the outfall pipes have altered off-shore currents resulting in severe scouring and erosion of the steel pipes (World Bank, 1977). Finally, the steel pipes were washed away. Currently sewage is pumped onto the beach and then washed into the sea with the tides. This is a serious health hazard which requires immediate attention. Plans have already been prepared for the construction of waste stabilization ponds to the west of the Central Accra Pumping Station at a cost of $500,000. Financial aid is being sought for the project.

7.7.7 Revenue Collection

Billing for sewerage services has been added on to the water bill as 25 per cent or 35 per cent of the water bill. Collection is through customer payment at the various revenue collection offices in the city of Accra.

7.7.8 Community Participation

The Central Accra Sewerage Project was justified at appraisal partly on the health benefit to be captured through improved sanitation in the low income housing area. Most of the housing lacked the household plumbing and the drainage system to connect to the sewerage system. It is expected that a fund will be created to finance house connections on credit basis and the cost recovered over a period from the householders.

PLATE 7.13
CORRODED DISUSED STEEL SEWAGE OUTFALL

PLATE 7.14
RAW SEWAGE PUMPED ON TO THE BEACH

7.8 REPLACEMENT OF BUCKET COMMUNAL LATRINES WITH KUMASI-TYPE VENTILATED IMPROVED PIT LATRINES

7.8.1 Background

The Kumasi Metropolitan Assembly is charged with the responsibility of operating waste disposal systems in metropolitan Kumasi. Excreta disposal system is based, partly, on the use of both private and communal bucket latrines. These involve the recruitment of a large labour force to empty the buckets and transport the excreta to holding tanks at vantage points in the city. Vehicles then convey the excreta to the trenching grounds, 11km outside the city. Faced with persistent demand for higher wages and shortage of labour the Kumasi Metropolitan Assembly decided to privatise the collection system for the private latrines and initiate replacement of the communal bucket latrines with Kumasi-type ventilated improved pit latrine (K-VIP Latrine). The K-VIP latrine is a permanent alternating double or multiple pit latrine with adjacent privy rooms having access to a common pit in the communal type.

7.8.2 Project Implementation

Initially the Kumasi Metropolitan Assembly awarded contracts for eight 10 compartment K-VIP latrines - six in the city central area and two in the peri-urban area (Figure 7.9). These projects were undertaken by local contractors in 1985. The Kumasi Metropolitan Assembly then decided to undertake eight projects by force account. Requests from communities in the Kumasi District, that is, outside the city limits but within the administrative area of the Kumasi Metropolitan Assembly started coming in for assistance to build K-VIP latrines not necessarily to replace an existing pan latrine. The Kumasi City Council provided assistance in the form of materials - cement, pre-cast slabs and roofing sheets - and also provided technical assistance in the form of skilled artisans to help train local artisans on the job. By December 1988 80 of such projects were at various stages of completion. All completed projects are handed over to the community for operation and maintenance.

7.8.3 Project Capital Cost

Project cost for ten compartment K-VIP latrines varied depending on the construction institutional arrangements. The range of capital cost was \$11500-\$20231 with an average cost of \$15865.

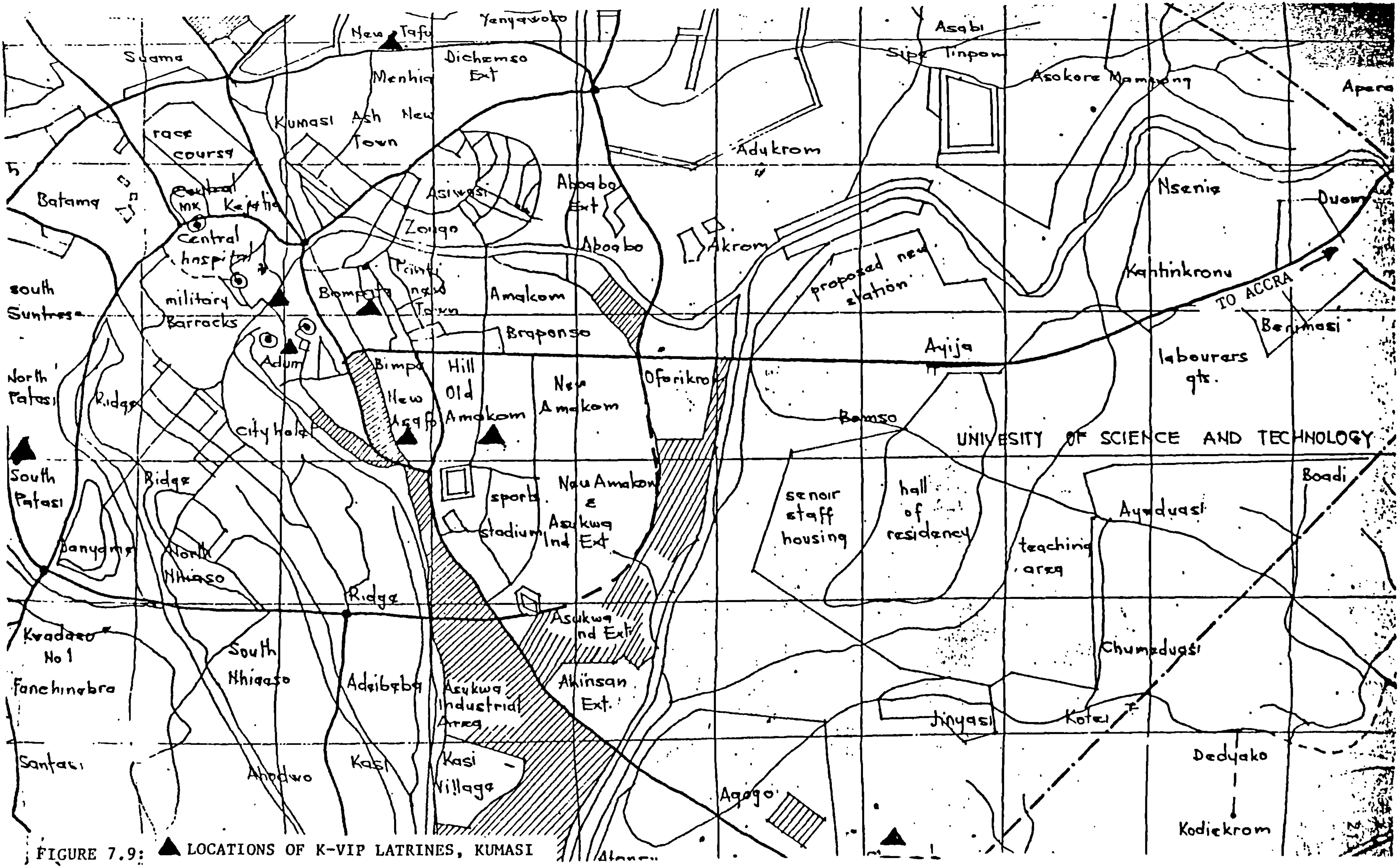


FIGURE 7.9: ▲ LOCATIONS OF K-VIP LATRINES, KUMASI

7.8.4 Operation and Maintenance

The K-VIP latrine is a community operated facility. In the central area the K-VIP latrines replaced larger capacity latrines, that is, the ten compartment K-VIP latrine replaced a 36 seater bucket latrine or in some cases 28 seater aqua privy latrine. There is therefore very intensive use of the latrines. The design allows 30 persons per privy room per day and for pits to alternate on a two-year cycle. In practice there are 52 persons per privy room and the pits fill up in 5-7 months. From observation it seems gases produced in the pit during the decomposition process do not escape fast enough and therefore get entrained in the sludge causing bulking of the sludge, sometimes causing the pit covers to be lifted with spillage of sludge. Bulked sludge can be removed using ordinary cesspit empityers (for septic tank de-sludging). No special arrangements have been made for de-sludging K-VIP latrines and with already over-burdened fleet of vacuum tankers it is very difficult to obtain de-sludging services on time. Where only one or two pits fill early the privy rooms leading to those pits are locked up to allow the pit to rest. The sludge collapses in about one week and the rooms are re-opened. One sanitary labourer is retained for cleaning up daily and washing the privy rooms weekly. Anal cleansing material deposited in baskets are burnt daily.

Annual Operation and Maintenance Cost is $1380.

7.8.5 Revenue Collection

There is an admission charge which is paid to an operator who then dispenses newsprint for anal cleansing. The operator accounts for the daily collection to the local organisation in charge of the latrine.

7.8.6 Community Participation

In the central area in Kumasi the latrines are operated by the local branch of the Committee for the Defense of the Revolution except in two areas where the local chief has appointed a local management team or a local latrine rehabilitation committee had been in existence and therefore assumed responsibility for the new latrine. Revenue collectors and sanitary labourers are paid from the revenue collected. Outside the central area no admission fee is charged but the community cleans up the latrine and pays for de-sludging through a head tax.

PLATE 7.15

TEN COMPARTMENT URBAN K-VIP LATRINE WITH OPERATOR'S SHELTER

PLATE 7.16

MANUAL EMPTYING OF URBAN K-VIP LATRINE

7.9 RURAL KUMASI-TYPE VENTILATED IMPROVED PIT LATRINE PROJECT

7.9.1 Background

In 1982 the Ministry of Rural Development and Cooperatives decided to implement a rural sanitation project based on the communal Kumasi-type Ventilated Improved Pit (K-VIP) latrine. Initially 20 ten-compartment K-VIP latrines were to be provided in each of seven regions of Ghana as a pilot project. The regions selected were Greater Accra, Eastern, Ashanti, Brong Ahafo, Volta, Central and Western. If the project proved successful then a full-scale project will be launched to provide 20 ten-compartment K-VIP latrines in each of the 64 districts in Ghana. Communities to benefit from the project should have population below 2000 persons. The ten-compartment K-VIP latrine is a permanent alternating pit latrine capable of serving 300 persons.

7.9.2 Developing Policy

No established policy exists for the provision of sanitation services but responsibility devolves on the District Assembly. Small communities with population up to 2000 have generally provided traditional pit latrines on their own initiative. This project was to introduce the ventilated improved pit latrine technology to the rural community and hopefully initiate a chain reaction resulting in the general adoption of the technology.

7.9.3 Project Implementation

The project was implemented as a joint venture between the communities and the government. Initially all communities interested were to deposit an amount equal to half the cost of external inputs to the project. In addition the communities were to provide all local inputs and labour. The government on its part will provide all materials not available locally together with technical assistance in the form of skilled artisans to train local artisans on the job. Two governmental organisations were charged with the responsibility of implementing the project - the Department of Rural Housing and Cottage Industries and the Department of Community Development. Technical officers from the two organisations were sent to the Department of Civil Engineering, University of Science and Technology, Kumasi to be trained as trainers. These trainers were deployed in selected technical schools to train the final year masonry students and these students sent out to the communities that paid up their contributions. In all 43 communities contributed $7272 each for the project to commence. Excavation of pits took considerable time. By April 1983 the Ghanaian currency had been devalued from $1-2.75 cedis to $1-20.55 cedis. Successive devaluations followed. The price of cement was 25 cedis per 50 kg at the beginning of the project, rose to 400 cedis per 50 kg. Government contribution in terms of materials was inadequate and most projects fell behind schedule. In January 1989 communities were informed to look elsewhere for funds to complete their projects. Total number of projects completed was 25.

7.9.4 <u>Project Capital Cost</u>

Capital cost for a ten-compartment K-VIP latrine constructed over the period 1982-1988 ranged from $8500 to $14545 due to changes in the exchange rate. Average Capital Cost was $11550.

7.9.5 <u>Operation and Maintenance</u>

Communities operate and maintain the latrines through the Town Development Committees and the Committees for the Defense of the Revolution. In some areas some women are assigned the task of cleaning up the latrine and burning anal cleansing material everyday and are exempted from weekly communal labour. Privy room and access are washed once a week. In other areas the responsibility is assigned to school children around the ages of 12-15 years. Local artisans involved in the construction carry out repairs as and when required. With the low level of usage none of the latrines completed had full pits requiring de-sludging. It is expected that when the occasion arises manual methods of de-sludging will be employed. The sludge will be spread to dry and then burnt.

Cost of Annual Operation and Maintenance is $850 per latrine.

7.9.6 <u>Revenue Collection</u>

No admission fee is charged for use of the latrine. It is expected that when the need arises to incur major expenditures, say, in de-sludging fitted pits a head tax will be imposed to raise funds.

PLATE 7.17
RURAL K-VIP LATRINE WITH TRADITIONAL PIT LATRINE

PLATE 7.18
RURAL K-VIP LATRINE UNDER CONSTRUCTION - NOTE QUALITY OF DWELLING HOUSES AND LATRINE SUPERSTRUCTURE

7.9.7 Community Participation

Community involvement with the project from construction to operation and maintenance is very high. Communities are expected to review their requirements from time to time and construct additional units through self-reliance.

7.10 TRADITIONAL PIT LATRINE PROJECT

7.10.1 Background

As a result of health educational campaigns launched in the 1950s and 1960s by the Department of Social Welfare and Community Development pit latrine construction was accepted widely in rural communities in Ghana. Today the traditional pit latrine constitutes the first attempts by rural and peri-urban communities to solve their sanitation problem.

7.10.2 Project Implementation

The project selected is the provision of two 16-hole traditional pit latrines (one for males one for females) at the village of Esreso, 8km to the west of Kumasi. The decision to build the latrines had been taken at a joint meeting of the Town Development Committee and the Committee for the Defense of the Revolution. The site was selected by the chief and members of the committees. The village masons and carpenters set out the position of the two pits. Pit sizes were 1.2m wide x 9.8m long x 7.3m deep each. Excavation was carried by the young men and the women moved the soil away from the pits. The hard wood planks of size 50mm x 150mm x 1.8m purchased from local dealers were placed across the pits at 150mm intervals. The superstructure was formed with small tree branches and the excavated material was used to form the walls of the structures. Second-hand galvanised iron sheets were purchased for the roofing. All construction work was carried out by local artisans and the community through self help. The entire project was completed in three months.

7.10.3 Project Capital Cost

Total Cost for two latrines	$1968 (approx. $2000)
Items purchased (in cash)	$1011.6
Communal labour and other materials not purchased	$ 956.4

Capital Cost per 16-hole latrine = $1000.

PLATE 7.19
TRADITIONAL PIT LATRINES AT ESRESO

PLATE 7.20
INTERNAL ARRANGEMENT OF TRADITIONAL PIT LATRINE _ NOTE ANAL CLEANSING MATERIAL

7.10.4 Operation and Maintenance

The latrines are operated and maintained by the community. Women are assigned to clean the latrine, and clear weeds and sweep the surroundings. Village artisans carry out repairs on the structures. After three years use sludge build up in the female pit is 0.94m and 0.79m in the male pit.

Annual Operation and Maintenance Cost is $155.

7.10.5 Community Participation

Community totally involved in decision making, construction and operation and maintenance of the project. Community organises fund raising annually through levies of $5.00 per male and $2.50 per female to finance development projects. Annual collection is in the range of $500-$750.

CHAPTER EIGHT

ANALYSIS OF DATA AND RESULTS

Data collected during the fieldwork have been summarised in the appendices. In this chapter an initial analysis is conducted on all available data and the results presented. Some results from this initial analysis have been used to develop the input and output factors required for Data Envelopment Analysis (DEA). These input and output factors have subsequently been used to formulate the various linear programming models in DEA. Solutions to the linear programming models obtained from the computer runs have been presented as the efficiency scores for the projects under investigation.

8.1 ANALYSIS OF DATA ON TECHNICAL FACTORS

8.1.1 Water Production Technology

Project	Analysis	Result
(i) Accra-Tema Water Supply, Phase 1	Selection of conventional treatment plant of capacity 145454 m^3/d (32 mgd) for Accra-Tema was valid but slow sand filters should have been considered as a treatment alternative. Level of automation in instrumentation for data logging and plant control was rather sophisticated.	Appropriate technology but the level of automation too sophisticated.

Phase 2	Selection of conventional treatment plant of capacity 68181 m_3 (15 mgd) for Accra-Tema was valid but investigation of slow sand alternative was too casual. Chemical solution pumps with delivery pipelines subject to power outages and blockage. Gravity dosers more appropriate.	Appropriate technology but some modification required.
(ii) <u>Borehole Water Supply</u>	Given the yield of boreholes in Ghana, technology selection for communities of size 2000-40000 persons should give prime consideration to groundwater sources.	Appropriate technology selected.
(iii) <u>Package Plant Water Supply</u>	Surface water sources for communities of 2000-5000 persons should be considered only after groundwater sources prove inadequate. Dependability of source during drought was not fully investigated. The Package Water Treatment Plant has many delicate parts too sophisticated for the rural environment. Slow sand filtration alternative should be fully investigated.	Inappropriate technology selected. The Package Plant is too sophisticated for rural areas.

(iv)	<u>2500 Drilled Wells Water Supply</u>	Groundwater sources are adequate for communities of 500-2000 persons. Drilling is expensive and should aim at locating high yielding wells which can be mechanised with a motorised pump. Low yielding wells should be fitted with hand pumps. Drilling purposely for low yielding wells to be fitted with hand pumps should be investigated together with the hand-dug well option. Selected Canadian hand pumps cannot be maintained by the communities i.e. not VLOM.	Appropriate technology selected with wrong hand pumps.
(v)	<u>3000 Drilled Wells Water Supply</u>	Groundwater sources are adequate for communities of 500-2000 persons. Hand dug well option was not fully investigated. The selection of hand pumps for the aggressive water encountered was wrong. Hand pumps with stainless steel or plastic components more appropriate.	Appropriate technology selected with wrong hand pumps.
(vi)	<u>Hand Dug Well</u>	Groundwater sources are adequate for communities of 100-500 persons. Hand dug wells are very appropriate. India Mart II hand pumps in use but will be changed later to Afridev hand pump.	Appropriate technology selected.

8.1.2 Water Distribution Technology

Project	Analysis	Result
(i) Accra-Tema Water Supply	Steel transmission mains with asbestos cement secondary and tertiary mains. Some old cast iron mains need to be replaced. uPVC pipes are used for some 100mm mains and for house connections. Coverage of the city is not complete. Rate of mains extension not fast enough.	The water distribution network is generally satisfactory except for slum areas and recently developed residential areas.
(ii) Borehole Water Supply	Water distribution network designed in anticipation of house connections. However only 10 per cent of potential connections were actually installed in 20 years. Thus distribution network is over-designed.	Water distribution network is over-designed.
(iii) Package Plant Water Supply	Water distribution network designed in anticipation of house connections. Less than 10 per cent connections actually installed in 20 years. Distribution network over-designed.	Water distribution network is over-designed.
(iv) 2500 Drilled Wells Water Supply	One well provided per 400 persons resulting in long queues. More wells should be provided to reduce queues and distances walked. Wet season traditional sources closer than wells. Thus wells used mainly in the dry season.	Wells used mainly in the dry season. More wells required.

(v)	3000 Drilled Wells Water Supply	One well provided per 400 persons. Distribution of wells not considered satisfactory due to queues.	Distribution of wells not considered satisfactory.
	Hand Dug Well	One well sunk by a village of 450 persons. More wells should be provided.	More wells required.

8.1.3 Waste Collection Technology

Project		Analysis	Result
(i)	Central Accra Sewerage	Collection system of sewers were designed for about four times the population currently using the facility. Most of the residents have no water connection and also cannot afford connection to the system.	Inappropriate technology selected. There is large over-capacity in the collection system.
(ii)	Urban K-VIP Latrine	Design capacity for 10 compartment K-VIP latrines is 300 persons but it is used by 520 persons. Facilities provided are inadequate.	Appropriate technology but the capacity provided is inadequate.
(iii)	Rural K-VIP Latrine	Materials employed for construction of superstructure (sand/cement blocks) are durable but expensive in the rural environment. With available land a moveable superstructure on a direct pit type of VIP latrine should be more appropriate.	Inappropriate variant of the right technology.

(iv) Traditional Pit Latrine	Poorly designed type of an appropriate technology. Improvements required in pit stability, squatting area and pit ventilation to offset obnoxious odours and fly breeding.	Appropriate technology that requires improved design.

8.1.4 Waste Treatment and Disposal Technology

Project	Analysis	Results
(i) Central Accra Sewerage	Currently sewage is untreated and the sea outfall has been washed away resulting in discharge of sewage on the beach. Treatment plant designed (waste stabilization ponds) but funds for construction not yet available.	Unacceptable pollution of the beach.
(ii) Urban K-VIP Latrine	On-site treatment of sludge. Desludging process not very well organised. Ordinary vacuum tankers inadequate for thick sludge. Brevac vacuum tankers should be considered. Manual pit emptying in use but provision for sludge drying inadequate.	Some latrines have been temporarily closed awaiting desludging. Land pollution and fly breeding associated with sludge drying.
(iii) Rural K-VIP Latrine	On-site treatment of sludge. Land available for sludge drying. Manual emptying feasible. Dry sludge is incinerated.	Appropriate solutions to treatment and disposal of sludge available.
(iv) Traditional Pit Latrine	On-site treatment and sludge disposal. Latrine is abandoned when full.	Appropriate treatment and disposal technology for rural areas.

8.1.5 <u>Operations</u>

Project	Analysis	Result
(i) Accra-Tema Water Supply	Availability of plans of operation and the observed level of adherence to plans in actual operations. Level of attainment of expected operational levels is assessed from observation given the available stocks of spares, availability of power, fuel, chemicals, transport and skilled manpower.	90 per cent attainment from observation.
(ii) Borehole Water Supply	Ditto	60 per cent attainment from observation.
(iii) Package Plant Water Supply	Ditto	50 per cent attainment from observation.
(iv) 2500 Drilled Wells Water Supply	Ditto	90 per cent attainment from observation.
(v) 3000 Drilled Wells Water Supply	Ditto	60 per cent attainment from observation.
(vi) Hand Dug Well	Ditto	90 per cent attainment from observation
(vii) Central Accra Sewerage	Ditto	90 per cent attainment from observation.
(viii) Urban K-VIP Latrine	Ditto	60 per cent attainment from observation.
(ix) Rural K-VIP Latrine	Ditto	80 per cent attainment from observation.
(x) Traditional Pit Latrine	Ditto	80 per cent attainment from observation.

8.1.6 Maintenance

Project	Analysis	Result
(i) Accra-Tema Water Supply	Availability of plans for maintenance and observed level of adherence to plans in actual maintenance activities given the available stocks of spares, availability of power, fuel, transport and skilled personnel.	90 per cent attainment by observation. In time of emergencies factories affected provide every assistance possible.
(ii) Borehole Water Supply	Ditto	70 per cent attainment by observation.
(iii) Package Plant Water Supply	Ditto	50 per cent attainment by observation.
(iv) 2500 Drilled Wells Water Supply	Ditto	90 per cent attainment by observation.
(v) 3000 Drilled Wells Water Supply	Ditto	60 per cent attainment by observation.
(vi) Hand Dug Well	Ditto	90 per cent attainment by observation.
(vii) Central Accra Sewerage	Ditto	90 per cent attainment by observation.
(viii) Urban K-VIP Latrine	Ditto	90 per cent attainment by observation.
(ix) Rural K-VIP Latrine	Ditto	90 per cent attainment by observation.
(x) Traditional Pit Latrine	Ditto	90 per cent attainment by observation.

8.1.7 Types of Faults

Project	Analysis	Result
Accra-Tema Water Supply	Power outages at Weija involved 193 faults lasting a total of 707 hrs 7min in 3 years (1986-88). Frequency of fault: 1 fault in 5.67 days. Duration: average 3.67 hrs/fault Plant down time: 2.7 per cent.	Down time 2.7 per cent Frequency 1 in 5.67 days Mean down time 3.67 hours
Borehole Water Supply	Percentage of down time calculated as percentage of time of no water production in 3 years.	21.7 per cent down time
Package Plant Water Supply	Percentage down time over 3 years. Also percentage of time when plant is operating with inadequate supply of chemicals including periods of chemical rationing.	20.3 per cent down time. 58.7 per cent poor quality water.
2500 Drilled Wells Water Supply	Target established is 90 per cent of pump operational at all times. Achievement is 85 per cent of all hand pumps operational.	Down time is 15 per cent.
3000 Drilled Well Water Supply	Target established is 90 per cent of pumps operating at all times. Achievement is 40 per cent of all hand pumps operational at all times.	Down time is 60 per cent.
Hand Dug Well	Pump down time is calculated as 2.3 per cent but water is available through the hatch.	Pump down time 2.3 per cent.

Central Accra Sewerage	Low flows due to under-utilization causing blockage and requring flushing. At any moment 10 per cent of the system requires flushing.	10 per cent system down time.
Urban K-VIP Latrine	Early filling of pits due to over-use causing some compartments to be shut down awaiting desludging. 10 per cent of the compartments cannot be used at any one time.	10 per cent down time.
Rural K-VIP Latrine	In the absence of a permanent attendant some compartments cannot be used due to fouling and improper use. 10 per cent of the compartments cannot be used at any time.	10 per cent down time.
Traditional Pit Latrine	In the absence of a permanent attendant some squatting positions cannot be used due to fouling and improper use. 10 per cent of the squatting positions cannot be used at any time.	10 per cent down time.

8.1.8 Quality

pH was used as an indicator of quality of water, sewage and sludge. Other quality parameters can be found in the appendix.

Project	Analysis	Result
Accra-Tema Water Supply	pH used as the indicator of quality.	7.0 - 8.1
Borehole Water Supply	Ditto	6.5 - 9.2
Package Plant Water Supply	Ditto	5.0 - 6.8
2500 Drilled Wells Water Supply	Ditto	5.8 - 7.2

3000 Drilled Wells Water Supply	Ditto	4.5 - 7.5 Aggressive water.
Hand Dug Well	Ditto	6.9
Central Accra Sewerage	Ditto	6.9 - 9.5
Urban K-VIP Latrine	Ditto	Less than 7.0
Rural K-VIP Latrine	pH used as parameter of quality.	Less than 7.0
Traditional Pit Latrine	Ditto	Less than 7.0

8.1.9 Quantity and Utilization

Project	Analysis	Result
Accra-Tema Water Supply	Plants at Kpong and Weija operated 24 hrs daily. Average daily production calculated from water production reports. Water utilization calculated as percentage population coverage.	Kpong 170136 m^3/d (37.34 mgd) Weija 71409 m^3/d (15.79 mgd) 80 per cent utilization
Borehole Water Supply	22.73 m^3/h (5000 gph) plant operated at 10.5 h/d with 21.7 per cent down time. Water utilization calculated as percentage of water from borehole source to all water used in household.	Water production 186.87 m^3/d. 50 per cent utilization
Package Plant Water Supply	18.18 m^3/h (4000 gph) plant operated at 8 h/d) with 20.3 per cent down time 9.09 m^3/h (2000 gph) plant operated at 8 h/d with 20.3 per cent down time. Water utilization calculated as percentage of water from package plant to all water used in household.	Water production 115.91 m^3/d. Water production 57.96 m^3/d. 40 per cent utilization

<u>2500 Drilled Wells Water Supply</u>	Water collection from well at 23.6 lpcd for 360 persons. Water used mainly in dry season.	8.5 m^3/d per well 40 per cent utilization
<u>3000 Drilled Wells Water Supply</u>	Average water used 23.6 lpcd for 400 persons. 60 per cent down time traditional sources heavily used.	9.44 m^3/d per well 30 per cent utilization
<u>Hand Dug Well</u>	Average water used 23.6 lpcd for 400 persons. Well water mostly used.	9.44 m^3/d per well 90 per cent utilization
<u>Central Accra Sewerage</u>	Sewage pumped from Central Accra Pumping Station. Average quantity of sewage pumped daily calculated from station reports. Utilization of sewerage system is calculated as number of connections effected to the potential number of connections.	Sewage pumped 2272.72 m^3/d (0.5 mgd) 20 per cent utilization
<u>Urban K-VIP Latrine</u>	Design sludge accumulation per person per year is 0.03 m^3. Rate of sludge accumulation could not be measured. Utilization measured as the percentage of actual users to potential users.	30 per cent utilization
<u>Rural K-VIP Latrine</u>	Design sludge accumulation per person per year is 0.03 m^3. Rate of sludge accumulation could not be measured. Utilization measured as the percentage of actual users to average village population.	10 per cent utilization

Traditional Pit Latrine	Design sludge accumulation per person per year is 0.03 m^3. Rate of sludge accumulation measured for the 3 year use. Utilization measured as the percentage of users to village population.	Female: 0.024 m^3 per person per year. Male: 0.034 m^3 per person per year. 44 per cent utilization

8.2 FINANCIAL ANALYSIS

Assumptions

(i) All projects are assumed to have 20 year life without any salvage value. The basis of this assumption is that due to inadequate funding of maintenance programmes, capital works deteriorate at a very fast rate in Ghana and major rehabilitation works are undertaken after about 20 years. The last 20 years have been very difficult years for Ghana.

(ii) The Public Investment Programme requires projects to achieve internal rate of return of 15 per cent or better (Republic of Ghana, 1987). 15 per cent used to discount irregular cash flows to present worth and then again used to obtain the annualised total cost or annual revenue.

(iii) The exchange rate operating in any particular year is used to convert all cash flows in cedis to the equivalent amount in US dollars.

8.2.1 Accra-Tema Water Supply

Phase 1 (1966-86) 145454.55 m^3/d

Capital Cost $34.834 million

Operation and Maintenance Cost provided an irregular annual cash flow. The equivalent annual cost was calculated as $3.8 million

Annualised Full Cost

$\$34.834\ (\text{CRF}, 15\%, 20)\ 10^6 + \$3.8 \times 10^6$

$\$34.834 \times 10^6\ (0.15976) + \$3.8 \times 10^6$

$\$5.56 \times 10^6 + \$3.8 \times 10^6$

Annualised Full Cost $9.36 million

Billing (Sales) provided an irregular annual cash flow

The Equivalent Annual Billing	\$3.98 million

Revenue (Collection) provided an irregular annual cash flow

The Equivalent Annual Revenue	\$2.49 million

Summary for Phase 1

Capital Cost	\$34.834 million
Annual Billing	\$ 3.98 million
Annual Revenue	\$ 2.49 million
Annual Operation and Maintenance Cost	\$ 3.80 million
Annualised Full Cost	\$ 9.36 million

Plant Capacity 145454.55 m^3/d

Financial Cost/m^3 $\frac{\$9.36 \times 10^6}{145454.55 \times 365} = \underline{\$0.176}$

Phase 2 (1984-2004)

Capital Cost \$51.7 million

Equivalent Annual Operation and Maintenance Cost as calculated from the irregular cash flow \$ 5.0 million

Annualised Full Cost

$\$51.7\ (CRF,\ 15\%,\ 20) \times 10^6 + \$5.0 \times 10^6$

$\$8.26 \times 10^6 + \$5.0 \times 10^6$

Annualised Full Cost	\$13.26 million
Equivalent Annual Billing	\$ 5.33 million
Equivalent Annual Revenue	\$ 3.62 million

Summary for Phase 2

Capital Cost	\$51.7 million
Annual Billing	\$ 5.33 million
Annual Revenue	\$ 3.62 million
Annual Operation and Maintenance Cost	\$ 5.00 million
Annualised Full Cost	\$13.26 million

Plant Capacity 68181.82 m^3/d

Financial Cost/m^3 $\frac{\$13.26 \times 10^6}{68181.82 \times 365}$ = $\underline{\$\ 0.533}$

8.2.2 Borehole Water Supply (91 units, 1969-89)

Capital Cost per unit	$118240
Annual Operation and Maintenance Cost per unit	$ 13500
Annualised Full Cost per unit	
$118240 (CRF, 15%, 20) + $13500	
$118240 (0.15976) + $13500	
$18890.02 + $13500	
Annualised Full Cost per unit	$ 32390
Average Annual Billing per unit	$ 2550
Average Annual Revenue per unit	$ 1785

Summary

Capital Cost per unit	$118240
Annual Billing per unit	$ 2550
Annual Revenue per unit	$ 1785
Annual Operation and Maintenance Cost per unit	$ 13500
Annualised Full Cost per unit	$ 32390

Plant Capacity per unit 22.73 m^3/h

Financial Cost/m^3 $\frac{\$32390}{22.73 \times 24 \times 365}$ = $\underline{\$0.163}$

8.2.3 Package Plant Water Supply (69 units, 1969-89)

Capital Cost per unit of 18.18 m^3/h plant (11 units)	$160,000
Capital Cost per unit of 9.09 m^3/h plant (58 units)	$102,100
Total Capital Cost for 69 units	$7,681,800
Average Capital Cost per unit	$111,330.43
Annual Operation and Maintenance	
for 18.18 m^3/h plant (11 units)	$17900
for 9.09 m^3/h plant (58 units)	$13200
Average Annual Operation and Maintenance Cost	$13949.28
Average Annualised Full Cost per unit	

$111330.73 (CRF, 15%, 20) + $13949.28

$111330.43 (0.15976) + $13949.28

$17786.15 + $13949.28

Average Annualised Full Cost per unit	$31735.43
Total Billing (69 units)	$115343
Average Annual Billing per unit	$1671.64
Total Annual Revenue (69 units)	$69208
Average Annual Revenue per unit	$1003

Average Plant Capacity per unit 10.54 m^3/h

Financial Cost/m^3 $\frac{\$31735.43}{10.54 \times 24 \times 365} = \underline{\$0.344}$

Summary

Average Capital Cost per unit	$111330.43
Average Annual Billing per unit	$ 1671.64
Average Annual Revenue per unit	$ 1003.00
Average Annual Operation and Maintenance Cost	$ 13949.28
Average Annual Full Cost per unit	$ 31735.43
Cost/m^3	$ 0.344

8.2.4 2500 Drilled Wells Water Supply (1973-93)

Capital Cost: well cost per unit	$5000
hand pump (10 year life)	$ 744
Annual Operation and Maintenance Cost per well	$ 92.06

Annualised Full Cost per well

$5000 (CRF, 15%, 20) + $744 (CRF, 15%, 10) + $ 92.06

$5000 (0.15976) + $744 (0.19925) + $92.06

$798.8 + $148.24 + $92.06 = $1030.10

Average Yield per well 19.64 m^3/d

Financial Cost/m^3 $\frac{\$1039.10}{19.64 \times 365} = \underline{\$0.145}$

Summary

Total Annual Billing (for 2500 wells)	$305934
Total Annual Revenue (for 2500 wells)	$128011

Total Annual Operation and Maintenance Cost

($92.06 x 2500) $230150

Total Annualised Full Cost ($1039.10 x 2500) $2,597,750

Cost/m^3 $0.145

8.2.5 3000 Drilled Wells Water Supply (1981-2001)

Capital Cost: well cost per unit $12856

hand pump (10 year life) $ 600

Annual Operation and Maintenance Cost $ 70.65

Annualised Full Cost

$12856 (CRF, 15%, 20) + $600 (CRF, 15%, 10) + $70.65

$12856 (0.15976) + $600 (0.19925) + $70.65

$2053.87 + $119.55 + $70.65 = $2244.07

Financial Cost/m^3 (well yield 19.64 m^3/d) $\frac{\$2244.07}{19.64 \times 365} = \$0.313$

Summary

Total Annual Billing (for 3000 wells) $434,547

Total Annual Revenue $61000

Total Annual Operation and Maintenance Cost

($70.65 x 3000) $211,950

Total Annualised Full Cost ($2244.07 x 3000) $6,732,210

Cost/m^3 $0.313

8.2.6 Hand Dug Well Water Supply (1985-2005)

Capital Cost: well cost $1603

hand pump (10 year life) $ 677

Annual Operation and Maintenance Cost $ 80

Annualised Full Cost

$1603 (CRF, 15%, 20) + $677 (CRF, 15%, 20) + $80

$256.10 + $134.89 + $80 = $470.99

Well yield 19.64 m^3/d

Financial Cost/m^3 $\frac{\$470.99}{19.64 \times 365} = \$0.066$

No Billing

Community contribution (in kind for capital cost) $853.4

(deposit for O & M cost) $ 80

Annualised Community Contribution

$853.4 (CRF, 15%, 20) + $80

$853.4 (0.15976) + $80 = $216.34

Summary

No Billing

Annualised Community Contribution	$216.34
Annual Operation and Maintenance	$80.00
Annualised Full Cost	$470.99
Cost/m^3	$0.066

8.2.7 Central Accra Sewerage (1973-93)

Capital Cost	$3.39 million
Annual Operation and Maintenance Cost	$150400

Annualised Full Cost

$\$3.39 \times 10^6$ (CRF, 15%, 20) + $150400

$\$3.39 \times 10^6$ (0.15976) + $150400

$541525 + $150400 = $691925

Design Population = 150000

Cost per person per annum = $\frac{\$691925}{150000}$ = $4.61

Assuming 12 persons per household (low income housing)

Capital Cost of conversion of household toilet and connection cost $5000

Annual Maintenance and extra cost of water $100

Annualised Cost

$5000(0.15976) + $100 = $989.8

Extra cost per person = $\frac{\$898.0}{12}$ = $74.90

Total Cost per person per annum $79.51

8.2.8 Urban K-VIP Latrine (1985-2005)

Average Capital Cost	$15865
Annual Operation and Maintenance Cost	$ 1380

Annualised Full Cost

$15865 (CRF, 15%, 20) + $1380

$15865(0.15975) + $1380 = $3914.59

Used by 520 persons

Annual Cost per person = $\frac{\$3914}{520}$ = $7.52

No Billing

Annual Revenue	$ 2700

Summary

No Billing	
Annual Revenue	$ 2700
Annual Operation and Maintenance Cost	$ 1380
Annualised Full Cost	$3914.59
Annual Cost per person	$ 7.52

8.2.9 Rural K-VIP Latrine (1982-2002)

Average Capital Cost	$11550
Annual Operation and Maintenance Cost	$ 840

Annualised Full Costs

$11550 (CRF, 15%, 20) + $840

$11550(0.15976) + $840 = $2685

Designed for 300 persons

Annual Cost per person	$8.95
Community Contribution: Capital Cost	$7272
O & M Cost	$ 840
Annualised Community Contribution	$2001.77

Summary

No Billing	
Annualised Community Contribution	$2001.77
Annual Operation and Maintenance Cost	$840
Annualised Full Cost	$2685
Annual Cost per person	$8.95

8.2.10 Traditional Pit Latrine (1985-2005)

Capital Cost	\$2000
Annual Operation and Maintenance Cost	\$ 155
Annualised Full Cost	
\$2000(0.15976) + \$155	
\$319.52 + \$155 = \$474.52	
Designed for 960 persons	
Annual Cost per person = $\frac{\$474.52}{960}$ =	\$0.494
No Billing	
Community Contribute full cost	

Summary

No Billing	
Community Contribution (full cost)	\$474.52
Annual Operation and Maintenance Cost	\$155
Annualised Full Cost	\$474.52
Annual Cost per person	\$0.494

8.3 ECONOMIC ANALYSIS

Assumptions

(i) All projects are assumed to have an economic life of 20 years without any salvage value. The basis of this assumption is that due to inadequate funding of maintenance programmes capital works deteriorate at a fast rate in Ghana and major rehabilitation works are undertaken after 20 years. The last 20 years have been very difficult years for Ghana.

(ii) The Public Investment Programme in Ghana requires projects to achieve a minimum rate of return of 15 per cent. The social discount rate for the economic analysis is taken as 15 per cent.

(iii) The exchange rate operating in any particular year is used to convert all cash flows in cedis to the equivalent amount in US dollars. The Unit of Account in this thesis is the US dollar.

(iv) The shadow exchange rate conversion factor is taken as 1.5, that is, the ratio of the foreign exchange rate obtainable at the Foreign Exchange Bureau for 'non-essential' transactions, to the foreign exchange rate at the Foreign Exchange Auction used for official government transactions. Since the unit of account in this thesis is US dollar the conversion factor becomes $^1/1.5 = 0.667$. Therefore all local costs in dollars obtained by conversion of the cedi price to US dollars using the official exchange rate have to be multiplied by 0.667 to obtain the border prices in US dollars.

(v) The shadow wage rate conversion factor was taken as 2.0. This factor reflects discussions with Dr. Sharma, World Bank Office, Accra and at the Institute of Statistical Social and Economic Research, University of Ghana. Due to shortage of labour in agriculture during the planting and harvesting seasons the agricultural wage is double the minimum wage for unskilled labour. The government of Ghana, over the years, has maintained a low minimum wage as part of its fiscal policy.

(vi) For the purposes of comparison 40 litre per capita per day (lpcd) is assumed for all water projects.

8.3.1 Accra-Tema Water Supply

Phase 1

Capital Cost		$\$34.834 \times 10^6$
Foreign Cost Component	60%	$\$20.900 \times 10^6$
Unskilled labour component	10%	$\$ 3.483 \times 10^6$
Remaining local cost	30%	$\$10.450 \times 10^6$
Annual Operation & Maintenance Cost		$\$ 3.80 \times 10^6$
Foreign Cost Component	40%	$\$ 1.52 \times 10^6$
Unskilled labour component	10%	$\$ 0.38 \times 10^6$
Remaining local cost	50%	$\$ 1.90 \times 10^6$

Costs in dollars at border prices is the sum of the following:

(i) the foreign cost component,

(ii) the unskilled labour component x shadow wage conversion factor x shadow exchange rate conversion factor,

(iii) the remaining local cost x shadow exchange rate conversion factor.

Capital Cost at border prices:

Foreign cost component	$\$20.90 \times 10^6$
Unskilled labour component $\$3.483 \times 2.0 \times 0.667 \times 10^6$	$\$ 4.65 \times 10^6$
Remaining local cost $\$10.45 \times 0.667 \times 10^6$	$\$ 6.97 \times 10^6$
	$\$32.52 \times 10^6$

Annual Operation and Maintenance Cost at border prices:

Foreign cost component	$\$1.52 \times 10^6$
Unskilled labour component $\$0.38 \times 2.0 \times 0.667 \times 10^6$	$\$0.50 \times 10^6$
Remaining local cost $\$1.90 \times 0.667 \times 10^6$	$\$1.27 \times 10^6$
	$\$3.29 \times 10^6$

Annualised Economic Cost:

$\$32.52 \times 10^6$ (CRF, 15%, 20) + $\$3.29 \times 10^6$

$\$32.52 \times 10^6(0.15976) + \$3.29 \times 10^6$ $\$8.856 \times 10^6$

Plant capacity 145454.55 m^3/d

Annualised cost of 145454.55 m^3/d $\$8.856 \times 10^6$

$$\text{Cost}/m^3 = \frac{\$8.856 \times 10^6}{145454.55 \times 365} = \$0.167$$

Assume 40 lcpd

Cost per person = $0.167 x 40 x 365/1000 = <u>$2.43</u>

<u>Phase 2</u>

Capital Cost		$\$51.7 \times 10^6$
Foreign cost component	60%	$\$31.02 \times 10^6$
Unskilled labour component	10%	$\$ 5.17 \times 10^6$
Remaining local cost	30%	$\$15.51 \times 10^6$
Annual Operation and Maintenance Cost		$\$ 5.0 \times 10^6$
Foreign cost component	50%	$\$ 2.5 \times 10^6$
Unskilled labour component	10%	$\$ 0.5 \times 10^6$
Remaining local cost	40%	$\$ 2.0 \times 10^6$

Calculations are similar to Phase 1.

Annualised Economic Cost	$\$12.211 \times 10^6$
Plant capacity is 68181.82 m^3 (15 mgd)	
$\text{Cost}/m^3 = \dfrac{\$12.211 \times 10^6}{68181.82 \times 365} =$	\$0.491

Assuming 40 lpcd

Cost per person \$0.491 x 40 x 365/1000 =	<u>\$7.17</u>

8.3.2 <u>Borehole Water Supply</u>

Capital Cost		\$118240
Foreign cost component	65%	\$ 76856
Unskilled labour component	8%	\$ 9459.20
Remaining local cost	27%	\$ 31924.80
Annual Operation and Maintenance Cost		\$ 13500.00
Foreign cost component	25%	\$ 3375.00
Unskilled labour component	25%	\$ 3375.00
Remaining local cost	50%	\$ 6750.00

Calculations are similar to paragraph 8.3.1.

Annualised Economic Cost	\$ 30075.64
Plant capacity is 22.7 m^3/h	
$\text{Cost}/m^3 = \dfrac{\$30075.64}{22.75 \times 24 \times 365} =$	\$0.151

Assuming 40 lpcd

Cost per person = \$0.151 x 40 x 365/1000 =	<u>\$2.20</u>

8.3.3 <u>Package Plant Water Supply</u>

(a) <u>For 18.18 m^3/h Plant (11 units)</u>

Capital Cost		\$160000
Foreign cost component	60%	\$ 96000
Unskilled labour component	8%	\$ 12800
Remaining local cost	32%	\$ 51200
Annual Operating and Maintenance Cost		\$ 17900
Foreign cost component	35%	\$ 6265

Unskilled labour component	8%	\$ 1432
Remaining local cost	57%	\$ 10203

Calculations are similar to paragraph 8.3.1.

Annualised Economic Cost	\$ 38500.76
$\text{Cost/m}^3 = \frac{\$38500.76}{18.18 \times 24 \times 365} =$	\$0.242

(b) <u>For 9.09 m^3/h Plant (58 units)</u>

Capital Cost	\$102100
Annual Operation and Maintenance Cost	\$ 13200

Component percentages are the same as (a).

Calculations are similar to paragraph 8.3.1.

Annualised Economic Cost	\$ 26056.40
$\text{Cost/m}^3 = \frac{\$26056.40}{9.09 \times 24 \times 365} =$	\$0.327

$$\text{Weighted Average of Cost/m}^3 = \frac{\$11 \times 0.242 + 58 \times 0.327}{69} = \$0.313$$

Assume 40 lpcd

Cost per person = \$0.313 x 40 x 365/1000 = <u>\$4.56</u>

8.3.4 <u>2500 Drilled Wells Water Supply</u> (calculations are based on a single well)

Capital Cost: well cost		\$5000
Foreign cost component	70%	\$3500
Unskilled labour component	5%	\$ 250
Remaining local cost	25%	\$1250
Hand Pump (10 year life)		\$ 744
Foreign cost component	90%	\$ 699.6
Unskilled labour component	2%	\$ 14.88
Remaining local cost	8%	\$ 59.50
Annual Maintenance Cost		\$ 92.06
Foreign cost component	60%	\$ 55.24
Unskilled labour component	5%	\$ 4.60
Remaining local cost	35%	\$ 32.22

Proceed as in paragraph 8.3.1 to obtain costs at border prices.

Well cost: \$3500 + \$250 x 2 x 0.667 + \$1250 x 0.667 = \$4667.25

Hand pump: \$699.6 + \$14.88 x 2 x 0.667 + \$59.50 x 0.667 = \$709.29

Maintenance: \$55.24 + \$4.6 x 2 x 0.667 + \$32.22 x 0.667 = \$82.87

Annualised Economic Cost

\$4667.25 (CRF, 15%, 20) + \$709.29 (CRF, 15%, 10) + \$82.87

\$745.64 + \$141.33 + \$ 82.87 = \$969.84

Yield per well 19.64 m^3/d

$$\text{Cost}/m^3 = \frac{\$969.84}{7168.63} = \$0.135$$

Assuming 40 lpcd

Cost per person = \$0.135 x 40 x 365/1000 = <u>\$1.97</u>

8.3.5 <u>3000 Drilled Wells Water Supply</u> (calculations similar to above)

Capital Cost: well cost		\$12856
Foreign cost component	80%	\$10284
Unskilled labour component	5%	\$ 642.8
Remaining local cost	15%	\$ 1928.4
Hand Pump (10 year life)		\$ 600
Foreign cost component	90%	\$ 540
Unskilled labour component	5%	\$ 30
Remaining local cost	5%	\$ 30
Annual Maintenance Cost		\$ 70.65
Foreign cost component	60%	\$ 42.39
Unskilled labour component	5%	\$ 3.53
Remaining local cost	35%	\$ 24.73
Proceed as in paragraph 8.3.4		
Cost/m^3		\$0.303
Cost per person		<u>\$4.42</u>

8.3.6 <u>Hand Dug Well Water Supply</u>

Capital Cost: well cost		\$1603
Foreign cost component	25%	\$ 400
Unskilled labour component	35%	\$ 561.03
Remaining local cost	40%	\$ 641.20

Hand Pump		\$ 677
Foreign cost component	90%	\$ 609.3
Unskilled labour component	5%	\$ 33.85
Remaining local cost	5%	\$ 33.85
Annual Maintenance Cost		\$ 80.00
Foreign cost component	60%	\$ 48.00
Unskilled labour component	5%	\$ 4.00
Remaining local cost	35%	\$ 24.00

Proceed with calculation as in paragraph 8.3.4

Cost/m^3	\$0.064
Cost per person	<u>\$0.93</u>

8.3.7 <u>Central Accra Sewerage</u>

Capital Cost		$\$3.39 \times 10^6$
Foreign cost component	46%	$\$1.56 \times 10^6$
Unskilled labour component	20%	$\$0.68 \times 10^6$
Remaining local cost	34%	$\$1.15 \times 10^6$
Annual Operation and Maintenance Cost		\$150400
Foreign cost component	50%	\$ 75200
Unskilled labour component	10%	\$ 15040
Remaining local cost	40%	\$ 60160

Proceed with calculation as in paragraph 8.3.1 to obtain:

Annualised Economic Cost	\$651894	
Design population	150,000	
Cost per person = $\frac{\$651894}{150000}$ =	\$4.36	(1)

For house facilities:

Capital Cost		\$5000
Foreign cost component	50%	\$2500
Unskilled labour component	10%	\$ 500
Remaining local cost	40%	\$2000
Annual Operation and Maintenance Cost		\$ 100
Foreign cost component	60%	\$ 60
Unskilled labour component	10%	\$ 10
Remaining local cost	30%	\$ 30

Proceed with calculation as in paragraph 8.3.1.

Assume 12 persons per household.

Cost per person		$73.24 (2)
Total Cost per person [(1) + (2)] $4.36 + $73.24		$77.60

8.3.8 Urban K-VIP Latrine

Capital Cost		$15865
Foreign cost component	50%	$ 7932.50
Unskilled labour component	10%	$ 1586.50
Remaining local cost	40%	$ 6346
Annual Operation and Maintenance Cost		$ 1380
Foreign cost component	30%	$ 414
Unskilled labour component	20%	$ 276
Remaining local cost	50%	$ 690

Proceed with calculation as in paragraph 8.3.1 to obtain:

Annualised Economic Cost	$ 3520.4
Population using the facility	520
Cost per person = $\frac{\$3520.4}{520}$ =	$6.77

8.3.9 Rural K-VIP Latrine

Capital Cost		$11550
Foreign cost component	50%	$ 5775
Unskilled labour component	10%	$ 1155
Remaining local cost	40%	$ 4620
Annual Operations and Maintenance		$ 840
Foreign cost component	15%	$ 126
Unskilled labour component	20%	$ 168
Remaining local cost	65%	$ 546

Proceed with calculations as in paragraph 8.3.1 to obtain:

Annualised Economic Cost	$ 2445
Design population	300
Cost per person = $\frac{\$2445}{300}$ =	$8.15

8.3.10 Traditional Pit Latrine

Capital Cost		$2000
Foreign cost component	0%	-
Unskilled labour component	30%	$ 600
Remaining local cost	70%	$1400
Annual Operation and Maintenance Cost		$ 155
Foreign cost component	0%	-
Unskilled labour component	50%	$ 77.5
Remaining local cost	50%	$ 77.5

Proceed with calculations as in paragraph 8.3.1 to obtain:

Annualised Economic Cost	$ 432.06
Design population	960

Cost per person = $\frac{\$432.06}{960}$ = $0.450

8.3.11 Summary of Results

Project	Annualised Economic Cost per person
Accra-Tema Water Supply	Phase 1: $ 2.43
	Phase 2: $ 7.17
Borehole Water Supply	$ 2.20
Package Plant Water Supply	$ 4.56
2500 Drilled Wells Water Supply	$ 1.97
3000 Drilled Wells Water Supply	$ 4.42
Hand Dug Well Water Supply	$ 0.93
Central Accra Sewerage	$77.60
Urban K-VIP Latrine	$ 6.77
Rural K-VIP Latrine	$ 8.15
Traditional Pit Latrine	$ 0.45

8.4 ANALYSIS OF DATA ON INSTITUTIONAL FACTORS

8.4.1 Construction

Project	Analysis	Result
Accra-Tema Water Supply	Construction was by contract. Phase 1: West German contractor on supplier's credit. Phase 2: Italian contractor for dam; Canadian contractor for mechanical and electrical works, Ghanaian contractor for treatment plant and pipelines.	Mostly satisfactory. Cement mortar in steel pipes peeled off. Satisfactory except for significant delays.
Borehole Water Supply	Force account with minor contracts.	Satisfactory.
Package Plant Water Supply	Force account with minor contracts.	Satisfactory.
2500 Drilled Wells	Force account with Canadian professional input.	Satisfactory.
3000 Drilled Wells	Contract by West German contractor.	Completed ahead of schedule.
Hand Dug Well	Self help with donor technical assistance.	Satisfactory.
Central Accra Sewerage	Contract by Israeli contractors.	Satisfactory.
Urban K-VIP Latrine	Contract by small Ghanaian contractors later by force account and self help.	Unsatisfactory. Satisfactory.
Rural K-VIP Latrine	Self help with government technical assistance.	Satisfactory.
Traditional Pit Latrine	Self help.	Satisfactory.

8.4.2 Operation and Maintenance

Project	Analysis	Result
Accra-Tema Water Supply	544 skilled staff serving 80 per cent of 1.42 million population.	479 staff to 1 million population.
Borehole Water Supply	4 skilled staff to about 8,888 persons per installation.	450 staff to 1 million population.
Package Plant Water Supply	5 skilled staff to 5,000 persons per plant.	1,000 staff to 1 million population
2500 Drilled Wells	65 skilled staff for 900,000 persons served.	72 staff to 1 million population.
3000 Drilled Wells	79 skilled staff for 1,200,000 persons served.	66 staff to 1 million population.
Hand Dug Well	No skilled staff employed. 2 community workers assigned.	-
Central Accra Sewerage	46 skilled staff serving 40,000 persons using facility.	1,150 staff to 1 million population.
Urban K-VIP Latrine	No skilled staff employed. 3 caretaker staff for 520 persons served.	-
Rural K-VIP Latrine	No skilled staff employed. 2 community workers assigned.	-
Traditional Pit Latrine	No skilled staff employed. Community workers assigned.	-

8.4.3 Logistics

Project	Analysis	Result
Accra-Tema Water Supply	Fuel and chemicals supplied as top priority. 3 month storage for chemicals.	Satisfactory supplies.
Borehole Water Supply	Fuel storage tanks available but fuel supply is intermittent.	Frequent fuel shortages.
Package Plant Water Supply	Storage for both fuel and chemicals available but supply is intermittent.	Frequent fuel and chemical shortages.
2500 Drilled Wells	Spare parts available due to CIDA support. Fuel supplies to Upper Regions is a major logistic problem in Ghana.	Satisfactory stocks of spare parts. Unsatisfactory supply of fuel.
3000 Drilled Wells	Fuel supplies are good but bureaucratic bottlenecks hamper regular supply of spare parts in spite of West German support.	Unsatisfactory spare parts stocks.
Hand Dug Well	No logistic problem.	-
Central Accra Sewerage	More flushing vehicles required.	Unsatisfactory flushing of sewers.
Urban K-VIP Latrine	Unavailability of desludging vehicles.	Rate of desluding unsatisfactory.
Rural K-VIP Latrine	No logistic problem.	-
Traditional Pit Latrine	No logistic problem.	-

8.4.4 Training

Project	Analysis	Result
Accra-Tema Water Supply	Training available at GWSC institutions and other higher government institutions. High labour turnover means training of more staff.	More training required. World Bank and ODA are providing assistance.
Borehole Water Supply	Ditto	Ditto.
Package Plant Water Supply	Ditto	Ditto
2500 Drilled Wells	Several training programmes by CIDA. Training of pump caretakers still in progress.	GWSC staff trained on-the-job. 2 caretakers trained per pump.
3000 Drilled Wells	On the job training for GWSC worker on handpump maintenance and metal fabrication. No training for community-based caretakers.	GWSC staff trained on the job. No training for hand pump caretakers.
Hand Dug Well	No training.	No training.
Central Accra Sewerage	Some on-the-job training. No formal training of GWSC staff in sewerage operations.	Training unsatisfactory. Training institutions required.
Urban K-VIP Latrine	No training.	Operators not trained.
Rural K-VIP Latrine	On-the-job training in construction. No training in operations.	No community workers trained in operations.
Traditional Pit Latrine	Training required to upgrade facilities.	Facilities should be upgraded through training.

8.4.5 Legal Responsibility/Declared Aims

Project	Analysis	Result
Accra-Tema Water Supply	GWSC Act of Incorporation defective. New Act under review to provide for decentralisation, tariff revision and community participation.	A rejuvenated and vigorous GWSC expected.
Borehole Water Supply	Ditto	Ditto
Package Plant Water Supply	Ditto	Ditto
2500 Drilled Wells	GWSC responsible for pump maintenance. CIDA responsible for spares and vehicles. Plans for eventual community takeover.	New programme to work towards community takeover.
3000 Drilled Wells	GWSC/Govt of West Germany joint responsibility for (a) Upgrading pumps in aggressive water areas, (b) Community education, (c) Eventual community-based maintenance.	Proposals for community-based maintenance under consideration.
Hand Dug Well	Joint responsibility by Water Aid and communities to develop long term maintenance system.	GWSC approached for support under National Hand Dug Well programme.
Central Accra Sewerage	New GWSC Act to strengthen the institution for effective discharge of sewerage responsibilities.	GWSC to be more vigorous in promoting connections.

Urban K-VIP Latrine	District Assemblies and communities require guidance to construct cheaper latrines.	More communities to benefit from cheaper latrines.
Rural K-VIP Latrine	Ditto	Ditto
Traditional Pit Latrines	Communities require guidance to improve latrines by providing vents.	Less objectionable odours and fly breeding.

8.5 ANALYSIS OF DATA ON SOCIAL FACTORS

8.5.1 Taste and Odour

Project	Analysis	Result
Accra-Tema Water Supply	Algal blooms on the Weija Lake impart taste and musty odour to treated water from Weija.	Kpong water preferred to Weija water as drinking water.
Borehole Water Supply	Slight bitter taste due to tolerable levels of iron and manganese.	Taste tolerable.
Package Plant Water Supply	No taste and odour problems but severe colour problems persist when chemicals are short or rationed.	No taste and odour problems but frequent colour problems.
2500 Drilled Wells	No taste and odour problems.	-
3000 Drilled Wells	High levels of iron and manganese impart bitter taste. Water discolours food (plantain and cassawa) cooked in it.	Several wells rejected by communities on account of taste, etc.
Hand Dug Wells	No taste and odour problems.	-
Central Accra Sewerage	No odour problems.	-

Urban K-VIP Latrines	Some odour problems due anal cleansing materials left in privy rooms and reverse airflow into privy rooms when pit covers not properly sealed.	Odour bearable.
Rural K-VIP Latrines	Some odour problem due to anal cleansing materials left in privy rooms.	Odour bearable.
Traditional Pit Latrine	Severe odour problems which can be alleviated through provision of vents.	Odour bearable only to local users.

8.5.2 Distance Travelled

Project	Analysis	Result
Accra-Tema Water Supply	Areas without yard taps.	10-100m
	Areas without distribution systems.	100-500m
	Traditional sources.	Heavily polluted
Borehole Water Supply	Water distribution system fully developed.	10-150m (average 80m)
	Traditional source	Average 700m
Package Plant	Water distribution system fully developed.	10-150m (average 80m)
	Traditional source.	Average 800m.
2500 Drilled Wells	Sparsely distributed population.	10-800m (average 340m)
	Traditional source.	Average 1.6km in dry season
3000 Drilled Wells	Wells located within the community.	50-200m (average 150m)
	Traditional source.	Average 700 m

Hand Dug Well	Well located close to the community. Traditional source.	50-250m (average 150m) 300m
Central Accra Sewerage	Household facilities used. Public flush toilets not connected to sewerage yet.	0-10m
Urban K-VIP Latrine	Latrines are located in designated sanitary areas in the city of Kumasi.	10-200m (average 100m)
Rural K-VIP Latrine	Latrines located at one end of the community	20-250m (average 100m)
Traditional Pit Latrine	Latrine located at one end of the community	20-250m (average 100m)

8.5.3 Queuing Period

Project	Analysis	Result
Accra-Tema Water Supply	Queuing in slum areas at community standpipes.	0-30min (average 20min)
Borehole Water Supply	Queuing at standpipes is a major problem. Traditional sources used.	0-60min (average 40min)
Package Plant Water Supply	Queuing at standpipes is a major problem. Traditional sources used.	0-60min (average 40min)
2500 Drilled Wells	Queuing periods are very high.	Average 83min sometimes exceeds 2hrs
3000 Drilled Wells	Reasonable queuing periods except for early morning before farming activities.	0-40min (average 20min)
Hand Dug Well	Queuing in the mornings and evenings.	Average 20min

Central Accra Sewerage	Not applicable.	-
Urban K-VIP Latrine	Queuing in the mornings and in the evenings.	0-22min (average 10min)
Rural K-VIP Latrine	No queues.	Zero. Alternative use of traditional pit or bush
Traditional Pit Latrine	No queues.	Zero. Alternative use of bush.

8.5.4 Types of Water Collection Containers

On all projects water is carried mainly on the head by mostly women and children. For individual carriers containers vary from 5 litres to about 35 litres. The average size is about 18 litres. Carriers using trolleys have containers of sizes up to 200 litres. Where water tankers are used their sizes range from $4.5m^3$ to $7m^3$.

8.5.5 Anal Cleansing Materials

In the service area of the Central Accra Sewerage toilet roll and old newsprint used. Material is usually flushed down but some users accumulate anal cleansing material in waste basket and burn them daily. This is to prevent blocking of household sewers.

In the communities using the various latrines anal cleansing materials include corn-cobs, pieces of wood, water, old rags, newsprint (dispensed at the Urban K-VIP latrine on payment of admission charge) leaves and sometimes stones. Smearing of walls is a common practice. Waste basket is usually provided to collect materials for burning. Unavailability and cost of toilet roll precludes its use by most people.

8.5.6 Facilities for Children

Project	Analysis	Result
Accra-Tema Water Supply	Water supply by mainly yard taps and house connections. Children are adequately taken care of.	No separate water supply for children required.
Borehole Water Supply	Children are vulnerable when queues become violent otherwise children can use facilities.	No separate facilities required for children.
Package Plant Water Supply	Ditto	Ditto
2500 Drilled Wells	Ditto	Ditto
3000 Drilled Wells	Ditto	Ditto
Hand Dug Well	Hand pump installed on a high well head. Children can use hand pump with short strokes (not desirable).	Pedestal required for children to stand on or lower well head.
Central Accra Sewerage	Household facilities in use. Children adequately catered for.	No separate facilities for children.
Urban K-VIP Latrine	Children excluded from use of some facilities.	Open defecation for children. Separate facilities required.
Rural K-VIP Latrine	Children may use the facility, or use adjacent traditional pit latrine or use the bush.	Separate facilities required for children.
Traditional Pit Latrine	Some children use the facility. Others use chamber pots. Others practise open defecation.	Separate improved facilities required for children.

8.5.7 <u>Community Involvement in the Project</u>

Elements of Involvement	Accra-Tema Water Supply	Borehole Water Supply	Package Plant Water	2500 Drilled Wells	3000 Drilled Wells	Hand Dug Well	Central Accra Sewerage	Urban K-VIP Latrine	Rural K-VIP Latrine	Traditional Pit Latrine
Request for Project	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Level of Service/ Coverage	No	No	No	No	No	Yes	No	No	Yes	Yes
Dialogue	No	No	No	No	No	Yes	No	No	Yes	Yes
Commitment	No	No	No	No	No	Yes	No	Yes	Yes	Yes
Appropriate Technology	No	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes
Willingness to Pay	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Cost Recovery	Yes	No	No	No	No	Yes	No	Yes	Yes	Yes
Ability to Pay	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Decision Making	No	No	No	No	No	Yes	No	Yes	No	Yes
Responsibility	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Score: Yes=0; No=1	6	6	7	5	6	0	8	2	3	0

8.5.8 Population Factors

Project	Analysis	Result
Accra-Tema Water Supply	Analysis of Data on 1984 Population Census by the Ghana Statistical Service.	Population Accra-Tema (1984) 1185454 Rural Greater Accra 234612 Total 1420066 Growth rate 3.3 per cent Population Density Accra-Tema 150 persons/hectare Other Details National Growth Rate 2.6 per cent Age composition 0-14 years 45 per cent 15-64 years 51 per cent 65 & over 4 per cent Education 56 per cent literate Female to Male Ratio 1.03
Borehole Water Supply	Ditto	Pop. Served (1984) 808808 Pop. Density 80 persons/hectare Other Details - as above.
Package Plant Water Supply	Ditto	Pop. Served (1984) 345000 Pop. Density 80 persons/hectare Other Details - as above.
2500 Drilled Wells	Ditto	Design Pop. 900000 Population (1984) 1097863 Pop. Density 5 persons/hectare Other Details - as above.
3000 Drilled Wells	Ditto	Population Served 951040 Pop. Density 70 persons/hectare Other Details - as above.

Hand Dug Well	Ditto	Village Population 420 Pop. Density 60 persons/hectare Other Details - as above.
Central Accra Sewerage	Ditto	Design Population 150000 Pop. Density 200 persons/hectare Other Details - as above.
Urban K-VIP atrine	Data collected and analysed for each project	Design Population/latrine 300 Population using latrine 520 Potential users of latrine 1750 Pop. Density 100 persons/hectare Other Details - as above.
Rural K-VIP Latrine	Ditto	Design Population/latrine 300 Population using latrine 180 Average village population 1800 Pop. Density 70 persons/hectare Other Details - as above.
Traditional Pit Latrine	Ditto	Design Population 960 Poulation using latrine 238 Village Population 540 Pop. density 60 persons/hectare

8.5.9 Alternative Facilities in Use

Project	Analysis	Result
Accra-Tema Water Supply	No acceptable alternatives exist. Local streams are polluted and wells ar saline.	No acceptable alternative exist.
Borehole Water Supply	Traditional stream sources are still in use. There are also some hand dug wells with rope and bucket.	Alternative sources heavily used.
Package Plant Water Supply	Ditto	Ditto
2500 Drilled Wells	Traditional sources are nearer in the wet season than wells. Some hand dug wells are in use.	Traditional sources used in wet season.
3000 Drilled Wells	Traditional sources heavily used due to water quality problems in wells. Some hand dug wells are in use.	Some drilled wells abandoned for the traditional sources.
Hand Dug Well	Traditional sources still in use though not very much.	Well water mostly used.
Central Accra Sewerage	Bucket latrine, K-VIP latrines, the water closet and septic tanks and open defecation at the beach are in use.	Sewerage system under-utilised.
Urban K-VIP Latrine	Bucket latrine, Aqua Privy latrine, water closet and septic tank and open defecation are in use. Facilities are inadequate for the potential users.	All alternative facilities are heavily used.

Rural K-VIP Latrine	Traditional Pit Latrine and open defecation in the bush or on the beach are still used.	Utilisation of K-VIP latrine is low.
Traditional Pit Latrine	Open defecation in the bush or on the beach is still practised.	Alternative facilities equally used.

8.6 ANALYSIS OF DATA ON ENVIRONMENTAL FACTORS

8.6.1 Sullage Disposal for Water Supply Projects

Project	Analysis	Result
Accra-Tema Water Supply	Sullage is discharged into storm drains and eventually reach water courses. Some sullage is intercepted into the Central Accra Sewerage system. An estimated amount of $2.0 per person required to connect household to storm drains or to provide a local soakage pit.	Water courses are heavily polluted. Stagnant sullage breeds mosquitoes. Storm drains usually choked with solid waste.
Borehole Water Supply	Sullage is spread out to control dust or run into natural storm gulleys.	Most sullage evaporates or seeps into the ground. No pollution.
Package Plant Water Supply	Ditto	Ditto
2500 Drilled Wells	Ditto	Ditto
3000 Drilled Wells	Ditto	Ditto
Hand Dug Wells	Ditto	Ditto

8.6.2 Sewage on the Beach

Project	Analysis	Result
Central Accra Sewerage	Design of waste stabilisation ponds have been completed. Construction cost is estimated at $0.5 million and for the 150,000 design population is $3.3 per person. An alternative permanent outfall is considered too expensive.	Waste stabilisation ponds selected at $3.3 per person. Negotiations for financing is in progress.

8.6.3 Disposal of Sludge from K-VIP Latrines

With the Urban K-VIP Latrine project, the Kumasi Metropolitan Assembly provides cesspit emptyers to help desludge K-VIP latrines. Where the sludge is too thick for the vacuum pumps manual desludging is used. Land around the latrine should be prepared to receive the sludge for drying and incineration otherwise sludge is transported 11.2km to trenching grounds to be buried. In both cases it is estimated that an amount of $1.0 per user is required for proper sludge disposal to avoid land pollution.

Rural K-VIP latrines are desludged manually and the sludge dried and incinerated on site. It is estimated that an amount of $1.0 per user will be required to ensure the proper sludge disposal to avoid land pollution.

8.7 DATA ENVELOPMENT ANALYSIS

8.7.1 Project Data for DEA

Input and output factors for data envelopment analysis are derived from the relevant sections of the foregoing analysis, that is, sections 8.1 to 8.6.

Technical Input Factor

This factor is computed as the foreign cost component of capital cost. It is derived from section 8.3 on Economic Analysis. For example, the Accra-Tema Water Supply project has 60 per cent foreign cost component of capital cost, the technical input factor is recorded as 0.60.

In the projects with hand pumps the total foreign cost component is computed as the ratio of the sum of the foreign costs of the well and the hand pump to the total capital cost of the well and the hand pump. For example, from section 8.3.4:

2500 Drilled Wells: $\frac{70\% \text{ of } \$5000 + 90\% \text{ of } \$744}{\$5744} = 0.72$

Similar Technical Input Factors are derived for all projects.

Financial Input Factor

This factor is computed as:

$$1 - \frac{\text{Annual Revenue or Annualised Community Contribution}}{\text{Annualised Full Cost}}$$

These figures are obtained from section 8.2 on financial Analysis.

Thus for Accra-Tema Water Supply: Phase 1, Section 8.2.1:

$$\text{Financial Input Factor} = 1 - \frac{\$2.49}{\$9.36} = \underline{0.73}$$

Economic Input Factor

This factor was computed in section 8.3 and summarised in section 8.3.11.

Institution Input Factor

This factor was computed in section 8.4.2.

Social Input Factor

This factor was computed as scores of lack of community involvement in section 8.5.7.

Environmental Input Factor

This factor is computed as cost per person for pollution prevention in section 8.6.

Reliability Output Factor

This factor is computed as 1 - System Down time from section 8.1.7

For Package Plant: Reliability is:

(1 - System Downtime) (1 - Unavailability of Chemicals)

0.797 x 0.413 = 0.33.

Utilization Output Factor

This factor is computed as described in section 8.1.9 where results are also recorded.

Convenience Output Factor

This factor is computed as population density and recorded in section 8.5.8.

8.7.2 Summary of DEA Input and Output Factors

Summary of DEA Input and Output Factors

	INPUT FACTORS						OUTPUT FACTORS		
PROJECT	Technical	Financial	Economic	Institu-tional	Social	Environ-mental	Relia-bility	Utiliz-ation	Convenience
Accra-Tema Water	0.60	0.73	2.43	479	6	2.0	0.97	0.80	150
Borehole Water	0.65	0.95	2.20	450	6	0	0.78	0.50	80
Package Plant Water	0.60	0.97	4.56	1000	7	0	0.33	0.40	80
2500 Drilled Wells	0.72	0.95	1.97	72	5	0	0.85	0.40	5
3000 Drilled Wells	0.84	0.99	4.42	66	6	0	0.40	0.30	70
Hand Dug Well	0.44	0.54	0.93	0	0	0	0.98	0.90	60
Central Accra Sewerage	0.46	0.88	77.60	1150	8	3.3	0.90	0.20	200
Urban K-VIP Lat.	0.50	0.31	6.77	0	2	1.0	0.90	0.30	100
Rural K-VIP Lat.	0.50	0.22	8.15	0	3	1.0	0.90	0.10	70
Traditional Pit Latrine	0	0	0.45	0	0	0	0.90	0.44	60

8.7.3 Formulation of Linear Programming Models

Run 1: 2 Output Factors - Reliability and Utilisation

6 Input Factors

10 Projects

Let U_1 and U_2 be the output weights for Reliability and Utilisation respectively and V_1, V_2, V_3, V_4, V_5, V_6 the input weights for technical, financial, economic, institutional, social and environmental factors respectively.

(i) Formulating the model for Accra-Tema Water Supply project, maximise the Objective Function.

$$0.97U_1 + 0.80U_2 + 0V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 + 0V_6 \qquad [1]$$

The available software for the Simplex Method is a minimisation programme, the maximisation programme is equivalent to minimisation of the negative of the Objective Function. Therefore, minimise the Objective Function.

$$-0.97U_1 - 0.80U_2 - 0V_1 - 0V_2 -+ 0V_3 - 0V_4 - 0V_5 - 0V_6$$

subject to

Equality constraint

$$0U_1 + 0U_2 + 0.6V_1 + 0.73V_2 + 2.43V_3 + 479V_4 + 6.0V_5 + 2V_6 = 1$$

and 10 Inequality constraints

$$-0.97U_1 - 0.80U_2 + 0.60V_1 + 0.73V_2 + 2.43V_3 + 479V_4 + 6.0V_5 + 2V_6 \geq 0$$
$$-0.78U_1 - 0.50U_2 + 0.65V_1 + 0.95V_2 + 2.20V_3 + 450V_4 + 6.0V_5 + 0V_6 \geq 0$$
$$-0.33U_1 - 0.40U_2 + 0.60V_1 + 0.97V_2 + 4.56V_3 + 1000V_4 + 7.0V_5 + 0V_6 \geq 0$$
$$-0.85U_1 - 0.40U_2 + 0.72V_1 + 0.95V_2 + 1.97V_3 + 72V_4 + 5.0V_5 + 0V_6 \geq 0$$
$$-0.40U_1 - 0.30U_2 + 0.84V_1 + 0.99V_2 + 4.42V_3 + 66V_4 + 6.0V_5 + 0V_6 \geq 0$$
$$-0.98U_1 - 0.90U_2 + 0.44V_1 + 0.54V_2 + 0.93V_3 + 0V_4 + 0V_5 + 0V_6 \geq 0$$
$$-0.90U_1 - 0.20U_2 + 0.46V_1 + 0.88V_2 + 77.60V_3 + 1150V4 + 8.0V_5 + 3.3V_6 \geq 0$$
$$-0.90U_1 - 0.30U_2 + 0.50V_1 + 0.31V_2 + 6.77V_3 + 0V_4 + 2.0V_5 + 1.0V_6 \geq 0$$
$$-0.90U_1 - 0.10U_2 + 0.50V_1 + 0.22V_2 + 8.15V_3 + 0V_4 + 3.0V_5 + 1.0V_6 \geq 0$$
$$-0.90U_1 - 0.44U_2 + 0V_1 + 0V_2 + 0.45V_3 + 0V_4 + 0V_5 + 0V_6 \geq 0$$

This is a linear programming model with 8 variables and 11 constraints which is solved by the Copyright 1986 SGF Software on an IBM compatible personal computer to obtain the efficiency score for Accra-Tema Water Supply project.

Similarly, for the 9 remaining projects the 10 Inequality constraints remain the same but the objective functions and the Equality constraints differ.

For the 9 projects the objective function and the equality constraint are stated. To this should be added the 10 inequality constraints above to complete the linear programming formulation.

(ii) Thus for the Borehole Water Supply project.
Minimise the Objective Function.
$-0.78U_1 - 0.50U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$
subject to
$0U_1 + 0U_2 + 0.65V_1 + 0.95V_2 + 2.20V_3 + 450V_4 + 6.0V_5 + 0V_6 = 1$
and 10 inequality constraints above.

(iii) Package Plant Water Supply project.
Minimise the Objective Function
$-0.33U_1 - 0.40U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$
subject to
$0U_1 + 0U_2 + 0.60V_1 + 0.97V_2 + 4.56V_3 + 1000V_4 + 7.0V_5 + 0V_6 = 1$
and 10 inequality constraints above.

(iv) 2500 Drilled Wells Water Supply project.
Minimise the Objective Function
$-0.85U_1 - 0.40U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$
subject to
$0U_1 + 0U_2 + 0.72V_1 + 0.95V_2 + 1.97V_3 + 72V_4 + 5.0V_5 + 0V_6 = 1$
and 10 inequality constraints above.

(v) 3000 Drilled Wells Water Supply project
Minimise the Objective Function
$-0.40U_1 - 0.30U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$
subject to
$0U_1 + 0U_2 + 0.84V_1 + 0.99V_2 + 4.42V_3 + 66V_4 + 6.0V_5 + 0V_6 = 1$
and 10 inequality constraints above.

(vi) Hand Dug Well Water Supply project

Minimise the Objective Function

$-0.98U_1 - 0.90U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.44V_1 + 0.54V_2 + 0.93V_3 + 0V_4 + 0V_5 + 0V_6$

and 10 inequality constraints above.

(vii) Central Accra Sewerage project

Minimise the Objective Function

$-0.90U_1 - 0.20U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.46V_1 + 0.88V_2 + 77.60V_3 + 1150V4 + 8.0V_5 + 3.3V_6 = 1$

and 10 inequality constraints above.

(viii) Urban K-VIP Latrine project

Minimise the Objective Function

$-0.90U_1 - 0.30U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.50V_1 + 0.31V_2 + 6.77V_3 + 0V_4 + 2.0V_5 + 1.0V_6 = 1$

and 10 inequality constraints above.

(ix) Rural K-VIP Latrine project

Minimise the Objective Function

$-0.90U_1 - 0.10U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.50V_1 + 0.22V_2 + 8.15V_3 + 0V_4 + 3.0V_5 + 1.0V_6 = 1$

and 10 inequality constraints above.

(x) Traditional Pit Latrine project

Minimise the Objective Function

$-0.90U_1 - 0.44U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.45V_1 + 0V_2 + 0V_3 + 0V_4 + 0V_5 - 0V_6 = 1$

and 10 inequality constraints above.

Each linear programming model formulated as above is solved to provide the efficiency score for the particular project.

Run 2: 2 Outputs - Reliability and Utilisation

6 Inputs

(a) 6 Water Projects (b) 4 Sanitation Projects

(a) Let U_1 and U_2 be the output weights for Reliability and Utilisation respectively and V_1, V_2, V_3, V_4, V_5, V_6 be the input weights for technical, financial, economic, institutional, social and environmental factors respectively.

(i) Accra-Tema Water Supply project

Minimise the Objective Function

$-0.97U_1 - 0.80U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.60V_1 + 0.73V_2 + 2.43V_3 + 479V_4 + 6.0V_5 + 2V_6 = 1$

and 6 Inequality constraints corresponding to the water projects in the 10 inequality constraints above.

$-0.97U_1 - 0.80U_2 + 0.60V_1 + 0.73V_2 + 2.43V_3 + 479V_4 + 6.0V_5 + 2V_6 \geq 0$

$-0.78U_1 - 0.50U_2 + 0.65V_1 + 0.95V_2 + 2.20V_3 + 450V_4 + 6.0V_5 + 0V_6 \geq 0$

$-0.33U_1 - 0.40U_2 + 0.60V_1 + 0.97V_2 + 4.56V_3 + 1000V_4 + 7.0V_5 + 0V_6 \geq 0$

$-0.85U_1 - 0.40U_2 + 0.72V_1 + 0.95V_2 + 1.97V_3 + 72V_4 + 5.0V_5 + 0V_6 \geq 0$

$-0.40U_1 - 0.30U_2 + 0.84V_1 + 0.99V_2 + 4.42V_3 + 66V_4 + 6.0V_5 + 0V_6 \geq 0$

$-0.98U_1 - 0.90U_2 + 0.44V_1 + 0.54V_2 + 0.93V_3 + 0V_4 + 0V_5 + 0V_6 \geq 0$

This is a linear programming model lwith 8 variables and 7 constraints which is then solved to give the efficiciency score of the Accra-Tema Water Supply project with respect to the other 5 water projects.

(ii) Borehole Water Supply project

Minimise the Objective Function

$-0.78U_1 - 0.50U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2\ 0.65V_1 + 0.95V_2 + 2.20V_3 + 450V_4 + 6.0V_5 + 0V_6 = 1$

and 6 inequality constraints as above.

(iii) Package Plant Water Supply project

Minimise Objective Function

$-0.33U_1 - 0.40U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.60V_1 + 0.97V_2 + 4.56V_3 + 1000V_4 + 7.0V_5 + 0V_6 = 1$

and 6 inequality constraints as above.

(iv) 2500 Drilled Wells Water Supply project

Minimise the Objective Function

$-0.85U_1 - 0.40U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.72V_1 + 0.95V_2 + 1.97V_3 + 72V_4 + 5.0V_5 + 0V_6 = 1$

and 6 inequality constraints as above.

(v) 3000 Drilled Wells Water Supply project

Minimise the Objective Function

$-0.40U_1 - 0.30U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.84V_1 + 0.99V_2 + 4.42V_3 + 66V_4 + 6.0V_5 + 0V_6 = 1$

and 6 inequality constraints as above.

(vi) Hand Dug Well Water Supply project

Minimise the Objective Function

$-0.98U_1 - 0.90U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.44V_1 + 0.54V_2 + 0.93V_3 + 0V_4 + 0V_5 + 0V_6 = 1$

and 6 inequality constraints.

Each linear programming model is solved to give the efficiency score of the particular project with respect to the 5 other water projects.

(b) The linear programmes for the 4 sanitation projects are formulated as in Run 1 but the inequality constraints are 4 corresponding to the sanitation projects in the original 10 constraints. Therefore:

(vii) Central Accra Sewerage project

Minimise the Objective Function

$-0.90U_1 - 0.20U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

Equality constrain

$0U_1 + 0U_2 + 0.46V_1 + 0.88V_2 + 77.60V_3 + 1150V4 + 8.0V_5 + 3.3V_6 = 1$

and 4 inequality constraints

$-0.90U_1 - 0.20U_2 + 0.46V_1 + 0.88V_2 + 77.60V_3 + 1150V4 + 8.0V_5 + 3.3V_6 \geq 0$

$-0.90U_1 - 0.30U_2 + 0.50V_1 + 0.31V_2 + 6.77V_3 + 0V_4 + 2.0V_5 + 1.0V_6 \geq 0$

$-0.90U_1 - 0.10U_2 + 0.50V_1 + 0.22V_2 + 8.15V_3 + 0V_4 + 3.0V_5 + 1.0V_6 \geq 0$

$-0.90U_1 - 0.44U_2 + 0V_1 + 0V_2 + 0.45V_3 + 0V_4 + 0V_5 + 0V_6 \geq 0$

This is a linear programming model with 8 variables and 5 constraints which is solved to give the efficiency score of the Central Accra Sewerage project with respect to the other 3 sanitation projects.

(viii) Urban K-VIP Latrine project

Minimise the Objective Function

$-0.90U_1 - 0.30U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.50V_1 + 0.31V_2 + 6.77V_3 + 0V_4 + 2.0V_5 + 1.0V_6 = 1$

and 4 inequality constraints as above.

(ix) Rural K-VIP Latrine project

Minimise the Objective Function

$-0.90U_1 - 0.10U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0.50V_1 + 0.22V_2 + 8.15V_3 + 0V_4 + 3.0V_5 + 1.0V_6 = 1$

and 4 inequality constraints as above.

(x) Traditional Pit Latrine project

Minimise the Objective Function

$-0.90U_1 - 0.44U_2 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

$0U_1 + 0U_2 + 0V_1 + 0V_2 + 0.45V_3 + 0V_4 + 0V_5 + 0V_6 = 1$

and 4 inequality constraints as above.

The linear programming models are solved to give the efficiency score of the particular project with respect to the other 3 sanitation projects.

<u>Run 3:</u> 3 Outputs - Reliability, Utilisation and Convenience
6 inputs
10 Projects

Let U_1, U_2 and U_3 be the output weights for Reliability, Utilisation and Convenience respectively.

Formulating the linear programmes follows the same procedure as in Run 1 except that the term U_3 is introduced for the convenience output factor.

(i) Accra-Tema Water Supply project
Minimise the Objective Function

$-0.97U_1 - 0.80U_2 - 150U_3 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to
Equality constraint

$0U_1 + 0U_2 + 0U_3 + 0.60V_1 + 0.73V_2 + 2.43V_3 + 479V_4 + 6.0V_5 + 2V_6 = 1$

and 10 inequality constraints

$-0.97U_1 -0.80U_2 -150U_3 +0.60V_1 +0.73V_2 +2.43V_3 +479V_4 +6.0V_5 +2V_6 \geq 0$
$-0.78U_1 -0.50U_2 -80U_3 +0.65V_1 +0.95V_2 +2.20V_3 +450V_4 +6.0V_5 +0V_6 \geq 0$
$-0.33U_1 -0.40U_2 -80U_3 +0.60V_1 +0.97V_2 +4.56V_3 +1000V_4 +7.0V_5 +0V_6 \geq 0$
$-0.85U_1 -0.40U_2 -5U_3 +0.72V_1 +0.95V_2 +1.97V_3 +72V_4 +5.0V_5 +0V_6 \geq 0$
$-0.40U_1 -0.30U_2 -70U_3 +0.84V_1 +0.99V_2 +4.42V_3 +66V_4 +6.0V_5 +0V_6 \geq 0$
$-0.98U_1 -0.90U_2 -60U_3 +0.44V_1 +0.54V_2 +0.93V_3 +0V_4 +0V_5 +0V_6 \geq 0$
$-0.90U_1 -0.20U_2 -200U_3 +0.46V_1 +0.88V_2 +77.6V_3 +1150V4 +8.0V_5 +3.3V_6 \geq 0$
$-0.90U_1 -0.30U_2 -100U_3 +0.50V_1 +0.31V_2 +6.77V_3 +0V_4 +2.0V_5 +1.0V_6 \geq 0$
$-0.90U_1 -0.10U_2 -70U_3 +0.50V_1 +0.22V_2 +8.15V_3 +0V_4 +3.0V_5 +1.0V_6 \geq 0$
$-0.90U_1 -0.44U_2 -60U_3 +0V_1 +0V_2 +0.45V_3 +0V_4 +0V_5 +0V_6 \geq 0$

This is a linear programming model with 9 variables and 11 constraints which is solved to give the efficiency score of the Accra-Tema Water Supply project with respect to the other 9 projects.

For each of the 9 projects the linear programming model is formulated as above, introducing the term U_3 and solved to give the efficiency score of each particular project with respect to the other 9 projects.

Run 4: 3 Outputs - Reliability, Utilisation and Convenience
6 Inputs
(a) 6 Water Projects (b) 4 Sanitation Projects

The formulation of the linear programming models follow the procedure in Run 2 except that the term U_3 is introduced as in Run 3. For example:

(a) Accra-Tema Water Supply project
Minimise the Objective Function
$-0.97U_1 - 0.80U_2 - 150U_3 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$
subject to
Equality constraint
$0U_1 + 0U_2 + 0U_3 + 0.60V_1 + 0.73V_2 + 2.43V_3 + 479V_4 + 6.0V_5 + 2V_6 = 1$
and 6 inequality constrains corresponding to the 6 water projects in the 10 inequality constraints for Run 3.

$$-0.97U_1 - 0.80U_2 - 150U_3 + 0.60V_1 + 0.73V_2 + 2.43V_3 + 479V_4 + 6.0V_5 + 2V_6 \geq 0$$
$$-0.78U_1 - 0.50U_2 - 80U_3 + 0.65V_1 + 0.95V_2 + 2.20V_3 + 450V_4 + 6.0V_5 + 0V_6 \geq 0$$
$$-0.33U_1 - 0.40U_2 - 80U_3 + 0.60V_1 + 0.97V_2 + 4.56V_3 + 1000V_4 + 7.0V_5 + 0V_6 \geq 0$$
$$-0.85U_1 - 0.40U_2 - 5U_3 + 0.72V_1 + 0.95V_2 + 1.97V_3 + 72V_4 + 5.0V_5 + 0V_6 \geq 0$$
$$-0.40U_1 - 0.30U_2 - 70U_3 + 0.84V_1 + 0.99V_2 + 4.42V_3 + 66V_4 + 6.0V_5 + 0V_6 \geq 0$$
$$-0.98U_1 - 0.90U_2 - 60U_3 + 0.44V_1 + 0.54V_2 + 0.93V_3 + 0V_4 + 0V_5 + 0V_6 \geq 0$$

This is a linear programming model with 9 variables and 7 constraints which is solved to give the efficiency score for the Accra-Tema Water Supply project with respect to the other 5 water projects.

For each of the other 5 water projects the linear programming model is formulated as above and solved to provide the efficiency score of that particular project with respect to the other five water projects.

(b) Central Accra Sewerage project

Minimise the Objective Function

$-0.90U_1 - 0.20U_2 - 200U_3 - 0V_1 - 0V_2 - 0V_3 - 0V_4 - 0V_5 - 0V_6$

subject to

Equality constraint

$0U_1 + 0U_2 + 0U_3 + 0.46V_1 + 0.88V_2 + 77.6V_3 + 1150V4 + 8.0V_5 + 3.3V_6 = 1$

and 4 inequality constraints corresponding to the 4 sanitation projects in the 10 inequality constraints in Run 3.

$-0.90U_1 - 0.20U_2 - 200U_3 + 0.46V_1 + 0.88V_2 + 77.6V_3 + 1150V4 + 8.0V_5 + 3.3V_6 \geq 0$

$-0.90U_1 - 0.30U_2 - 100U_3 + 0.50V_1 + 0.31V_2 + 6.77V_3 + 0V_4 + 2.0V_5 + 1.0V_6 \geq 0$

$-0.90U_1 - 0.10U_2 - 70U_3 + 0.50V_1 + 0.22V_2 + 8.15V_3 + 0V_4 + 3.0V_5 + 1.0V_6 \geq 0$

$-0.90U_1 - 0.44U_2 - 60U_3 + 0V_1 + 0V_2 + 0.45V_3 + 0V_4 + 0V_5 + 0V_6 \geq 0$

This is a linear programming model with 9 variables and 5 constraints solved to give the efficiency score of the Central Accra Sewerage with respect to the other 3 sanitation projects.

For each of the other 3 sanitation projects the linear programming model is formulated as above and solved to give the efficiency score of that particular project with respect to the other 3 sanitation projects.

8.7.4 Summary of Efficiency Scores (See Appendix K)

Project	Run 1	Run 2	Run 3	Run 4
Accra-Tema Water Supply	0.196	0.732	0.270	1.000
Borehole Water Supply	0.232	0.539	0.272	0.903
Package Plant Water Supply	0.090	0.325	0.132	0.978
2500 Drilled Wells	0	0.530	0.216	0.530
3000 Drilled Wells	0.060	0.222	0.119	0.636
Hand Dug Well	0.990	1.000	0.484	1.000
Central Accra Sewerage	0.006	0.006	0.019	0.019
Urban K-VIP Latrine	0.066	0.006	0.111	0.111
Rural K-VIP Latrine	0.055	0.055	0.064	0.064
Traditional Pit Latrine	1.000	1.000	1.000	1.000

CHAPTER NINE

DISCUSSION

(Table 9.1 provides a summary of the Input and Output Factors cited in the discussion.)

9.1 ACCRA-TEMA WATER SUPPLY PROJECT

9.1.1 Technical Input Factor

The measure for technical input is the foreign exchange component expressed as a ratio of the total capital cost. The ratio was computed as 0.60 for the Accra-Tema Water Supply Project. The reasons for this level of foreign cost is twofold, the mode of financing the project and the complexity of the technology. Large urban water supply development in Ghana necessarily requires a surface water source. The Phase 1 project involved the Volta River source, 54km to the west of Tema. This project required large capacity pumps, large diameter steel pipelines and other accessories which have to be imported. In addition, the raw water, initially at least, required pre-treatment. This meant a full conventional treatment plant should be provided, again involving a high level of foreign costs. Financing for this project was largely by supplier's credit. This mode of financing is considered generally expensive and would thus increase the foreign costs. The contractors had to be a foreign company to be able to arrange the financing. However due to the high technical skills required in construction a large number of foreign technical personnel had to be brought in. A training contract also involved training of Ghanaian professionals and technicians in West Germany. Further, West German professionals and technicians were retained in Ghana for long periods to ensure that the local personnel were fully conversant with the plant.

In the Phase 2 project various sources of financing were employed. World Bank financing of the Weija Dam required that contracts are awarded on international competitive bidding. Local expertise in dam construction is minimal. The foreign contractor selected was involved in the more complex Volta Dam project and therefore had a good track record. However, a foreign contractor inevitably increases the foreign

Table 9.1

Summary of DEA Input and Output Factors

	INPUT FACTORS						OUTPUT FACTORS		
PROJECT	Technical	Financial	Economic	Institu-tional	Social	Environ-mental	Relia-bility	Utiliz-ation	Convenience
Accra-Tema Water	0.60	0.73	2.43	479	6	2.0	0.97	0.80	150
Borehole Water	0.65	0.95	2.20	450	6	0	0.78	0.50	80
Package Plant Water	0.60	0.97	4.56	1000	7	0	0.33	0.40	80
2500 Drilled Wells	0.72	0.95	1.97	72	5	0	0.85	0.40	5
3000 Drilled Wells	0.84	0.99	4.42	66	6	0	0.40	0.30	70
Hand Dug Well	0.44	0.54	0.93	0	0	0	0.98	0.90	60
Central Accra Sewerage	0.46	0.88	77.60	1150	8	3.3	0.90	0.20	200
Urban K-VIP Lat.	0.50	0.31	6.77	0	2	1.0	0.90	0.30	100
Rural K-VIP Lat.	0.50	0.22	8.15	0	3	1.0	0.90	0.10	70
Traditional Pit Latrine	0	0	0.45	0	0	0	0.90	0.44	60

cost of the project. Foreign accessories required for the distribution system were also financed by the World Bank.

The portion of the project financed by CIDA required the appointment of a Canadian consultant, Canadian contractors in construction and largely Canadian suppliers of electrical and mechanical equipment. Again the selection of conventional treatment plant with rapid gravity filters increased the foreign cost of the project. No serious attempt was made to study the slow sand filtration as an alternative.

The African Development Bank appointed a local contractor for their portion of the project. However, the bank had to provide the initial financing for plant and equipment to enable the contractor to mobilise effectively. There were delays which finally led to a second local contractor being engaged to complete the work. Again steel pipelines were required for the raw water and final water transmission lines which had to be imported.

Reducing the foreign cost of water supply to large urban areas will prove difficult given the type of financing required and the lack of adequate information on the efficacy of slow sand filtration on the quality of raw waters likely to be encountered. Further as demand increases larger diameter pipelines will be required and these are not produced locally. Pipe accessories like valves will not be produced locally for the foreseeable future. However it is possible to begin with the use of local consultants and contractors to reduce the level of fees and profits in foreign exchange. The multilateral donor agencies including the World Bank, the African Development Bank and the United Nations Development Programme have declared their intention to pursue such policies.

9.1.2 <u>Financial Input Factor</u>

The factor as computed for Accra-Tema Water Supply project was 0.73. The ratio involves the annual revenue collection and the full annual cost of full cost recovery. Revenue collection depends mainly on the tariff structure and the institutional arrangement for tariff collection. The structure, to date, has been determined by government. Accra-Tema Metropolitan area of GWSC has over the years gradually eliminated the public stand-pipe supply replacing it with community managed stand-pipes which are metered. Most domestic supplies are unmetered and are therefore billed on a flat rate which does not reflect the quantities of water consumed. In the Five-Year Development Plan large quantities of meters will be ordered for installation with a target to achieve 100 per cent metering.

Revenue Collection in the Phase 1 period averaged 62 per cent of billing. In the Phase 2 period in progress revenue collection is 68 per cent of billing. However a current appraisal of ATMA financial performance indicates the account receivable was 61 per cent of annual revenue in 1983, went up to 110 per cent in 1984. In 1985 it was 49 per cent and in 1986 57 per cent. In addition to the above poor performance on account receivable, billings are usually three months in arrears (ADB, 1988 op. cit.). Billing has been computerised but ATMA does not possess a computer and therefore uses the computer of another organisation. The arrangement has not been satisfactory. ATMA is allowed only eight computer hours a week causing delays in billing. ADB is addressing the problem in the Accra-Tema Water Supply Phase 3 project which includes the purchasing of two mini-computers for billing and accounting systems.

It is believed that there are numerous illegal connections in the supply area. These connections seem to have been installed with the help of ATMA employees. The worst cases of these connections are by farmers along the Kpong-Tema pumping mains who have openly challenged, using fire arms, the ATMA personnel deployed to detect connection. The government had to intervene by a decree banning farming along the transmission mains. To further check unaccounted for water ATMA has set up a task force for leak detection. It is expected that unaccounted for water will be reduced from the current levels of 25 per cent to 15 per cent within the shortest possible time.

Again, in a bid to improve collection, ADB has approved the purchasing of 50 motor cycles for collectors and requested that collectors be bonded through an insurance scheme or a sponsorship agreement and that a more attractive incentive scheme be worked out for these collectors. ATMA is also to increase its collection points throughout the supply area. The ADB is demanding a collection programme from GSWC as condition for approving the loan for the Phase 3 project.

In order to reduce the deficit on full cost recovery it is important to take a look at the cost structure of ATMA operations and to try to reduce costs wherever possible. Staff redundancies have already been identified.

With the new increases in tariff, revenues will increase substantially. ATMA constitutes about 53 per cent of the installed capacity but due to the preponderance of industrial, commercial and house connection is expected to generate the bulk of the GWSC revenue. Indeed GWSC expects to break even on operations and maintenance cost through cross-subsidisation of the rural operations from urban operations. Increased revenues from ATMA over and above their operations and maintenance costs will substantially reduce the financial input factor. Rehabilitation work under Phase 3 should also provide extra water to cover hitherto unserved areas.

9.1.3 Economic Input Factor

This factor was computed as $2.43 per person. It was based on the economic costs for the Phase 1 project which, for the purposes of comparison with the other projects, seemed more realistic. Phase 2 costs include items designed to cater for future demand, for example, the dam and the transmission lines, including intake structures and pump house.

The economic cost involve the foreign and local components of the capital cost and also the foreign and local components of the operation and maintenance cost. Discussion on foreign component of capital cost is found under the technical input factor. However the economic input factor gives more weight to the foreign component through the application of the shadow price of foreign exchange. Local costs are financed by the government through the Annual Development Budget. These costs include the purchasing of locally produced construction inputs such as cement, reinforcement, bars, asbestos cement pipes, aggregate (due cognisance is taken of the fact that these inputs require foreign inputs in their production processes), and also payment for skilled and unskilled labour for construction. Unskilled labour was computed as 10 per cent of capital cost and weighted by the conversion factor for unskilled labour.

Operations and maintenance cost include chemicals, electricity, fuel, spare parts and personnel costs for both skilled and unskilled labour. 50 per cent of operation and maintenance costs constitute the foreign component which is shadow priced. The percentage of foreign costs could have been higher but for the fact that chemical costs have been reduced due to improvement in raw water quality at Kpong with the construction of the Volta Dam. Indeed with the production of abundant cheap electricity from the Volta Dam, ATMA being a major consumer, through the 24 hour operation at the treatment plants and the pumping stations, has been able to secure lower electricity tariff by purchasing power direct from the producers, Volta River Authority, instead of the power retailers, Electricity Corporation of Ghana. The bulk of the energy requirements of ATMA is mainly in local currency, thus reducing the burden on the economy generally. Local cost items include personnel cost to be reduced through retrenchment of labour at the lower ranks. Unskilled labour computed as 10 per cent of operation and maintenance cost will be reduced in the process.

Operations and maintenance costs are financed from revenue. The government provides the foreign exchange which ATMA has to purchase through the foreign exchange auction system.

9.1.4 Institutional Input Factor

This factor was computed as 479 skilled personnel employed per million of population served. The Accra-Tema Water Supply project is the most sophisticated and complex system in operation in Ghana. Its strategic importance is unquestioned. It is operated by some of the best operators available.

The Kpong Headworks operates the raw water pumps on three shifts of eight hours each, with a fourth shift off-duty. Each shift has a supervisor who coordinates pumping with the treatment personnel. The pump attendants also operate the intake mechanical screens and the intake gates in the event of maintenance activities or as routine operation to ensure the units remain serviceable at all times. Treatment attendants are used interchangeably between the clariflocculators and the filter house. Treatment attendants at the clariflocculators ensure the operation of chemical dosing equipment and monitor the operation of the clariflocculators which are acting currently only as sedimentation tanks since the alum dosing has been discontinued. Pre-chlorination is practised to control the growth of algae. In the filter house the operators see to the proper operation of the filters and also ensure effective sequencing of backwashing at the old plant and manual operation at the new plant when the automatic backwash is out of commission. The entire treatment process is backed by the plant control laboratory under the supervision of a professional chemist/bacteriologist. Pumping of final water to Tema and to Accra at the high lift station and the other booster stations is operated by pump attendants under their shift supervisors. The attendants also record operational statistics whenever the plant control and data logging panels do not function. The operational system is backed by a plant workshop manned by engineers, technicians and electrical/mechanical artisans. Similar operations take place at Weija Headworks which also serves as a training plant for the GWSC Operators School located there. The ODA and the World Bank are funding a project to upgrade the Weija Operators School into an International Water Training Centre for all English speaking West African states. The centre will provide management training as well. ATMA is also benefiting from the twinning of Thames Water Board with GWSC under which ATMA personnel will be trained at the Thames Water Board and also staff from the Board will be seconded to ATMA for on-the-job training. Incentives will have to be worked out to ensure the retention of trained personnel.

9.1.5 Social Input Factor

This factor had a score of six for the Accra-Tema Water Supply project. This demonstrates the level of community involvement in large urban water schemes. The sub-factors are:

(a) *Community request*: yes, there is a demonstrated community request for water supply and further extensions to the scheme. Alternative supply to the Accra-Team Water Supply project is virtually non-existent. Groundwater sources are saline and inadequate. Small streams in the neighbourhood of Accra-Tema are heavily polluted. Indeed it is the periodic drought in the Accra area which receives the lowest rainfall in Ghana, that prompted the World Health Organisation to engage consultants for the Accra-Tema Water Supply project. Since then physical development of the Accra-Tema Metropolitan Area coupled with rapid population increase has outstripped ATMA capability to keep pace with water demand. Requests for mains extensions arrive every day and programmes for improvements to areas of low pressure, due to excessive draw-off, are being implemented at too slow a pace. Certainly the community request for better service has been in evidence and timely response from ATMA is what is needed.

(b) *Level of Service/Coverage*: community involvement in the determination of level of service/coverage is non-existent. ATMA decides, based on what is desirable and what their resources can achieve. ATMA decided that the level of service in the supply area must be house connections and yard taps to ensure effective revenue collection and proceeded to disconnect stand-pipes. There is, however, the need for community involvement in ATMA actions in high density housing, slums and peri-urban areas to achieve a consensus to avoid undue hardship to the residents. Further extension of the idea of community operated stand-pipes will be in the right direction.

(c) *Commitment*: the commitment of the community to the project was not solicited. This is because the project was being centrally planned, implemented and managed. Funds came from outside the community, that is, from government and donor agencies. It is, however, suggested that projects in high density housing areas, slums and peri-urban communities should solicit the commitment of the community to ensure protection of water facilities and reduce vandalism.

(d) *Appropriate Technology:* there was no community involvement in the selection of technology for the project. Perhaps the project was deemed too complex for the public to understand. It is necessary that the community should be given the chance to comment on proposals during the planning stages. It is advocated that a public hearing should form part of the planning process.

(e) *Willingness to Pay*: judging from the community performance on payment of water bills it is clear that there is the willingness to pay. There is evidence of prospective customers in unserved areas offering to contribute to the cost of mains extension to newly developed areas.

(f) *Ability to Pay*: the ability of the bulk of the consumers to pay for water services in the large urban areas is evident since the minimum charge is based on five per cent of the household income (that is two minimum wage earners). However consumers in the supply area living far away from the distribution mains and having to pay for water supplied by water vendors may pay up 10 per cent of the household income.

(g) *Cost Recovery*: the level of cost recovery was decided by the government but the community is aware that the cost of water is subsidised by the government. A formal interaction between ATMA and the community on cost recovery is crucial as rates are further increased towards full cost recovery.

(h) *Responsibility*: the mode of delivery of water services in the large urban area does not call on the community to share in the responsibilities involved other than the payment of water rates. Communities should assume more responsibility for reporting pipe leakages even if the fault does not affect their own supply. Prevention of vandalism should also be the community responsibility.

(i) *Dialogue*: currently there is no established dialogue between ATMA and the community on the resolution of conflicts. Effective dialogue may avoid disconnection of service to recover arrears in rate payment.

(j) *Decision Making*: in the delivery of water service to large urban communities there is no community involvement in the decision making process. Communities may or may not be informed of decisions of ATMA. It is expected that the newly elected Accra Metropolitan Assembly with its public utility sub-committee will henceforth be involved in decisions to improve water supply to the Accra-Tema Metropolitan Area.

9.1.6 Environmental Input Factor

This factor was computed as $2.0 per person. Sullage disposal is by means of open channels which collect sullage from bathrooms, kitchens and laundry areas around the household and discharge into the public storm sewers which eventually discharge into an interceptor in the sewered areas or into a natural waterway or stream. Sullage disposal is far from satisfactory in Accra. Storm drains are not designed with adequate gradient and therefore have poor flow characteristics. Moreover most walkways along the streets are not paved. Large amounts of soil gets pushed into the drains and storm water laden with sediment often deposits silt in the drains. Furthermore solid waste management is very poor in Accra with the result that solid waste is dumped into storm drains. These drains are often clogged due to poor maintenance and pools of sullage form in the drain and sometimes overflow into the streets. The problem is so serious that when there is a heavy rainfall storm drains are unable to cope with the run-off and therefore flooding in Accra is quite frequent during the rainy season. Major desilting of storm drains have been undertaken recently but unless regular maintenance is carried out on these drains the problem will not be solved. Accra is a mosquito infested area and there is no doubt that the sullage disposal problem is a major contributor to the situation. What is required is an integrated approach to solve the storm water, solid waste and sewage disposal problem and effectively manage the system through inter-agency cooperation.

9.1.7 Reliability Output Factor

The reliability output factor was computed as 0.97. This is equivalent to complete outage of water supply of about 11 days in a year. The Accra-Tema Water Supply system is an integrated system from two sources, Weija and Kpong. Outages are mainly caused by electricity cuts to the Weija Headworks. However, the system is provided with storage capacities distributed around the city. The most vulnerable section is western Accra which, to date, relies on the clear wells of the treatment plants at Weija. The McCarthy Hill Reservoir which should have been constructed during the Phase 2 was intended to provide the required storage for western Accra. It is now to be constructed during the Phase 3 project period to be funded by the ADB. Reliability of the supply from the standpoint of the individual household depends on supply outages from various causes including pipe bursts, low pressure levels and faulty operation of the distribution system. These faults affect sections of the city at any particular time and residents affected do fetch water from the unaffected areas. These situations constitute a nuisance rather than being a public health hazard. Supply outages to sensitive areas such as hospitals, schools and markets which are likely to degenerate into public health hazards are dealt with expeditiously backed by supply of water by tanker service. These institutions are required to have adequate internal storage to minimise the effect of such outages. Special emergency gangs handle supply outages to areas with major industries relying on water as a prime input. In most cases these industries assist the repair gang to complete the work in good time to minimise the economic loss. The main problem facing the distribution maintenance section is the provision of adequate stocks of spare parts and appropriate tools to further reduce repair time. The public relations section of ATMA usually informs the public in advance of any planned outages to enable residents to store water. These announcements are made on radio and television together with information vans which broadcast in the areas to be affected.

9.1.8 Utilization Output Factor

This factor was computed as 0.80 for the Accra-Tema Water Supply project. Water utilization in large urban areas is literally instantaneous and does not require community education to convince consumers of the health benefits obtainable from the utilization of the improved source. This is probably due to the lack of reliable traditional source, the lack of traditional attachment to a particular source of water, and the large numbers of migrant population who adapt easily to their new environment and accept the utilization of the improved source as part of the attractions of the large urban environment.

The utilization factor reflects the population of Accra-Tema which is effectively served by the existing system. Extension of the system to newly developed areas should increase the utilization factor. For Accra-Tema this will mean expansion of the existing treatment plants. The impending Phase 3 works is mainly concerned with rehabilitation of the existing Pintsch-Bamag Plants at both Weija and Kpong, the Paterson-

Candy plant at both Weija and Kpong together with renewal of plant and equipment at the Stage 1 works at Kpong. After the Phase 3 works to be completed by 1990 total capacity of the Accra-Tema Water Supply system will be 305,000 m^3/d which is less than present demand of 470,000 m^3/d with 100 per cent coverage. It is estimated that the present capacity should be duplicated to meet demand of 1994 (ADB, 1988, op. cit.). Currently demand is severely suppressed due to lack of connection to consumer premises. Major plant expansion programmes for the Accra-Tema Water Supply Phase 4 has been studied by the consultants TAHAL Consulting Engineers. The alternatives involve total development of the capacity at Weija and several stages of development of the Kpong source. The main difference between the two sources is that while Weija water requires large quantities of chemicals for treatment, Kpong water requires more energy for pumping to Tema and Accra. However, meeting future demand from either Weija or Kpong will require capital expenditures in excess of $150 million. This capital might be difficult to raise unless ATMA can demonstrate its ability to repay loans from revenue collection without adding to the burden of central government development budget. Maintaining the present level of utilization or improving upon it will depend on how quickly decisions can be taken on the financial and physical development programmes of ATMA.

9.1.9 <u>Convenience Output Factor</u>

This factor was computed as 150 persons per hectare for the Accra-Tema Water Supply project. Convenience varies widely over the population of Accra-Tema. There is the low density housing, that is, 50 persons per hectare with multi-tap convenience. Then there is the medium density housing, that is, 50-150 persons per hectare, also with multi-tap convenience. This is followed by the high density housing, that is, 150-350 persons per hectare with mostly yard taps and some community operated stand-pipes. Finally, there are poor areas with population densities in excess of 350 persons per hectare with few yard taps and community operated stand-pipes. It is evident from observation that when taps are placed inside houses water consumption increases dramatically. A survey in Accra (GWSC, 1981a, op. cit.) revealed that per capita consumption of water in households with multitaps (house connections) was 137 lpcd, for those with yard connections consumption was 85 lpcd and for those drawing from community operated stand-pipes 30 lpcd. It is necessary to encourage yard connections for people in poor areas. One way to achieve this is to provide soft loans in the form of materials for connections and the amounts recovered together with the regular tariffs. It is suggested that a pilot scheme be mounted, if successful, a revolving fund can then be created for the purpose. Increased consumption presupposes that the water will be made available through capacity increases discussed earlier.

9.2 BOREHOLE WATER SUPPLY PROJECT

9.2.1 Technical Input Factor

This factor was computed as 0.65 for the Borehole Water Supply project. Borehole drilling in Ghana had been carried out in the earlier years using percussion rigs and lately by using rotary drilling rigs. These rigs are imported items whose cost is shared by the number of boreholes drilled. Borehole lining with steel or plastic casing also has a foreign component. Pumps and generators are entirely foreign cost items. Distribution mains are locally manufactured asbestos cement or uPVC pipes using imported raw materials and machinery. Distribution accessories such as valves, hydrants, tees and bends are all imported items. Service reservoir, usually a pressed steel tank, is also an imported item. Pump houses also have foreign cost items. Hence the borehole water supply system which appears to have simple structures or components, has more than average foreign cost components. Geology has a big effect on drilling costs and the harder formations encountered in West Africa require expensive heavy duty drilling rigs. However judicious selection of rigs devoid of unnecessary sophistication might help bring down costs. As the national electricity grid gets extended to these small urban areas, the generator is eliminated to further reduce the foreign exchange component of the installation.

9.2.2 Financial Input Factor

This factor was computed as 0.95 for the Borehole Water Supply project. Revenue performance of this project has not been encouraging for several reasons. The level of service is mainly through public stand-pipes. GWSC is now trying to get the communities interested in managing their own stand-pipes so that these can be metered. GWSC is also experimenting with direct sales at the stand-pipes. The low levels of tariffs have also been a major contributory element in the high deficit ratio. The recent increase in tariffs should be backed by a more vigorous effort in revenue collection. However, production levels should be increased to avoid the situation where communities are divided into zones which are supplied in rotation, some on three day rotation and some on even weekly rotation. Revenue collection is one area in which community involvement is likely to yield positive results especially where production is deliberately cut back because of poor revenue collection. Further extension of the distribution system should be based on strict revenue generating criteria. Cost reduction measures should be instituted especially for energy costs and personnel redundancies.

9.2.3 Economic Input Factor

This factor was computed as $2.20 per person for the Borehole Water Supply project. For capital cost shadow pricing was applied to the foreign cost of 65 per cent and unskilled labour of eight per cent. In the case of operation and maintenance cost the foreign component was 25 per cent and the unskilled labour was also 25 per cent, both of which were shadow priced. In drilling operation most of the local cost is made up of wages and allowances of the skilled operators of the rig and in the equipment installation team. Unless logistic support is improved drilling operations take unduly long periods with attendant high out-station allowances. Maintaining radio contact with field operations is a must. Unskilled labour was employed mainly for trench excavation for pipe laying.

Foreign costs for operation and maintenance include fuel, spare parts and vehicle costs. Local costs are mainly personnel costs and local elements of energy costs. Borehole water supply has low economic cost of water and should be exploited wherever possible. Even where surface water is the main source it is possible to consider borehole supply for supplementary water while awaiting extensions to the surface supply scheme.

9.2.4 Institutional Input Factor

This factor was computed as 450 skilled personnel for a million population served by the Borehole Water Supply Project. Operation and maintenance of borehole schemes require mainly pump and engine attendants backed by repair mechanics. Due to the low yield of boreholes a disproportionate number of boreholes are required to supply a required quantity of water. Each borehole installation has to be adequately staffed thus greater numbers of skilled staff will be required than for high yielding boreholes.

This factor also reflects the training requirements for the skilled personnel for the project. The water works attendants school at Owabi Headworks in Kumasi provides training for pump and engine attendants. Attendants usually start as apprentices at one of the borehole stations where they acquire knowledge of the basic units employed at the station. The training at the school provides them with the qualification to be promoted to the grade of an attendant. Refresher courses are organised on a five year rotation where attendants may be introduced to new equipment introduced into GWSC. With several donors offering aid different makes of equipment are being introduced frequently. Opportunity exist for attendants to become station managers after being introduced to management courses.

9.2.5 Social Input Factor

This factor was computed as 6.0 for the Borehole Water Supply project.

(a) *Request*: request for water supply schemes from communities is usually made during a visit by a government official to the community or in a formal letter to the District or Regional Government Offices. This project was undertaken by the National Liberation Council government to satisfy some of these requests.

(b) *Level of Service/Coverage*: the level of service was decided by the GWSC. Hence pipes were laid in anticipation of the communities financing their internal plumbing and connection to the mains. This did not materialise and the bulk of the consumers are served from community stand-pipes. Indeed house connection and yard taps serve only about 10 per cent of the community. Coverage was up to the limits of physical development when the initial construction took place. However extensions have not kept pace with physical development. To achieve total coverage currently will require community involvement to decide on the level of service to the new areas and thus sizes of pipes to be laid. The extent of coverage will also depend upon available production capacity.

(c) *Dialogue*: no formal channels for dialogue with the community existed. GWSC had the funds to execute the project as fast as possible to make the necessary political impact. There was little time for dialogue with the community. Dialogue with the community has begun on revenue issues and will have to be maintained to discuss the future of some of these projects.

(d) *Commitment*: again, from the manner in which this project was implemented no commitment was solicited from the community. In future such commitment should be formally concluded between GWSC and the communities at the beginning of the project.

(e) *Appropriate Technology*: the selection of the appropriate technology was done by GWSC without the involvement of the community. Borehole supply is the most appropriate for these communities with adequate groundwater resources.

(f) *Willingness to Pay*: although no attempt was made initially to assess willingness to pay on this project communities have demonstrated their willingness to pay the existing rates. 70 per cent collection in 1988 is a good achievement which can be improved upon if GWSC will itself improve its revenue operations; such improvement should involve the community.

(g) *Cost Recovery*: with the bulk of consumers on minimum or life-line tariff rates cost recovery cannot be a major consideration yet. Gradual introduction of the idea in consultation with the community should have a good chance of success.

(h) *Ability to Pay*: Minimum or life-line tariff rates are computed as five per cent of the minimum wage for a household income and should therefore be affordable.

(i) *Decision Making*: community involvement in decision making is essentially non-existent. With the current deplorable state of the project and the planned rehabilitation programme the time is ripe for the communities to be involved in making decisions on the future of their water supply. Some communities may opt to take over and operate these schemes with assistance from GWSC.

(j) *Responsibility*: sharing of responsibility was not a consideration on this project. GWSC assumed full responsibility for every aspect of the delivery of the service. Future projects should investigate the possibility of the community taking over responsibilities that it can better discharge and GWSC taking on the rest.

9.2.6 Environmental Input Factor

This factor was computed as zero for the Borehole Water Supply project. Sullage is disposed of by spreading to control dust or by channelling into natural gullies where most of it either evaporates or infiltrates into the ground. A more profitable use could be made of sullage for irrigating backyard gardens. Backyard gardens are not a common feature around houses in these small urban areas but can be encouraged. In northern Ghana where there are long dry periods sullage has been used to cultivate certain crops.

9.2.7 Reliability Output Factor

This factor was computed as 0.78. This means that supply is likely to go off 80 days in the year. Reliability of the borehole supply depends primarily on availability of energy, that is, fuel and electricity supplies. Energy supply to the various stations is usually arranged on contract with one of the fuel retailing companies or in the case of electricity by the state-owned Electricity Corporation of Ghana. By and large the problem of non-supply has been non-payment by the GWSC because not enough revenue is being generated. Maintenance of borehole installations with Pleuger submersible pumps have been arranged on contract with Water Engineering Company, agents of Pleuger pumps. Generators are maintained by the GWSC regional maintenance units. Lack of spares makes adherence to preventive maintenance schedules difficult causing frequent breakdown of equipment. Increases in tariff rates should make more funds available for spare parts, fuel and other operation and maintenance input required to improve reliability.

9.2.8 Utilization Output Factor

This factor was computed as 0.50 for the Borehole Water Supply project. Water utilization in small urban communities is a rather complex phenomenon. When water from the improved source is available most people would use it but there are others who would still go to the traditional source because they are used to the taste which to them is more satisfying than mineralised groundwater. When the improved source becomes unreliable and queues grow longer, a lot more people are forced to use the traditional source. A project of this kind requires a formal effort at community education to ensure utilization. In a situation where project production capacities have remained constant for twenty years resulting in inadequate supplies, community education will be of no benefit. A vicious circle is created in which inadequate service forces the community to use the traditional source more and more resulting in poor payment of revenues which further reduces the number of hours of service and again forces more people to the traditional source. The lack of resources to improve the supply position nationally has only worsened the situation. GWSC will have to win back the confidence of the communities through dialogue backed by mobilization of adequate resource to provide an acceptable service.

9.2.9 Convenience Input Factor

This factor was computed as 80 persons per hectare for the Borehole Water Supply project. Convenience, in this case, means bringing water to a medium density population through a few house connections and yard taps and predominantly community operated or GWSC operated stand-pipes. This provides saving in time which is quantifiable as part of the benefits of the project. Traditional sources are typically about 700 metres away. Stand-pipes are however only 80 metres away, on the average. However, some of this convenience is lost when the queues grow longer and longer. Waiting periods was 40 minutes on the average. As waiting periods grow longer the likelihood of quarrels at stand-pipes increases. Thus one type of discomfort in the form of drudgery of hauling water from distant traditional sources is replaced with another type of discomfort of waiting in queues and having to put up with quarrels. Convenience increases water consumption but in this case increase in consumption can only be realised through encouraging more yard taps and house connections where the production has been improved. GWSC should find the resources to provide material loans to the communities to improve on the convenience of supply.

9.3 PACKAGE PLANT WATER SUPPLY PROJECT

9.3.1 Technical Input Factor

This factor was computed as 0.65 for the Package Plant Water Supply project. The foreign costs of the project consists of the supply of raw water pumps, generator sets, the treatment plant and elevated pressed-steel tank. Other items include the foreign cost components of pump house, treatment house and distribution pipes. The Paterson-Candy International Package Treatment Plant was being introduced into Ghana for the first time and this required an additional installation and training contract in foreign exchange for the manufacturer's agents to train local personnel in plant installation. This plant is a sophisticated plant with various automatic devices. These devices break down frequently resulting in unnecessary outages. Local modification to the plant was carried out to make it essentially manually operated discarding the automatic devices purchased with foreign exchange. The chemical dosing units have some delicate parts that require skilful handling to keep them functioning. Such delicate equipment operated in very remote areas in Ghana are unlikely to last long, it is therefore not surprising that most dosers had broken down. As a rule when only one out of the three dosers is operating it is assigned to alum dosing. The tendency therefore is to cannibalise the other two dosers to keep the alum doser functioning. In future it is expected that slow sand filtrations option will be investigated thoroughly in order to replace the package plants with less complicated technology involving less foreign costs.

9.3.2 Financial Input Factor

This factor was computed as 0.97 for the Package Plant Water Supply project. This means only three per cent of full cost is recovered through the revenue collected. The level of service is essentially through community operated and GWSC operated stand-pipes.

This means almost all consumers are paying the minimum or life-line tariff rate. This, coupled with the fact that the package plant does not provide satisfactory service, has forced consumers back to the traditional sources. Again one of these vicious circle situations in creating low revenue generation, low quality of service, leading to lower revenue generation. Small urban communities do not accept improved water supply easily without community education and where they are forced to rely more on their traditional sources it will require a major effort to win them back so that they will accept to pay for safe water. GWSC will have to improve the service and then get the community involved in revenue collection.

9.3.3 Economic Input Factor

This factor was computed as $4.56 per person for the Package Plant Water Supply project. The capital cost has a foreign component of 60 per cent and an unskilled labour component of eight per cent. The operations and maintenance cost has a foreign component of 35 per cent and unskilled labour component of eight per cent. These components were appropriately shadow priced. Foreign cost items of capital cost have already been discussed. Local cost is made up of local component of locally manufactured materials for construction, local skilled labour and unskilled labour who were employed to be trained in plant installation and those engaged in excavation and pipe laying for the distribution network. Pipe sizes in distribution network were selected in anticipation of house and yard connections. After 20 years of operation less than 10 per cent of the consumers are connected, the rest are served by stand-pipes. The grossly under-utilised network constitutes misapplication of scarce resource that could have been used to increase coverage. In future demand projection will have to be less optimistic.

Operation and maintenance costs include chemicals, fuel, spare parts, and labour. Logistic support for timely supply of chemicals and fuel has not been satisfactory. Reduction in chemical use through application of slow sand filters needs to be investigated. Staff redundancies especially in unskilled labour will have to be tackled.

9.3.4 Institutional Input Factor

This factor was computed as 1,000 skilled employees to one million population served for the Package Plant Water Supply project. Skilled personnel required include treatment attendants trained in the operation of the package treatment plant, pump and engine attendants, artisan mechanic/electrical, and pipe fitters. Special courses had to be mounted at the Owabi Training School for the package plant operators. However, plant operation is still far from satisfactory. In May 1988 a team of experts from Paterson-Candy International, the manufacturers, were invited to assess the requirements for the rehabilitation of the package plants. In their report it was clear that these operators require further training to improve their skills. This assessment comes from the manufacturer twenty years after the plants have been in operation. The important issue here is that why should plants requiring such high quality personnel be deployed in rural areas where supervision is likely to be minimal and logistic support likely to be weak. Skilled personnel are scarce resources in developing countries including Ghana and every attempt should be made to cut down on their requirements for plant operations. The Package Plant should be replaced at the earliest convenience.

9.3.5 Social Input Factor

This factor was computed as 7.0 for the Package Plant Water Supply project.

(a) *Request*: the project was executed in response to the request by numerous small urban centres without water supply at the time. It is common for these communities to write to district or regional government representatives for assistance to provide infrastructural facilities and water supply is a priority project. Criterion for selection of communities was the size of population which should exceed 2,000 for the community to be considered for the project.

(b) *Level of Service/Coverage*: the level of service was decided by GWSC. Stand-pipes were provided at vantage points in the community but the distribution network was designed for house connections and yard taps. Consumers were to provide their internal plumbing and pay for connection to the system. The required private investment was perceived to be too high and less than 10 per cent connected.

(c) *Dialogue*: there was no attempt to establish formal dialogue with the community. Projects were to be completed and commissioned at a fast rate to make the desired political impact.

(d) *Appropriate Technology*: the community was not involved in the selection of the technology and the technology selected by GWSC was inappropriate. The treatment plant was too sophisticated for the environment in which it operated.

(e) *Willingness to Pay*: the community was not surveyed to establish their willingness to pay but a revenue collection rate of 60 per cent indicates that the community is willing to pay. GWSC needs to improve revenue and production operations to achieve better results.

(f) *Cost Recovery*: the community was not involved in setting cost recovery targets. GWSC established the tariff with government approval. The community is however aware that the rate charged is subsidised by government.

(g) *Ability to Pay*: the minimum tariff rate paid by most consumers on this project is calculated at five per cent of the household income on minimum wage. The community is able to pay rates from their assessed income.

(h) *Commitment*: the community was not required to demonstrate their commitment to the project in any way. GWSC planned and executed the project with funds provided by the government.

(i) *Decision Making*: the community was not consulted on any issues involved with the project and thus was not involved in the decision making process.

(j) *Responsibility*: the community was not required to share in the responsibility of delivery of the service except for payment of rates. Any shortfalls in revenue collection was made up by the government subsidy.

9.3.6 Environmental Input Factor

This factor was computed as zero for the Package Plant Water Supply project. Sullage disposal is by spreading to control dust or allowing sullage to flow through natural gullies where most of it evaporates or infiltrates into the ground.

9.3.6 Reliability Output Factor

This factor was computed as 0.33 for the Package Plant Water Supply project. The low reliability is due to the combined effect of plant outage and lack of chemicals to produce the required quality of water. Plant outage depends on the unavailability of fuel mainly. Fuel supply depends on the availability of funds to purchase fuel and the ease of access to the pumping station located up to 8 km from the community. In some instances where pump houses are inaccessible to vehicles the pump and engine attendants have to carry the fuel on their heads to the pump house everyday. Improved revenue collection should improve the availability of fuel. Chemicals are imported, distributed to regional storage depots and then released as and when required to the various stations. When chemicals are in short supply available stocks are reserved for the conventional treatment plants in the large urban areas and the package plants are deprived of chemicals. In most cases, where fuel is available and chemicals are unavailable water is pumped through the system and the low quality water contaminates the mains with the result that when chemicals become available water quality takes some time to improve. Ideally the distribution system should be flushed with water with high dosage of bleaching powder any time raw water is pumped through the plant. This is not done because bleaching powder is also a scarce commodity. Plants need good logistic support to operate properly and must be replaced with other technologies demanding less logistic support.

9.3.8 Utilization Output Factor

This factor was computed as 0.40 for the Package Plant Water Supply project. Utilization of improved sources in small urban communities requires education since the cultural attachment to traditional sources are not easily broken. The problem is made worse if the improved source is not reliable. Provision of good quality water to stand-pipes with long queues does not encourage water utilization at the improved source. Consumers drift to the traditional sources to satisfy their water needs. Package plant water supply system is too unreliable to encourage water utilization at the levels that would capture most of the health benefits.

9.3.9 Convenience Output Factor

This factor was computed as 80 persons per hectare for the Package Plant Water Supply project. Water supply to a medium density population through mainly stand-pipes is the level of convenience provided on this project. Time savings and the reduced drudgery that the project produces are benefits conferred on the community. However some of this convenience is lost in having to wait in queues for up to 60 minutes. Reliability of the supply will have to be improved and the number of stand-pipes increased or, preferably, house connections and yard taps encouraged through the provision of loans in the form of materials recoverable over reasonable periods so as not to create undue hardship.

9.4 2500 DRILLED WELLS WATER SUPPLY PROJECT

9.4.1 Technical Input Factor

This factor was computed as 0.72 for the 2500 Drilled Wells Water Supply project. The foreign cost of the project was made up of the fees of the foreign consultants, the Canadian specialists and advisers, purchase of drilling rigs, hand pumps and the foreign components of locally supplied materials such as cement. Financing of the project was through bilateral grants and loans from CIDA which restricts supplies contracts to Canadian products and this causes lack of competitiveness which results in high prices. Hand pumps purchased from Canada, for instance, are far more expensive than Indian hand pumps of perhaps better reliability. A national hand pump committee has been working on the possibilities of producing locally made hand pumps. The University of Science and Technology in Kumasi has produced a hand pump which is undergoing field tests and improvements on defective parts. A locally produced hand pump should reduce the foreign costs on future projects. Further improvement in the capabilities of the drilling section of the

GWSC should encourage the unit to undertake large scale drilling operations without foreign technical assistance. Foreign experts deployed in rural environment are expensive judging from all the facilities and allowances to be provided to make them comfortable. Foreign financial aid will be required on such projects in the foreseeable future but there is the need to relax some of the restrictions on supply sources to obtain cheaper prices. Loans and grants without strings are difficult to obtain but this is what countries like Ghana need to finance such projects.

9.4.2 Financial Input Factor

This factor was computed as 0.95 for the 2500 Drilled Wells Water Supply project. This is one of the projects in which the consumers were told by politicians that no tariffs will be paid for water supply. Later tariffs were established only through very intensive community education. The tariff rate is based on cost of hand pump maintenance per annum distributed equally among 20 households which constitute the pump community. Most of the collection is made during the harvest season by the leader of the pump community and the amount paid to GWSC. Collection rate of 42 per cent of bills is rather low. Rapid changes in the tariff rate due to successive changes in the foreign exchange rate seems to have confused the communities. Further hand pumps are rather far from most settlements and the queueing time of 83 minutes on the average would not encourage payment. In the rainy season most consumers fetch water from nearby streams. Achieving full cost recovery on this project will take a very long time.

9.4.3 Economic Input Factor

The economic input factor was computed as $1.97 per person for the 2500 Drilled Wells Water Supply project. The foreign cost consisting of 70 per cent of well drilling cost, 90 per cent of hand pump costs and 60 per cent of maintenance cost together with unskilled labour component made up of five per cent well drilling cost, two per cent of hand pump costs and five per cent of maintenance cost were appropriately shadow priced. Capital costs have earlier been discussed. Maintenance costs are made up of imported spare parts and the operation of a centralised maintenance system. Attempts have been made to fabricate some spare parts locally to reduce costs. The centralised maintenance system is adopted because the hand pumps selected cannot be effectively maintained by the communities. Unless the hand pumps are replaced with the village level operation and maintenance (VLOM) types community-based maintenance system cannot be adopted. Some cost reduction has been achieved by operating from district centres rather than from a single central point.

9.4.4 Institutional Input Factor

This factor is computed as 72 skilled personnel for one million population served. The type of hand pumps in use necessitates the employment of skilled personnel for maintenance. The numbers of skilled personnel should be drastically reduced with a community-based maintenance system. A pilot scheme to select VLOM pump and to train local pump caretakers is being financed by CIDA.

9.4.5 Social Input Factor

This factor was computed as 5.0 for the 2500 Drilled Wells Water Supply project.

(a) *Request*: the Upper Regions of Ghana have long dry spells when most water sources dry up. Requests for tackling the water supply problems in these regions have been under consideration for some time. The offer by the government of Canada to finance water supply particularly in these regions made it easier to satisfy these requests.

(b) *Level of Service/Coverage*: the communities were not consulted in deciding on the level of service, that is, hand pumps on drilled wells. However to achieve as much coverage as possible pumps had to be located far apart in this area with a highly scattered population.

(c) *Dialogue*: no dialogue was established with the communities during the drilling phase but the Water Utilisation project was established to redress that deficiency.

(d) *Commitment*: the communities were not required to show any commitment to the project in the drilling stages as communities were told the service will be provided free of charge.

(e) *Appropriate Technology*: communities were not consulted in the selection of technology for the project. However the choice of technology by GWSC and consultants was appropriate for the scale of the project. The hand dug well should be fully investigated for future projects.

(f) *Willingness to Pay*: communities initially were not expected to contribute to the cost of the service. After GWSC took the decision to impose tariff the communities showed willingness to pay. However there have been several tariff reviews which is tending to confuse the communities.

(g) *Cost Recovery*: the communities were not consulted on the level of cost recovery, that is, pump maintenance cost.

(h) *Ability to Pay*: the tariff rates are well within five per cent of household incomes and the communities should therefore be able to pay.

(i) *Decision Making*: the communities were initially not involved in the decision making process. However the Water Utilization project is gradually getting the communities to take decisions after discussion of issues. Communities were involved in the decision to collect the rates and pay to GWSC. Future projects will certainly involve the communities in all levels of decision making.

(j) *Responsibility*: the Water Utilization project has enabled the communities to share in the responsibility of providing the service. Pump pad extension, pump sanitation and revenue collection are responsibilities undertaken by communities.

9.4.6 Environmental Input Factor

This factor was computed as zero for the 2500 Drilled Wells Water Supply project. Sullage is spread to control dust. The Upper Regions of Ghana have long dry periods with high evaporation rate. Sullage is used sometimes to water gardens. At the various hand pumps waste water is channelled into animal troughs for watering cattle and goats. Sullage disposal does not present a problem in this environment.

9.4.7 Reliability Output Factor

This factor was computed as 0.85 for the 2500 Drilled Wells Water Supply project. The high level of reliability is due to the maintenance support provided by CIDA in the form of vehicles, tools and spare parts. The presence of the CIDA group on Water Utilization ensures that resources meant for well maintenance are not diverted for other purposes. The CIDA Maintenance Advisers before their departure set up the maintenance organisation with its reporting system which has been followed by the staff that took over. Fuel supply problems tend to reduce the number of vehicles available for both inspection and maintenance thus making it difficult to achieve the target of 0.90 or better. The real problem is what happens when CIDA withdraws the maintenance support. Before this happens the pumps should have been replaced and a maintenance fund in foreign exchange should have been created. Urban systems in the Upper Regions are rather weak financially and there is always the temptation that the GWSC Regional Management might use such funds for the urban systems. The solution to the problem is not yet apparent and in the meantime CIDA will have to provide for this project as a permanent item on its aid programme to Ghana.

9.4.8 Utilization Output Factor

This factor was computed as 0.40 for the 2500 Drilled Wells Water Supply project. Water supply utilization for rural communities requires persistent education. This project realised this early and set up a parallel Water Utilization project alongside the technical drilling and maintenance projects. However distances to the hand pumps are considerable i.e. an average of 340 metres and the queues are long. Thus in the rainy season when traditional sources are nearer than hand pumps, these pumps are only used by those living near them. Utilization drops drastically in the rainy season. To improve utilization new wells should be constructed. A similar scale drilling programme will require sponsorship but CIDA is unlikely to get involved on a major scale. It is advocated that communities should be encouraged to start hand dug wells with government support. A hand dug well programme is in place but the scale is insignificant. A major mobilisation effort based on community/government/aid donor partnership will be required.

9.4.9 Convenience Output Factor

This factor was computed as five persons per hectare for the 2500 Drilled Wells Water Supply project. Providing water at convenient locations for such a sparsely populated area is expensive. The facilities provided under this project are grossly inadequate; already there are over 400 persons for each hand pump which is rather high. To achieve greater convenience the well communities will have to mobilise to provide at least one extra well, preferably hand dug, wherever the geology will permit such construction.

9.5 3000 DRILLED WELLS WATER SUPPLY PROJECT

9.5.1 Technical Input Factor

This factor was computed as 0.84 for the 3000 Drilled Wells Water Supply project. This project was financed by a bilateral loan from the government of the Federal Republic of Germany. The consultants and the contractors were both German. The contractors' personnel were mostly German, that is, drillers, drivers, storekeepers, mechanics etc. and only a few Ghanaians as helpers. Drilling rigs were of a highly sophisticated type which the contractor shipped back after the contract. The contract was completed well ahead of schedule. The foreign cost as well as cost per well was very high, that is, more than twice the cost of wells drilled in similar terrain in Ghana by other organisations. The project could have been organised in a similar manner to the Canadian project where only key staff were Canadian and GWSC drilling staff extensively used. Future drilling projects should employ local resources as much as possible.

9.5.2 Financial Input Factor

This factor was computed as 0.99 for the 3000 Drilled Wells Water Supply project. The high value of this factor is due to a combination of a very low revenue collection rate, i.e. 14 per cent and a high cost of delivery of service. Again, consumers on this project were informed by politicians they will not have to pay for the service provided. Since the introduction of rates the water quality problems have increased the rate of hand pump down time reducing the quality of service provided. Communities that have gone back to their traditional sources are reluctant to pay for the poor service. No community education programme was instituted to accompany the introduction of rates and water quality problems have undermined social acceptability of the water supply and the accompanying rates.

9.5.3 Economic Input Factor

This factor was computed as $4.42 per person for the 3000 Drilled Wells Water Supply project. Shadow pricing was applied to all foreign costs and unskilled labour cost. This project had high foreign costs for reasons stated earlier. Maintenance cost is made up of cost of spare parts and the operation of a centralised maintenance system. Proposals for moving on to community based maintenance system is still under consideration. Aggressive water produced at the majority of the wells due to low pH values have increased the spare parts requirements. Indeed in some of these wells the galvanised iron rods and rising mains are to be changed to stainless steel components virtually doubling the cost of the hand pumps. The economic cost will have to be compared with cost of cheaper wells like hand dug wells and the cost of hand pumps with essentially plastic and therefore corrosive resistant components, for example, the Vergnet hand pump.

9.5.4 Institutional Input Factor

This factor was computed as 66 skilled employees to one million population served for the 3000 Drilled Wells Water Supply project. The centralised maintenance system based at district centres requires skilled personnel for inspection tours and above/below grade maintenance functions. The pumps purchased for the project are not the VLOM type and therefore will continue to require skilled personnel for most maintenance operation. The proposals for community-based maintenance system should include replacement of the hand pump with VLOM type. On this project several German personnel have been retained in the Maintenance Unit to train the skilled personnel required. German maintenance managers are still in charge of the various regional centres supervising several district centres. A spare parts fabrication unit is beginning to turn out small items and develop the skills of machinists, welders and other artisans. The basic problem that requires immediate solution is the type of pump that should be installed in the aggressive water environment then the skills of the artisans will be orientated toward the maintenance of these pumps. In the present situation, artisans will require retraining on any future pump selected.

9.5.5 Social Input Factor

This factor is computed as 6.0 for the 3000 Drilled Wells Water Supply project.

(a) *Request*: request for improved water supplied is usually made to district or regional government representatives. This project was conceived to satisfy such requests from communities of population between 500 and 2000. Most of these communities have traditional sources which are perennial and thus water supply may not be a top priority request.

(b) *Level of Service/Coverage*: communities were not consulted on the level of service provided. Hand pumps were provided at 300 persons per hand pump and in clusters as settlements are more aggregated in southern Ghana.

(c) *Dialogue*: there was no dialogue established between GWSC and communities. Once the contract was signed the consultant and contractor mobilised effectively to complete the work well ahead of schedule. There was no intention of involving the community in any way that might delay project implementation.

(d) *Commitment*: communities were not required to demonstrate commitment to the project in any way. After the construction the Town Development Committees and Committee for the Defense of the Revolution have been contacted to help with revenue collection.

(e) *Appropriate Technology*: communities were not involved in the selection of technology for the project. Choice of technology was appropriate because of the scale and the rate of implementation. However hand dug wells are a close substitute although the rate of construction might be slower.

(f) *Willingness to Pay*: the communities have not shown much willingness to pay. The service has been poor and communities perceive their traditional sources as satisfactory alternatives. In some locations where hand pumps operate satisfactorily traditional sources are still heavily used.

(g) *Cost Recovery*: communities have not been involved in discussions on cost recovery except when they were informed of the purpose of the tariffs, that is, for the recovery of the maintenance cost of the hand pumps. Full cost recovery is improbable in the foreseeable future.

(h) *Ability to Pay*: tariff rates are well within the ability of the community to pay.

(i) *Decision Making*: communities were not involved in the decision making process in connection with this project. Communities had to accept what decisions GWSC handed down. Future projects will require complete community involvement at all levels of the decision making process.

(j) *Responsibility*: communities were not required to share in the responsibility of delivery of service. Communities have lately been involved in revenue collection and pump sanitation.

9.5.6 <u>Environmental Input Factor</u>

This factor was computed as zero for the 3000 Drilled Wells Water Supply project. Sullage disposal is by means of spreading to control dust or allowing infiltration into the ground. Sullage can still be used profitably by watering gardens although gardens around houses are not a common feature in the southern Ghana villages benefiting from this project.

9.5.7 <u>Reliability Output Factor</u>

This factor was computed as 0.40 for the 3000 Drilled Wells Water Supply project. This project selected the pump with the best performance in the 2500 Wells Project i.e. the Moyno hand pump and the India Mk 2 which had been acclaimed as a good pump. Target for pump reliability was set at 0.90 or better. Spare parts were provided under the German Maintenance Assistance. Due to lack of agreement at government/donor level approval of funds slowed down and the spare parts stock got depleted. At the same time the effect of the aggressive water on the pump parts had taken hold and corrosion was rampant. Hand pumps were breaking down frequently and some pumps were cannibalised to keep others going. The problem is wrong selection of pumps and therefore certain pump parts need to be replaced. Stainless steel parts have been ordered and work should start soon on replacement in order to improve pump reliability.

9.5.8 Utilization Output Factor

This factor was computed as 0.30 for the 3000 Drilled Well Water Supply project. Improved water supply to rural communities which have dependable traditional sources require intensive community education to encourage the community to discard the traditional sources. On this project there was no education component and therefore where the improved sources proved reliable there is still extensive use made of the traditional sources. Most consumers believe the water from traditional sources is more satisfying than the usually mineralised well water. Water utilization on this project has been hampered by high iron content which makes the water taste bitter, discolours foods like cassava and plantain cooked in it and also stains the laundry. The source of the iron is the pump parts corroded by the aggressive well water. As a result of the corrosion pumps break down more frequently further forcing consumers to use traditional sources. Improvement in utilization on this project will require improvement in service as a prerequisite followed by very intensive community education. Disconnection of hand pumps for non payment will only drive consumers back to the traditional sources. Health benefits can only be captured through utilization of the improved source. Persuasion through dialogue should be used more and more and disconnection used only as a last resort or if possible other sanctions like reduced assistance from government for other development projects could be applied.

9.5.9 Convenience Output Factor

This factor was computed as 70 persons per hectare for the 3000 Drilled Wells Water Supply project. Communities covered by this project are clustered settlements thus allowing wells to be drilled closer to the houses. Further, wells are provided in groups, with a minimum number of two wells in a community; each well serving 300 persons. When break down occurs at some of the wells, other wells are available but then the queues get longer. Average queuing time observed was 20 minutes. Queues occur in the early mornings when most people fetch water before leaving for the farm. In the afternoons some hand pumps are hardly used however queues do occur but to a lesser extent in the evenings when people return from the farms. With a predominantly farming community most people find it inconvenient to carry well water all the way to the farm and therefore drink from their traditional sources while working on the farm. This happens six days of the week. If farmers will be educated to carry water from the improved source to the farm then it should be convenient to fetch well water on the way to the farm and that means more wells to cope with the peak demand.

9.6 HAND DUG WELL WATER SUPPLY PROJECT

9.6.1 Technical Input Factor

This factor was computed as 0.44 for the Hand Dug Well Water Supply project. Foreign costs on this project include hand pumps, foreign components of cement and reinforcement bar costs, tools and equipment (including air compressors and breakers). The foreign cost of hand dug wells can be reduced by lining the well with brick or masonry instead of the concrete rings. Manufacture of bricks can be organised as a cottage industry to support the National Hand Dug Well Programme. In several areas in Ghana stones are available to be fashioned into size for well lining. Tools for excavation can be moulded and fashioned by local blacksmiths from scrap iron. The hand dug well will play a major role in the delivery of water services in rural Ghana and no effort should be spared in developing methods of construction that would minimise foreign inputs.

9.6.2 Financial Input Factor

This factor was computed as 0.54 for the Hand Dug Well Water Supply project. In this project no tariffs are instituted but the community contributes to the capital cost by providing local materials and labour for construction. Hand pump maintenance is covered by the community contribution initially and subsequently through fund raising activities. The community, indeed, has to deposit their maintenance funds before the project can start. With this early commitment the community is motivated to go through with the project in order to reap the benefits. In this way the community is encouraged to proceed towards self-reliance in development projects. However equity demands that if the small rural communities can be made to commit so much resources before the benefits will flow then all other communities, large or small, urban or rural, should be expected to commit same resources. If this is done available loans and grants can be stretched to cover a larger population.

9.6.3 Economic Input Factor

This factor was computed as $0.93 per person for the Hand Dug Well Water Supply project. The various means by which capital costs might be reduced have been discussed earlier. Maintenance cost can be reduced by making use of the Afridev pump or similar VLOM pump instead of the India Mk 2 pumps.

9.6.4 Institutional Input Factor

This factor was computed as zero for the Hand Dug Well Water Supply project. Presently there is no permanently organised maintenance unit to undertake repairs as has been described for other hand pump projects. It is therefore assumed that the community who owns the well does not employ any skilled personnel to maintain the pump but pays an outside organisation to maintain the pump. When the Afridev pump is installed some village hand pump mechanics will be trained to maintain the pump. Since the well design allows the use of the well with or without the pump the need for skilled personnel is very much reduced. In the case of the drilled well there is an urgency in the repair of pumps since without the pump the facility cannot be used.

9.6.5 Social Input Factor

This factor was computed as zero for the Hand Dug Well Water Supply project. This means a total community involvement in all aspects of the project.

(a) *Request*: the project demands that all communities wishing to be considered under the Water Aid hand dug well programme formally apply to the Akuapem Rural Development Foundation for consideration and the village of Timber Nkwanta formally applied and was selected.

(b) *Level of Service/Coverage*: the community was consulted and in fact agreed to the provision of a hand dug well with a hand pump.

(c) *Dialogue*: the project supervisor met the village leaders and established dialogue on the project from the beginning. The community had the opportunity of communicating with the project supervisor on any issue pertaining to the project. Conflicts are easily resolved and a consensus forged before any action is taken.

(d) *Commitment*: the project sponsors require a firm commitment on the part of the community in the form of cash deposit against hand pump maintenance, supply of sand and stone which should be available at the site before construction can start and the agreed days for the supply of labour for the construction. These are firm commitments on the part of the community to ensure that the project is successfully executed. This level of commitment should be emulated by similar projects.

(e) *Appropriate Technology*: the community is fully involved in the selection and installation of the technology for the project. The hand dug well with a hand pump and a hatch for fetching water in the event of the pump becoming inoperable is the most appropriate technology for rural water supply to both small and large rural communities.

(f) *Willingness to Pay*: willingness to pay is amply demonstrated by the willingness of the community to deposit cash for pump maintenance even before the construction starts. This is followed with supply of local materials and labour.

(g) *Cost Recovery*: a reasonably high level of cost recovery is achieved even before the project is ready for use. Further cost recovery can be achieved if more and more local materials are used in construction.

(h) *Ability to Pay*: an initial head tax collected to pay for the initial deposit represents the main cash contribution for the project. Other community contributions involve non cash allocation of time to work on the project. Limiting cash contribution to the head tax is well within the community's ability to pay.

(i) *Decision Making*: this project involves the community at all levels of decision making from the initial request for the project to the final involvement in project maintenance. Indeed the project is a model of total community involvement.

(j) *Responsibility*: the community shares of responsibility is spelled out at the initial dialogue between the project supervisor and the community leaders. An agreement is reached on all issues before the commencement of the project.

9.6.6 Environmental Input Factor

This factor was computed as zero for the Hand Dug Well Water Supply project. Sullage disposal is by means of spreading to control dust. Sullage could be used profitably to water gardens. However, the community is made up of farmers who grow everything on their farms and therefore do not need gardens around their homes.

9.6.7 Reliability Output Factor

This factor was computed as 0.98 for the Hand Dug Well Water Supply project. The hand dug well with a hand pump and a hatch for using rope and bucket is a very reliable installation. Pump reliability is not as critical as with a drilled well although the use of rope and bucket is likely to impair the quality of the water. Absolute reliability cannot be guaranteed since there should be occasions when the well is completely shut down to clean the lining of any algae growth or to repair any cracks. The possibility of the well itself going dry in the event of drought was not considered since this is a factor common to all sources of supply both surface water and ground water.

9.6.8 Utilization Output Factor

This factor was computed as 0.90 for the Hand Dug Well Water Supply project. In rural water supply there are always consumers who will continue to use the traditional source due to some special preferences they have for such sources. However since some queuing takes place in the mornings some consumers still use the traditional source. Improving utilization beyond this point will involve digging additional wells. The community will have to weigh the incremental cost against the incremental benefit of attaining 100 per cent utilization.

9.6.9 Convenience Output Factor

This factor was computed as 60 persons per hectare. On the average people walk 150 metres to the hand pump and about 300 metres to the traditional source. The convenience gained is not very much thus quality considerations were more important to the community in accepting to undertake the project. Some queuing takes place even with the traditional source close by. To eliminate the queue it is possible to install more than one hand pump on hand dug wells.

Hand pump installation on the head wall of the well makes pump operation rather inconvenient for children. The tendency is to operate the pump with short strokes which is detrimental to the pump rods. A short pedestal for children will improve convenience.

9.7 CENTRAL ACCRA SEWERAGE PROJECT

9.7.1 Technical Input Factor

This factor was computed as 0.46 for the central Accra Sewerage project. The foreign cost consisted of cost of pumps, foreign component of locally manufactured concrete pipes and concrete manholes, supply of manhole covers, fees for consultants and profit of foreign contractors. This project was financed by the World Bank and the government of Ghana. The World Bank involvement meant that contractors had to be selected by International Competitive Bidding; the consultants had already been engaged by the WHO for the Accra-Tema Water Supply and Sewerage Master Plan. Local contractors, at the time, did not possess the expertise to undertake major sewerage projects. Manhole covers can be produced by local foundries which were established after the project. Future extensions to the project should involve less foreign exchange as more and more services are provided locally. Aid agencies should be prepared to finance local costs to help develop local technical capability and local industries.

9.7.2 Financial Input Factor

This factor was computed as 0.88 for the Central Accra Sewerage project. The project at the appraisal stage was expected to attract 300 connections per annum. Indeed revenue projections were based on this rate of connection. However customers were expected to provide their internal plumbing and pay for the connection cost. This financial burden proved unbearable for the poor people living in the predominantly low-income housing areas with the result that connections so far have mainly come from commercial and industrial premises. The GWSC has prepared a financial package to help pre-finance such connections and to recover the loans together with the tariff. This package will have to be implemented with intensive community education backed by legislation. It is hoped that by making it financially attractive to connect to the sewerage system other sanitation systems such as the VIP latrine and septic tank, will prove too expensive to undertake. Enough public facilities will have to be provided with a reasonable admission charge to take care of the large population in the area that use the beach for open defecation. The programme of pre-financing connections will have to be followed closely for any lessons that will be learned for future application in similar situations. It is suggested that unless extensions are made to industrial and medium income housing areas the revenue situation will not improve very much.

9.7.3 Economic Input Factor

This factor was computed as $77.60 per person. This factor includes investment in internal plumbing and connection fees. Foreign and unskilled labour components in both capital and operation and maintenance cost were appropriately shadow priced. Excavation for sewers were done manually and this accounted for 20 per cent of the capital cost. Capital cost was reduced initially by the temporary outfall donated by an oil company. With the collapse of the outfall extra capital cost will be incurred to treat the sewage prior to disposal. Operation and maintenance cost are high for the present population being served. This is again due to the lack of connection to the facility. As more connections are effected the cost per person served of operation and maintenance should fall. The level of maintenance at present will have to be improved to arrest deterioration of plant and structures. Increases in rates should make more resources available for maintenance.

9.7.4 Institutional Input Factor

This factor was computed as 1150 skilled employees to a million population served for the Central Accra Sewerage project. Skilled personnel are employed to operate the pumps, maintain the sewers and other facilities and to effect connections to the system. Further maintenance support is provided by the ATMA main workshop. No staff at the Sewerage Division has had any formal training in sewerage operation. On the job training was provided by the expatriate staff retained after the construction and who have also departed. There are no local institutions geared for training sewerage operators as exists for water supply. It is possible to adapt facilities at the water supply training school to accommodate sewerage operators. However there will be the need to train the trainers on properly operated sewerage works preferably with waste stabilisation ponds as the treatment unit. The management of GWSC should show more concern for the requirements of the Sewerage Division. Presently no laboratory facilities are available and thus no laboratory staff are available. Various factories and industries are being connected and there is no institutional arrangement for monitoring the effluents being admitted into the sewers. With a treatment plant in operation the type of effluent permissible is crucial and data should be collected from now.

9.7.5 Social Input Factor

This factor was computed as 8.0 for the Central Accra Sewerage project.

(a) *Request*: the community did not make any request for an improved sanitation technology. The existing technology was the bucket latrine, the aqua privy and some septic tanks. The consultants had recommended the improvement in technology but failed to conduct a social analysis of the problem.

(b) *Level of Service/Coverage*: the community was not consulted on the level of service or the coverage of the project. The original designs of the Master Plan was for total coverage of Accra.

(c) *Dialogue*: no contact was established with the community on the need for the community to get involved with the project. It was not deemed necessary to establish dialogue with the community as the project was being executed by the government for the community. Public hearing is not an established practice in Ghana.

(d) *Commitment*: the community was not expected to demonstrate commitment to the project. Indeed the community was not committed to connect to the system.

(e) *Appropriate Technology*: the community was not involved in the selection of technology for the project. The technology selected by the consultants turned out to be inappropriate. In future early community involvement might avoid such mistakes.

(f) *Willingness to Pay*: the customers so far connected have shown their willingness to pay. It is thought that these are the customers that perceived the need for such a service. For most of the industrial and commercial customers the sewerage system is a form of government subsidy to their operations as they would have incurred or were incurring higher costs to dispose of their sewage.

(g) *Cost Recovery*: the issue of cost recovery has not been discussed with customers since participation is so minimal. A reasonable level of participation is needed to make such discussions realistic.

(h) *Ability to Pay*: customers connected certainly possess the ability to pay for the service since they were fully aware of the financial implications of using the service.

(i) *Decision Making*: the community was not involved in the decision making process at any stage of the project. Decision making was the exclusive preserve of GWSC on the advice of the consultants.

(j) *Responsibility*: the community was not expected to share in the responsibility of providing the service. Responsibility for providing internal plumbing and connection to the system is optional and most people refused to accept that responsibility.

9.7.6 Environmental Input Factor

This factor was computed as $3.3 per person for the Central Accra Sewerage project. The original design of the sewage disposal system provided a permanent outfall of 1.8 metre diameter. The cost was found to be prohibitive and when Mobil Oil offered the 300mm pipeline this was used as a temporary outfall. Later coastal defence work was carried out near the outfall and this changed the pattern of currents and the outfall was eroded and swept away. Since then sewage has been pumped onto the shore and washed away at high tide. This arrangement pollutes the beach. The identified solution is to build waste stabilisation ponds to treat the sewage before disposal. Elimination of pollution at the beach should be attractive to the tourist industry.

9.7.7 Reliability Output Factor

This factor was computed as 0.90 for the Central Accra Sewerage project. The project has high reliability because there is over-capacity. Capacities of pumps and sewers were provided to take care of higher sewage flow from the intended future extensions. Lack of total reliability is due to the clearing of blockage to about 10 per cent of the customers annually.

9.7.8 Utilization Output Factor

This factor was computed as 0.20 for the Central Accra Sewerage project. Low utilization is due to the high level of sophistication of the technology employed and the lack of private finance to connect to the system. It is hoped that the GWSC financial package to assist prospective customers will improve utilization. However the long term utilization improvement will require extensions to industrial areas north of the current sewered area.

9.7.9 Convenience Output Factor

This factor was computed as 200 persons per hectare for the Central Accra Sewerage project. The convenience provided by sewerage systems in sanitation is hardly matched by technologies relying on pit latrines. Sewerage is very convenient to industries and commercial premises already connected to inefficient septic tanks where cesspit emptyers are deployed to pump and transport sewage continuously throughout the daily hours of operation. The socio-economic conditions in the low-income housing area cannot support a high level of convenience in sanitation. It is observed that a large portion of the cost of sewerage schemes actually pays for the convenience provided and that health benefits from sanitation can be fully captured at much lower cost levels affordable to low income groups.

9.8 URBAN KUMASI-TYPE VENTILATED IMPROVED PIT (K-VIP) LATRINE PROJECT

9.8.1 Technical Input Factor

This factor was computed as 0.50 for the Urban K-VIP Latrine project. The foreign component of the capital cost was made up of foreign inputs in the locally manufactured building materials such as cement, reinforcement bars and roofing sheets. In addition some vehicles such as the Brevac suction tankers or night soil carting trucks may be required for pit emptying. In computing the above factor it was assumed that any vehicles for pit emptying will be hired and the hiring charges were included in the operation and maintenance costs. To reduce the foreign cost in construction materials such as bricks, bamboo reinforcement and shingles which are wholly produced locally should be used. Ghana is an exporter of timber but not much timber is used in construction. This is because preservation of timber is not well established and unseasoned timber is easily attacked by termites. Timber could be a good material for the superstructures of these latrines.

9.8.2 Financial Input Factor

This factor was computed as 0.31 for the Urban K-VIP Latrine project. Revenue from user charges paid before admission cover operation and maintenance cost and a fraction of the capital cost. Users are still to get used to the admission charges since its introduction is only recent and fortuitously coincided with the construction of the K-VIP latrines. Other types of latrines which are also community operated require payment of same charges before use. The operation of the K-VIP latrine should offer a better service in the form of a neat, odourless and fly proof latrine in order to be able to raise the charges further to move closer to full cost recovery. Also cost reduction in construction using local materials are described above should augment efforts towards full cost recovery.

9.8.3 Economic Input Factor

This factor was computed as $6.77 per person for the Urban K-VIP Latrine project. Foreign components and unskilled labour components in both capital cost and operation and maintenance costs were appropriately shadow priced. Reduction in capital costs have been discussed above. Operation costs from pit emptying should be reduced by the use of manual emptying wherever possible. Sludge should be allowed to dry and then incinerated. To do this effectively will require free land around the latrine.

9.8.4 Institutional Input Factor

This factor was computed as zero for the Urban K-VIP Latrine project. The normal operation and maintenance of the K-VIP Latrine does not require the employment of skilled personnel on a permanent basis. Indeed it requires only one unskilled labourer to keep the latrine tidy at all times. The other employee collects the admission charges and supervises the unskilled labourer. When pit emptying is due a report is made to the community leaders who arrange for the emptying to be carried out either manually on contract or by hired vehicles.

9.8.5 Social Input Factor

This factor was computed as 2.0 for the Urban K-VIP Latrine project.

(a) *Request*: there has been persistent requests from the public to the Kumasi Metropolitan Assembly to close down and replace the bucket latrines because there were not enough employees to operate it satisfactorily. Committees for the Defense of the Revolution, formed in various areas in the city of Kumasi and the rest of the country after the 1981 military takeover, had assumed responsibility for communal latrines.

(b) *Level of Service/Coverage*: the Kumasi Metropolitan Assembly decided to replace some of the bucket latrines. The available resources together with assistance from various church groups could cover eight latrines initially but later extended by community self help.

(c) *Dialogue*: no formal dialogue was established between the Kumasi Metropolitan Assembly and the various areas until the Committees took over the operation of the public toilets.

(d) *Commitment*: the Committees had already demonstrated their commitment to the operation and maintenance of communal latrines in the city prior to the project. Other communities which joined the project later were committed to cash and labour contributions to the project.

(e) *Appropriate Technology*: the technology selected was appropriate. Although the initial eight latrines had to be built more as demonstration units of a new technology, once they were shown to work satisfactorily the various communities took their decisions independently to participate in the project.

(f) *Willingness to Pay*: users have amply demonstrated their willingness to pay for the use of the latrines.

(g) *Cost Recovery*: the user fees and the community cash contributions are healthy indicators that communities are prepared to cover a substantial part of the cost of delivery of the service.

(h) *Ability to Pay*: users are able to pay since charges are equivalent to five per cent of the minimum wage. Children should not pay the charges. Where children are made to pay the charge could prove prohibitive as the respondents to the survey revealed.

(i) *Decision Making*: the Kumasi Metropolitan Assembly initiated the project but decision making rests with the communities.

(j) *Responsibility*: the communities have accepted to share in the responsibility of providing the service. Communities operate and maintain the latrines and also organise the collection of funds and make labour available for the community self-help projects.

9.8.6 Environmental Input Factor

This factor was computed as $1.0 per person for the Urban K-VIP Latrine project. Sludge disposal is the main environmental pollution hazard on this project. The factor measures the cost of avoiding or minimising environmental pollution around the latrine during de-sludging and subsequent disposal of sludge.

9.8.7 Reliability Output Factor

This factor was computed as 0.90 for the Urban K-VIP Latrine project. Reduced reliability on this project is due to the lack of adequate back-up services for pit emptying. Due to intensive use of the latrine, pits need to be de-sludged more often. The facilities of the Kumasi Metropolitan Assembly for assisting in pit de-sludging are very much the same facilities used for septic tank de-sludging. Requests for the service from the communities take too long to be honoured, this leads to occasional closing of some compartments of the latrine. Thus the full capacity of the latrine may be unavailable at certain times resulting in 10 per cent loss of capacity. Manual de-sludging has been employed but the operation requires a vehicle to convey the sludge away and again the appropriate vehicles are not always available. Facilities for pit emptying in the urban setting will have to be improved. In addition extra latrine units are required to ease the pressure on the earlier units and allow for operation within the designed capacity of the latrine.

9.8.8 Utilization Output Factor

This factor was computed as 0.30 for the Urban K-VIP Latrine project. Although the latrines are heavily used the capacity provided is inadequate for the demand. The law requesting all landlords to provide latrines in each dwelling place does not state the number of persons per latrine compartment, hence the number of latrines provided in most rented homes are grossly inadequate, thus putting more pressure on the communal latrines. More latrines should be provided in individual homes as well as increasing communal facilities to check indiscriminate defecation on refuse dumps and storm drains.

9.8.9 Convenience Output Factor

This factor was computed as 100 persons per hectare for the Urban K-VIP Latrine project. Communal latrines in the urban setting should normally be provided for the convenience of the floating population. Facilities in individual homes should be adequate for the convenience of the residents. Inadequate communal facilities create queues in the morning and evening with users having to wait for an average of ten minutes. For improved convenience more latrines should be provided in the individual houses as well as increasing public and communal facilities.

9.9 RURAL KUMASI-TYPE VENTILATED IMPROVED PIT (K-VIP) LATRINE PROJECT

9.9.1 Technical Input Factor

This factor was computed as 0.50 for the Rural K-VIP Latrine project. The foreign component of the capital cost consists of the foreign costs of all construction materials used such as cement, reinforcement bars, and galvanised iron roofing sheets. To reduce the foreign cost of the project building materials which are wholly produced locally will have to be used. In the rural areas most houses are built in switch or mud and wattle construction and rendered on the outside with cement mortar. The superstructure of the K-VIP latrine should be built of similar construction materials. Use of local materials in new construction should be preceded by demonstration units acceptable to the community. In one rural area the community rejected the use of bamboo reinforcement for squatting slabs and pit covers. In all other areas mild steel bars had been used. The community believed mild steel bars had been supplied for the project but someone cleverly wanted to substitute bamboo reinforcements and divert the mild steel bars to personal use. Cheaper construction is not always acceptable to the rural community.

9.9.2 Financial Input Factor

This factor was computed as 0.22 for the Rural K-VIP Latrine project. This project insisted on communities making a cash deposit in addition to providing all locally available materials, labour for construction and subsequently to operate and maintain the latrines. The total community contribution fully covered operation and maintenance cost and a substantial part of the capital cost. Cost reduction measures as discussed above should make achievement of full cost recovery a real possibility.

9.9.3 Economic Input Factor

This factor was computed as $8.15 per person for the Rural K-VIP Latrine project. The foreign component and the unskilled labour components of both capital and operation and maintenance costs were appropriately shadow priced. Cost reduction measures have already been discussed but it should be emphasised that pit emptying in the rural area does not require any vehicles since the sludge age renders it safe for manual emptying, drying and incineration. Resources need not be committed for hiring these facilities.

9.9.4 Institutional Input Factor

This factor was computed as zero for the Rural K-VIP Latrine project. In this project no staff are permanently employed for operation and maintenance. Members of the community share the responsibility of operating and since no admission charge is required no revenue staff is required. Operation is not entirely satisfactory since anal cleansing material is thrown everywhere. There is the need to train at least two persons in each community proper operation and maintenance of the latrine.

9.9.5 Social Input Factor

This factor was computed as 3.0 for the Rural K-VIP Latrine programme.

(a) *Request*: communities wanting to participate in the project had to send a formal request to the regional offices of the Department of Rural Housing and Cottage Industries who were the executing agency. Communities that satisfied the eligibility criteria of cash deposit, supply of local materials and labour, were selected.

(b) *Level of Service/Coverage*: communities were aware of the level of service i.e. communal latrines and coverage was determined by the number of latrines the communities were prepared to construct.

(c) *Dialogue*: dialogue between the executing agency and the community was established as soon as the eligibility criteria are satisfied. Programme of work had to be agreed upon. Conflicts on the job had to be resolved through dialogue.

(d) *Commitment*: the communities had to demonstrate commitment to the project by satisfying the eligibility criteria already mentioned.

(e) *Appropriate Technology*: the community was not involved in the selection of technology for the project. The technology selected is appropriate but rather expensive due to the construction materials used. Construction of K-VIP latrines using cheaper locally produced materials will be the solution to the rural sanitation problem in Ghana.

(f) *Willingness to Pay*: the high cost of the K-VIP latrine discouraged many communities from taking part in the project. Most villages were unwilling to pay the initial deposit requested and in addition provide local materials and labour. It seems rural communities are always expected to prefinance development projects while urban areas are able to obtain financing either from government sources or donor agencies and then pay through tariff. The latter procedure should make the community more willing to pay.

(g) *Cost Recovery*: those communities that accepted the project conditions were aware of the level of cost recovery and did participate successfully.

(h) *Ability to Pay*: communities that participated demonstrated ability to pay. Most communities paid their contributions through head tax, local council contribution, or by a resident philantropist. If other communities were willing to pay they could have raised the money through fund raising activities.

(i) *Decision Making*: communities are not involved in the decision making process. Even when they accept to participate in the project they have to abide by decisions of project planners.

(j) *Responsibility*: communities agreed to share in the responsibility of providing the sanitation service. Communities cover all operation and maintenance costs and contribute substantially to the financing of the capital cost.

9.9.6 Environmental Input Cost

This factor was computed as $1.0 per person for the Rural K-VIP Latrine project. This factor is an indicator of the environmental pollution avoided or reduced during de-sludging and subsequent drying and incineration of the sludge. Improper handling of the sludge could create insanitary conditions around the latrine.

9.9.7 Reliability Output Factor

This factor was computed as 0.90 for the Rural K-VIP Latrine project. The rural K-VIP latrine is not permanently manned. Users could create unsightly conditions in some compartments which make other users avoid using those compartments. It is only at the next cleaning by the voluntary cleaner that these compartments become available for use. Also compartments nearer the entrances are used more frequently that others causing early filling of those pits. When this happens those compartments are closed forcing users into the other compartments. Loss of compartments due to these measures account for 10 per cent loss of capacity or availability which reduces total reliability to 90 per cent reliability.

9.9.8 Utilization Output Factor

This factor was computed as 0.10 for the Rural K-VIP Latrine project. Utilization of the improved latrine is low because the old traditional pit latrine is available for use by those who prefer that facility and open defecation is still practised in the bush and along the beaches. No formal community education accompanied the construction of the latrine. The Town Development Committees and the Committees for the Defense of the Revolution are using persuasion to encourage the use of the K-VIP Latrine. It is believed that if admission charge is imposed people will be driven to use other facilities. The introduction of a new technology will require some time to gain wide acceptance.

9.9.9 Convenience Output Factor

This factor was computed as 70 persons per hectare for the Rural K-VIP Latrine project. The provision of the K-VIP latrines in close proximity with the traditional pit latrines did not improve convenience. The latrines were located at one end of the community and those people at the other end found it more convenient to use the bush for open defecation. The relative absence of odours in the K-VIP latrine did not seem to provide attractive convenience in use. It is not clear whether additional facilities well distributed in the community to improve convenience will encourage utilization. As it is, provision of private latrines can only be a very long term prospect.

9.10 TRADITIONAL PIT LATRINE PROJECT

9.10.1 Technical Input Factor

This factor was computed as zero for the Traditional Pit Latrine project. The latrine was constructed from locally produced construction materials and did not require any foreign inputs. This is a case in which the latrine superstructure is built in the same materials as the dwelling houses. The roofing material was of discarded galvanised iron sheets but could easily be replaced with thatch roof as indeed some of the dwellings are roofed with thatch. The modified form of the traditional pit latrine will continue to serve a majority of communities in the rural areas. These latrines should, as a matter of policy, be constructed in materials available in the particular localities. Designs for these latrines should be produced and vigorously promoted. It is possible to make the construction of latrines from materials wholly produced locally a pre-requisite for government funds for other development projects.

9.10.2 Financial Input Factor

This factor was computed as zero for the Traditional Pit Latrine project. The latrine is wholly provided by the community and completely operated by it without outside assistance. By adopting this as the basic unit for rural sanitation incremental improvements can be made, each improvement being within the capability of the community to finance.

9.10.3 Economic Input Factor

This factor was computed as $0.45 per person for the Traditional Pit Latrine project. The unskilled labour component of the total cost was appropriately shadow priced. Resources used on this project are entirely locally produced and are available at low cost. Improvements will require more local materials and will increase the economic input factor.

9.10.4 Institutional Input Factor

This factor was computed as zero for the Traditional Pit Latrine project. There is no need to employ any skilled personnel for the operation, maintenance and management of the project. However this latrine will require improvement and communities will have to be trained on how to incorporate new features, such as locally produced vent pipes.

9.10.5 Social Input Factor

This factor was computed as zero for the Traditional Pit Latrine project.

(a) *Request*: the community recognised the need for a communal latrine and recognised also that the latrine will have to be built from their own resources.

(b) *Level of Service/Coverage*: the latrine as constructed had the capacity to serve the entire community. The level of service was selected by the community.

(c) *Dialogue*: dialogue is maintained between the leaders and members of the community at all times on development projects and the traditional pit latrine is just one of these projects.

(d) *Commitment*: the community was committed to provide the pit latrine for themselves because it was their own decision taken on account of a perceived need.

(e) *Appropriate Technology*: the technology selected is appropriate to the requirements of the community but the design should be modified to improve the stability of the structure and to minimise odours.

(f) *Willingness to Pay*: members of the community were willing to provide cash and to expend time and energy to construct the traditional pit latrine for themselves.

(g) *Cost Recovery*: all costs were borne by the community. Full cost recovery was ensured by the decision to construct the latrine entirely from the community's resources.

(h) *Ability to Pay*: the ability to pay was ensured by using construction materials that involved as little cash as possible.

(i) *Decision Making*: all decisions on the project were made by the community from project identification through to operation and maintenance.

(j) *Responsibility*: the community assumed full responsibility for the project.

9.10.6 Environmental Input Factor

This factor was computed as zero for the Traditional Pit Latrine project. The latrine was constructed at the leeward end of the community and at least 20 metres from the nearest dwelling to minimise odours getting into the community. The pit latrine will be sealed off with soil when full and another constructed elsewhere. No environmental pollution is anticipated.

9.10.7 Reliability Output Factor

This factor is computed as 0.90 for the Traditional Pit Latrine. Reduced reliability is due to the unavailability of 10 per cent of the squatting positions for use through fouling and improper use. If the latrine has a permanent attendant fouling is reported by users and the mess cleaned but with attendants cleaning up daily the fouled squatting position is avoided by users until cleaned up.

9.10.8 Utilization Output Factor

This factor was computed as 0.44 for the Traditional Pit Latrine project. Utilization is low because open defecation in the bush is still practised. The strong obnoxious smell is a deterrent mainly to visitors to the community who would rather indulge in open defecation than use the traditional pit latrine. Some residents who work in urban areas use facilities there and would use local facilities only at the weekend or in emergencies. Smoking a pipe or cigarettes is believed to combat the smell.

9.10.9 Convenience Output Factor

This factor was computed as 60 persons per acre for the Traditional Pit Latrine project. The location of the latrine at one end of the community makes it rather inconvenient for those residing towards the other end. Indeed wherever the bush is nearer people find it more convenient to use the bush. Lack of privacy in the Traditional Pit Latrine compels some people to use the bush.

9.11 EFFICIENCY SCORES

Efficiency scores obtained from the computer runs are presented below.

Run 1: 2 Outputs: Reliability and Utilization
All 10 projects as DMUs.

Run 2: 2 Outputs: Reliability and Utilization
6 Water projects as DMUs followed by
4 Sanitation projects as DMUs.

Run 3: 3 Outputs: Reliability, Utilization and Convenience
All 10 projects as DMUs.

Run 4: 3 Outputs: Reliability, Utilization and Convenience
6 Water projects as DMUs followed by
4 Sanitation projects as DMUs.

Table 9.2 Project Efficiency Scores

Project	Run 1	Run 2	Run 3	Run 4
Accra-Tema Water	0.196	0.732	0.270	1.000
Borehole Water	0.232	0.539	0.272	0.903
Package Plant Water	0.090	0.325	0.132	0.978
2500 Wells Water	0	0.530	0.216	0.530
3000 Wells Water	0.069	0.222	0.119	0.636
Hand Dug Well Water	0.990	1.000	0.484	1.000
Central Accra Sewerage	0.006	0.006	0.019	0.019
Urban K-VIP Latrine	0.066	0.066	0.111	0.111
Rural K-VIP Latrine	0.055	0.055	0.064	0.064
Trad. Pit Latrine	1.000	1.000	1.000	1.000

Table 9.3 Project Efficiency Ranking

Project Type	Ranking	Run 1	Run 2	Run 3	Run 4
Water	1	Hand Dug Well	Hand Dug Well	Hand Dug Well	Hand Dug Well
	2	Borehole	Accra-Tema	Borehole	Accra-Tema
	3	Accra-Tema	Borehole	Accra-Tema	Package Plant
	4	Package Plant	2500 Wells	2500 Wells	Borehole
	5	3000 Wells	Package Plant	Package Plant	3000 Wells
	6	2500 Wells	3000 Wells	3000 Wells	2500 Wells
Sanitation	1	Trad. Pit Latrine	Trad. Pit Latrine	Trad. Pit Latrine	Trad. Pit Latrine
	2	Urban K-VIP Latrine	Urban K-VIP Latrine	Urban K-VIP Latrine	Urban K-VIP Latrine
	3	Rural K-VIP Latrine	Rural K-VIP Latrine	Rural K-VIP Latrine	Rural K-VIP Latrine
	4	Cen. Accra Sewerage	Cen. Accra Sewerage	Cen. Accra Sewerage	Cen. Accra Sewerage

9.11.1 Accra-Tema Water Supply

In Run 1 the traditional pit latrine was the only efficient project and therefore dominated the rest of the projects. Accra-Tema efficiency score was 0.196 relative to the traditional pit latrine. This is a low score in spite of the very different delivery systems adopted by the two projects which, by observation, are equally capable of generating efficient projects. In Run 2 the efficiency of Accra-Tema was 0.732 relative to the Hand Dug Well, a marked improvement in the absence of the traditional pit latrine. In Run 3 the efficiency of Accra-Tema was 0.270 relative to the traditional pit latrine. This is a modest improvement due to the inclusion of the convenience factor but the efficiency is low due to the extreme domination of the traditional pit latrine. In Run 4 Accra-Tema became efficient emphasising the importance of the convenience factor this project. The traditional pit latrine and the hand dug well have a delivery system which is highly community based while Accra-Tema relies on a centralised system to operate a more sophisticated system. Large urban communities require systems similar to the Accra-Tema system but the question is whether the level of skills, supervision and logistic support can be provided at the same level as obtains in Accra-Tema. Standards at Accra-Tema become the model that all large urban schemes will be expected to attain and therefore should strive to achieve.

9.11.2 Borehole Water Supply

In Run 1 the efficiency score was 0.232 relative to the traditional pit latrine. This seems to suggest that the Borehole project could emulate some of the strong community-based attributes of the traditional pit latrine. In Run 2 the efficiency score was 0.539 relative to the hand dug well. This score shows an improvement over that obtained in Run 1. The hand dug well delivery system is also community-based but being a groundwater project it should be a better model for the Borehole water supply than the traditional pit latrine. In Run 3 the efficiency score was 0.272 relative to the traditional pit. Compared with Run 1 the inclusion of the convenience factor in Run 3 did not have much effect relative to the traditional pit latrine. In Run 4 however the efficiency score was 0.903 relative to Accra-Tema and the hand dug well. The inclusion of the convenience factor improved the efficiency score considerably. The Borehole scheme can benefit from a good centralised delivery system or a well organised community-based system. Various communities should be given the chance to choose which model they prefer and should be supported to develop the selected system to the highest level achievable. As water supply to small urban communities the Borehole scheme compared with the Package Plant on Table

9.3 shows the Borehole as superior in Run 1, 2 and 3 and slightly inferior in Run 4. The Borehole scheme being the more easily managed system is recommended for small urban communities wherever feasible.

9.11.3 Package Plant Water Supply

In Run 1 the efficiency score was 0.091 relative to the traditional pit latrine. This is a very low score which suggests that the Package Plant delivery system can be improved with some community-based inputs. In Run 2 the efficiency score was 0.325 relative to the hand dug well. A modest improvement over Run 1 due to the exclusion of the traditional pit latrine which exerts extreme local influence on the projects. In Run 3 the efficiency score was 0.132 relative to the traditional pit latrine. The inclusion of the convenience factor slightly improves the efficiency score but this improvement is absorbed in the domination by the traditional pit latrine. In Run 4 the efficiency score was 0.978 relative to the Accra-Tema project and the Hand Dug Well. This shows that in the absence of the traditional pit latrine and with the inclusion of the convenience factor the Package Plant seemed to assert itself. However, the score attained seemed unexpectedly high especially when it exceeds the efficiency of the Borehole in Run 4. The Package Plant requires a strong centralised delivery stem to make it efficient. However, in the environment where it is deployed the plant is far removed from the centre hence supervision is weak and support is lacking. Replacement with boreholes or slow sand filters would make them perform better with a community-based delivery system.

9.11.4 2500 Wells Water Supply

In Run 1 the efficiency score was zero relative to the traditional pit latrine. This result is not realistic but several computer runs to check for any errors produced the same result. This project certainly requires to emulate the community-based attributes of the traditional pit latrine. In Run 2 the efficiency score was 0.530 relative to the hand dug well. In other words the hand dug well is about twice as efficient as the drilled wells project in the Upper Region. Future extensions to the project should consider hand dug wells with strong community-based delivery system. In Run 3 the efficiency score was 0.216 relative to the traditional pit latrine. The increase in efficiency score from zero in Run 1 to 0.216 in Run 3 cannot be attributed to the inclusion of the convenience factor, which factor happens to be of a low value on this project. In Run 4 the inclusion of the low convenience factor did not change the efficiency score of 0.533 relative to the hand dug well as recorded in Run 2. The convenience factor did not have any influence on the project. This is to be expected since the long distance walked by the consumers did not confer any benefits in convenience. As water supply to large rural communities comparison with 3000 wells on Table 9.3 indicates that this project had superiority in Runs 2 and 3 but was inferior in Runs 1 and 4. There was no conclusive evidence on which project, the 2500 wells or the 3000 wells, was superior over all. In terms of delivery of water projects the consistently low ranking of drilled wells in Table 9.3 suggests that these projects be investigated again vis-a-vis all alternative supply systems including multiple hand dug wells and even several hand pumps installed on one borehole with a good yield.

9.11.5 <u>3000 Wells Water Supply</u>

In Run 1 the efficiency score was 0.069 relative to the traditional pit latrine. The low efficiency again indicates the difference in the delivery systems where this project relies on centralised and external support the traditional pit latrine is strictly community-based. The community-based maintenance system to be introduced on this project should emulate the community mobilisation techniques on the traditional pit latrine project. In Run 2 the efficiency score was 0.222 relative to the hand dug well. In other words the hand dug well was four to five times more efficient. Future extensions to this project should include the hand dug well option. In Run 3 the efficiency score was 0.119 relative to the traditional pit latrine. The inclusion of the convenience factor showed only a modest increase as compared to Run 1. In Run 4 the efficiency score was 0.636 relative to the Accra-Tema project and the hand dug well. The inclusion of the convenience factor showed a marked improvement from the efficiency score in Run 2. The convenience factor is important on this project especially when compared with the 2500 wells project. The reliability problems on this project should have made it decidedly inferior to the 2500 wells but the convenience factor seemed to compensate for any losses due to reliability. However both projects need further investigation together with all other feasible options. On the 3000 wells programme the proximity of traditional sources should make small improvements to these sources a feasible option to be considered. Drilling of wells purposely for hand pumps should be the last resort when all options have failed.

9.11.6 Hand Dug Well

In Run 1 the efficiency score was 0.99 relative to the traditional pit latrine. The hand dug well delivery system is almost as efficient as the traditional pit. Further reduction in external inputs should make it equally efficient as the traditional pit latrine. In Run 2 the absence of the traditional pit latrine, the hand dug well dominated the water projects and was the only project with efficiency score of 1. In Run 3 with the inclusion of the convenience factor the efficiency score reduced drastically to 0.48 relative to the traditional pit latrine. All the other projects seemed to gain in efficiency at the expense of the hand dug well although none gained enough to be superior to the hand dug well. Run 4 showed the hand dug as efficient together with Accra-Tema project. From Table 9.3 the hand dug well ranks at the top of all the water projects. This suggests that it should be the first consideration for any water supply scheme especially with the rural water schemes and even in some small urban schemes. Over the years hand dug wells have been used for emergency supplies in Ghana. A major national programme for hand dug well construction is required to supplement various supplies in need of rehabilitation and capacity augmentation.

9.11.7 Central Accra Sewerage

In Run 1 the efficiency score was 0.006 relative to the traditional pit latrine. This is a very low efficiency rating suggesting very drastic changes in the delivery system of the Central Accra Sewerage. In Run 2 the efficiency score was still 0.006 which was expected since the traditional pit latrine still dominated the sanitation projects. In Run 3 the inclusion of convenience factor raised the efficiency score to only 0.19. This is surprising since convenience was the best output of this project relative to all the projects and should have caused a greater improvement in the efficiency score. However the strong positive community-based attributes of the traditional pit latrine seem to off-set any gains in output through convenience by the Central Accra Sewerage project. Run 4 produced the same efficiency score of 0.019 as in Run 3. The Central Accra Sewerage is a sophisticated system requiring certain pre-requisites to make it efficient. It is almost impossible to cease operations once some customers are connected. The attempt at pre-financing connections is welcome but what happens if the attempt fails to produce the desired result? The project will remain a burden on the finances of the GWSC. It is advocated that at some stage a meeting of all consumers be convened to decide on the future of the project. The richer industries and commercial companies which, in effect, are being subsidised in the cost of their waste disposal could be asked to contribute additional financial resources to keep the system in operation.

9.11.7 Urban K-VIP Latrine

In Run 1 the efficiency score was 0.066 relative to the traditional pit latrine. This score is very low suggesting improvement in the delivery of the service. Run 2 gave an efficiency score of 0.066 which is the same as in Run 1. The inclusion of the convenience factor raised the efficiency score to 0.111 in Runs 3 and 4. This project is essentially community-based and should eliminate as far as possible external inputs. Provision of more facilities will increase utilization and hence raise the efficiency. The traditional pit latrine model of sanitation delivery is the target to aim at.

9.11.8 Rural K-VIP Latrine

In Run 1 the efficiency score was 0.055 relative to the traditional pit latrine. The project is delivered in similar socio-economic context as the traditional pit latrine but the design of the latrine based on the ventilated pit latrine incorporates too many so-called improvements which seem beyond the capacity of the delivery system to accommodate. For example, although most dwelling houses in the community will be constructed in mud walls the superstructure of the K-VIP Latrine is constructed in materials foreign to the community. Ideas that make the community unduly dependent on outside help should be avoided. Run 2 is essentially the same as Run 1 hence the same efficiency score is recorded. Run 3 gave an efficiency score of 0.064 which is only a slight improvement over Run 1. This is to be expected since the inclusion of convenience should equally affect the Rural K-VIP Latrine and the traditional pit latrine.

9.11.9 Traditional Pit Latrine

The efficiency scores for Runs 1, 2, 3 and 4 are unity. The project is efficient because the delivery system involves no foreign exchange, there is full cost recovery, there is no need for skilled personnel, there is total community involvement, no environmental pollution and very low economic cost. If offers the most attractive solution to the sanitation problem in the rural areas in Ghana. However certain design defects, such as lack of venting facilities, will have to be corrected using local materials such as bamboo. The improvements have to be carried out with the full participation of the community. District assemblies being the focal point of sanitation activities and being the political institution closest to the communities should commission local experts to draw up designs and make them available to the communities for the comments, modifications and implementation with the support from the technical division of the Department of Community Development.

9.12 SIGNIFICANCE OF DATA ENVELOPMENT ANALYSIS FOR THE WATER AND SANITATION SECTOR

The application of Data Envelopment Analysis to projects in the water and sanitation sector indicates, reference Table 9.3, that two basic technologies are efficient in the water sub-sector, that is, the hand dug well and the conventional water treatment plant; and that the pit latrine is the basic technology for the sanitation sector. Existing GWSC strategy for delivery of water supply service in Ghana relies on the conventional water treatment schemes for large urban communities under GWSC central management and hand dug wells for small rural communities under decentralised community management. These aspects of the strategy are vindicated under DEA. However, the other aspects of boreholes and package plants both operated under GWSC management for supply to small urban communities and drilled wells for large rural communities also under GWSC management did not perform well under DEA. On closer examination borehole schemes are not too complex technically especially where pump maintenance is executed by contract. A pilot scheme should be mounted to test the efficacy of community-based management for borehole projects. The package plant, on the other hand, is a sophisticated plant requiring skilled treatment operators, good logistic support and close supervision. Its management is beyond the capabilities of the communities. Therefore either GWSC strengthens the local management and ensures adequate support, which will be difficult to achieve or else accepts the recommendation here to replace all the package plants with less sophisticated schemes such as boreholes, slow sand filters or even multiple hand dug wells. The drilled wells with hand pumps as mentioned elsewhere require further investigation together with other feasible options including boreholes with multiple hand pumps, multiple hand dug wells and small improvements to the traditional sources.

In the sanitation sub-sector incremental improvements to the basic pit latrine technology on the lines suggested by Kalbermatten *et al* (1982) should be the strategy to follow. Note that the final stage of this strategy is not conventional sewerage, as implemented for the Central Accra Sewerage, but solids interceptor tanks with small bore sewers.

DEA should be applied to all projects using a common technology. For example, all projects using the conventional water treatment plants should be analysed to bring out any local problems affecting their efficiency. Efficient projects can be further analysed to provide standards of performance required for all projects in a particular technological grouping. Standards obtained in this way are derived from actual practice in the local environment and hence can be said to be achievable. As and when other projects become efficient through better management the efficiency frontier will change and the newly efficient projects can be analysed to provide lessons for the other projects. In this way standards can be raised gradually in the expectation that inefficient projects will work towards being declared efficient. The competitive situation created can be used to reward operators on projects that achieve efficient status.

Implementation of DEA requires that data on input and output measures should be available. The data requirements will impose the discipline of collection of appropriate data on all projects. Existing data collection procedures are geared towards the final use of these data. Hence all financial data are geared towards producing annual financial statements which are a statutory requirement. Technical data collected in the form of water production reports. plant outages, and maintenance reports are not used to any appreciable extent because the end use of the data collected has not been determined. The data for DEA is specified in consultation with key staff involved and data format prepared to facilitate the collection process. Issuing DEA quarterly, semi-annual or annual reports will demonstrate the use of the data collected and how the results affect each and every project. Project staff will be keen to find out how their project ranks with similar projects and thus obtain a feedback on their performance.

DEA addresses the issue of foreign inputs in projects in the sector in several ways emphasising its importance. This has implications for funding in the sector. External financial assistance on projects has the tendency of increasing the foreign input on the project. Lack of adequate government funding of projects necessarily means reliance on foreign assistance. Indeed where a project is donor-assisted, government counterpart funds are more easily available which is likely to result in a preponderance of projects with relatively high foreign inputs. The problem here is how to convince donor agencies to finance local costs or even untie foreign loans in order to allow supplies from cheaper sources. Financing local costs will encourage local consultants, contractors and local industries to participate in the projects which should reduce costs. Again on sector funding, there is the tendency for projects in the urban centres to be funded directly by government with less than full cost recovered from beneficiaries. Rural communities, however, are requested to contribute funds even before the project starts. It is now an accepted fact that all communities should contribute towards full cost recovery but equity demands that communities be treated equally. It is certainly a greater burden to contribute at the front end than to contribute on consumption of the services. Rural communities being poorer should not be made to bear a greater burden than their richer urban communities.

9.13 APPLICATIONS OF DEA

In project evaluation, data on all input and output factors will have to be assembled, as has been done in this thesis, for all projects using similar technology. The linear programming model will then be formulated as demonstrated in Chapter Five on methodology and then solved to provide efficiency scores which can be used to rank the projects. Further analysis of the projects declared efficient should indicate the improvements required on the inefficient projects. Ex post evaluation can be conducted on a five year or ten year cycle to provide new directions for sector policy reviews.

In project appraisal all data on project inputs will be assembled, as for project evaluation, on any new project planned. Realistic project output levels will be forecast using professional judgement based on experience with similar projects. Previous evaluation of similar projects will be required to provide the efficiency frontier against which the new project will be measured. By formulating a linear programming model based on the input levels as planned and output levels as forecast an efficiency score can be obtained relative to the existing projects. Adjustment can be made to the planned input levels to achieve an efficiency score of unity. The input levels so obtained should provide the basis for design of the optimal delivery of the service.

Another application of the DEA will be in project monitoring. At the appraisal stage the project output level forecasts will be available. When the project becomes operational actual output levels can be obtained and compared with actual input levels through DEA. Project monitoring can be done on quarterly, semi-annual or annual basis depending on what time interval is considered realistic. Ex post evaluation on the other hand will be carried out on five or ten year cycles.

9.14 HYPOTHESIS

The foregoing discussion demonstrates the use of the DEA as an appraisal and evaluative framework based on technical, financial, economic institutional, social and environmental input factors to identify efficient projects deemed effective and sustainable delivery systems for water supply and sanitation services. These projects can serve as models for timely remedial action on inefficient projects. Milton Friedman (1953) states '...the only relevant test of the validity of a hypothesis is comparison of its predictions with experience.....'. Experience confirms the findings of DEA as applied to projects in Ghana. Thus validating the hypothesis which states that timely delivery of effective and sustainable water and sanitation services in Ghana is achievable through an appraisal and evaluative framework that gives due consideration to technical, financial, economic, institutional, social and environmental factors.

CHAPTER TEN

CONCLUSION AND RECOMMENDATIONS

Existing appraisal and evaluation methodologies provide for separate assessment of the technical, financial, economic, institutional, social and environmental aspects of projects without any unifying theory to combine these aspects into a single measure of project performance. Data Envelopment Analysis is proposed as a basic methodology for combining input and output factors of projects into a single efficiency score. The efficacy of the methodology has been demonstrated in the application to data from the water and sanitation sector in Ghana. The single measures, that is, the efficiency scores, have been used to rank projects according to their actual performances in the context of the Ghanaian environment in which these projects are operated. Projects are appraised or evaluated with respect to a frontier of the best practice in the sector in Ghana; the standards are not externally derived but what is achievable given all the constraints in the sector. The methodology is recommended to all countries which are likely to conduct sector studies to take stock of performance during the International Drinking Water and Sanitation Decade.

In order to facilitate the general use of Data Envelopment Analysis in the sector it is recommended that a handbook be prepared setting out the procedure and the data requirements. Each country may have to conduct research to identify appropriate measures of input and output factors. It is further recommended that the dissemination of information on Date Envelopment Analysis should be taken on by the World Bank's International Training Network for Water and Waste Management. The process of dissemination of information should begin with a series of conferences and seminars which should involve other development banks, bilateral donor agencies and various sector institutions involved in appraisal and evaluation of water and sanitation projects. The International Training Network Centres can then follow up with the in-country training and establishment of the data bases.

The application of Data Envelopment Analysis to data from Ghana provided the following conclusions; recommendations for further studies have been suggested where appropriate.

(i) In water supply, the hand dug well and the conventional treatment plant were the efficient systems identified. The hand dug well has a community-based delivery system while the conventional treatment plant had a centralised delivery system. It is recommended that the slow sand filter option should be fully investigated. Rapid sand filtration with chemical pre-treatment should be employed only when it has been proved conclusively that slow sand filtration cannot produce the requisite final water quality.

(ii) Some borehole water supply projects can be handed over to the communities to operate as a pilot scheme to prove the efficacy of the community-based delivery system. If this proves satisfactory then communities should be given the option to run their borehole supplies. So far centralised operation of all borehole water supplies have not proved efficient.

(iii) Package plant water supply systems should be replaced by alternative systems that can be operated by the communities. Suggested alternatives include slow sand filtration treatment plants, boreholes and multiple hand dug wells.

(iv) Drilled wells for single hand pumps should be further investigated together with other alternatives such as hand dug wells, boreholes with multiple hand pumps and small improvements to traditional water sources.

(v) In sanitation the basic technology of the pit latrine with community-based delivery system should be the model to adopt. Improvements to the basic technology will be undertaken with the full participation of the communities. All stages of upgrading of the pit latrine should be acceptable and affordable to the communities.

(vi) All projects should include a timetable for achieving full cost recovery which should be fair to both urban and rural communities. The system whereby rural communities are made to contribute at the front-end while urban communities are able to obtain financing either from the government or foreign donors is inequitable and should be streamlined to ensure equity for all communities.

(vii) Cost reduction measures should be encouraged on all projects. In furtherance of this aim local consultants, contractors and wherever possible local materials should be employed on projects. Financing of projects by donors should include local financing to help realise the cost reduction objective.

(viii) Skilled personnel are a scarce resource in Ghana and every effort should be made to limit demand for this resource on water supply and sanitation projects. However, to ensure adequate supply of skilled personnel training institutions should be well funded to discharge their responsibilities. It is recommended that the question of training institutions for the sanitation sub-sector should be seriously addressed in order to provide District Assemblies with the much needed personnel to enable the Assemblies discharge the gigantic responsibility in sanitation.

(ix) The sanitation sub-sector requires a strong institution that will provide planning and technical support to District Assemblies. The absence of an institution similar to GWSC in sanitation partly accounts for the poor performance to date.

(x) Community involvement in projects is beneficial regardless of whether the projects have community-based or central delivery systems. Metropolitan Assemblies in the cities and District Assemblies in the urban and rural areas should ensure that there is enough community involvement in the decision making process to offset the imposition of inappropriate projects similar to the Central Accra Sewerage project.

(xi) Environmental factors especially sullage and sludge/sewage disposal should be given greater attention in project design. The present casual attention to sewage disposal is unacceptable since beach pollution would inhibit the development of a potentially lucrative tourist industry in Ghana in addition to the public health hazard created.

(xii) Years of economic decline in Ghana have had serious adverse effect on water supply and sanitation installations round the country. Project reliability has suffered due to diminished resources for operation and maintenance. To prevent future recurrence of such undesirable situations projects will have to be designed to maximise reliability. This means unnecessary sophistication will have to be eliminated and resources for operation and maintenance should be completely mobilised within the community. Water supply and sanitation systems that depend on external inputs for operation and maintenance are highly vulnerable to interruptions in the flow of these inputs and should therefore minimise, if not eliminate, these external inputs.

(xiii) Project benefits are captured only when project outputs are utilised. Utilisation of project outputs should be promoted through early community involvement and education.

(xiv) Enhancement of convenience and accessibility of project facilities promote utilisation of project outputs and should be emphasised in project design.

(xv) Data Envelopment Analysis should be adopted as an appraisal and evaluative framework for water supply and sanitation projects in Ghana. Research must be conducted to verify and approve or modify input and output factors as specified in this thesis. Data collection on a continuous basis will then have to be established.

(xvi) Handbooks and training materials will have to be prepared and managers in the water supply and sanitation sector from the district level to the national level will have to be trained at the International Training Network Centre recently established at the University of Science and Technology, Kumasi, Ghana.

(xvii) Data Envelopment Analysis should be applied to specific classes of projects, for example, conventional water treatment plants, borehole water supply projects, package plants, urban K-VIP latrines, rural K-VIP latrines etc. Efficient projects identified in each class should be used to set standards for the others in that class. Attainment of efficient status should be used to reward operators on those projects.

Finally, it is hoped that this modest research contribution in the application of Data Envelopment Analysis to water supply and sanitation projects will only be the beginning of further work to establish DEA as a useful tool in the sector.

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APPENDIX A

DATA ON ACCRA-TEMA WATER SUPPLY PROJECT

1. Technical Factors

(a) Water Production Technology: as described in Chapter 7.

(b) Water Distribution Technology: as described in Chapter 7.

(Sources: 1. *Accra-Tema Water Supply and Sewerage Project - Review of Master Plan Vol. 1*, December 1981.
2. *The Master Plan Engineering Report for the Accra-Tema Metropolitan Area: Vols 1-4*, 1965.
3. TAHAL Consulting Engineers - Tel-Aviv, Israel and Accra, Ghana.

(c) Operations:
Consultant/manufacturers instructions and handbooks are available to operators who were trained on the plants by the foreign technical staff who commissioned the plants. Phase 1 works at Kpong had all key staff trained in West Germany.

Plans for: Plant operating plans and schedules have been prepared and are available to operators. Distribution operations plans and schedules have been prepared and are available to the distribution staff. The entire distribution area has been divided into districts which include Accra Central District, Accra West District, Accra Northwest District, Accra North District, Accra East District, Madina District, Dansoman District and Tema District.

Actual Operations: Operations of Kpong and Weija Treatment Plans are as close to design and operating schedules as possible. Observation of operations for 42 days indicated 90 per cent attainment of plans and schedules. Due to improvement in raw water quality at Kpong, alum dosage has been discontinued. There is however a tendency for shorter filter runs i.e. reduction from the initial 72 hours with pre-treatment to 24 hours without pre-treatment.

Weija treatment experiences frequent power outages and frequent choking of alum and lime pipelines. Alternative manual lime dosage are provided. Backwashing of filter causes loss of filter media necessitating frequent sand topping.

Periodic flushing of distribution not operated satisfactorily. There are no continuous recording pressure gauges to permanently monitor the system.

Plans for Effective Operations: Electricity Corporation of Ghana is carrying out rehabilitation works to improve the power supply to Weija. No standby generators are deemed necessary. Portable pressure recorder have been ordered to improve distribution operations. Leakage survey has been revived, after a long break, to reduce unaccounted-for water.

(d) Maintenance - Plans for:

Plans for maintenance are available in consultant/manufacturers instructions and handbooks. Some instructions have been consolidated into preventive maintenance and inspection/lubrication schedules. Plans for preventive maintenance of the distribution system are available.

Actual Maintenance: Preventive maintenance is well operated at Kpong however some electrical modules for plant control and data logging have broken down. Kpong treatment works is schedules for major rehabilitation under the Phase III programme. Kpong-Tema-Accra steel transmission under rehabilitation due to failure of the cathodic protection. Weija plant is new and has large stocks of spare parts purchased during plant commissioning. Preventive maintenance schedules are well operated. After observation - 42 days observation - it is assessed that 90 per cent of all maintenance work scheduled is attained.

Requirements for Effective Maintenance: Training of supervisors in maintenance management and artisan/tradesmen for improved maintenance practices.

(e) Faults:

Power outages at Weija are very frequent. 193 faults occurred lasting a total of 707 hours 7 mins in 3 years (1986-88).

Frequence of fault: 1 fault in 5.67 days

Duration: Average 3.67 hours per fault.

Plant downtime is: 2.7 per cent

(f) Water Quality:

Average measurements of various water quality parameters are presented for Weija and Kpong. More than 50 samples were taken at each source by chemists.

	Weija Water		Kpong Water	
Parameter	Raw	Final	Raw	Final
pH			7.1	7 - 8.1
Temperature (^{o}C)	27	27	28	28
Colour	80	5	7	5
Total Hardness (mg/l)	95	117	26	27
Nitrate (mg/l)	0.64	0.37	0.6	0.4
Sulphates (mg/l)	8.8	17.4	NIL	NIL
Chlorides (mg/l)	38	43	6.3	10.0
Silica (mg/l)	11.1	7.3	10	9.7
Iron (mg/l)	0.47	NIL	0.1	NIL
Manganese (mg/l)	0.36	NIL	0.18	NIL
Total Solids (mg/l)	56.4	54	284	281
Residual Chlorine (mg/l)	-	0.33	-	0.8

(g) Water Quality and Utilisation:

Treatment plants at Kpong and Weija are operated 24 hours daily. Three year average production at Kpong was 170136m^3/d (37.34 mgd) and at Weija 71409 m^3/d (15.79 mgd).

Water distribution in the Accra-Tema Supply area serves 80 per cent of the population.

Water utilisation is taken as 80 per cent.

(Source: Monthly Production Reports - Kpong and Weija, GWSC Files.
African Development Bank (1988))

2. <u>Financial Factors</u>

(i) *Cost*

(a) <u>Capital Cost:</u>

Phase 1 was completed at a cost of $34.834 million on supplier's credit guaranteed by the government of the Federal Republic of Germany. (Source: World Bank (1969).

Foreign cost component: 60 per cent

Phase 2

Project costs are presented below (World Bank, 1983b).

Component		Local Cost cedis	Foreign Cost US$
IDA		23,823,000	10,357,000
CIDA		4,224,000	8,644,000
ADB		13,849,000	8,200,000
GWSC		25,552,000	-
Total		**67,448,000**	**27,201,000**
	(US$	**24,526,545)**	
Grand Total	**US$**	**51,727,545**	

Foreign costs adjusted to 60 per cent since the GWSC components contain foreign elements not accounted for above.

(b) <u>Operation and Maintenance</u>

Phase 1

Figures derived from the accounts of the Accra-Tema Metropolitan area of GWSC provided an irregular cash flow. The annual equivalent at 15 per cent and 20 years was calculated as $3.80 million.

(Sources: Annual Accounts ATMA - GWSC
World Bank (1969, 1974, 1977, 1983.)

Phase 2

Equivalent Annual Operating and Maintenance cost was calculated as $5.0 million.

(Sources: Annual Accounts ATMA - GWSC.)

(c) Design Life

Civil Works - 50 years

Electrical/Mechanical Equipment - 20 years

Pipelines - 50 years

(Sources: GWSC Assets Capitalisation/Depreciation Section
TAHAL Consulting Engineers.)

(d) Replacement Cost

Current cost escalated by the rate of inflation.

(ii) *Income*

(a) Tariff: $0.17 - 0.77 per m^3$

Unmetered house connection	$1.80 per month per household
Drawers from standpipes	$0.80 per month per household
Wells with handpump	$0.50 per month per household

(b) Billing/Collection:

Billing provided an irregular cash flow with an equivalent annual billing of Phase 1: $3.98 million

Phase 2: $5.33 million

Collection:

Phase 1: $2.49 million

Phase 2: $3.62 million

(Source: GWSC Revenue Section.)

(c) Government Financing:

Government financing is a grant to GWSC - 25,552,000 cedis (US$9,291,636) for Phase 2 project.

(d) Local Government Financing:

There is no local government financing in both Phase 1 and 2.

(e) Donor Financing:

Phase 1: Government of Federal Republic of Germany suppliers credit $34.834 million

Phase 2:	IDA (Loan)	\$10.4 million
	CIDA (Loan converted to grant)	\$10.18 million
	ADB (Loan)	\$13.24 million

(f) Community Financing:

No community financing involved in both Phase 1 and 2.

(iii) Ability to Pay

Drawers from standpipes paid \$1.40 per household per month. However standpipes have been reduced to the barest minimum. Water from community standpipes is charged at \$1 per m^3 (rather expensive). Minimum charge for unmetered house connection is \$1.80 per household per month which is about 5 per cent of household income of 2 people earning minimum wages (\$18.36 per month) i.e. \$36.72 per month.

(iv) Willingness to Pay

Willingness to pay is demonstrated by the rates paid to water vendors which is in the range \$1-\$5 per m^3.

(Source: Interviews with water vendors in Accra.)

3. Economic Factors

(i) Cost

(a) Capital Cost:

Phase 1: \$34.834 million

Foreign cost component:	60 per cent
Unskilled labour component:	10 per cent
Remaining local cost:	30 per cent

Phase 2: \$51.7 million

(b) Operations and Maintenance:

Phase 1

Annual Operations and Maintenance Cost: \$3.80 million

Foreign cost component:	40 per cent
Unskilled labour component:	10 per cent
Remaining local cost:	50 per cent

Phase 2

Annual Operation and Maintenance Cost: $5.00 million

(c) Design Life:

Civil Work: 50 years

Electrical/mechanical Equipment: 20 years

(d) Replacement Cost:

Current cost escalated by the rate of inflation.

(ii) Benefit

(a) Revenue:

Annual Revenue:	Phase 1	$2.49
	Phase 2	$3.62

(b) Least Cost Solution:

Conventional water treatment plant with rapid gravity filters should be compared with slow sand filters producing comparable water quality. Consultants only mention the slow sand filter as an alternative without providing designs for the slow sand filter for comparison with the rapid gravity filters.

(iii) Shadow Prices

(a) Exchange Rate:

Official Exchange Rate (Auction Rate since 1987)

1967	US$1.00 - 1.02 cedis	1984	US$1.00 - 35.99 cedis
1971	US$1.00 - 1.82 cedis	1985	US$1.00 - 54.37 cedis
1972	US$1.00 - 1.28 cedis	1986	US$1.00 - 90.00 cedis
1973	US$1.00 - 1.15 cedis	1987	US$1.00 - 162.37 cedis
1978	US$1.00 - 2.75 cedis	1988	US$1.00 - 200 cedis
1983	US$1.00 - 20.33 cedis	1989	US$1.00 - 280 cedis

(Sources: *Quarterly Digest of Statistics*, December 1987.
Ghana Commercial Bank Quarterly Economic Reviews
West Africa - various editions.)

Black Market Rates		Forex Bureau Rates	
1983	US$1.00 - 97 cedis	1987	US$1.00 - 250 cedis
1984	US$1.00 - 135 cedis	1988	US$1.00 - 300 cedis
1985	US$1.00 - 160 cedis	1989	US$1.00 - 360 cedis

(Source: Younger, 1989 and West Africa - various editions.)

Discussion with World Bank officials in Accra and at the Institute of Social and Statistical Research, University of Ghana, Legon Accra gave shadow price of exchange rate as 1.5 x Official Rate reference 1987, 1988 Forex Rate/Auction Rate.

(b) Wages:

Minimum Wage

1986	$1.00 per day	$27 per month
1987	$0.68 per day	$18.36 per month
1988	$0.68 per day	$18.36 per month
1989	$0.68 per day	$18.36 per month

Agricultural Wage

1987	$1.54 per day	$41.58 per month
1988	$1.50 per day	$40.50 per month
1989	$1.53 per day	$41.31 per month

Discussion with World Bank officials in Accra and at the Institute of Social and Statistical Research, University of Ghana, Legon gave the shadow price of Unskilled Worker as two times the minimum wage.

(Source: *Quarterly Digest of Statistics* and Ministry of Agriculture, Ghana.)

(c) Land:

Most land is held as leasehold. Agricultural land is leased at $20 per acre per annum.

(iv) Interest Rates

Interest Rates (% per annum)

	Pre-October 1983	October 1983	August 1984	December 1984	May 1985	September 1985	October 1986	March 1987
BANK OF GHANA								
Discount Rate	10.5	14.5	16.5	18.0	18.0	18.5	20.5	23.0
Advances to Government	10.5	14.5	16.5	18.0	18.0	18.5	20.5	23.5
Treasury Bill Discount Rate	9.5	13.0	15.5	16.75	16.75	17.75	19.75	22.75
COMMERCIAL BANKS								
Savings Deposits	8.0	11.0	13.0	14.5	15.5	16.5	18.5	21.5
Time or Fixed Deposits								
Three months	8.25	11.25	13.25	14.75	15.75	16.75	18.75	21.75
Six months	8.5	11.5	13.5	15.0	16.0	17.0	19.0	22.0
Twelve months	9.0	12.5	14.5	16.0	17.0	18.0	20.0	23.0
Twenty-four months	-	-	-	-	18.0	18.0	22.0	25.0
Lending Rates								
With Bank of Ghana Guarantee	-	-	-	-	20.0	20.5	2.30	-
Without Bank of Ghana Guarantee	-	-	-	-	22.5	23.0	23.0	-
Agriculture, Forestry	-	-	-	-	16.0	18.5	22.5	23.0
All Other Sectors	-	-	-	-	20.0	20.5	23.0	26.0

Source: *Quarterly Digest of Statistics* (various issues), Statistical Service, Accra.

Public Investment Programme - 15 per cent minimum.

(v) *Consumer Price Index*

	Weights	1980	1981	1982	1983	1984	1985	1986
Bev & Tobacco	6.2	514.3	1178.8	1059.2	2303.8	3907.2	4801.5	6369.4
Clothing	19.2	398.6	926.7	1049.0	2085.5	3604.3	4643.7	5732.6
Rent Fuel & Power	6.8	397.8	647.4	691.0	1721.9	3142.7	3372.8	4807.3
Furniture	5.1	471.8	1207.0	1256.4	2429.1	4765.2	5404.0	6829.0
Health	1.8	433.8	727.1	796.1	1991.6	3143.8	4100.2	4754.5
Trans & Comm	4.3	398.8	789.1	796.7	1608.4	3031.4	4741.5	6364.6
Recreation	5.5	404.4	744.2	1019.6	1406.6	2660.6	4435.3	5317.0
Miscellaneous	1.9	431.1	850.2	1167.0	2255.1	3919.7	4987.1	5917.2
Combined Index	100.0	401.2	868.7	1062.4	2357.4	3304.2	3647.2	4543.1
Change over Previous Year (%)			116.5	22.3	121.8	40.2	10.4	24.6

Source: *Quarterly Digest of Statistics*, Vol. V, No. 1, March 1987, Statistical Service, Accra.

4. Institutional Factors

(i) *Construction*

Phase 1

The main works of treatment plant, transmission mains and reservoirs were executed on contract by West German contractor - STEPRI. Local contractors were engaged for the High and Medium Pressure Zone Reservoirs and for distribution pipelines. Force account was used for separating the distribution network in zones.

Phase 2

Weija dam was constructed by an Italian contractor, mechanical/electrical equipment supply and installation was executed on contract by the Canadian contractors - Adam Clark. Treatment plant and transmission mains were executed on contract by local contractors. Distribution pipelines were undertaken by local contractor.

(ii) *Operation and Maintenance*

Weija Headworks is operated by a staff of 105 persons and Kpong Headworks is operated by 96 persons and Distribution System is operated by 343 persons. However, the operation of the entire works in Accra-Tema Metropolitan are includes other treatment networks at Weija and Kpong, booster stations, workshops, meter shop and the Area Manager's office. Supporting staff from head office also carry out services on behalf of Accra-Tema Metropolitan Area. It is assessed that 544 skilled persons are engaged in providing water supply services to 80 per cent of the 1.42 million persons in the supply area.

(iii) *Logistics*

Fuel supply is executed on contract by the Ghana Oil Company operating from the refinery at Tema. ATMA has two main fuel depots in Accra. Weija and Kpong have smaller depots since most equipment is operated with electrical power.

Kpong and Weija have capacity to store three months stock of chemicals. The main chemical depot for GWSC is located at Tema which also stocks chemicals for the whole country. The treatment works at both Kpong and Weija enjoy priority in the allocation of chemicals when there are late arrivals of orders from abroad.

(iv) *Training*

Water treatment attendants and pump and engine attendants are trained at the GWSC Operator School at Owabi, Kumasi. Middle level staff are trained at the GWSC Technician/Supervisor Staff School at Weija. This school is currently being developed by the World Bank and the ODA to serve English-speaking West Africa. A government sponsored Management Development and Productivity Institute also draws staff at District Manager level for courses in Effective Supervisory Practices. GWSC Top Management and the Professional personnel have access to overseas post-graduate training and can also attend short courses at the Ghana Institute of Management and Public Administration.

(v) *Legal Responsibility/Declared Aims*

GWSC was created by an Act of Parliament (Act 310) effective from September 1966 and was charged with:

(a) the provision, distribution and conservation of the supply of water in Ghana for public, domestic and industrial purposes, and

(b) the establishment, operations and control of sewerage systems of such purposes.

The Act, after 20 years, has been found to be defective. A new Act is under consideration by the government to allow effective decentralisation and community participation. Further GWSC will be able to establish tariffs that will enable it to attract loans and repay them from their own resources.

Donors continue to support the Accra-Tema Metropolitan Area in order to make it strong enough to provide cross-subsidisation for the smaller urban and rural supplies.

5. <u>Social Factors</u>

(i) *Taste/Odour*

Algal blooms on the Weija lake impart taste and musty odour to the water. he taste and odour are bearable. Areas to the west of Accra which receive water from Weija treatment plant are mainly affected. Kpong water is preferred to Weija water.

(ii) *Distances Travelled*

Those in the inner city without yardtaps travel up to 100 metres to neighbours or water vendors or community standpipes. In the peri-urban areas distances travelled may be up to 500 metres. No acceptable traditional sources available.

(iii) *Queuing Period*

Queuing period in the slum and peri-urban areas are up to 30 minutes at the community standpipes or private water vendors. (Observations were carried out in the Nima slum area.)

(iv) *Type of Collection Containers*

Individual carriers:	10 - 35 litres average 18 litres
Carts:	up to 200 litres
Water Tanks:	4500 - 7500 litres

(v) *Community Involvement*

(a) <u>Request for project:</u>

Yes, consumers request for extensions.

(b) <u>Level of Services/Coverage:</u>

Community is not involved in the decision on level of service or coverage provided.

(c) <u>Dialogue:</u>

There is no established dialogue with community.

(d) <u>Commitment:</u>

Community is not required to show commitment to the project in any way.

(e) Appropriate Technology:

The community is not involved in selection of technology. However, the slow sand filtration option should have been considered. Public hearing on projects is recommended.

(f) Willingness to Pay:

Community has demonstrated willingness to pay.

(g) Cost Recovery:

The community is aware that the service is subsidised.

(h) Ability to Pay:

The community possesses the ability to pay. Minimum charges are within 5 per cent of income.

(i) Decision Making:

Community is not generally involved in decision making.

(j) Responsibility:

Community does not share in the responsibility to provide the service.

(vi) Population

Population in the service area is 1.42 million (1984).

Population structure:

0 - 14 years	45 per cent
15 - 65 years	51 per cent
> 65 years	4 per cent
Education	56 per cent primary school or better
Female to Male ratio:	1.03
Religion:	Mostly Christian or Animist
Population Density:	150 persons per hectare

(vii) Alternative Facilities

No acceptable alternatives exists. Streams are highly polluted and wells are saline.

6. <u>Environmental Factors</u>

Sullage disposal is into open drains except in houses which are connected to sewers. Some sullage is intercepted into the Central Accra Sewerage. Proper sullage disposal depends on each house connecting to the city open storm drains or providing individual house soakage pits. Storm drains need to be kept clear of any solid waste to avoid ponding of sullage creating nuisance and promoting breeding of mosquitoes.

It is estimated that $2.0 per person is required to provide connection to the open drains or to provide a soakage pit.

APPENDIX B

DATA ON BOREHOLE WATER SUPPLY PROJECT

1. Technical Factors

(a) Water Production Technology: as described in Chapter 7.

(b) Water Distribution Technology: as described in Chapter 7.

(Sources: (i) Occurrence of Groundwater, Ghana Sector Study, 1970.
(ii) Draft Five Year Development Plan, May 1986.)

(c) Operations - Plans For:

Borehole schemes were planned to be operated 24 hours a day: on three shifts of 8 hours. Manuals for operations are available. Attendants are trained to detect faults and to keep operational records.

Actual Operations: Communities with good revenue collection performance are operated on 24 hour basis. Most schemes operate on a 4 - 10 hour per day basis. A few schemes are operated on alternate days. Where the capacity of the installation is inadequate sections of the community are served on rotational basis. For example, the town of Suhum is served on a three-day rotation for three sections of the town. The Akim-Oda town is served on a seven-day rotation.

Effective Operations Requirements: Improved revenue collection and improved fuel supply.

(d) Maintenance:

All Pleuger Submersible Pumps are maintained on contract by Water Engineering Company, agents of Pleuger Pumps. Pumps are inspected every three months. Other installations are maintained by the GWSC Regional and District staff.

Actual Performance: Water Engineering Company, generally adhers to the three-monthly visits. However, the company has no regional workshops and major repairs have to be carried out in Accra causing long periods (several months) of delay. GWSC regional workshops operate within the constraints of available spare parts.

Requirements for Effective Maintenance: Spare submersible pumps should be available for replacement of pumps requiring attention in Accra. Spares for generator sets, engines and reciprocating pumps should be made available under strict security. Training of maintenance personnel should be continuous.

Operations and Maintenance procedures were observed for 32 days to assess the percentage attainment of Operation and Maintenance plans and schedules.
60 per cent attainment for Operations assessed.
70 per cent attainment for Maintenance schedules assessed.

(e) Faults:

Average hours of Operation:	10.5 hrs/day
Down time (period of no production):	21.7 per cent

(Source: Production Reports for the 20 stations visited. GWSC - 1986-88.)

(f) Water Quality:

Water quality data from a sample of 375 boreholes were collected and analysed by Mallari (1969) and Amuzu (1974).

Calcium:	Range of concentration 0.8-1000 mg/l. Only 2 per cent of samples exceed Maximum Permissible Level of 200 mg/l.
Chloride:	Range 0.0-2700 mg/l with 2 per cent of samples exceeding Maximum Permissible Level of 600 mg/l.
Iron:	31 per cent of samples exceed Maximum Permissible Level of 1.0 mg/l. Range of concentration 0-26.5 mg/l.
Magnesium:	1 per cent of samples in excess of Maximum Permissible Level of 150 mg/l.
Sulphate:	2 per cent of samples were in excess of the Maximum Permissible Level of 400 mg/l. The highest concentration found was 971 mg/l.

Total Dissolved Solids: 2 per cent of samples were in excess of Maximum Permissible Level of 1,500 mg/l as $CaCO_3$. The highest concentration was 3038 mg/l.

Total Hardness: 2 per cent of samples were in excess of the Maximum Permissible Level of 500 mg/l as $CaCO_3$.

Nitrate: Concentrations were all within the Maximum Permissible Level of 45 mg/l.

Manganese: 17 per cent of the samples exceeded the Maximum Permissible Level of 0.05 mg/l. The range of concentrations measured was 0-4.5 mg/l.

pH: 40 per cent of samples were outside the desirable range of 7.0-8.5. Most samples were probably less than 7.0.

(g) Water Quantity and Utilisation:

Yields of boreholes visited were in the range of 5.0-40 m^3/h. Depth of borehole depends on the formation in which it is located. Borehole logs for all boreholes drilled are available at the Drilling Section of GWSC. A typical borehole log is as follows:

Town:	Effiduase	
Borehole No:	AC 2	
Static Water Level:	1.2m	
Dynamic Water Level:	23.8m	
Yield:	11.9 m^3/h	
Depth:	76m	
Date Drilled:	20-1-64	
Geological Log:	0 - 13.1m	Laterite and Clay
	13.1m - 21.4m	Sand Stone
	21.4m - 61m	Weathered Granite
	61m - 76m	Hard Granite

The typical borehole installation will have two boreholes with capacity of about 22.73 m^3/h.

Water utilisation was assessed on the percentage of borehole water to all water used in the household. With 200 households surveyed, the percentage utilisation had a mean of 50 per cent.

2. Financial Factors

(i) *Cost*

(a) Capital Cost (1989 Exchange rate $1 - 1.02 cedis)

Capacity of installation:	22.73 m^3/h
Drilling of 2 Boreholes:	$20,000
2 Submersible Pumps:	$ 8,240
4 Generation Sets:	$40,000
2 Generator Rooms:	$10,000
1 Elevated Tank:	$10,000
Distribution Network:	$30,000
Total	**$118,240**

Foreign cost component is estimated at 65 per cent.

Total cost for 91 projects $10,759,840

(b) Operations:

Cost of operations per installation per annum:

Personnel:	$6,000
Fuel/Electricity:	$3,000
Transportation:	$ 500
Overhead:	$1,000
Total	**$10,500**

Foreign cost component - 25 per cent.

(c) Maintenance:

Maintenance cost per installation per annum: $3,000

Foreign cost component: 25 per cent

(Source: GWSC Projects Section, Head Office.
Production Reports, Head Office.
GWSC Operations and Maintenance Department.)

(d) Design Life:

Civil Works:	50 years
Boreholes:	20 years
Pumps:	20 years
Generator Sets:	20 years

(Source: GWSC Assets Depreciation Section.)

(f) <u>Replacement Cost</u>:

Current cost escalated by the inflationary rate. Plans exist for plant replacement in the Five-Year Development Plan.

(ii) *Income*

(a) <u>Tariff:</u>

$0.17 - 0.77 per m^3

Unmetered house connection:	$1.80 per month per household
Drawers from standpipes:	$0.80 per month per household
Wells with handpump:	$0.50 per month per household

(b) Average Annual Billing per unit: $2,500

Average Annual Revenue per unit: $1,785

(Source: Revenue Section, GWSC, Head Office.)

(c) <u>Government Finance:</u>

Borehole schemes were financed entirely from government sources. For 91 projects government provided $10,759,840. Government provides subsidy for operations and maintenance cost.

(d) There was no local government, donor or community finance involved in the Borehole Water Supply Project.

(e) <u>Ability to Pay:</u>

Minimum tariff is computed at 5 per cent the household income i.e. two persons earning minimum wage.

(f) <u>Willingness to Pay:</u>

Low quality of service provided by the Borehole Water Supply scheme has resulted in the intensive use of traditional sources. Consumers should be consulted to ascertain willingness to pay for improved service.

3. Economic

(i) Cost

(a) Capital Cost per installation: $118,240

Foreign cost component:	65 per cent
Unskilled labour component:	8 per cent
Remaining local cost:	27 per cent

(b) Annual Operation and Maintenance Cost: $13,500

Foreign cost component:	25 per cent
Unskilled labour component:	25 per cent
Remaining local cost:	50 per cent

(c) Design Life: see Financial Factors.

(iii) Benefit

(a) Revenue:

Average annual revenue from 91 projects is: $162,435.

(b) Least Cost Solution:

The project offers least cost solution for water supply to communities between 2000-40,000 persons wherever borehole yields are found to be adequate.

(iv) Shadow Prices

(a) Exchange Rate: See Appendix A.

(b) Wages: See Appendix A.

(c) Land: See Appendix A.

(v) Interest Rates See Appendix A.

4. Institutional Factors

(i) Construction

Construction of project was mainly by force account with some jobs awarded on contract where force account could not be effectively mobilised. Drilling was by force account, however, boreholes drilled earlier by contract were incorporated into the project.

Submersible pumps were supplied by Pleuger Pumps, West Germany. Generator sets were supplied by Brush, Britain. Pressed steel tanks were supplied by Braithwaite, Britain.

(ii) *Operations and Maintenance*

Pleuger pumps are maintained on contract by Water Engineering Company, agents of Pleuger Pumps. GWSC operates and maintains all other facilities under its regional and district organisations. The typical installation of two boreholes will be operated by a staff of three pump and engine attendants and two watchmen. However, supporting staff from the regional and district office and overhead staff from GWSC head office provide various services to the stations. Thus an equivalent of four skilled staff are responsible for each station.

(iii) *Logistic*

Fuel (diesel oil) is the main commodity to be supplied on regular basis. This is a major task given the standard of roads. 91 stations spread around the country are supplied on monthly basis. Fuel storage tanks are available at each station. However, large stocks cannot be held at individual stations for security reasons. Also, fuel supplies have been tied to the level of revenue collection at the various stations.

(iv) *Training*

Training of pump and engine attendants takes place on rotational basis at the GWSC Operators School at Owabi, Kumasi. Attendants are trained and given refresher courses on a five year rotation.

(v) *Legal Responsibility*

GWSC by its Act of Incorporation is responsible for providing water supplies to all communities. Communities, with population in excess of 2000 persons, which can be supplied from groundwater sources are included in this project.

5. Social Factors

(i) *Taste/Odour*

The iron content can be quite high but in most cases the iron levels are tolerable. Water has a slight bitter taste which the communities, generally, get used to. There were no serious complaints.

(ii) *Distance Travelled*

The borehole schemes have a fully developed distribution system. Distance travelled 20-150m with an average of 80 metres. Traditional sources have an average distance of 700m.

(iii) *Queuing Period*

Queuing is a major problem on these projects, hence traditional sources are heavily used. Queues are sometimes formed with containers even when the taps are not running. Queuing period can be up to 60 minutes with an average of 40 minutes.

(iv) *Type of Collection Containers*

Size of collection containers are in the range of 10 - 35 litres with an average of 18 litres.

(v) *Children*

Children can draw water without any difficulty when queues are orderly. When quarrels and struggles develop children may queue for longer periods.

(vi) *Community Involvement*

(a) Request for Project:

Yes, communities made request for project.

(b) Level of Service/Coverage:

No, communities were not consulted.

(c) Dialogue:

No, there is no established dialogue between GWSC and communities.

(d) Commitment:

Communities were not required to show any commitment to the project in any way.

(e) Appropriate Technology:

Choice of technology was appropriate.

(f) Willingness to Pay:

Communities have shown willingness to pay by paying about 70 per cent of the bills.

(g) Cost Recovery:

Communities were not consulted on cost recovery. Level of tariff is low.

(h) Ability to Pay:

Community has ability to pay rates at their current levels. For using standpipes flat rate of $0.80 per month is charged to a household income of $36.72 per month.

(i) Decision Making:

No, community is not involved in general decision making.

(j) Responsibility:

Community does not share in the responsibility for the delivery of the service.

(vii) Population

Most of the communities served are in the population range of 2000 - 10,000 persons with a few up to 40,000. Population served by 91 borehole water supplies is 808,808 (1984) giving an average of 8,888 persons per installation. Projected population 943,473 (1990).

Population density:	80 persons per hectare
Population Structure:	
0 - 14 years	51 per cent
15 - 56 years	45 per cent
> 65 years	4 per cent

Education 56 per cent: Primary school or better.
Religion: Mostly Christian or Animist

Smaller communities are typically farmer communities but significant commercial activity exist in large communities.

(viii) Alternative Facilities

The traditional sources are still in use. Some hand dug wells with rope and bucket are available in the project area.

6. <u>Environmental Factors</u>

Sullage Disposal

Sullage is spread out to control dust or else allowed to run into natural storm gullies. No serious environmental problem exists.

7. <u>Borehole Stations Visited</u>

Upper West Region - Wa, Lawra, Jirapa
Upper East Region - Nayrongo, Paga, Bawku
Brong Ahafo Region - Nsawkaw, Seikwa
Ashanti Region - Juabeng, Effiduasi
Western Region - Bogoso, Aboso
Central Region - Diaso
Eastern Region - Adeiso, Suhum, Akim Oda
Volta Region - Agbozume, Abor, Anyako Afiadenyigba

APPENDIX C

DATA ON PACKAGE PLANT WATER SUPPLY PROJECT

1. Technical Support

(a) Water Production Technology: as described in Chapter 7.

(b) Water Distribution Technology: as described in Chapter 7.

(Sources: GWSC Project files, Head office.
Paterson Candy International, Instruction Manual 1969.)

(c) Operations - Plans for:

The complete manual for installation, operation and maintenance is available. This plant is a relatively sophisticated and all personnel involved with this operation - technical assistants, chemists, and the operators had to undergo special training. Plans are available for the regular delivery of fuel and chemicals.

Actual Operations:

Operations involve keeping the river intake clear of debris and mud; keeping the raw water pumps operable with adequate supply of fuel. At the treatment plant, chemicals i.e. alum, soda ash and bleaching power are prepared to the required strength, sieved to remove any particles likely to block the small-bore connecting tubings and the chemicals are fed into the dosers. Feeding chemicals into the dosers is a delicate operation which often results in tearing of the flexible sac in the doser - spare flexible sacs are not always available.

Filter automatic backwash systems broke down and could not be repaired. Thus all plants have been modified to manual backwash.

Irregular supply of chemicals result in partial or lack of treatment. Raw water is pumped through the filters causing mudballs in the filters and causing early replacement of filter media.

Requirements for Effective Operations:

Availability of fuel and chemicals will have to be improved. Lack of chemicals resulted in poor quality water 58.7 per cent of the time (1986-88). River intakes are usually quite a distance from the communities and access roads need to be effectively maintained. Operators require further training as most of them still do not fully understand the plant operation even after 20 years due probably to frequent personnel movements from plant to plant.

Observed attainment of Operation Plans is 50 per cent.

(d) Maintenance - Plan for:

Maintenance schedules are available in the Installation, Operation and Maintenance Manual. Procurement of spares however depend on the availability of foreign exchange.

Actual Maintenance:

Level of preventive maintenance was observed as 50 per cent due to lack of spare parts. Paterson Candy International do not have an accredited local agent. A survey of maintenance needs on the 69 package plants carried out in 1984 revealed that six settling tanks, 29 filters and 29 elevated tanks require repairs while 61 dosing devices require replacement.

GWSC maintains a Package Plant Maintenance Unit which provides support for the regions. Since 1987 the West German government has been providing assistance for the rehabilitation of package plants.

Requirements for Effective Maintenance:

Spare parts and transport (vehicles) are the main requirements for effective maintenance. Staff training in maintenance should be improved.

(e) Faults:

From the 20 plants investigated:

Average hours of operation:	8 hours per day
Downtime (period of no production):	20.3 per cent
Percentage of time when plants operate no chemicals or inadequate supply of chemicals:	58.7 per cent

(f) Water Quality:

For most water quality parameters surface water are within the acceptable limits established by the WHO Water Quality Standards. However, lack of chemicals for treatment provided:

pH values in the range:	5.0 - 6.8
Colour in treated water:	5 - 175 Hazen Units
Taste/odour:	acceptable

Lack of equipment prevent regular bacteriological tests. However occasional tests show 70 per cent positive growth. This is because the occasional lack of chemicals allow the bacteria to grow in the distribution system. Hence when chemicals become available later treated water is contaminated on entering the distribution system.

(g) Water Quantity and Utilisation:

Package plants are rated at 9.09 m^3/h (2000 gph) or 18.18 m^3/h (4000 gph). These are operated, on the average, at 8 h/d with 20.3 per cent down. Water production for 9.09 m^3/h plant is on the average 57.96 m^3/d and for the 18.18 m^3/h plant 115.91 m^3/d. Water utilisation from the 20 plants visited and 200 households surveyed was 40 per cent.

2. Financial Factors

(i) *Cost*

(a) Capital Cost: (1969 Exchange Rate $1 - 1.02 cedis)

Size of Plant	*9.09 m^3/h*	*18.18 m^3/h*
2 Pumps	$ 6,400	$ 8,200
2 Generator sets	$ 20,000	$ 34,000
Treatment Plant	$ 15,700	$ 24,800

2 Pump/Treatment Rooms	$ 10,000	$ 10,000
Elevated Tank	$ 10,000	$ 18,000
River Intake	$ 10,000	$ 15,000
Distribution	$ 30,000	$ 50,000
Total	**$102,100**	**$160,000**
Number Installed	58	11

Total Capital Cost **$7,681,800**

Foreign cost component **60 per cent**

(b) <u>Operations:</u>

Annual operational cost as below:

Size of Plant	*9.09 m^3/h*	*18.18 m^3/h*
Personnel	$ 6,000	$ 6,000
Fuel/Electricity	$ 1,500	$ 3,000
Transportation	$ 500	$ 500
Chemicals	$ 1,200	$ 2,400
Overhead	$ 1,000	$ 2,000
Total	$10,200	$13,900

Foreign cost component: **35 per cent**

(c) <u>Maintenance:</u>

Annual maintenance cost:

Size of Plant	*9.09 m^3/h*	*18.18 m^3/h*
	$ 3,000	$ 4,000

Foreign cost component: 35 per cent

(d) <u>Design Life:</u>

Civil Works:	50 years
Pumps:	20 years
Treatment Plant:	20 years
Generator Set:	20 years

(Sources: GWSC Projects Section, Head Office
GWSC Operations and Maintenance Department, Head Office
GWSC, Assets Depreciation Section, Head Office.)

(e) Replacement Cost:

Current prices plus escalation based on the inflation rate. Plans for replacement are available in the GWSC 5-year Development Plan.

2. Income

(a) Tariff: $0.17 - 0.77 per m^3

Unmetered house connection:	$1.80 per month per household.
Drawers from standpipes:	$0.80 per month per household.
Wells with handpump:	$0.50 per month per household.

(b) Average Annual Billing per unit: $1671.64.

Average Annual Revenue per unit: $1003.00

(Source: Revenue Section, GWSC, Head Office.)

(c) Government Finance:

Package plant projects were financed entirely from government sources. For 69 projects amount provided was $7,681,800.

(d) There was no local government, donor or community finance involved in the Package Plant Water Supply project.

(e) Ability to Pay:

Minimum tariff is computed at 5 per cent of the household income i.e. two persons earning minimum wage.

(f) Willingness to Pay:

Low quality of service provided by the package plant water supply has resulted in intensive use of traditional sources. Consumers should be consulted in willingness to pay for improved service.

3. Economic Factors

(i) Cost

(a) Total Capital Cost: $7,681,800

Capital cost of 18.18 m^3/h plant:	$160,000
Capital cost of 9.09 m^3/h plant:	$102,100
Foreign cost component:	60 per cent

Unskilled labour component:	8 per cent
Remaining local cost:	32 per cent

(b) Annual Operations and Maintenance Cost (18.18 m^3/h): $17,900

Annual Operations and Maintenance Cost (9.09 m^3/h): $13,200

Foreign cost component:	35 per cent
Unskilled labour component:	8 per cent
Remaining local cost:	57 per cent

(c) Design Life - see Financial Factors.

(d) Replacement Cost - see Financial Factors.

(ii) Benefit

(a) Revenue:

Average annual revenue from the 69 installations amount to $69,208.

(b) Least Cost Solution:

Package plants were deployed at a time when the government of Ghana wanted a quick solution to water supplies problems of certain communities. The long term solution would probably depend on the slow sand filter.

(iii) Shadow Prices

(a) Exchange Rate - see Appendix A.

(b) Wages - see Appendix A.

(c) Land - see Appendix A.

(iv) Interest Rates

See Appendix A.

4. <u>Institutional Factors</u>

(i) *Construction*

Construction of the package plant projects was by force account with minor contracts awarded when force account could not be organised effectively. A special task force was formed for the installation of package plants with Paterson Candy technical staff in charge.

(ii) *Operation and Maintenance*

These projects are operated and maintained by GWSC under its regional and district organisation. The typical station will be operated by two treatment attendants and two pump and engine attendants and two watchmen. Various stations will come under the District Manager. Artisan pipefitters and mechanics will be sent from the district centre to the station for routine maintenance and for emergency duties. For the larger stations revenue staff will be posted there permanently. For the smaller stations revenue staff will be sent on specific days of the week for collection.

Major maintenance work will be done by staff from the regional workshops or from the package plant maintenance units based in Kumasi. An equivalent of five skilled personnel operate each scheme taking account of regional and head office staff.

(iii) *Logistics*

Fuel requirements depend on the size of plant but supplies are sent monthly. However frequent shortages occur due to transportation difficulties or lack of funds to purchase fuel. Chemical requirements include up to 750 kg of Alum, 250 kg Bleaching power and 250 kg of Sodium Carbonate or Soda Ash per month. Stocks up to three months can be held at the stations but transportation difficulties and late arrivals of chemicals from abroad cause frequent shortages. Some chemicals such as bleaching powder and soda ash have ready markets and require strict security to check theft.

(iii) Training

Operators are trained at the GWSC Training School at Owabi, Kumasi on a five year rotation. District managers are given management and supervisory courses at the Management Development and Productivity Institute, Accra.

(iv) Legal Responsibility

GWSC has legal responsibility for providing water supplies to all communities in Ghana. Package plants have to be used to treat surface waters in small urban communities.

5. <u>Social Factors</u>

(i) Taste/Odour

No complaints were received for taste/odour problem. Complaints were recorded for colour when there is no alum for water treatment. In all communities water supply from the package plant sources is supplemented with water from the traditional sources. Therefore untreated water pumped through the distribution system at least saves the community from walking to traditional sources.

(ii) Distance Travelled

Water distribution system is fully developed. Distance walked is in the range of 10-150m with an average of 80m. Average distance to traditional sources is 800m.

(iii) Queuing Period

Queuing is a serious problem on this project. Queuing period is up to 60 minutes with an average of 40 minutes.

(iv) Type of Collection Containers

Sizes of collection containers range from 10-35 litres with an Average of 18 litres.

(v) Children

Children can draw water easily from standpipes except when queues become violent.

(vi) Community Involvement

(a) Request for Project:

Yes, communities requested for the project.

(b) Level of Service/Coverage:

The community was not consulted on the level of service provided. GWSC decided on these issues.

(c) Dialogue:

There is no established dialogue between GWSC and the communities.

(d) Commitment:

The communities were not required to show any in any way, their commitment to the project.

(e) Appropriate Technology:

The choice of technology was not appropriate to the environment in which the project is located. Communities were not consulted on technology selection.

(f) Willingness to Pay:

Communities have demonstrated their willingness to pay the bills. Communities should be consulted on additional payments required to improve the service.

(g) Cost Recovery:

Communities have not been consulted on cost recovery. Tariff to communities cannot recover any appreciable percentage of cost.

(h) Ability to Pay:

The minimum flat rate for water collected from standpipes is within 5 per cent of the household income based on two persons earning the minimum wage.

(i) Decision Making:

Communities are not involved generally in decisions pertaining to their water supply projects.

(j) Responsibility:

The communities do not share in the responsibility of providing the service.

(vii) Population Factors

Communities with population in excess of 2,000 benefited from the 69 projects. Total population served 345,000 persons (1984) giving an average of 5,000 persons per project.

Age Distribution:	0 - 14 yrs:	51 per cent
	14 - 65 yrs:	45 per cent
	>65 yrs:	4 per cent

Population Density: 80 persons per hectare

Female to Male Ratio: 1.03

Education: 56 per cent primary school or better

Religion: majority Christian or Animist

(Source: *Quarterly Digest of Statistical Service*, Ghana.)

(vii) Alternative Facilities

Communities make extensive use of their traditional sources since the improved source is not dependable. Some hand dug wells are also in use.

6. Environmental Factors

Sullage Disposal

Sullage is spread to reduce dust or allowed to flow in natural storm drains where it either evaporates or soaks into the ground.

7. Package Plant Stations Visited

Northern Region - Walewale, Nalerigu
Brong Ahafo Region - Nkoranza, Atebubu, Bomaa
Ashanti Region - Tepa, Wiamoasi, Jakobu, Kona, Obogu
Western Region - Mpohor, Dompim
Central Region - Ekotsi, Essarkyer
Eastern Region - Osino, Anyinam, Kibi, Akwadum
Volta Region - Tsito, Tokokoe

APPENDIX D

DATA ON 2500 DRILLED WELLS WATER SUPPLY PROJECT

1. Technical Factors

(a) Water Production Technology: as described in Chapter 7.

(b) Water Distribution Technology: as described in Chapter 7.

(c) Operations - Plans For:

Hand pumps are community operated. Water Utilisation project has been designed to teach communities proper operation of hand pump and hand pump sanitation practices.

Actual Operation:

Communities generally appreciate the lessons from the Water Utilisation project. Pumps sites are generally kept clean.

Requirements for Effective Operations:

Some communities need to extend the pump pad (apron) and to construct animal troughs to improve drainage around the pumps.

(d) Maintenance:

Plans for maintenance: The maintenance organisation was set up to achieve the following targets:

90 per cent of all pumps operational at all times.

80 per cent of all repairs by motorist (pump mechanic on motor bike).

34 per cent of all pumps inspected per month (i.e. 100 per cent inspection of all pumps in 3 months).

Zero backlog each month (no carry over of faulty pumps).

Also various targets for site improvements are set for particular districts. Site improvements include retraining of pump caretakers, backfilling around handpumps, maintenance of access roads, construction of extended pump pads and construction of animal troughs.

Actual Maintenance:

An average 85 per cent of hand pumps in operation has been achieved. Other maintenance activities achieved their targets, i.e. 80 per cent repairs done by motorist and 100 per cent of pump inspected in three months.

Plans for Effective Maintenance:

To date Canadian International Development Agency has been responsible for the provision of spare parts for pumps, pumps for replacement and for purchase of vehicles. So long as this aid is made available it is likely that the maintenance levels can be maintained and improved upon. All agencies concerned with the project are apprehensive about the sustainability of the maintenance programme when CIDA withdraws. Community-based maintenance system with VLOM handpumps are planned for the future. It is estimated that 90 per cent of operation and maintenance plans were achieved.

(e) Types of Faults:

Percentage of handpumps kept in operations annually. Average - 85 per cent.

1976	88 per cent	1982	84 per cent
1977	87 per cent	1983	82 per cent
1978	83 per cent	1984	81 per cent
1979	83 per cent	1985	84 per cent
1980	87 per cent	1986	92 per cent
1981	78 per cent	1987	95 per cent

Percentage of Moyno Handpumps affected by various defects over a 3-year period

Nature of Defect	*Worm Stator*	*Broken Rod*	*Loose Rod*	*Broken Pipe*	*Loose Pipe*	*Worn Thrust Spacer*
% of pumps affected	68	15	8	12	23	23

<u>Percentage of Monarch Handpumps affected by various defects over a 3-year period</u>

Nature of Fault	*Broken Guide Rod*	*Broken Pump Rod*	*Loose Rod*	*Broken Shoulder Bolts*	*Broken Shackle Bearing*	*Broken Fulcrum Bearing*
% of pumps affected	46	26	36	36	57	28

Source: *Report on Operation and Maintenance Upper Region Project*, 1988.

(f) <u>Water Quality:</u>

Water quality analysis indicates that well water is well within acceptable limits.

pH:	6.5 - 7.5
Total Iron:	0 - 0.4 mg/l
Nitrate:	1 - 25 mg/l
Chloride:	0 - 16 mg/l

(g) <u>Water Quantity and Utilisation:</u>

Survey of water collection conducted by CIDA in 1985 revealed water collection of between 22 - 26 litre per person per day with an average of 23.6 litres per person. However in the rainy season traditional sources are nearer than wells and are therefore mostly used. A survey, conducted by interviewing 80 dispersed households, indicated that 40 per cent of water used is drawn from the wells. Water utilisation is taken as 40 per cent.

2. <u>Financial Factors</u>

(i) Cost

(a) <u>Capital Cost:</u>

Capital cost of well construction:	$5,000 per well
Cost of handpump:	$ 744 per pump

(Source: Project Manager, John Poulson.
CIDA, Technological Evaluation Report, 1985.)

(b) <u>Operations and Maintenance:</u>

Annual Operations and Maintenance cost: $92.06

(Source: *Operations and Maintenance Report, Upper Region*, 1988.)

(c) Design Life:

Wells: 20 years

Handpumps: 10 years

(d) Replacement Cost:

Current cost escalated by inflation rate.

(ii) Income

(a) Tariff:

$0.50 per month per household for consumers of water from wells with handpump.

(b) Billing/Collection:

Annual billing for 2,500 wells:	$305,934
Annual Revenue:	$128,011

(Source: GWSC Revenue Section.)

(c) Government Finance:

This project was composed of many other separate projects but the government expenditure was lumped together. Ghana government spent over 100 million cedis over a long period (15 years). Possibly 50 million cedis may have gone into drilling. Ghana government finances the local costs of operations and maintenance. Collection from tariffs introduced in 1985 will be used to purchase some spare parts as an initial effort towards taking over completely from CIDA at a future date.

(d) Donor Financing:

Canadian International Development Agency has financed various aspects of the Upper Regions project. Total CIDA involvement until 1990 is reckoned at 34.8 million Canadian dollars. All assistance has been converted into grant.

(Source: CIDA Project Manager, Upper East.)

(e) Community Contribution:

The communities are to finance five bags of cement to extend the pump pad (apron), to backfill around the apron and to construct animal water trough. Communities are expected to maintain access roads to the pumps to help the GWSC Maintenance Team when working on handpump and to collect and pay tariff to GWSC.

(f) Ability to Pay:

Tariff level of $0.50 per month per household is affordable to households with income of $36.72 per month i.e. within 5 per cent of household income.

(g) Willingness to Pay:

At the initial stages of the project communities were promised that there will be no tariff. With the introduction of tariff and the Water Utilisation Programme communities have accepted payment and are willing to pay. However, distances walked are rather long and availability of alternative sources in the rainy season could jeopardise early willingness to pay unless more wells are constructed.

3. Economic Factors

(i) *Costs*

(a) Capital Cost:

Well cost:	$5,000
Foreign cost component:	70 per cent
Unskilled labour component:	5 per cent
Remaining local cost:	25 per cent
Handpump cost:	$744
Foreign cost component:	90 per cent
Unskilled labour component:	2 per cent
Remaining local cost:	8 per cent

(b) Annual Operation and Maintenance Cost: $92.06

Foreign cost component:	60 per cent
Unskilled labour component:	5 per cent
Remaining local cost:	35 per cent

(c) Design Life:

Wells:	20 years
Handpumps:	10 years

(d) Replacement Cost:

Current cost escalated by the rate of inflation

(ii) Benefit

(a) Revenue:

Annual revenue for 2,500 wells: $128,011

(b) Least Cost Solution:

Drilled wells will have to be compared with hand dug wells in the Upper Region. In the rainy season other sources become available leading to partial abandonment of drilled wells. Wells with multiple hand pumps could help reduce the queuing period.

(iii) Shadow Prices

See Appendix A.

(iv) Interest Rates

See Appendix A.

4. Institutional Factors

(i) Construction

Force account with Canadian professional input. Various Canadian advisers include:

- Resident Management Adviser
- Adviser (Drilling Superintendent)
- Adviser (Workshop Superintendent)
- Adviser (Hydrogeologist)
- Adviser (Regional Workshop)
- Adviser/Trainer (Field Mechanic)
- Adviser/Trainer (Electronics)
- Construction Superintendent
- Construction Assistant
- Utility Man (Construction)

(ii) Operations and Maintenance

Operation and Maintenance Unit was headed by Adviser (Maintenance) from 1973 until January 1988 when GWSC took over. The Adviser (Maintenance) departed in May 1988. The Maintenance Unit is presently organised as below:

Unit	*Staff*	*Vehicles*	*Handpumps*
<u>Upper East Region</u>			
Head Office	4	1 Toyota Pick-up	-
Bolgatanga District	15	1 Bedford Truck 1 Toyota Pick-up 5 Motorbikes	590
Navrongo District	6	1 Toyota Pick-up 2 Motorbikes	187
Sandema District	3	2 Motorbikes	162
Bawku District	12	1 Bedford Truck 1 Toyota Pick-up 5 Motorbikes	754
<u>Upper West Region</u>			
Wa District	10	1 Toyota Pick-up 4 Motorbikes	447
Lawra District	8	1 Toyota Pick-up 3 Motorbikes	406
Tumu District	7	1 Toyota Pick-up 2 Motorbikes	162

The Maintenance Unit is supported by staff of the GWSC Upper East and West Regional Organisation, GWSC, head Office in Accra also provides logistic support. It is reckoned that a staff of 65 skilled staff provide the service to 900,000 persons.

(iii) Logistics

One of the major problems facing the Upper Regions is movement of fuel from Tema 800km into the regions. Frequent fuel shortage is experienced which adversely affect both urban and rural water supplies. Effect on the handpump maintenance programme is the increase in vehicle downtime. Fuel shortages cause up to 20 per cent downtime for motor cycles and 8 per cent downtime for service vehicles.

(iv) Training

For each pump two persons have been trained as pump caretakers (1 male/1 female). These people identify faults and report to GWSC. Pumps are not VLOM and thus local repairers cannot be trained.

Also two persons (1 male/1 female) from each pump community (usually one pump to 20 households) have been trained as Community Water Organisers.

In 1984 the training centred on community education. In 1986 it was water education for health. In 1987 the emphasis has been shifted to diarrhoea and oral rehydration therapy.

Other training programmes have been planned for the Water Utilisation project Phase II Extension scheduled for completion in 1990. These include further on-the-job training for GWSC staff, formal courses for GWSC staff, training visits to other handpump projects within Ghana, and formal training to GWSC staff abroad and attendance to relevant conferences.

(Source: CIDA Project Manager, Upper East.)

(v) Legal Responsibility/Declared Aims

GWSC has taken over the responsibility for handpump maintenance effective January 1988. CIDA will continue to provide assistance in the form of vehicles, spare parts (for both handpumps and vehicles) and also provide funds for a new UNDP pilot project to transfer maintenance responsibility to the communities. Pumps to be deployed in the pilot project area include Afridev, Volanta, Nira and Aquadev. The objective is to select a suitable pump for countrywide use.

5. <u>Social Factors</u>

(i) Taste/Odour

No complaints have been received on the taste and odour problem except for occasional reports that well water is not satisfying.

(ii) Distance Travelled

Consumers considered served by each handpump reside within the radius of 800m. Average distance walked is 340 metres. Traditional sources are located at an average of 1.6km.

(iii) Queuing Period

Queuing period is up to two hours with an average of 83 minutes.

(iv) Types of Collection Containers

Size of collection container vary from 10 litres to 35 litres with average of 18 litres.

(v) Children

Handpumps can be operated by children.

(vi) Community Involvement

(a) Request for Project:

Yes, communities requested for the project.

(b) Level of Service/Coverage:

No, communities were not consulted on the level of service provided or on the coverage of the project.

(c) Dialogue:

There was no established dialogue with the communities but later with the Water Utilisation project this is now being established.

(d) Commitment:

The communities were not required to show any commitment to the project.

(e) Appropriate Technology:

The technology selected is appropriate for the scale of the project executed. However, hand dug wells should also be considered.

(f) Willingness to Pay:

Communities have demonstrated willingness to pay the tariff established.

(g) Ability to Pay:

Communities possess the ability to pay tariff since tariff is within 5 per cent of the household income.

(h) Cost Recovery:

Communities are not consulted on cost recovery levels and are unaware of subsidies provided.

(i) Decision Making:

Communities were not involved generally in decision making on the project. Water Utilisation project is meant to involve communities in current decisions.

(j) Responsibility:

Communities are sharing in the responsibility of providing the service by pump pad extension, maintenance of access roads and providing help to GWSC

(vii) Population Factors

Population served by the project is 900,000 giving 360 persons per well.

Population Structure:	0 - 14 yrs:	45 per cent
	14 - 65 yrs:	51 per cent
	>65:	4 per cent
Population Density:	5 persons per hectare	
Religion:	90 per cent Animist	

(viii) Alternative Facilities

Some hand dug wells are in use. In the rainy season other sources become available, for example, dug-outs near rivers.

6. Environmental Factors

Water spilled at the hand pump drain into the animal trough for watering livestock. Sullage from houses is used to water garden or spread to control dust. Most sullage evaporate in the dry hot climate hence no nuisance is caused.

APPENDIX E

DATA ON 3000 DRILLED WELLS WATER SUPPLY PROJECT

1. Technical Factors

(a) Water Production Technology: as described in Chapter 7.

(b) Water Distribution Technology: as described in Chapter 7.

(c) Operations - Plans for:

Handpumps are community operated. Communities are expected to extend the pump apron backfill around the extended pad and improve the drainage around the pump.

Actual Operations:

Only 40 per cent improvements have been achieved at pump sites.

Requirements for Effective Operation:

No community education programme has been established. Proposals for community education are still under consideration. Effective community education is urgently required to improve pump operation and sanitation around pump installations.

(d) Maintenance - Plans for:

90 per cent pump should be in operation at all times, i.e. 10 per cent downtime. All pumps should be inspected at least once in every three months.

Actual Maintenance:

10 per cent downtime target was achieved in the initial stages of the project, i.e. 1984/85 but pump breakdown increased rapidly due to corrosion and lack of spare parts. By June 1988 50 per cent of pumps had broken down. By December 1988 60 per cent pumps were not operating.

Requirements of Effective Maintenance:

Stainless steel parts are required to replace galvanised iron rods and pipes. Orders have been placed for these parts. However, the proposal to link replacement of parts with the establishment of community-based maintenance programme and community education has not been accepted.

(Source: Proposals for the Development of a Community-based Maintenance System in the 3000 Wells Programme, IGIP Consulting Engineers.)

(e) Types of Faults:

Faults, on this project, are dominated by the effects of low pH water on the pump rods and pipes. After corrosion is firmly established pumps can only be made reliable by replacement of galvanised iron parts with stainless steel parts. Downtime of pumps is 60 per cent. Stainless steel parts will double the cost of pumps.

(f) Water Quality:

80 per cent of well water have pH in the range 4.5-7.0. Further alkalinity levels are low and the water is generally soft. These factors combine to make the water aggressive. The project has accepted iron concentration of up to 5 mg/l although WHO Drinking Water Standards specify maximum permissible level of 1 mg/l. Iron levels in excess of 5 mg/l have caused abandonment of some wells. High iron levels cause bitter taste, brownish colour, stain laundry and discolour food stuff cooked in it.

(g) Water Quantity and Utilisation:

Observation at 35 villages with handpumps indicated that water quantities used are between 20-30 litres per person per day (average 23.6 lpcd). However, general water utilisation has been affected by pump breakdown, water quality problems causing abandonment of well even when hand pump is still operating. Further GWSC has initiated action to recover revenue arrears by disconnecting handpumps. Water utilisation assessment on the whole project was 30 per cent.

2. <u>Financial Factors</u>

(i) *Cost*

(a) <u>Capital Cost:</u>

Drilling and handpump installation cost were quoted by IGIP Consultants as:

63.4 million Deutschmarks and 55.9 million cedis (1978-84)

DM63.4 million ($1.00 - 2.22DM):	$28.55 million
55.9 million cedis at various rates:	$11.82 million
Total Cost (3000 wells)	**$40.37 million**

(Source: International Drilling Consultants - Final Report Vol. 1.)

Cost of each well and handpump:	$13,456
Cost of handpump:	$ 600
Cost of well:	$12,856

(b) <u>Operation and Maintenance Cost:</u>

Annual Operation and Maintenance Cost: $70.65

(Source: IGIP Consultants System Cost of Handpump. Operated Boreholes in Ghana.)

(c) <u>Design Life:</u>

Wells:	20 years
Pumps:	10 years

(d) <u>Replacement</u> Cost:

Current costs escalated by rate of inflation.

(ii) *Income*

(a) <u>Tariff:</u> $0.50 per month per household

(b) <u>Billing and Collection:</u>

Annual billing (for 3000 wells):	$434,547
Annual revenue (for 3000 wells):	$ 61,000

(Source: GWSC Revenue Section.)

(c) Government Finance:

Various amounts disbursed by government amounted to $11.82 million.

(d) Donor Finance:

Government of the Federal Republic of Germany provided $28.55 million initially as a loan but later converted into a grant.

(e) Community Contribution:

Communities are expected to extend pump apron, backfill around the apron and ensure proper pump sanitation.

(f) Ability to Pay:

Tariff level of $0.50 should be affordable at a household income of $36.72 per month.

(g) Willingness to Pay:

At the beginning of the project communities were informed that no tariffs will be instituted. After drilling water quality problems have caused widespread rejection of well water. No community education has been carried out and therefore very low levels of tariff payment achieved. Communities are unwilling to pay for the service unless there is an improvement.

3. **Economic Factors**

(i) *Cost*

(a) Capital Cost:

Well cost:	$12,856
Foreign cost component:	80 per cent
Unskilled labour component:	5 per cent
Remaining local cost:	15 per cent
Handpump:	$600
Foreign cost component:	90 per cent
Unskilled labour component:	5 per cent
Remaining cost component:	5 per cent

(b) Operation and Maintenance:

Annual Operation and Maintenance cost:	$70.65
Foreign cost component:	60 per cent
Unskilled labour component:	5 per cent
Remaining local cost:	35 per cent

(c) Design Life:

Well:	20 years
Handpump:	10 years

(d) Replacement Cost:

Current cost escalated by the rate of inflation.

(ii) Benefit

(a) Revenue:

Annual Revenue for 3000 wells: $61,000

(b) Least Cost Solution:

In every location drilled well will have to be compared with other alternatives, such as the hand dug well, small improvements to traditional sources and even high yielding boreholes with multiple hand pumps. Drilled wells with single handpump cannot be the least cost solution at each site of the 3000 wells.

(c) Shadow Prices: see Appendix A.

(d) Interest Rates: see Appendix A.

4. Institutional Factors

(i) Construction

Drilling was executed on contract by the West German firm, Prakla Seismos Geotechnik, January 81 - December 1982.

(ii) Operations and Maintenance

Drilling to took place in six regions.

Ashanti Region:	1017 wells	Western Region:	594 wells
Central Region:	354 wells	Eastern Region:	561 wells
Volta Region:	337 wells	Brong Ahafo:	97 wells

Maintenance is organised from:
1 base workshop in Kumasi, Ashanti.
1 western regional workshop, Sekondi/Takoradi.
1 eastern regional workshop, Nsawam.
1 central regional workshop, Cape Coast.
1 Volta regional workshop, Ho.

There are also ten district workshops. Expatriate staff include:
1 maintenance manager.
5 maintenance supervisors.
GWSC staff include:
1 co-manager, Accra.
1 principal superintendent, Nsawam.
1 senior superintendent, Kumasi.
2 senior superintendents, Nsawam.
For the various workshops:
4 superintendents.
1 foreman.
62 junior foremen/artisan (mech.) drivers, rigmen, storekeepers, watchmen.

Vehicles include 14 Unimog, 4 wheel drive trucks, Yamaha, DT 175 motorbikes.

Taking account of supporting staff from GWSC regional offices and GWSC head office staff, it is estimated that a total of 79 skilled personnel provide the service for 1,200,000 population.

(iii) Logistics

Provision of spare parts when required is the main logistic problem on this project.

(iv) *Training*

Training of GWSC staff has been mainly on-the-job for the maintenance of handpumps. At the base workshops in Kumasi modifications to the India Mk 2 has been carried out. Mechanics have been trained to manufacture some minor parts of the India Mk 2. No training of community members has taken place even for the detection of faults. Community education proposals under consideration.

(v) *Legal Responsibility/Declares Aims*

Up to the present KfW, agents of the government of the Federal Republic of Germany, has been responsible for all off-shore costs of the project including the maintenance phase. To sustain the project stainless steel parts have been ordered in addition to several other spare parts. Financial support from KfW will be required for the foreseeable future. It is the joint responsibility of KfW and GWSC to establish the community education programme to ensure the future success of the community-based maintenance programme.

5. <u>Social</u>

(i) *Taste/Odour*

High iron content imparts a bitter taste to the water. This has contributed to the rejection of most of the wells by the communities.

(ii) *Distance Travelled*

Wells are located in the communities. Distances walked are in the range of 50-200m with an average of 150m. Traditional sources are located at an average distance of 700m.

(iii) *Queuing Period*

Queuing period is up to 40 minutes with an average of 20 minutes. Several observations were made at the handpumps during early mornings and in the evenings when queues develop.

(iv) *Types of Collection Containers*

Collection container in use are in the range of size 10-35 litres with an average of 18 litres.

(v) *Children*

Children are able to use the handpumps quite easily.

(vi) *Community Involvement*

(a) Request for Project:

Yes, communities requested for the project.

(b) Level of Service/Coverage:

No, communities were not consulted on the level of service provided or the coverage of the project.

(c) Dialogue:

No, there is no established dialogue between the communities and GWSC.

(d) Commitment:

Communities were not required to show any commitment to the project.

(e) Appropriate Technology:

Although communities were not involved in the selection of technology the drilled well with handpump is appropriate for the communities.

(f) Willingness to Pay:

Communities have demonstrated their unwillingness to pay for unsatisfactory services.

(g) Cost Recovery:

Communities were not consulted in the establishment of tariff level.

(h) Ability to Pay:

Communities possess the ability to pay current level of tariff.

(i) <u>Decision Making:</u>

Communities are generally not involved in decision making on the project.

(j) <u>Responsibility:</u>

Communities have been charged with the responsibility of extending pump aprons, backfilling around the apron, sanitation around the handpumps and revenue collection.

(v) Alternative Facilities

Southern Ghana has several perennial streams. Most villages have more than one traditional source of water. Hand dug wells are also in use.

(vii) Population Factors

The project was executed to serve 1,200,000 persons thus providing a well for 400 persons. Population density in the project area is 70 persons per hectare.

Population Structure:	0 - 14 yrs:	45 per cent
	14 - 65 yrs:	51 per cent
	>65 yrs:	4 per cent
Female to Male ratio:	1.03	
Education:	56 per cent primary school or better	
Religion:	mostly Christian or Animist	

6. <u>Environmental Factors</u>

Sullage Disposal

Sullage is disposed of by spreading to control dust or by allowing it to flow through natural gullies. No nuisance is caused as most sullage either evaporate or sink into the ground.

APPENDIX F

DATA ON HAND DUG WELL WATER SUPPLY PROJECT

1. Technical Factors

(a) Water Production Technology: as described in Chapter 7.

(b) Water Distribution Technology: as described in Chapter 7.

(Source: Project Supervisor, Akuapem Rural Development Foundation.)

(c) Operations - Plans for:

Community operates the project through the water committee. Community is responsible for good sanitary conditions around the well.

Actual Operations:

Water committee appoints a woman weekly to clean the well site. The site is very clean.

Requirement of Effective Operations:

Handpump is rather high for children. A pedestal is required for children to stand on to enable them to operate the pump with long strokes.

(d) Maintenance - Plans for:

Pump breakdown is reported to the project supervisor.

Actual Maintenance:

Water Aid has provided handpumps and spare parts for maintenance. The project supervisor maintains the handpumps himself. The handpump at Timber Nkwanta required attention five times in three years.

Requirements for Effective Maintenance:

Currently only three wells fitted with handpumps have been completed and therefore maintenance by the project supervisor seems adequate but as more wells are completed a more permanent maintenance organisation will have to be created. Water Aid is currently negotiating with GWSC to take part in the National Hand Dug Well Programme and a Memorandum of Understanding is due to be signed soon. Water Aid would then be able to integrate their maintenance programme with the GWSC maintenance organisation. Water Aid will supply spare parts and vehicles.

It is estimated that 90 per cent of all operation and maintenance plans were achieved.

(e) <u>Types of Faults:</u>

Five faults were attended to in the three years of operation. However when the pump breaks down water can still be drawn by means of rope and bucket through the hatch created in the well cover for this purpose. A fault takes five days to be attended to on the average. Hence 25 days of pump downtime in three years. Downtime of handpump is calculated as 2.3 per cent however water is available through the hatch.

(f) <u>Water Quality:</u>

Colour:	< 5 units
pH:	6.9
Hardness:	*116 mg/l* $CaCO_3$
Total Iron:	0.89 mg/l
Manganese:	0.3 mg/l

Quality of water is within acceptable limits.

(g) <u>Water Quantity and Utilisation:</u>

Water use from observation is between 20-30 lpcd with an average of about 23.6 lpcd. Well water is mostly used in the community and from the household survey 90 per cent utilisation is assessed.

2. <u>Financial Factors</u>

(i) *Cost*

(a) <u>Capital Cost:</u>

Cost of handpump:	\$677.0
40 bags of cement:	\$197.0

6 m^3 of stones:	$147.8
3 m^3 of sand:	$ 9.3
Other materials:	$ 18.0
Labour:	$615.9
Equipment/labour/overheads:	$615.0
Total	**$2280.0**

(b) Operation and Maintenance:

Annual operation and maintenance cost: $80

(Source: Project Supervisor, ARDF.)

(c) Design Life:

Well: 20 years

Handpump: 10 years

(d) Replacement Cost:

Current cost escalated by the rate of inflation.

(ii) Income

(a) Tariff:

No tariff were charged for water consumed but the community had to raise the $184 (10,000 cedis on 1985) required through a head tax of $1.84 (100 cedis in 1985) per adult.

(b) Billing/Collection:

An amount of $184 was paid to the Akuapem Rural Development Foundation for maintenance.

(c) Donor Finance:

Water Aid finance in the capital cost amounted to $1426.6. In addition spare parts are provided for maintenance of handpump.

(d) Community Finance:

Community contribution in cash and in kind amounted to $853.4. In addition $184 was deposited towards maintenance cost.

(e) Ability to Pay:

By custom most communities have one non-farming day each week and this is devoted to community work. Contribution in kind in terms of collection of sand and stones are undertaken on such days. Head tax of \$1.84 is a form of development tax per head which is quite acceptable to communities. Communities, in fact, have the ability to pay.

(f) Willingness to Pay:

Communities have demonstrated their willingness to pay by accepting and abiding by the conditions for participating in the project.

3. Economic Factors

(i) *Cost*

(a) Capital Cost:

Well cost:	\$1603
Foreign cost component:	25 per cent
Unskilled labour component:	35 per cent
Remaining local cost:	40 per cent
Handpump:	\$677
Foreign cost component:	90 per cent
Unskilled labour component:	5 per cent
Remaining local cost:	5 per cent

(b) Operation and Maintenance Cost:

Annual operation and maintenance cost:	\$80
Foreign cost component:	60 per cent
Unskilled labour component:	5 per cent
Remaining local cost:	35 per cent

(c) Design Life:

Well:	20 years
Handpump:	10 years

(d) Replacement Cost:

Current cost escalated by the rate of inflation.

(ii) Income

(a) Revenue:

No billing for use of water. $184 collected from head tax to pay for maintenance deposit.

(b) Least Cost Solution:

Hand dug wells are a least cost solution for most areas in Ghana.

(c) Shadow Prices: see Appendix A.

(d) Interest Rates: see Appendix A.

4. Institutional Factors

(i) Construction

Construction of the well was undertaken by self-help with technical assistance provided by the project supervisor who is an agent of Akuapem Rural Development Foundation and Water Aid.

(ii) Operation and Maintenance

Operations are carried out by the community and maintenance undertaken by the project supervisor. In the long term maintenance may be transferred to GWSC and when the pump is changed to an Afridev, hand pump community-based maintenance system may be adopted.

(iii) Logistics

No logistic problems encountered.

(iv) Training

No training is provided but it is important that community education and training of pump caretakers be instituted prior to the introduction of the community-based maintenance system.

(v) Legal Responsibility/Decared Aims

Water Aid is the voluntary effort of the British Water Industry for the Water Decade. The principal roles Water Aid seeks to play are:

(a) supporting self help initiatives;

(b) strengthening local institutions.

(c) enabling other aid organisations to maximise their impact in the water and sanitation sector.

The Akuapem Rural Development Foundation is the local institution that liaises with Water Aid and selects communities for the project and also supervises the construction of the projects.

5. <u>Social Factors</u>

(i) Taste/Odour

No taste/odour problems have been encountered on this project.

(ii) Distance Travelled

The well is at an end of the village. Range of distance walked is 50-250m with an average of 150m.

(iii) Queuing Period

Queuing takes pace in the mornings and the evenings with an average period of 20 minutes.

(iv) Types of Containers

Range of sizes of containers used is 10-30 litres with an average of 18 litres.

(v) Children

The well head is about 0.6m from the ground. Children can operate the handpump with short strokes. A pedestal should be provided for the children to stand on.

(vi) Community Involvement

(a) <u>Request for Project:</u>

Yes, community requested for the project.

(b) Level of Service/Coverage:

Yes, community decided on the level of service and coverage.

(c) Dialogue:

Yes, there is an established dialogue between the project supervisor and the community.

(d) Commitment:

The community is required to demonstrate commitment to the project by providing cash deposit prior to collection of sand and stones.

(e) Appropriate Technology:

The hand dug well is an appropriate technology for small communities.

(f) Willingness to Pay:

The community has demonstrated its willingness to pay by providing the initial deposit required.

(g) Cost Recovery:

The community was involved in the decision on what level of cost was to be recovered from the community.

(h) Ability to Pay:

Community possess the ability to pay.

(i) Decision Making:

Community is generally involved in decisions on the project.

(j) Responsibility:

Community shares in the responsibility for the delivery of the service.

(vii) Population Factors

Timber Nkwanta has a population of 420 persons. It has a six year primary school but older children attend middle school at Adawso three miles away. Religion is most Christian. Population density is 60 persons per hectare.

(viii) Alternative Facilities

The traditional source, a stream, is only 45m away from the well.

6. Environmental Factors

Sullage Disposal

Sullage is spread to control dust or by throwing it into the bush. No nuisance is caused by sullage in the community.

APPENDIX G

DATA ON CENTRAL ACCRA SEWERAGE PROJECT

1. Technical Factors

(a) Sewage Collection Technology: as described in Chapter 7.

(b) Sewage Treatment/Disposal: as described in Chapter 7.

(Source: GWSC (1981b), Accra Tema Water Supply and Sewerage Project. *Review of Master Plan - Final Report - Vol. 2.*)

(c) Operations - Plans for:

Operating manuals for the pumping stations and flushing programmes for all sewers are available.

Actual Operations:

After 15 years operation only 395 connections out of the expected 2000 have been effected, therefore low flows occur in the sewers. Flushing of sewers have to be carried out regularly. Sullage is admitted into the sewers at fixed locations to augment the flow. One flushing wagon is available.

Accra Central Pumping Station rated at 59090 m^3/d is operating at 2273 m^3/d. The wet well is filled on the average once every hour, the duty pump is switched on automatically and the sewage is pumped out in 5-10 minutes. Total pumping hours is 2-3 hours per day but occasionally pumps operate for five hours.

High Street Pumping Station operates for only 10 minutes a day and is therefore not manned full time.

Korle Bu Pumping Station has not functioned since it was commissioned. The sewer feeding the pumping station was poorly constructed by a local contractor and is therefore not used. A new sewer is yet to be laid.

Requirements for Effective Operations:

None of the present operating staff have had any formal training in sewerage operation. Some on-the-job training was provided which seems inadequate. The GWSC will have to do more promotional activities to encourage households to connect to the system. Building toilet facilities and connecting to the system costs $5000 and GWSC is considering providing soft loans to landlords. More flushing wagons will be required to improve the effectiveness of flushing. It is assessed that 90 per cent of operational pans are achieved.

(d) Maintenance - Plan for:

Maintenance manuals provide schedule for inspection and preventive maintenance. Various mechanical and electrical equipment have been programmed for periodic maintenance.

Actual Maintenance:

Low utilisation of the sewerage system means most plant are not doing a full duty. Maintenance requirements have been quite low. However some equipment have not had much attention. These include the standby generator, comminutors and ventilation equipment for the wet well area. Spare parts are required to rehabilitate these units. There is a tendency to remove parts from the inoperative Korle Bu pumping units for use elsewhere. To avoid cannibalisation of the Korle Bu pumps spares will have to be provided on time.

Two vehicles are available for both operations and maintenance duties and are adequate.

Requirements for Effective Maintenance:

The Sewerage Division should receive a lot more attention from management of GWSC although not much revenue accrues from sewerage services. Operating pumps and other equipment should be protected with effective maintenance through the availability of spare parts. However, it is estimated that 90 per cent of all maintenance plans are achieved.

(e) <u>Types of Faults:</u>

The dominant fault is the low level of utilisation and hence regular flushing of sewers. It is reckoned that at any moment 10 per cent of the sewerage system will be under flushing. Inspection of the sewers revealed that although only partially used there is no corrosion in the sewers, however, manhole ladders needed painting.

(f) <u>Quality of Sewage:</u>

BOD (5 day at 20°C):	282-500 mg/l
pH:	6.9 - 9.5
Total suspended solids:	2000 - 7500 mg/l
Total sulphides:	0.1 - 1.1 mg/l with a typical value of 0.3 mg/l

(Source: Analysis by GWSC-Accra Tema Area Chemist and Tahal Consulting Engineers.)

(g) <u>Sewage Quantity:</u>

The average sewage flow including intercepted sullage is 2272 m^3/d.-

2. <u>Financial Factors</u>

(i) Cost

(a) <u>Capital Cost:</u> $3.39 million

Foreign cost component: $1.56 million (46 per cent)

(Source: Tahal Consulting Engineers.)

(b) <u>Operation Cost:</u>

Annual Operation Cost: $134,400

(c) <u>Maintenance Cost:</u>

Annual Maintenance Cost: $16,000

(Source: Sewerage Division, GWSC.)

(e) <u>Design Life:</u>

Civil Works (including sewers):	50 years
Mechanical and Electrical Equipment:	20 years

(f) Replacement Cost:

Current cost escalated by the rate of inflation.

(ii) Income

(a) Tariff

Up to 1986:	25 per cent of Water Bill
From 1987:	35 per cent of Water Bill

(b) Billing and Collection:

Average annual billing:	$96,038
Average annual revenue:	$80,672

(Source: GWSC Revenue Section.)

(c) Government Finance:

Government financing of the capital cost was $1.84 million.

(d) Donor Finance:

World Bank/IDA financed the foreign component of capital cost amounting to $1.56 million.

(e) Ability to Pay:

The households connected to the Central Accra Sewerage System are in the middle and high income group together with commercial and industrial premises hence the ability to pay exists.

(f) Willingness to Pay:

The households connected to the system have demonstrated their willingness to pay. However a large number of households do not perceive enough benefits from the project to warrant investment in toilet facilities and connection to the system.

3. Economic Factors

(i) Cost

(a) Capital Cost:

Capital cost:	$3.39
Foreign cost component:	46 per cent

Unskilled labour component: 20 per cent

Remaining local cost: 34 per cent

(b) Operation and Maintenance Cost:

Annual operation and maintenance cost: $150,400

Foreign cost component: 50 per cent

Unskilled labour component: 10 per cent

Remaining local cost: 40 per cent

(c) Design Life:

Civil Works (including sewer): 50 years

Mechanical and Electrical Equipment: 20 years

(d) Replacement Cost:

Current prices escalated by the rate of inflation.

(ii) Benefit

(a) Revenue:

Average annual revenue: $80,672

(b) Least Cost Solution:

Sewerage system for a community with sub-standard housing and who cannot afford water connection much less provide flush toilet cannot be a least cost solution. Ventilated improved pit latrines are now being promoted in the project area in addition to encouraging connection to the sewerage system.

(iii) Shadow Prices

See Appendix A.

(iv) Interest Rates

See Appendix A.

4. <u>Institutional Factors</u>

(i) *Construction*

The Central Accra Sewerage was constructed on contract by the Israeli construction firm, Water Resources Development (International) Ltd.

(ii) *Operations and Maintenance*

The Sewerage Division is headed by an engineer supported by a technician engineer, superintendents and several artisans and administrative staff. However, the Accra Tema Metropolitan Area of the GWSC and the GWSC head office also provide supporting services. A total of 46 skilled staff provide the service for a designed 150,000 persons.

(iii) *Logistics*

The Sewerage Division needs funds to purchase items required. The Division is located at the centre of commercial activity in Accra and hence can obtain most of their requirements so long as funds are available.

(iv) *Training*

Lack of training is a major problem facing the Sewerage Division. None of the staff, including the engineer leading the Division, have any formal training in sewerage. Most of the staff have some on-the-job training organised by the expatriate engineer in charge of the Division during commissioning. A comprehensive training programme should be designed and an appropriate institution such as the GWSC Operators School at Weija equipped to undertake the training. Professional staff can be sent abroad for training.

(v) *Legal Responsibility/Declared Aims*

GWSC, by its Act of Incorporation, is responsible for all sewerage works in Ghana. So far GWSC operates only the Central Accra Sewerage and has nothing to do with the various small sewerage schemes dotted around the country. Also the Tema and Akosombo Sewerage schemes are run by local institutions. GWSC has been extremely slow in assuming full responsibility for sewerage, most probably because not much income can be earned from the service.

A clear cut policy of funding of sewerage services is required. Where appropriate, cheaper sanitation services should be provided in place of sewerage.

The World Bank has not shown much interest in sewerage since the Central Accra Sewerage project did not perform as well as expected. It is anticipated that the Italian government might finance the stabilisation ponds proposed to deal with the beach pollution problem.

5. Social Factors

(i) *Odour*

No complaints of odour nuisance have been recorded from consumers or the public.

(ii) *Distance Travelled*

In-house facilities provided. Some public toilets of the aqua privy or bucket latrine type are expected to be converted to flush toilets to serve the community not yet connected to the sewers.

(iii) *Anal Cleansing Material*

In the project area consumers use toilet roll or old newsprint. The material will normally be flushed down the toilet but where there is the likelihood of blockage of household sewers, material is accumulated in a basket and burnt every few hours.

(iv) *Children*

Facilities can be conveniently used by children.

(v) *Community Involvement*

(a) Request for Project;

No, the community did not request for the project.

(b) Level of Service/Coverage;

No, the community was not involved in the decision on the level of service or coverage of the project.

(c) Dialogue:

No dialogue was established between GWSC and the community on the project.

(d) Commitment:

The community was not expected to show commitment to the project in any way.

(e) Appropriate Technology:

Sewerage is not appropriate for most households in the project area.

(f) Willingness to Pay:

Those consumers connected to the system have demonstrated their willingness to pay for the service.

(g) Cost Recovery:

The consumers were not consulted on the level of cost recovery required by GWSC.

(h) Ability to Pay:

Consumers possess the ability to pay for the service.

(i) Decision Making:

The community is generally not involved in decision making on the project.

(j) Responsibility:

The community does not share in the responsibility for providing the service.

(vi) Population Factors

The design population for the project is 150,000 but the population served is 40,000. The project area has a population density of 200 persons per hectare. Most of the consumers are Christians and the educational level is 56 per cent primary school or better. Population structure reflects the national structure.

0 - 14 yrs:	45 per cent
14 - 65 yrs:	51 per cent
>65 yrs:	4 per cent

(vii) Alternative Facilities

The project area is served by private and communal bucket latrines and some aqua privies. However, the low income population prefer open defecation on the beach.

6. <u>Environmental Factors</u>

Sewage on the beach

Designs are available for stabilisation ponds to treat the sewage pumped onto the beach as a result of the failure of the ocean outfall. $500,000 is required to finance the project to serve the design population of 150,000 persons.

APPENDIX H

DATA ON URBAN KUMASI-TYPE VENTILATED IMPROVED PIT LATRINE PROJECT

1. Technical Factors

(a) Collection Technology: as described in Chapter 7.

(b) Treatment/Disposal Technology: as described in Chapter 7.

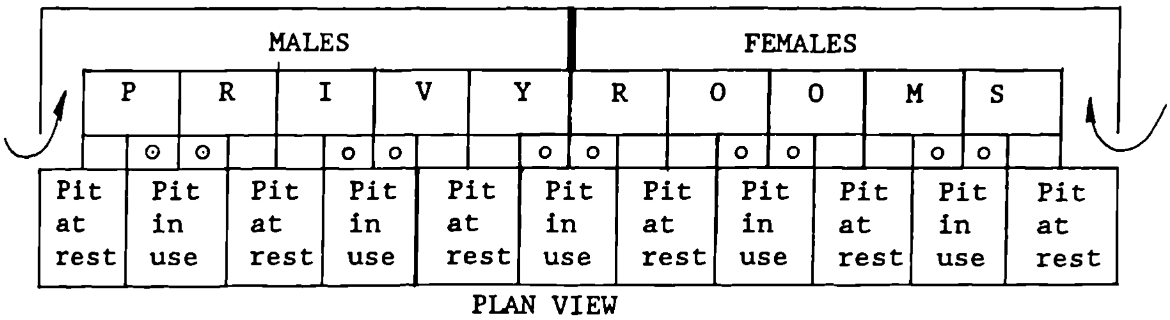


Figure H.1: 10-Compartment K-VIP Latrine Plan View

The K-VIP latrine is designed for 30 persons per privy room per day.

Assuming a solids accumulation rate of 0.03 m^3/year

2 privy rooms use one pit giving 60 persons per pit.

For 2-year period of use:

Volume of single pit = 2 x 0.03 x 60 m^3

= 3.6 m^3

Allow 4 m^3

Each pit size - 1m width

2m length

2m depth

(c) Operation:

No formal plans are available but the attendants have devised their operating procedures. However, formal training of operators is required. Formal operating manuals are required.

Actual Operation:

The K-VIP latrines in Kumasi are insufficient for the population using the facilities with the result that the pits are filling up within 5-7 months. Usually the pits get filled prematurely due to bulking sludge caused by entrainment of gases. Sometimes bulking sludge can lift the pit covers causing spillage of sludge. Bulked sludge can be removed with ordinary cesspit emptiers. When the truck is unavailable the privy rooms leading to the pit are locked to allow the pit to rest. The sludge collapses within one week and the privy rooms are re-opened. When several pits are full the empty pits (or pits at rest desludged) are put into use by interchanging the squatting slab and the blank slab in each privy room. When pits have been allowed to rest the sludge thickens and vacuum trucks purposely built for such sludge are required for desludging. Kumasi Metropolitan Assembly Cleansing Department presently does not have these purpose built vacuum trucks and desludging is therefore done manually using rope and bucket. Where the pressure on the K-VIP latrines is excessive, the bucket latrines have been re-opened to allow the K-VIP latrines to rest. After 12 months the K-VIP latrines will be completely desludged and put back into service.

Requirements for Effective Operation:

The design population for the K-VIP latrine should not be exceeded. This can be achieved by replacing the bucket latrines with at least the same capacity K-VIP latrine. That is, the capacity of K-VIP latrine provided should be equal to or greater than the capacity of the bucket latrine replaced. Operational manuals should be prepared and the attendants should be trained. In spite of the operational difficulties it is assessed that 60 per cent of operational requirements are achieved.

(d) Maintenance - Plans for:

No formal plans for maintenance are available but the management provide maintenance services as and when required.

Actual Maintenance:

A sanitary labourer is retained for sweeping the latrine and its surroundings daily. Weekly washing of the latrine is carried out. Any repairs are undertaken by hired labour.

Plans for Effective Maintenance:

Maintenance manuals should be prepared and attendants should be trained in the maintenance requirements of the K-VIP latrine. In spite of the difficulties it is assessed that 60 per cent of maintenance requirements are achieved.

(e) Type of Faults:

The dominant fault with the urban K-VIP latrine project is early filling of pits causing closure of some privy rooms which rooms therefore become unavailable to users. Observations at six different latrine locations revealed that 10 per cent of the privy rooms are unavailable at any time. Minor faults may be due to smell in the privy rooms due to anal cleansing materials left in basket. Improvement in ventilation of pit could also help reduce bulking of sludge in the pits. Further, entry of run-off water into the pits should be avoided by improving drainage in the pit area.

(f) Quality of Sludge:

Most of the pits were filling within 5-7 months. The sludge was therefore unsafe. A minimum of 12 months is required to render the sludge safe. pH of sludge was less than 7.0.

(g) Quantity of Sludge:

Quantity of sludge removed from a 10 compartment K-VIP latrine required 7000 litre cess pit emptyer to make four round trips to the trenching grounds. Where the sludge was solid enough, that is, approximately 70 per cent moisture content, two persons using shovel, rope and bucket required ten days to empty all pits. Sludge was spread out on land behind the latrine to dry.

(h) <u>Utilisation:</u>

Utilisation of facilities was assessed on the population using the facilities to the potential population. For the ten compartment latrine an average of 520 persons used the latrine. The potential population was about 1750 persons. Thus giving a utilisation rate of 30 per cent.

2. <u>Financial Factors</u>

(i) Cost

(a) <u>Capital Cost:</u>

The range of cost was $11500 - $20231 with an average of $15865.

(b) <u>Operation and Maintenance:</u>

The operation and maintenance cost was calculated at $1380 per annum.

(c) <u>Design Life:</u>

The K-VIP latrine is designed for 20 year life.

(Source: University of Science and Technology, Civil Engineering Department.)

(d) <u>Replacement Cost:</u>

Current cost escalated by rate of inflation.

(ii) Income

(a) <u>Tariff:</u>

An admission charge of $.025 per person per visit. The charge does not apply to children (if they are admitted at all) and the aged.

(b) <u>Billing and Collection:</u>

Average annual collection from a ten compartment latrine is $2700.

(c) <u>Local Government Finance:</u>

The Kumasi Metropolitan Assembly provided funds for capital cost for eight 10-compartments K-VIP latrines.

(d) Ability to Pay:

The tariff is within five per cent of the income of a minimum wage earner.

(e) Willingness to Pay:

A survey in which a total of 300 persons were interviewed at six different latrine sites revealed that 68 per cent of users did not think the charge was excessive if children were excluded, 18 per cent thought it was excessive and 14 per cent were unsure, or did not have an opinion.

A flush toilet operated by the Kumasi Metropolitan Assembly charges twice the rate for the K-VIP latrine and it is intensively used.

3. Economic Factors

(i) Cost

(a) Capital Cost:

Average capital cost per 10-compartment latrine is:	$15,865
Foreign cost component:	50 per cent
Unskilled labour component:	10 per cent
Remaining local cost:	40 per cent

(b) Operation and Maintenance Cost:

Annual operation and maintenance cost:	$1,380
Foreign cost component:	30 per cent
Unskilled labour component:	20 per cent
Remaining local cost:	50 per cent

(c) Design Life:

The K-VIP latrine is designed for a 20 year life.

(d) Replacement Cost:

Current cost escalated by the rate of inflation.

(ii) Benefit

(a) Revenue:

Annual revenue for each ten compartment K-VIP latrine is $2,700.

(b) Least Cost Solution:

The K-VIP latrine is a least cost solution if operated within the design population. Early filling of pits cause frequent desludging which increases cost. If an adequate number of latrines are provided overhead costs due to operator and cleaners will be spread over more units.

(c) Shadow Prices:

See Appendix A.

(d) Interest Rates:

See Appendix A.

4. Institutional Factors

(i) Construction

A total of eight ten compartment K-VIP latrines were awarded on contract to local contractors. Due to improper supervision the quality of work was not satisfactory.

Eight projects were undertaken on Force Account. However, currently, 80 projects are being undertaken by communities through self-help with technical and material assistance from the Kumasi Metropolitan Assembly.

(ii) Operation and Maintenance

Three caretaker workers paid from the admission charges operate the facility.
Two attendants for collection of charges and dispensing of newsprint for anal cleansing.
One cleaner
Pit emptying is done on contractual basis.

Supervision is by the Latrine Management Committee under either the local Committee for the Defense of the Revolution or the local Community Development Committee.

(iii) *Logistics*

The main logistic requirement is the cesspit emptyer or vacuum truck from the Kumasi Metropolitan Assembly. The service should be available once in three months for each ten compartment latrines for satisfactory operation.

(iv) *Training*

Prior to the introduction of the K-VIP latrines technical staff of some Metropolitan/District Assemblies were trained in the construction of the latrine. However, in anticipation of community-based operation and maintenance some community members should have been trained in the operation and maintenance aspects. With the rate of construction of the latrines, especially in the administrative area of the Kumasi Metropolitan Assembly, the need for training is even more urgent.

(v) *Legal Responsibility/Declared Aims*

The Kumasi Metropolitan Assembly is generally responsible for non-sewered sanitation. Faced with the difficulties of centralised delivery of the service, it was decided that community-based delivery system should be established. The Kumasi Metropolitan Assembly provides technical and material support for the communities to construction, operate, maintain the facilities and collect revenue.

5. <u>Social Factors</u>

(i) *Odour*

The K-VIP latrine, if operated properly, should have no smell and should not breed flies. All anal cleansing materials should be deposited in the pit. However the operation of the K-VIP latrine in Kumasi is far from ideal. Anal cleansing material is deposited in a basket and burnt periodically. Odours and some fly breeding do occur but this is bearable compared with the odours and fly breeding associated with the bucket latrines which the K-VIP latrines have replaced.

(ii) *Distance Travelled*

There is no saving in distance travelled due to this project since the K-VIP latrines have been constructed at the same sanitary sites where the bucket latrines are located. Distance walked is in the range of 10-200m with an average of 100m.

(iii) *Queuing Period*

Queuing occurs in the morning (5.00 - 7.00am) and in the evening (5.00 - 6.00pm). Range of queuing time is up to 22 minutes with an average of 10 minutes.

(iv) *Anal Cleansing*

Old newsprint is dispensed by the attendant but users carry other anal cleansing material such as old rags, leaves and pieces of wood.

(v) *Children*

Children in general have not been adequately catered for. Where they are excluded from the use of the K-VIP latrines they can be seen squatting in the open in the sanitary area and on refuse dumps. It is absolutely necessary that children are well taken care of by constructing a two or four compartment K-VIP latrine for the exclusive use of children.

(vi) *Community Involvement*

(a) Request for Project:

Yes, communities requested for the project.

(b) Level of Service/Coverage:

No, the community was not consulted on the level of service or coverage of the project.

(c) Dialogue:

There is no established dialogue between project planners and communities.

(d) Commitment:

Communities have to demonstrate their commitment by mobilising funds and self help.

(e) Appropriate Technology:

The K-VIP latrine is an appropriate technology. Although the communities were initially not aware of the existence of such technology lately the K-VIP latrine is specifically requested by communities.

(f) Willingness to Pay:

Communities have amply demonstrated their willingness to pay as the survey revealed.

(g) Cost Recovery:

Communities are aware of the cost implications of their request for a latrine.

(h) Ability to Pay:

The communities have the ability to pay for the service. Charges are within 5 per cent of income.

(i) Decision Making:

Communities are now involved in decisions on K-VIP latrine construction, operation and maintenance.

(j) Responsibility:

The communities share in the responsibility of providing the service. Communities operate and maintain the latrines. Also with the new self help projects communities provide funds and labour.

(vii) Population Factors

Design population for each ten compartment latrine is 300 for the population using the latrine. On the average the potential users of latrine assessed from the catchment area of each latrine is 1750 persons.

Population density in the project area is 100 persons per hectare. Population structure reflects the national structure.

(viii) Alternative Facilities

Various latrines are in use in the project area. These include bucket latrine, aqua privy latrine, water closet and septic tanks. Open defecation is still practised.

6. Environmental Factors

Sludge Disposal

Sludge from the K-VIP latrines is either transported 11.2km outside Kumasi to trenching grounds to be buried or where there is land around the latrine and the sludge is thick enough to warrant manual desludging, sludge is deposited on land and allowed to dry and then incinerated. Operation of the trenching ground to avoid environmental pollution or the preparation of land around the latrine to accept sludge for drying and subsequent incineration is estimated at $1.0 per user.

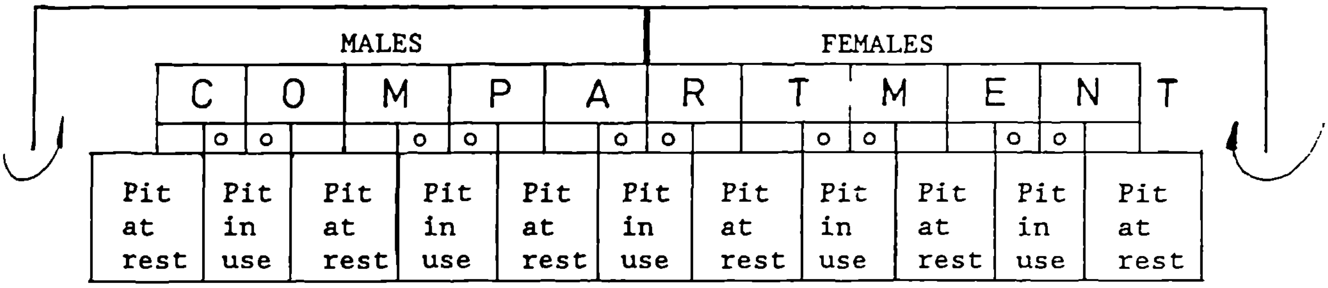
APPENDIX I

DATA ON RURAL KUMASI-TYPE VENTILATED IMPROVED PIT LATRINE PROJECT

1. <u>Technical Factors</u>

(a) <u>Collection Technology:</u> as described in Chapter 7.

(b) <u>Treatment/Disposal Technology:</u> as described in Chapter 7.



PLAN VIEW

Figure I.1: 10-Compartment K-VIP Latrine - Plan View

Each compartment takes 30 persons per day.
Assuming a solids accumulation rate of 0.03 m^3 per person per year
2 compartments are served by 1 pit giving 60 persons per pit
For a 2-year period of use

Volume of pit required	=	$2 \times 0.03 \times 60$ m^3
	=	3.6 m^3
Allow		4.0 m^3
Pit size should be:		1m width
		2m length
		2m depth

(c) <u>Operations - Plans for:</u>
No formal plans for operations are available but the communities have devised their operating procedures and schedules.

<u>Actual Operations:</u>
The Town Development Committees are in charge of latrine operations. In some communities the assignments of sweeping latrines and removal of anal cleansing material for burning has been given to certain women who are therefore exempted from

communal labour for other development projects. In other areas school children aged 10 - 15 years are assigned the task of cleaning the latrine every day and wash down the slabs and access every week.

Requirements for Effective Operation:

It will be more desirable if anal cleansing material were deposited in the pits. In the rural areas the level of use is within the design capacity and the rate of filling up would not be unduly affected by deposition of anal cleansing materials in the pit. Drainage in the pit area will have to be improved to avoid run-off water entering the pits. Training of some community members in the operations is necessary.

(d)) Maintenance - Plans for:

There are no formal plans for maintenance. The Town Development Committee requested assistance from the technical department of the district assemblies.

Actual Maintenance:

Artisans who were involved in the construction are usually requested to carry out minor repairs of the structure. No major maintenance work is required at the moment but painting inside the latrine may become necessary because of the smearing of walls with excreta by users.

Requirements for Effective Maintenance:

Maintenance manuals should be prepared and community members trained in inspection and maintenance procedures. The artisans should be given incentives to show interest in maintenance. It is assessed that 90 per cent of operation and maintenance requirements are achieved.

(e) Types of Faults:

Some odours and fly breeding occur but by far the most important fault is fouling of squatting area causing other users to avoid those compartments. From observation since the latrine is not attended to on a full-time basis, fouling causes 10 per cent loss of capacity. Fouled compartments cannot be used until they have been cleaned. Community education will be necessary to reduce such faults.

(f) Quality:

Pits are still in use and therefore sludge in contact with fresh excreta is not safe. pH is however less than 7.0. Since population using latrine is within the design population sludge produced will be thick with moisture content around 70 per cent. Manual desludging will be required.

(g) Quantity:

Quantity of sludge produced could not be assessed since cement mortar will be required to re-seal the slabs. Data from other projects suggest that 0.03 m^3 per person per year is appropriate for Ghana.

(h) Utilisation:

Average population using the K-VIP latrine was about 180 persons for an average size of community of 1,800 population. Ten per cent utilisation is recorded. Community education is required to encourage more people to use the facility.

2. Financial Factors

(i) *Cost*

(a) Capital Cost:

The range of capital costs for a single 10-compartment K-VIP latrine was $8500-$14545 with an average cost of $11550.
25 out of 43 projects started were completed.
(Source: Files of Ministry of Rural Development and Cooperatives.)

(b) Operations and Maintenance Costs:

Annual operation and maintenance cost is estimated at $840. This figure estimates the cost of communal labour and other requirements for operations and maintenance.

(c) Design Life:

The K-VIP latrine is designed for a 20 year life.

(d) Replacement Cost;
Current cost escalated by the rate of inflation.

(ii) Income

(a) Tariff;
No tariff has been instituted. Interview with Town Development Committees revealed that the communities already felt they have contributed enough to get the project constructed. Secondly, any attempt to institute tariff will deter people from using the latrine and drive them back into the bush. However, whenever the pits get full a head tax will be collected to desludge the latrine.

(b) Government Finance;
Total government involvement in the project was $1,228,858.
(Source: Files of Ministry of Rural Development and Cooperatives.)

(c) Local Government/Community Contributions;
The initial contribution of $7272 required was raised through various arrangements. Certain district assemblies paid on behalf of communities in their area, some communities paid through a head tax, still others were paid by a benefactor in the community or by a charitable organisation working in the community.

In addition to the initial contribution in cash, the communities also contributed local material such as sand, stones, timber and labour.

(d) Ability to Pay;
When the communities made the decision to participate in the project they generally demonstrated the ability to pay. In most cases it was the government contributions which arrived late or never arrived.

(e) Willingness to Pay:

Most communities had to assess their priorities in deciding whether to pay for a permanent latrine or continue to use their traditional pit latrines. The K-VIP latrine in the rural environment is expensive especially where land is plentiful. Out of 140 communities expected to participate only 43 paid the initial deposit. Communities were rather unwilling to pay.

3. Economic Factors

(i) Cost

(a) Capital Cost:

The range of capital cost was $8500-$14545 per 10-compartment latrine with an average of $11550.

Foreign cost component:	50 per cent
Unskilled labour component:	10 per cent
Remaining local cost:	40 per cent

(b) Operations and Maintenance:

Annual operations and maintenance cost was $840.

Foreign cost component:	15 per cent
Unskilled labour component:	20 per cent
Remaining local cost:	65 per cent

(c) Design Life:

The K-VIP is designed for a 20 year life.

(d) Replacement Cost:

Current cost escalated by the rate of inflation.

(ii) Benefit

(a) Revenue:

Nil, there is no admission charge.

(b) Least Cost Solution:

With land available provision of a permanent latrine is not a least-cost solution. Other alternatives such as improvement to the traditional pit or a non-alternating VIP latrine with a moveable superstructure should also be considered.

(c) <u>Shadow Price:</u>
See Appendix A.

(d) <u>Interest Rates:</u>
See Appendix A.

4. <u>Institutional Factors</u>

(i) *Construction*

The project was constructed on self-help with technical support from the Ministry of Rural Development and Cooperatives. Two institutions under that ministry, that is, the Department of Community Development and Department of Rural Housing and Cottage Industries, sent their works foremen to the Civil Engineering Department of the University of Science and Technology, Kumasi, to be trained in the construction of the K-VIP latrines. These foremen on completion of their training as trainers were sent to Technical and Vocational Institutions to train the final year block-laying classes. After the training, two students were, in turn, sent to each of the communities that contributed their matching funds. Supervision was by the trainer foremen.

The communities provided local tradesmen and unskilled labour as and when required. The idea was that once the local tradesmen were trained they could be used locally should the community decide, in future, to have more units or they could be used in the expanded project phase planned to follow the pilot project. With a series of currency devaluations prices locally increased rapidly, the flow of materials was slow and community deposits could not purchase much. The pilot project ground to a halt after the government funds were depleted. Communities which could not complete their projects were informed that they had to make their own arrangements to complete them. Later UNICEF, working through the Department of Community Development, is helping to complete some of the old projects. Further in the 1989 Budget, government provided funds under the Programme of Actions to Mitigate the Social Costs of Adjustment (PAMSCAD) for community initiated projects and some of these uncompleted projects could receive support from that programme.

(ii) Operations and Maintenance

Operations and maintenance of the K-VIP latrines are undertaken by the communities under their Town Development Committees and Committees for the Defense of the Revolution.

(iii) Logistics

There were logistic problems during construction. However no external inputs are required for operation and maintenance except for small quantities of cement which can be obtained easily.

(iv) Training

Local tradesmen were trained in the construction of the K-VIP latrines. There is the need for a follow-up training in operation and maintenance. An Operations and Maintenance Manual should be prepared and circulated among the communities.

(v) Legal Responsibility/Declared Aims

District Assemblies are responsible for providing sanitation facilities among other development requirements. Priorities for projects should come from the communities themselves working through Town Development Committees and Committees for the Defense of the Revolution. Communities are responsible for the operation and maintenance of sanitation facilities with assistance from the District Assemblies.

Various multilateral, bilateral and non-governmental organisations have declared their intentions to support sanitation programmes in rural areas.

5. <u>Social Factors</u>

(i) Odours

Odours are mainly due to the accumulation of anal cleansing materials in the latrine compartments. Depositing anal cleansing materials in the pits should reduce odours. However the level of odour is bearable.

(ii) *Distance Travelled*

The K-VIP latrine is usually located at one end of the town. Distances walked is between 20-250m with an average of 100m. The K-VIP is typically sited near the traditional pit latrine.

(iii) *Queuing Period*

No queues were observed. The traditional pit latrine and open defecation are still in use.

(iv) *Type of Anal Cleansing Material*

Corn cobs are by far the most common anal cleansing material used in the rural areas. Other items include leaves, old rags, paper (generally in short supply), wood and stones. Those without anal cleansing materials smear the walls with excreta. Some communities provide corn cobs in baskets to stop smearing of the walls.

(v) *Children*

In most cases children were not allowed to use the K-VIP latrines. Most children either use the traditional pit latrine or go into the bush.

(vi) *Community Involvement*

(a) <u>Request for Project:</u>

Yes, communities have to request for the project.

(b) <u>Level of Service/Coverage:</u>

Yes, communities were aware of the level of service but coverage depended on the resources of the community.

(c) <u>Dialogue:</u>

When the communities satisfied the criteria for participation dialogue was established to plan the construction of the projects.

(d) Commitment:

Yes, communities were required to demonstrate commitment to the project by paying the cash deposit required.

(e) Appropriate Technology:

The permanent K-VIP latrine is not appropriate to the rural communities.

(f) Willingness to Pay:

Cost of the K-VIP latrine was rather expensive for the rural communities hence only 43 out of the expected 140 communities paid cash deposits.

(g) Cost Recovery:

Communities were aware of the level of cost recovery required.

(h) Ability to Pay:

Communities that requested to participate in the project demonstrated their ability to pay for the project.

(i) Decision Making:

Most decisions were taken by the project planners. Even when communities had agreed to participate in the project communities had to abide by decisions by planners.

(j) Responsibility:

Communities agreed to share in the responsibility of providing the sanitation service.

(vii) Population Factors

Population of communities to be served by the project should be less than 2,000. Average population of communities served by the project was 1,800 persons. Population density was 70 persons per hectare. Age structure is taken as similar to the national age structure. Religion is mostly Christian or Animist. Educational level is 56 per cent primary school or better.

(viii) Alternative Facilities

The traditional pit latrine is extensively used. Open defecation in the bush or at the beach is also practised.

6. Environmental Factors

Sludge Disposal

The rural K-VIP latrines will be desludged manually and the sludge spread behind the latrine and allowed to dry before incineration. It is estimated that $1.00 per user will be required to create facilities to dispose of the sludge without creating any nuisance.

7. Rural K-VIP Latrines Visited

Ashanti Region - Asawase, Apaa, Achiase, Hwidiem
Brong Ahafo Region - Amantin
Central Region - Anomabu
Eastern Region - Kwamoso, Kwahu Fodua
Volta Region - Akatsi, Anfoega

APPENDIX J

DATA ON THE TRADITIONAL PIT LATRINE PROJECT

1. Technical Factors

(a) Collection Technology: as described in Chapter 7.

(b) Treatment/Disposal: as described in Chapter 7; on-site treatment and disposal.

(c) Operation - Plans for:

No formal plans are available. The Town Development Committee appoints women to clean latrines daily. Weeding around the latrine is done by general communal labour monthly.

Actual Operation:

All anal cleansing material left in the latrine is removed for incineration or burial as the latrine is cleaned. Weeding of access and area around the latrine is carried out monthly.

Requirements for Effective Operations:

All anal cleansing materials should be deposited in the pit although community leaders believe this will reduce the life of the pit. Community education is required to persuade community leaders and to teach the community the proper use of latrines to minimise fouling. It is estimated that 80 per cent of operation requirements are achieved.

(d) Maintenance - Plans for:

No formal plans are available. Community leaders rely on local artisans who constructed the latrine to carry out maintenance as and when required.

Actual Maintenance:

Any user can pass on complaints to community leaders. Regular backfilling around the superstructure on communal labour days avoids undermining of superstructure through erosion. There were no obvious maintenance problems.

Requirements of Effective Maintenance:
Periodic inspection of roofing, superstructure, squatting planks and for any signs of possible collapse of pit is vital. It is estimated that 90 per cent of maintenance requirements are achieved.

(e) Types of Faults:
Main faults include strong, obnoxious smells, fly breeding, lack of privacy and fouling of planks and latrine floor. Fouling of the planks make some of the squatting positions unattractive for users. By observation 10 per cent of the squatting positions are unavailable at any time.

(f) Quality of Sludge:
Fresh excreta is deposited each day and therefore sludge could not be analysed. The sludge is obviously not safe until the latrine is full and the site abandoned for at least 12 months. pH of the sludge is less than 7.0.

(g) Quantity of Sludge:
Sludge accumulation after a three year use was 0.94m in the female section and 0.79m in the male section.

(h) Utilisation:
An average of 132 females use the latrine while 96 males used it. Total usage is 238 persons for a village population of 540 persons. Defecation in the bush is still practised.

2. Financial Factors

(i) *Cost*

(a) Capital Cost:
Capital cost for the two units of 16 squatting holes latrine was estimated at $2,000.

(Source: Estimates were made from interviews with members of the Town Development Committee and the Committee for the Defense of the Revolution.)

All materials and labour provided in kind were estimated at the prevailing market prices.

(b) <u>Operation and Maintenance:</u>

Annual operation and maintenance cost is $155.

(All materials and labour provided in kind were estimated at the prevailing market prices.)

(c) <u>Design Life:</u>

The capacity of pit provided should be sufficient for over 20 years barring any pit collapse.

(e) <u>Replacement Cost:</u>

Current cost escalated by the rate of inflation.

(ii) Income

(a) <u>Tariff:</u>

There is no admission charge.

(b) <u>Community Finance:</u>

The Town Development Committee and the Committee for the Defense of the Revolution levy an annual head tax of $5.0 per male and $2.50 per female to finance development projects. Annual collections are in the range of $500-$750. The pit latrine project was financed out of that fund.

(c) <u>Ability to Pay:</u>

An annual levy of $5.00 is not excessive. However community members provide materials and labour in kind for development project.

(d) <u>Willingness to Pay:</u>

The community members willingly contribute towards their development projects.

3. Economic Factors

(i) Cost

(a) Capital Cost:

Cost of 2 units 16-hole latrines:	$2000
Foreign cost component:	zero
Unskilled labour component:	30 per cent
Remaining local cost:	70 per cent

(b) Operation and Maintenance Cost:

Annual operation and maintenance cost:	$155
Foreign cost component:	zero
Unskilled labour component:	50 per cent
Remaining local cost:	50 per cent

(c) Design Life:

Life of traditional pit latrine:	20 years

(d) Replacement Cost:

Current cost escalated by the rate of inflation.

(ii) Benefit

(a) Revenue:

Nil; no admission charge.

(b) Least Cost Solution:

The traditional pit is a least cost solution but requires improvement to minimise odours and fly breeding.

(c) Shadow Prices:

See Appendix A.

(d) Interest Rates:

See Appendix A.

4. <u>Institutional Factors</u>

(i) *Construction*

Project construction was by self-help.

(ii) *Operation and Maintenance*

Project operation and maintenance is by self-help under the management of the Town Development Committee and the Committee for the Defense of the Revolution.

(iii) *Logistic*

No logistic problem encountered.

(iv) *Training*

Community requires training in incremental improvements to the traditional pit latrine to make it more acceptable.

(v) *Legal Responsibility*

The community had taken on the responsibility of providing latrines for themselves. The responsibility of the District Assembly is to provide acceptable sanitation facilities for all communities but inadequate resources prevent full discharge of that responsibility.

5. <u>Social Factors</u>

(i) *Odours*

Traditional pit latrines have strong, obnoxious odours which only local residents can get used to. Non-residents on visit to the communities with the traditional pit latrine resort to open defecation. Odours can be minimised by providing vents to the latrine.

(ii) *Distance Travelled*

Distance walked ranged from 20m to 200m with an average of 100m.

(iii) *Queuing Period*

No queues develop since the latrine has a large capacity and also open defecation is practised.

(iv) *Anal Cleansing Materials*

Anal cleansing materials used include corn cobs, paper, wood, old rags, water, leaves and stones.

(v) *Children*

Most children use the traditional pit latrine. Those who cannot use the facility resort to open defecation.

(vi) *Community Involvement*

(a) Request for Project:

Yes, the community took the decision to build the traditional pit latrine.

(b) Level of Service/Coverage:

Yes, the community decided on the level of service.

(c) Dialogue:

The community leaders maintains dialogue with members of the community on all development projects.

(d) Commitment:

The community commits itself to certain development projects annually.

(e) Appropriate Technology:

The technology selected by the community was appropriate.

(f) Willingness to Pay:

The community demonstrated its willingness to pay by providing cash and labour for the project.

(g) Cost Recovery:

All project costs are borne by the community.

(h) Ability to Pay:

Most materials and labour were provided in kind. There was very little cash involved in the project.

(i) Decision Making:

All decisions were made by the community.

(j) Responsibility:

The community took full responsibility for the project.

(vii) Population Factors

The population of the community is 540. It has a primary school and religion is mainly Christian. Age structure is similar to the national age structure. The population density was 60 persons per hectare.

(viii) Alternative Facilities

Open defecation is still practised.

6. Environmental Factors

Sludge Disposal

On-site disposal of sludge takes place when the latrine is full and the pit is abandoned. No environmental nuisance is created.

APPENDIX K

C O M P U T E R   R U N S

RUN 1: ACCRA-TEMA WATER SUPPLY PROJECT

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                              SIMPL-X
                          ----------------
                    A program for solving
                    linear programming problems

                  (C) COPYRIGHT 1986 SGF SOFTWARE

/THE PROBLEM HAS    11 CONSTRAINTS AND    8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.970     -.800      .000      .000      .000      .000      .000      .000
 CONSTRAINT NO.           1
     -.970     -.800      .600      .730     2.430   479.000     6.000     2.000
               .00000
 CONSTRAINT NO.           2
      .780     -.500      .650      .950     2.200   450.000     6.000      .000
               .00000
 CONSTRAINT NO.           3
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               .00000
 CONSTRAINT NO.           4
      .850      .400      .720      .750     1.970    72.000     5.000      .000
               .00000
 CONSTRAINT NO.           5
     -.400     -.300      .840      .990     4.420    66.000     6.000      .000
>              .00000
 CONSTRAINT NO.           6
     -.980     -.900      .440      .540      .930      .000      .000      .000
               .00000
 CONSTRAINT NO.           7
     -.900     -.200      .460      .880    77.600  1150.000     8.000     3.300
               .00000
 CONSTRAINT NO.           8
      .900     -.300      .500      .310     6.770      .000     2.000     1.000
               .00000
 CONSTRAINT NO.           9
      .900     -.100      .500      .220     8.150      .000     3.000     1.000
               .00000
 CONSTRAINT NO.           10
      .900     -.440      .000      .000      .450      .000      .000      .000
               .00000
 CONSTRAINT NO.           11
      .000      .000      .600      .730     4.170   479.000     6.000     2.000
=             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -.196207

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.     .0000     .2453     .0000     .0000     .2398     .0000     .000
0

 VAR.  NO.          8
 SOL. VALU.     .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.     .3865     .4049     .9954     .3743     .9864     .0023    18.560
1

 VAR.  NO.          8         9        10        11
 SOL. VALU.    1.5499    1.9299     .0000     .0000
```

RUN 1: BOREHOLE WATER SUPPLY PROJECT

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                         SIMPL-X
                    -----------------
                 A program for solving
                linear programming problems

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/THE PROBLEM HAS   11 CONSTRAINTS AND   8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
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>              .00000
 CONSTRAINT NO.            2
     -.780      .500      .650      .950     2.200   450.000     6.000      .000
               .00000
 CONSTRAINT NO.            3
     -.330     -.400      .600      .970     4.560  1000.000     7.000      .000
/              .00000
 CONSTRAINT NO.            4
      .850     -.400      .720      .950     1.970    72.000     5.000      .000
               .00000
 CONSTRAINT NO.            5
      .100     -.300      .840      .990     4.420    66.000     6.000      .000
               .00000
 CONSTRAINT NO.            6
      .980     -.900      .440      .540      .930      .000      .000      .000
               .00000
 CONSTRAINT NO.
      .900     -.200      .460      .880    77.600  1150.000     8.000     3.300
               .00000
 CONSTRAINT NO.            8
     -.900     -.300      .500      .310     6.770      .000     2.000     1.000
>              .00000
 CONSTRAINT NO.            9
     -.900     -.100      .500      .220     8.150      .000     3.000     1.000
/              .00000
 CONSTRAINT NO.           10
     -.900      .440      .000      .000      .450      .000      .000      .000
               .00000
 CONSTRAINT NO.           11
      .000      .000      .650      .950     2.200   450.000     6.000      .000
=             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS            -.232438

 THE SOLUTION VALUES FOR THE VARIABLES ARE
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 SOL.  VALU.      .0000      .4649      .0000      .0000      .4545      .0000      .000
0

 VAR.  NO.          8
 SOL.  VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1          2          3          4          5          6
 SOL.  VALU.      .7326      .7676     1.8868      .7095     1.8696      .0043     35.17
7

 VAR.  NO.          8          9         10         11
 SOL.  VALU.     2.9378     3.6581      .0000      .0000
```

RUN 1: PACKAGE PLANT WATER SUPPLY PROJECT

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                              SIMPL-X
                         ----------------
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                     linear programming problems

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/THE PROBLEM HAS   11 CONSTRAINTS AND   8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
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>              .00000
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               .00000
 CONSTRAINT NO.            3
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               .00000
 CONSTRAINT NO.            4
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               .00000
 CONSTRAINT NO.            5
     -.400     -.300      .840      .990     4.420    66.000     6.000      .000
>              .00000
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>              .00000
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>              .00000
 CONSTRAINT NO.            8
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>              .00000
 CONSTRAINT NO.            9
     -.900     -.100      .500      .220     8.150      .000     3.000     1.000
>              .00000
 CONSTRAINT NO.            10
      .900     -.440      .000      .000      .450      .000      .000      .000
>              .00000
 CONSTRAINT NO.            11
      .000      .000      .600      .970     4.560  1000.000     7.000      .000
=             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -.089713

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.      .0000     .2243     .0000     .0000     .2193     .0000      .000
0

 VAR.  NO.          8
 SOL. VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.      .3535     .3703     .9103     .3423     .9020     .0021    16.972
6

 VAR.  NO.          8         9        10        11
 SOL. VALU.     1.4174    1.7648     .0000     .0000
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RUN 1: 2500 DRILLED WELLS WATER SUPPLY PROJECT

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                              SIMPL-X
                       ---------------------
                     A program for solving
                    linear programming problems

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/THE PROBLEM HAS    11 CONSTRAINTS AND    8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.850      -.400      .000      .000      .000      .000      .000      .000
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              .00000
 CONSTRAINT NO.              2
     -.780       .500      .650      .950     2.200   450.000     6.000      .000
              .00000
 CONSTRAINT NO.              3
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              .00000
 CONSTRAINT NO.              4
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              .00000
 CONSTRAINT NO.              5
      .400       .700      .840      .990     4.420    66.000     6.000      .000
              .00000
 CONSTRAINT NO.              6
     -.980       .900      .440      .540      .930      .000      .000      .000
>             .00000
 CONSTRAINT NO.              7
     -.900      -.200      .460      .880    77.600  1150.000     8.000     3.300
>             .00000
 CONSTRAINT NO.              8
     -.900      -.300      .500      .300     6.770      .000     2.000     1.000
              .00000
 CONSTRAINT NO.              9
     -.900      -.100      .500      .220     8.150      .000     3.000     1.000
              .00000
 CONSTRAINT NO.              10
     -.900      -.440      .000      .000      .450      .000      .000      .000
              .00000
 CONSTRAINT NO.              11
      .000       .000      .720      .950     1.970    72.000     5.000      .000
=            1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS              .000000

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.         1          2          3          4          5          6          7
 SOL.  VALU.     .0000      .0000      .0000      .0000      .0000      .0000      .200
0

 VAR.  NO.         8
 SOL.  VALU.     .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
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 SOL.  VALU.    1.2000     1.2000     1.4000     1.0000     1.2000      .0000     1.600
0

 VAR.  NO.         8          9         10         11
 SOL.  VALU.     .4000      .6000      .0000      .0000
```

RUN 1: 3000 DRILLED WELLS WATER SUPPLY PROJECT

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                              SIMPL-X
                         -----------------
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                     linear programming problems

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/THE PROBLEM HAS   11 CONSTRAINTS AND   8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.400     -.300      .000      .000      .000      .000      .000      .000
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               .00000
 CONSTRAINT NO.            2
     -.780     -.500      .650      .950     2.200   450.000     6.000      .000
               .00000
 CONSTRAINT NO.            3
      .330      .400      .600      .970     4.560  1000.000     7.000      .000
               .00000
 CONSTRAINT NO.            4
      .850      .400      .720      .950     1.970    72.000     5.000      .000
               .00000
 CONSTRAINT NO.            5
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               .00000
 CONSTRAINT NO.            6
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               .00000
 CONSTRAINT NO.            7
     -.900     -.200      .460      .880    77.600  1150.000     8.000     3.300
               .00000
 CONSTRAINT NO.            8
     -.900     -.300      .500      .310     6.770      .000     2.000     1.000
               .00000
 CONSTRAINT NO.            9
     -.900     -.100      .500      .220     8.150      .000     3.000     1.000
               .00000
 CONSTRAINT NO.            10
     -.900     -.440      .000      .000      .450      .000      .000      .000
               .00000
 CONSTRAINT NO.            11
      .000      .000      .840      .990     4.420    66.000     6.000      .000
=             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS           -.069416

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.     .0000     .2314     .0000     .0000     .2262     .0000      .000
0

 VAR.  NO.          8
 SOL. VALU.     .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.     .3647     .3820    1.1242     .3531     .9306     .0022    17.510
3

 VAR.  NO.          8         9        10        11
 SOL. VALU.    1.4623    1.8200     .0000     .0000
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RUN 1: HAND DUG WELL WATER SUPPLY PROJECT

```
                              SIMPL-X
                          ---------------- -
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                     linear programming problems

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/THE PROBLEM HAS    11 CONSTRAINTS AND    8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.980      -.900       .000       .000       .000       .000       .000       .000
 CONSTRAINT NO.              1
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                .00000
 CONSTRAINT NO.              2
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>               .00000
 CONSTRAINT NO.              3
     -.330      -.100       .600       .970      4.560   1000.000      7.000       .000
>               .00000
 CONSTRAINT NO.              4
      .850       .400       .720       .950      1.970     72.000      5.000       .000
                .00000
 CONSTRAINT NO.              5
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                .00000
 CONSTRAINT NO.              6
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                .00000
 CONSTRAINT NO.              7
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>               .00000
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/               .00000
 CONSTRAINT NO.              9
     -.900      -.100       .500       .220      8.150       .000      3.000      1.000
/               .00000
 CONSTRAINT NO.             10
     -.900      -.440       .000       .000       .450       .000       .000       .000
                .00000
 CONSTRAINT NO.             11
      .000       .000       .440       .540       .930       .000       .000     . .000
=             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -.989736

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1          2          3          4          5          6          7
 SOL. VALU.      .0000     1.0997      .0000      .0000     1.0753      .0000       .000
0

 VAR.  NO.          8
 SOL. VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1          2          3          4          5          6          7
 SOL. VALU.     1.6364     1.8157     4.4634     1.6784     4.4228      .0103     83.122
0

 VAR.  NO.          8          9         10         11
 SOL. VALU.     6.9497     8.6535      .0000      .0000
```

RUN 1: CENTRAL ACCRA SEWERAGE

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                         SIMPL--X
                     -----------------
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                 linear programming problems

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/THE PROBLEM HAS   11 CONSTRAINTS AND   8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
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               .00000
 CONSTRAINT NO.            2
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               .00000
 CONSTRAINT NO.            3
      .330      .400      .600      .970     4.560  1000.000     7.000      .000
               .00000
 CONSTRAINT NO.            4
      .850     -.400      .720      .950     1.970    72.000     5.000      .000
               .00000
 CONSTRAINT NO.            5
     -.400     -.300      .840      .990     4.420    66.000     6.000      .000
>              .00000
 CONSTRAINT NO.            6
     -.980      .900      .440      .540      .930      .000      .000      .000
>              .00000
 CONSTRAINT NO.            7
     -.900     -.200      .460      .880    77.600  1150.000     8.000     3.300
               .00000
 CONSTRAINT NO.            8
     -.900     -.300      .500      .310     6.770      .000     2.000     1.000
               .00000
 CONSTRAINT NO.            9
      .900     -.100      .500      .220     8.150      .000     3.000     1.000
>              .00000
 CONSTRAINT NO.            10
     -.900     -.440      .000      .000      .450      .000      .000      .000
               .00000
 CONSTRAINT NO.            11
      .000      .000      .460      .880    77.000     6.000  1150.000     8.000
=             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS              -.005844

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 SOL.  VALU.      .0065     .0000     .0000     .0000     .0130     .0000     .000
0

 VAR.  NO.          8
 SOL.  VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL.  VALU.      .0253     .0235     .0571     .0201     .0548     .0057     1.001
9

 VAR.  NO.          8         9        10        11
 SOL.  VALU.      .0821     .1000     .0000     .0000
```

RUN 1: URBAN K-VIP LATRINE PROJECT

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                              SIMPL-X
                         -----------------
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                      linear programming problems

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/THE PROBLEM HAS   11 CONSTRAINTS AND   8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.900     -.300      .000      .000      .000      .000      .000      .000
 CONSTRAINT NO.            1
      .970     -.800      .600      .730     2.430   479.000     6.000     2.000
               .00000
 CONSTRAINT NO.            2
      .730     -.500      .650     -.950     2.200   450.000     6.000      .000
>              .00000
 CONSTRAINT NO.            3
     -.330     -.400      .600      .970     4.560  1000.000     7.000      .000
               .00000
 CONSTRAINT NO.            4
      .850      .400      .720      .950     1.970    72.000     5.000      .000
               .00000
 CONSTRAINT NO.            5
      .400      .300      .840      .990     4.420    66.000     6.000      .000
>              .00000
 CONSTRAINT NO.            6
     -.980      .900      .440      .540      .930      .000      .000      .000
>              .00000
 CONSTRAINT NO.            7
     -.900     -.200      .460      .880    77.600  1150.000     8.000     3.300
               .00000
 CONSTRAINT NO.            8
      .900     -.300      .500      .310     6.770      .000     2.000     1.000
>              .00000
 CONSTRAINT NO.            9
     -.900     -.100      .500      .220     8.150      .000     3.000     1.000
               .00000
 CONSTRAINT NO.            10
     -.900     -.440      .000      .000      .450      .000      .000      .000
               .00000
 CONSTRAINT NO.            11
      .000      .000      .500      .310     6.770      .000     2.000     1.000
=             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS              -.066470

 THE SOLUTION VALUES FOR THE VARIABLES ARE
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 SOL. VALU.      .0739     .0000     .0000     .0000     .1477     .0000      .000
0

 VAR.  NO.          8
 SOL. VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
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 SOL. VALU.      .2873     .2710     .6492     .2282     .6233     .0650    11.395
9

 VAR.  NO.          8         9        10        11
 SOL. VALU.      .9335    1.1374     .0000     .0000
```

RUN 1: RURAL K-VIP LATRINE PROJECT

```
                                SIMPL-X
                           ----------------
                       A program for solving
                      linear programming problems

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/THE PROBLEM HAS   11 CONSTRAINTS AND   8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.900      -.100       .000       .000       .000       .000       .000       .000
 CONSTRAINT NO.              1
     -.970      -.800       .600       .730      2.430    479.000      6.000      2.000
>          .00000
 CONSTRAINT NO.              2
     -.780      -.500       .650       .950      2.200    450.000      6.000       .000
>          .00000
 CONSTRAINT NO.              3
     -.330      -.440       .600       .970      4.560   1000.000      7.000       .000
>          .00000
 CONSTRAINT NO.              4
      .850       .400       .720       .950      1.970     72.000      5.000       .000
           .00000
 CONSTRAINT NO.              5
      .400       .300       .840       .990      4.420     66.000      6.000       .000
           .00000
 CONSTRAINT NO.              6
     -.980      -.900       .440       .540       .930       .000       .000       .000
/          .00000
 CONSTRAINT NO.              7
     -.900      -.200       .460       .880     77.600   1150.000      8.000      3.300
/          .00000
 CONSTRAINT NO.              8
     -.900      -.300       .500       .310      6.770       .000      2.000      1.000
>          .00000
 CONSTRAINT NO.              9
      .900       .100       .500       .220      8.150       .000      3.000      1.000
,          .00000
 CONSTRAINT NO.             10
      .900      -.440       .000       .000       .450       .000       .000       .000
           .00000
 CONSTRAINT NO.             11
      .000       .000       .500       .220      8.150       .000      3.000      1.000
=         1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS           -.055215

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.           1          2          3          4          5          6          7
 SOL. VALU.        .0613      .0000      .0000      .0000      .1227      .0000      .000
0

 VAR.  NO.           8
 SOL. VALU.        .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.           1          2          3          4          5          6          7
 SOL. VALU.        .2387      .2221      .5393      .1896      .5178      .0540     9.466
7

 VAR.  NO.           8          9         10         11
 SOL. VALU.        .7755      .9448      .0000      .0000
```

RUN 1: TRADITIONAL PIT LATRINE PROJECT

```
                              SIMPL-X
                         -----------------
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                      linear programming problems

                    (C) COPYRIGHT 1986 SGF SOFTWARE

/THE PROBLEM HAS   11 CONSTRAINTS AND   8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.900     -.440      .000      .000      .000      .000      .000      .000
 CONSTRAINT NO.            1
      .970     -.800      .600      .730     2.430   479.000     6.000     2.000
               .00000
 CONSTRAINT NO.            2
     -.780     -.500      .650      .950     2.200   450.000     6.000      .000
/              .00000
 CONSTRAINT NO.            3
     -.330     -.400      .600      .970     4.560  1000.000     7.000      .000
,              .00000
 CONSTRAINT NO.            4
      .850      .400      .720      .950     1.970    72.000     5.000      .000
               .00000
 CONSTRAINT NO.            5
      .400     -.300      .840      .990     4.420    66.000     6.000      .000
               .00000
 CONSTRAINT NO.            6
     -.980     -.900      .440      .540      .930      .000      .000      .000
/              .00000
 CONSTRAINT NO.            7
     -.900     -.200      .460      .880    77.600  1150.000     8.000     3.300
>              .00000
 CONSTRAINT NO.            8
     -.900     -.300      .500      .300     6.770      .000     2.000     1.000
               .00000
 CONSTRAINT NO.            9
     -.900     -.100      .500      .220     8.150      .000     3.000     1.000
,              .00000
 CONSTRAINT NO.           10
     -.900     -.140      .000      .000      .450      .000      .000      .000
               .00000
 CONSTRAINT NO.           11
      .000      .000      .000      .000      .450      .000      .000      .000
=             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -1.000000

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.    1.1111     .0000     .0000     .0000    2.2222     .0000     .000
0

 VAR.  NO.          8
 SOL. VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.    4.3222    4.0222    9.7667    3.4333    9.3778     .9778   171.444
5

 VAR.  NO.          8         9        10        11
 SOL. VALU.   14.0444   17.1111     .0000     .0000
```

RUN 2: ACCRA-TEMA WATER SUPPLY PROJECT

```
                         SIMPL-X
                    -----------------
               A program for solving
              linear programming problems

            (C) COPYRIGHT 1986 SGF SOFTWARE

/THE PROBLEM HAS     7 CONSTRAINTS AND    8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
   -.970    -.800     .000     .000     .000      .000     .000     .000
 CONSTRAINT NO.        1
   -.970    -.800     .600     .730    2.430   479.000    6.000    2.000
>           .00000
 CONSTRAINT NO.        2
   -.078    -.500     .650     .950    2.200   450.000    6.000     .000
>           .00000
 CONSTRAINT NO.        3
    .330    -.400     .600     .970    4.560  1000.000    7.000     .000
            .00000
 CONSTRAINT NO.        4
    .850     .400     .720     .950    1.970    72.000    5.000     .000
            .00000
 CONSTRAINT NO.        5
    .400     ..00     .840     .990    4.420    66.000    6.000     .000
>           .00000
 CONSTRAINT NO.        6
   -.980    -.900     .440     .540     .930      .000     .000     .000
>           .00000
 CONSTRAINT NO.        7
    .000     .000     .600     .730    4.170   479.000    6.000    2.000
=          1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -.732178

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.         1         2         3         4        5        6       7
 SOL. VALU.      .7548     .0000     .0000    1.3699    .0000    .0000    .000
0

 VAR.  NO.         8
 SOL. VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.         1         2         3         4        5        6       7
 SOL. VALU.      .2678    1.2425    1.0797     .6598   1.0542    .0000    .000
0
```

RUN 2: BOREHOLE WATER SUPPLY PROJECT

```
                              SIMPL-X
                         -----------------
                        A program for solving
                       linear programming problems

                     (C) COPYRIGHT 1986 SGF SOFTWARE


/THE PROBLEM HAS     7 CONSTRAINTS AND    8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.780      -.500      .000      .000      .000      .000      .000      .000
 CONSTRAINT NO.            1
     -.970      -.800      .600      .730     2.430   479.000     6.000     2.000
/           .00000
 CONSTRAINT NO.            2
      .780      -.500      .650      .950     2.200   450.000     6.000      .000
            .00000
 CONSTRAINT NO.            3
      .330       .400      .600     -.970     4.560  1000.000     7.000      .000
            .00000
 CONSTRAINT NO.            4
      .850      -.400      .720      .950     1.970    72.000     5.000      .000
            .00000
 CONSTRAINT NO.            5
     -.400      -.300      .840      .990     4.420    66.000     6.000      .000
            .00000
 CONSTRAINT NO.            6
     -.980      -.900      .440      .540      .930      .000      .000      .000
>           .00000
 CONSTRAINT NO.            7
      .000       .000      .650      .950     2.200   450.000     6.000      .000
-          1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -.538775

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.      .6907     .0000    1.5385     .0000     .0000     .0000     .000
0

 VAR.  NO.          8
 SOL. VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.      .2531     .4612     .6951     .5206    1.0160     .0000     .000
0
```

RUN 2: PACKAGE PLANT WATER SUPPLY PROJECT

```
                              SIMPL-X
                          ----------------.
                     A program for solving
                    linear programming problems

                  (C) COPYRIGHT 1986 SGF SOFTWARE

/THE PROBLEM HAS     7 CONSTRAINTS AND    8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
      .330      .400      .000      .000      .000      .000      .000      .000
 CONSTRAINT NO.          1
     -.970     -.800      .600      .730     2.430   479.000     6.000     2.000
               .00000
 CONSTRAINT NO.          2
     -.780     -.500      .650      .950     2.200   450.000     6.000      .000
               .00000
 CONSTRAINT NO.          3
      .330     -.400      .600      .970     4.560  1000.000     7.000      .000
               .00000
 CONSTRAINT NO.          4
      .850     -.400      .720      .950     1.970    72.000     5.000      .000
               .00000
 CONSTRAINT NO.          5
      .400  [illegible]   .840      .990     4.420    66.000     6.000      .000
               .00000
 CONSTRAINT NO.          6
     -.980     -.900      .440      .540      .930      .000      .000      .000
               .00000
 CONSTRAINT NO.          7
      .000      .000      .600      .970     4.560  1000.000     7.000     -.000
=            1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -.325926

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1          2         3          4          5          6          7
 SOL. VALU.      .0000      .8148    1.6667      .0000      .0000      .0000      .000
0

 VAR.  NO.          8
 SOL. VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1          2         3          4          5          6          7
 SOL. VALU.      .3481      .6759      .6741      .8741     1.1556      .0000      .000
0
```

RUN 2: 2500 DRILLED WELLS WATER SUPPLY PROJECT

```
                          SIMPL-X
                     -----------------
                  A program for solving
                 linear programming problems

              (C) COPYRIGHT 1986 SGF SOFTWARE

/THE PROBLEM HAS    7 CONSTRAINTS AND   8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    -.850     -.400      .000      .000      .000      .000      .000      .000
 CONSTRAINT NO.            1
     .970     -.800      .600      .730     2.430   479.000     6.000     2.000
>              .00000
 CONSTRAINT NO.            2
     .780     -.500      .650      .950     2.200   450.000     6.000      .000
/              .00000
 CONSTRAINT NO.            3
     .330     -.400      .600      .970     4.560  1000.000     7.000      .000
               .00000
 CONSTRAINT NO.            4
     .850      .100      .720      .950     1.970    72.000     5.000      .000
               .00000
 CONSTRAINT NO.            5
     .100      .300      .840      .990     4.420    66.000     6.000      .000
/              .00000
 CONSTRAINT NO.            6
    -.980     -.900      .440      .540      .930      .000      .000      .000
               .00000
 CONSTRAINT NO.            7
     .000      .000      .720      .950     1.970    72.000     5.000      .000
=             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS           -.530045

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.         1         2         3         4         5         6         7
 SOL.  VALU.     .6236     .0000    1.3889     .0000     .0000     .0000     .000
0

 VAR.  NO.         8
 SOL.  VALU.     .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.         1         2         3         4         5         6         7
 SOL.  VALU.     .2285     .4164     .6276     .4700     .9172     .0000     .000
0
```

RUN 2: 3000 DRILLED WELLS WATER SUPPLY PROJECT

```
                              SIMPL-X
                         - ----- ---------.
                      A program for solving
                     linear programming problems

                   (C) COPYRIGHT 1986 SGF SOFTWARE

/THE PROBLEM HAS    7 CONSTRAINTS AND    8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    -.400       .300       .000       .000       .000       .000       .000       .000
 CONSTRAINT NO.            1
     .970      -.800       .600       .730      2.430    479.000      6.000      2.000
              .00000
 CONSTRAINT NO.            2
     .780      -.500       .650       .950      2.200    450.000      6.000       .000
              .00000
 CONSTRAINT NO.            3
     .330       .400       .600       .970      4.560   1000.000      7.000       .000
              .00000
 CONSTRAINT NO.            4
     .850       .400       .720       .950      1.970     72.000      5.000       .000
              .00000
 CONSTRAINT NO.            5
     .400       .300       .840       .990      4.420     66.000      6.000       .000
              .00000
 CONSTRAINT NO.            6
    -.980       .900       .440       .540       .930       .000       .000       .000
              .00000
 CONSTRAINT NO.            7
     .000       .000       .840       .990      4.420     66.000      6.000       .000
             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -.222635

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.         1          2          3          4          5          6          7
 SOL. VALU.      .5566      .0000      .0000     1.0101      .0000      .0000      .000
0

 VAR.  NO.         8
 SOL. VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.         1          2          3          4          5          6
 SOL. VALU.      .1975      .5255      .7961      .4865      .7774      .0000      .000
0
```

RUN 2: HAND DUG WELL WATER SUPPLY PROJECT

```
                              SIMPL-X
                         -----------------
                      A program for solving
                     linear programming problems

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/THE PROBLEM HAS    7 CONSTRAINTS AND   8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    -.980     -.900      .000      .000      .000      .000      .000      .000
 CONSTRAINT NO.           1
     .970     -.800      .600      .730     2.430   479.000     6.000     2.000
              .00000
 CONSTRAINT NO.           2
    -.780     -.500      .650      .950     2.200   450.000     6.000      .000
              .00000
 CONSTRAINT NO.           3
     .330     -.400      .600      .970     4.560  1000.000     7.000      .000
              .00000
 CONSTRAINT NO.           4
     .850      .400      .720      .950     1.970    72.000     5.000      .000
              .00000
 CONSTRAINT NO.           5
    -.400     -.700      .840      .990     4.420    66.000     6.000      .000
              .00000
 CONSTRAINT NO.           6
    -.980     -.900      .440      .540      .930      .000      .000      .000
              .00000
 CONSTRAINT NO.           7
     .000      .000      .440      .540      .930      .000      .000      .000
=            1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          1.000000

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.         1         2         3         4         5         6         7
 SOL. VALU.   1.0204     .0000     .0000    1.8519     .0000     .0000      .000
0

 VAR.  NO.         8
 SOL. VALU.    .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.         1         2         3         4         5         6         7
 SOL. VALU.    .3621     .9633    1.4596     .8919    1.4252     .0000      .000
0
```

RUN 2: CENTRAL ACCRA SEWERAGE PROJECT

```
                              SIMPL-X
                              ---- ---------
                       A program for solving
                      linear programming problems

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/THE PROBLEM HAS    5 CONSTRAINTS AND   8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.900     -.200      .000      .000      .000      .000      .000      .000
 CONSTRAINT NO.             1
     -.900     -.200      .460      .880    77.600  1150.000     8.000     3.300
               .00000
 CONSTRAINT NO.             2
      .900     -.300      .500      .310     6.770      .000     2.000     1.000
               .00000
 CONSTRAINT NO.             3
      .900      .100      .500      .220     8.150      .000     3.000     1.000
               .00000
 CONSTRAINT NO.             4
      .700      .140      .000      .000      .450      .000      .000      .000
               .00000
 CONSTRAINT NO.             5
      .000      .000      .460      .880    77.600  1150.000     8.000     3.300
              1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS              -.005799

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.      .0064     .0000     .0000     .0000     .0129     .0000     .000
0

 VAR.  NO.          8
 SOL. VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1         2         3         4         5
 SOL. VALU.      .9942     .0814     .0992     .0000     .0000
```

RUN 2: URBAN K-VIP LATRINE PROJECT

```
                                SIMPL-X
                                - -- -- --------
                          A program for solving
                         linear programming problems

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/THE PROBLEM HAS     5 CONSTRAINTS AND    8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE                         .000        .00
      .900      .300      .000      .000      .000       .000
 CONSTRAINT NO.            1                                           8.000       3.30
     -.900     -.200      .460      .880    77.600   1150.000
            .00000
 CONSTRAINT NO.            2                                           2.000       1.000
      .900     -.300      .500      .310     6.770       .000
            .00000
 CONSTRAINT NO.            3                                           3.000       1.000
      .900      .100      .500      .220     8.150       .000
            .00000
 CONSTRAINT NO.            4                                            .000        .000
      .900      .440      .000      .000      .450       .000
            .00000
 CONSTRAINT NO.            5                                           2.000       1.000
      .000      .000      .500      .310     6.770       .000
           1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS           -.066470

 THE SOLUTION VALUES FOR THE VARIABLES ARE                        6
 VAR.  NO.         1          2          3          4          5        .0000      .000
 SOL. VALU.     .0739      .0000      .0000      .0000      .1477
0

 VAR.  NO.         8
 SOL. VALU.     .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.         1          2          3          4          5
 SOL. VALU.   11.3959      .9335     1.1374      .0000      .0000
```

RUN 2: RURAL K-VIP LATRINE PROJECT

```
                              SIMPL-X
                         -----------------
                       A program for solving
                      linear programming problems

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/THE PROBLEM HAS     5 CONSTRAINTS AND    8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.900      -.300       .000       .000       .000        .000        .000       .000
 CONSTRAINT NO.             1
      .900       .200       .460       .880     77.600    1150.000       8.000      3.300
               .00000
 CONSTRAINT NO.             2
     -.900      -.300       .500       .310      6.770        .000       2.000      1.000
               .00000
 CONSTRAINT NO.             3
      .900      -.100       .500       .220      8.150        .000       3.000      1.000
               .00000
 CONSTRAINT NO.             4
      .900       .440       .000       .000       .450        .000        .000       .000
               .00000
 CONSTRAINT NO.             5
      .000       .000       .500       .220      8.150        .000       3.000      1.000
-             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -.055215

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1          2          3          4          5          6          7
 SOL. VALU.      .0613      .0000      .0000      .0000      .1227      .0000       .000
0

 VAR.  NO.          8
 SOL. VALU.      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1          2          3          4          5
 SOL. VALU.     9.4663      .7755      .9448      .0000      .0000
```

RUN 2: TRADITIONAL PIT LATRINE PROJECT

```
                              SIMPL-X
                         --- -----------
                     A program for solving
                    linear programming problems

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 THE PROBLEM HAS     5 CONSTRAINTS AND    8 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.900      .440      .000      .000      .000      .000      .000      .000
 CONSTRAINT NO.             1
      .900     -.200      .460      .880    77.600  1150.000     8.000     3.300
               .00000
 CONSTRAINT NO.             2
      .900     -.300      .500      .310     6.770      .000     2.000     1.000
               .00000
 CONSTRAINT NO.             3
      .900     -.100      .500      .220     8.150      .000     3.000     1.000
               .00000
 CONSTRAINT NO.             4
      .900     -.440      .000      .000      .450      .000      .000      .000
               .00000
 CONSTRAINT NO.             5
      .000      .000      .000      .000      .450      .000      .000      .000
             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          1.000000

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.    1.1111     .0000     .0000     .0000    2.2222     .0000     .000
0

 VAR.  NO.          8
 SOL. VALU.     .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1         2         3         4         5
 SOL. VALU.  171.4444   14.0444   17.1111     .0000     .0000
```

RUN 3: ACCRA-TEMA WATER SUPPLY PROJECT

```
                              SIMPL-X
                       A program for solving
                       linear programming problems

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THE PROBLEM HAS  11 CONSTRAINTS AND  9 VARIABLES
THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
   -.970     -.800  -150.000      .000      .000      .000      .000      .000
THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    .000
CONSTRAINT NO.                 1
   -.970     -.800  -150.000      .600      .730     2.430   479.000     6.000
   2.000
>           .00000
CONSTRAINT NO.                 2
   -.780     -.500   -80.000      .650      .950     2.200   450.000     6.000
    .000
>           .00000
CONSTRAINT NO.                 3
   -.330     -.400   -80.000      .600      .970     4.560  1000.000     7.000
   1.000
>           .00000
CONSTRAINT NO.                 4
   -.850     -.400    -5.000      .720      .950     1.970    72.000     5.000
    .000
>           .00000
CONSTRAINT NO.                 5
   -.400     -.300   -70.000      .840      .990     4.420    66.000     6.000
    .000
>           .00000
CONSTRAINT NO.                 6
   -.980     -.900   -60.000      .440      .540      .930      .000      .000
    .000
>           .00000
CONSTRAINT NO.                 7
   -.900     -.200  -200.000      .460      .880    77.600  1150.000     8.000
   3.300
>           .00000
CONSTRAINT NO.                 8
   -.900     -.300  -100.000      .500      .310     6.770      .000     2.000
   1.000
>           .00000
CONSTRAINT NO.                 9
   -.900     -.100   -70.000      .500      .220     8.150      .000     3.000
   1.000
>           .00000
CONSTRAINT NO.                10
   -.900     -.440    60.000      .000      .000      .450      .000      .000
    .000
>           .00000
CONSTRAINT NO.                11
    .000      .000      .000      .600      .730     4.170   479.000     6.000
   2.000
=          1.00000
AN OPTIMAL SOLUTION HAS BEEN LOCATED

THE MINIMUM OF THE OBJECTIVE FUNCTION IS           -.269785

THE SOLUTION VALUES FOR THE VARIABLES ARE
VAR.  NO.         1         2         3         4         5         6        7
SOL. VALU.    .0000     .0000     .0018     .0000     .0000     .2398     .0000
>

VAR.  NO.         8         9
SOL. VALU.    .0000     .0000

THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
VAR   NO.         1         2         3         4         5         6        7
SOL. VALU     .8130     .3837     .9496     .4634     .9341     .1151   18.249

VAR.  NO.         8         9        10        11
SOL. VALU.   1.4436    1.8285     .0000     .0000
```

RUN 3: BOREHOLE WATER SUPPLY PROJECT

```
                              SIMPL-X
                          ---------------
                       A program for solving
                    linear programming problems

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THE PROBLEM HAS   11 CONSTRAINTS AND   9 VARIABLES
THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
   -.780     -.500   -80.000      .000      .000      .000      .000      .000
THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    .000
CONSTRAINT NO.                1
   -.970     -.800  -150.000      .600      .730     2.430   479.000     6.000
   2.000
>             .00000
CONSTRAINT NO.                2
   -.780     -.500   -80.000      .650      .950     2.200   450.000     6.000
    .000
>             .00000
CONSTRAINT NO.                3
   -.330     -.400   -80.000      .600      .970     4.560  1000.000     7.000
    .000
>             .00000
CONSTRAINT NO.                4
   -.850     -.400    -5.000      .720      .950     1.970    72.000     5.000
    .000
>             .00000
CONSTRAINT NO.                5
    .400     -.300   -70.000      .840      .990     4.420    66.000     6.000
    .000
>             .00000
CONSTRAINT NO.                6
   -.920     -.900   -60.000      .440      .540     -.930      .000      .000
    .000
              .00000
CONSTRAINT NO.                7
   -.900     -.200  -200.000      .460      .880    77.600  1150.000     8.000
   3.300
>             .00000
CONSTRAINT NO.                8
   -.900     -.330  -100.000      .500      .310     6.770      .000     2.000
   1.000
>             .00000
CONSTRAINT NO.                9
   -.900     -.100   -70.000      .500      .220     8.150      .000     3.000
   1.000
              .00000
CONSTRAINT NO.               10
   -.900     -.440   -60.000      .000      .000      .450      .000      .000
    .000
>             .00000
CONSTRAINT NO.               11
    .000      .000      .000      .650      .950     2.200   450.000     6.000
    .000
=            1.00000
AN OPTIMAL SOLUTION HAS BEEN LOCATED

THE MINIMUM OF THE OBJECTIVE FUNCTION IS              -.272727

THE SOLUTION VALUES FOR THE VARIABLES ARE
VAR.  NO.          1         2         3         4         5         6         7
SOL.  VALU.    .0000     .0000     .0034     .0000     .0000     .4545     .0000


VAR.  NO.          8         9
SOL.  VALU.    .0000     .0000

THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
VAR.  NO.          1         2         3         4         5         6         7
SOL.  VALU.    .5932     .7273    1.8000     .8784    1.7705     .2182    34.590


VAR.  NO.          8         9        10        11
SOL.  VALU.   2.7364    3.4659     .0000     .0000
```

RUN 3: PACKAGE PLANT WATER SUPPLY PROJECT

```
                                   SIMPL-X
                                -------------
                           A program for solving
                           linear programming problems

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 /THE PROBLEM HAS   11 CONSTRAINTS AND   9 VARIABLES
  THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
       -.330     -.440    -80.000        .000        .000        .000        .000
  THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
       .000
  CONSTRAINT NO.               1
       -.970     -.800   -150.000        .600        .730       2.430     479.000
       2.000
 >              .00000
  CONSTRAINT NO.               2
       -.780     -.500    -80.000        .650        .950       2.200     450.000
        .000
 >              .00000
  CONSTRAINT NO.               3
       -.330     -.400    -80.000        .600        .970       4.560    1000.000
        .000
 >              .00000
  CONSTRAINT NO.               4
       -.850     -.400     -5.000        .720        .950       1.970      72.000
        .000
                .00000
  CONSTRAINT NO.               5
        .400     -.300    -70.000        .840        .990       4.420      66.000
        .000
                .00000
  CONSTRAINT NO                6
        .940      .900     60.000        .440        .540        930        .000
        .000
                .00000
  CONSTRAINT NO.               7
       -.900     -.200   -200.000        .460        .880      77.600    1150.000
       3.300
 >              .00000
  CONSTRAINT NO.               8
       -.900     -.300   -100.000        .500        .310       6.770        .000
       1.000
                .00000
  CONSTRAINT NO.               9
       -.900     -.100    -70.000        .500        .220       8.150        .000
       1.000
 >              .00000
  CONSTRAINT NO.              10
       -.900     -.440    -60.000        .000        .000        .450        .000
        .000
 /              .00000
  CONSTRAINT NO.              11
        .000      .000       .000        .600        .970       4.560    1000.000
        .000
 =             1.00000
  AN OPTIMAL SOLUTION HAS BEEN LOCATED

  THE MINIMUM OF THE OBJECTIVE FUNCTION IS             -.131579

  THE SOLUTION VALUES FOR THE VARIABLES ARE
  VAR.  NO.           1          2          3          4          5          6
  SOL. VALU.       .0000      .0000      .0016      .0000      .0000      .2193
0

  VAR.  NO.           8          9
  SOL. VALU.       .0000      .0000

  THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
  VAR.  NO.           1          2          3          4          5          6
  SOL. VALU.       .2862      .3509      .8684      .4238      .8542      .1053
6

  VAR.  NO.           8          9         10         11
  SOL. VALU.      1.3202     1.6722      .0000      .0000
```

RUN 3: 2500 DRILLED WELLS WATER SUPPLY PROJECT

```
                              SIMPL-X
                              -------
                      A program for solving
                     linear programming problems

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/THE PROBLEM HAS   11 CONSTRAINTS AND   9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.850     -.400    -5.000       .000       .000       .000       .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
      .000
 CONSTRAINT NO.                1
     -.970     -.800  -150.000       .600       .730      2.430    479.000
     2.000
                .00000
 CONSTRAINT NO.                2
     -.780     -.500   -80.000       .650       .950      2.200    450.000
      .000
>               .00000
 CONSTRAINT NO.                3
     -.330     -.400   -80.000       .600       .970      4.560   1000.000
      .000
>               .00000
 CONSTRAINT NO.                4
     -.850     -.400    -5.000       .720       .950      1.970     72.000
      .000
                .00000
 CONSTRAINT NO.                5
     -.400      .300   -70.000       .840       .990      4.420     66.000
      .000
>               .00000
 CONSTRAINT NO.                6
     -.980     -.900   -60.000       .440       .540       .930       .000
      .000
>               .00000
 CONSTRAINT NO.                7
     -.900     -.200  -200.000       .460       .880     77.600   1150.000
     3.300
>               .00000
 CONSTRAINT NO.                8
     -.900     -.300  -100.000       .500       .310      5.770       .000
     1.000
>               .00000
 CONSTRAINT NO.                9
     -.900     -.100   -70.000       .540       .220      8.150       .000
     1.000
>               .00000
 CONSTRAINT NO.               10
     -.900     -.440    60.000       .000       .000       .450       .000
      .000
>               .00000
 CONSTRAINT NO.               11
      .000      .000      .000       .720       .950      1.970     72.000
      .000
=              1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS           -.215736

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.         1          2          3          4          5          6
 SOL.  VALU.     .2538      .0000      .0000      .0000      .0000      .5076
0

 VAR.  NO.         8          9
 SOL.  VALU.     .0000      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.         1          2          3          4          5          6
 SOL.  VALU.     .9873      .9188     2.2310      .7843     2.1421      .2234
4

 VAR.  NO.         8          9         10         11
 SOL.  VALU.    3.2081     3.9086      .0000      .0000
```

RUN 3: 3000 DRILLED WELLS WATER SUPPLY PROJECT

```
                         SIMPL-X
                   ------------------
                A program for solving
                linear programming problems

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/THE PROBLEM HAS   11 CONSTRAINTS AND    9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.400     -.300   -70.000      .000      .000      .000      .000      .0(
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     .000
 CONSTRAINT NO.              1
    -.970     -.800  -150.000      .600      .730     2.430   479.000     6.000
    2.00(
>              .00000
 CONSTRAINT NO.              2
    -.780     -.500    80.000      .650      .950     2.200   450.000     6.000
     .000
>              .00000
 CONSTRAINT NO.              3
    -.330     -.400   -80.000      .600      .970     4.560  1000.000     7.0( )
     .000
>              .00000
 CONSTRAINT NO.              4
    - 850     -.400    -5.000      .720      .950     1.970    72.000     5.000
     .000
>              .00000
 CONSTRAINT NO.              5
    - 100      .300   - 70.000     .840      .990     4.420    66.000     6.000
     .00(
               .00000
 CONSTRAINT NO.              6
     .980     -.700    60.000      .440      .540      .930      .000      .0 )
     .000
>              .00000
 CONSTRAINT NO.              7
    -.900     -.200  -200.000      .460      .880    77.600  1150.000     8.000
    3.300
>              .00000
 CONSTRAINT NO.              8
    -.900     -.300  -100.000      .500      .310     6.770      .000     2.000
    1.000
>              .00000
 CONSTRAINT NO.              9
    -.900     -.100   -70.000      .500      .220     8.150      .000     3.0 )
    1.000
>              .00000
 CONSTRAINT NO.             10
    -.900     -.440   -60.000      .000      .000      .450      .000      .000
     .000
               .00000
 CONSTRAINT NO.             11
     .000      .000      .000      .840      .990     4.420    66.000     6.000
     .000
=            1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS              -.118778

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.         1          2          3          4          5          6          7
 SOL. VALU.    .0000      .0000      .0017      .0000      .0000      .2262      .000


 VAR.  NO.         8          9
 SOL. VALU.    .0000      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.         1          2          3          4          5          6          7
 SOL. VALU.    .2952      .3620      .8959      .4372      .8812      .1086     17.217
2

 VAR.  NO.         8          9         10         11
 SOL. VALU.   1.3620     1.7251      .0000      .0000
```

RUN 3: HAND DUG WELLS WATER SUPPLY PROJECT

```
                              SIMPL-X
                          A program for solving
                        linear programming problems

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/THE PROBLEM HAS   11 CONSTRAINTS AND   9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.980     -.900   -60.000      .000      .000      .000      .000      .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     .000
 CONSTRAINT NO.                 1
     -.970     -.800  -150 000      .600      .730     2.430   479.000     6.000
     2.000
               .00000
 CONSTRAINT NO.                 2
     -.780     -.500   -80.000      .650      .950  2020.000   450.000     6.000
      .000
>              .00000
 CONSTRAINT NO.                 3
     -.330     -.400   -80.000      .600      .970     4.560  1000.000     7.000
      .000
>              .00000
 CONSTRAINT NO.                 4
     -.850     -.400    -5.000      .720      .950     1.970    72.000     5.000
      .000
>              .00000
 CONSTRAINT NO.                 5
      .400     -.300   -70.000      .840      .990     4.420    66.000     6.000
      .000
               .00000
 CONSTRAINT NO.                 6
      .980      .900   -60.000      .440      .540      .930      .000      .000
      .000
               .00000
 CONSTRAINT NO.                 7
     -.900     -.200  -200.000      .460      .860    77.600  1150.000     8.000
     3.300
>              .00000
 CONSTRAINT NO.                 8
     -.900     -.300  -100.000      .500      .310     6.770       000     2.000
     1.000
>              .00000
 CONSTRAINT NO.                 9
     -.900     -.100    70.000      .500      .220     8.150      .000     3.000
     1.000
               .00000
 CONSTRAINT NO.                10
     -.900     -.440    60.000      .000      .000      .450      .000      .000
      .000
               .00000
 CONSTRAINT NO.                11
      .000      .000      .000      .440      .540      .930      .000      .000
      .000
=             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS             -.483874

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.     .0000     .0000     .0081     .0000     .0000    1.0753      .000
0

 VAR.  NO.          8         9
 SOL. VALU.     .0000     .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL. VALU.    1.4032 2171.4120    4.2581    2.0780    4.1882     .5161   81.678
5

 VAR.  NO.          8         9        10        11
 SOL. VALU.    6.4732    8.1990     .0000     .0000
```

RUN 3: CENTRAL ACCRA SEWERAGE PROJECT

```
                              SIMPL-X
                         -----------------
                       A program for solving
                      linear programming problems

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/THE PROBLEM HAS   11 CONSTRAINTS AND    9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.900     -.200  -200.000     .000       .000       .000       .000       .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
      .000
 CONSTRAINT NO.          1
     -.970     -.800  -150.000     .600       .730      2.430     479.000     6.000
     2.000
>            .00000
 CONSTRAINT NO.          2
     -.730     -.500   -80.000     .650       .950      2.200     450.000     6.000
      .000
             .00000
 CONSTRAINT NO.          3
     -.330     -.400   -80.000     .600       .970      4.560    1000.000     7.000
      .000
>            .00000
 CONSTRAINT NO.          4
      .850     -.400    -5.000     .720       .950      1.970      72.000     5.000
      .000
             .00000
 CONSTRAINT NO.          5
      .400      .300    70.000     .840       .090      +.420      56.000     6.000
      .000
             .00000
 CONSTRAINT NO.          6
      .980      . 00   -60.000     .440       .540       .930        .000      .000
      .000
>            .00000
 CONSTRAINT NO.          7
     -.900     -.200  -200.000     .460       .880     77.600    1150.000     8.000
     3.300
>            .00000
 CONSTRAINT NO.          8
     -.900     -.390  -100.000     .500       .310      6.770        .000     2.000
     1.000
             .00000
 CONSTRAINT NO.          9
     -.900     -.100   -70.000     .500       .220      8.150        .000     3.000
     1.000
             .00000
 CONSTRAINT NO.          10
     -.900     -.440   -60.000     .000       .000       .450        .000      .000
      .000
             .00000
 CONSTRAINT NO.          11
      .000      .000      .000     .460       .880     77.600    1150.000     8.000
     3.300
=            1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS                 -.019330

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1          2          3          4          5          6          7
 SOL. VALU.      .0000      .0000      .0001      .0000      .0000      .0129      .000
0

 VAR.  NO.          8          9
 SOL. VALU.      .0000      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1          2          3          4          5          6          7
 SOL. VALU.      .0168      .0206      .0510      .0249      .0502      .0062      .930

 VAR.  NO.          8          9         10         11
 SOL. VALU.      .0776      .0983      .0000      .0000
```

RUN 3: URBAN K-VIP LATRINE PROJECT

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                         SIMPL-X
                    ----------------
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                 linear programming problems

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THE PROBLEM HAS   11 CONSTRAINTS AND    9 VARIABLES
THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    -.900      .300   100.000      .000      .000      .000      .000      ..00
THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    .000
CONSTRAINT NO.              1
    -.970     -.800  -150.000      .600      .730     2.430   479.000     6.000
   <=.000
             .00000
CONSTRAINT NO.              2
    -.780     -.500   -60.000      .650      .950     2.200   450.000     6.000
    .000
>            00000
CONSTRAINT NO.              3
    -.330     -.400   -80.000      .600      .970     4.560  1000.000     7..00
    .000
>            .00000
CONSTRAINT NO.              4
    -.850     -.400    -5.000      .720      .950     1.970    72.000     5.000
    .000
             .00000
CONSTRAINT NO               5
    -.4 0     -.300   -70.000      .840      .990     4.420    66.000     6.000
    .000
             0.000
CONSTRAINT NO.              6
    -. 80     -.900   -60.000      .440      .540      .950       000      ..00
    .000
             .00000
CONSTRAINT NO.              7
    -.900     -.200  -200.000      .460      .880    77.600  1150.000     8.000
    3.300
>            .00000
CONSTRAINT NO.              8
    - 900     -.300  -100.000      .500      .310     6.770      .000     2.000
    1.000
>            .00000
CONSTRAINT NO.              9
    -.900     -.100   -70.000      .500      .220     8.150      .000     3.000
    1.000
             .00000
CONSTRAINT NO.             10
    -.900     -.440   -60.000      .000      .000      .450      .000      .000
    .000
>            .00000
CONSTRAINT NO.             11
    .000      .000      .000      .500      .310     6.770      .000     2.000
    1.000
=          1.00000
AN OPTIMAL SOLUTION HAS BEEN LOCATED

THE MINIMUM OF THE OBJECTIVE FUNCTION IS           -.110783

THE SOLUTION VALUES FOR THE VARIABLES ARE
VAR. NO.         1         2         3         4         5         6         7
SOL. VALU.    .0000     .0000     .0011     .0000     .0000     .1477      .000
0

VAR. NO.         8         9
SOL. VALU.    .0000     .0000

THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
VAR. NO.         1         2         3         4         5         6         7
SOL. VALU.    .1928     .2363     .5849     .2855     .5753     .0709    11.240
8

VAR. NO.         8         9        10        11
SOL. VALU.    .8892    1.1263     .0000     .0000
```

RUN 3: RURAL K-VIP LATRINE PROJECT

SIMPL-X

A program for solving
linear programming problems


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/THE PROBLEM HAS   11 CONSTRAINTS AND   9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    -.900      -.300    -70.000       .000        .000        000        .000        .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    .000
 CONSTRAINT NO.               1
    .970      -.600   -150.000       .600        .730       2.430     479.000       6.000
   2.000
>           .00000
 CONSTRAINT NO.               2
    -.80      -.500    -80.000       .650        .950       2.200     450.000       6.000
    000
>           .00000
 CONSTRAINT NO.               3
   -.330      -.400    -80.000       .600        .970       4.560    1000.000       7.000
    .000
            .00000
 CONSTRAINT NO.               4
    .850      -.400     -5.000       .720        .950       1.970      72.000       5.000
    .000
            .[illegible]
 [illegible]                  5
   [illegible] .[illegible] [illegible]   .840        .990       4.420      66.[illegible]    6.[illegible]
   [illegible]
            [illegible]
 [illegible]                  6
   -.980       900     6?.000       .440        .540        .930        .000        .000
    .000
            .00000
 CONSTRAINT NO.               7
    .900      -.200   -200.000       .460        .880      77 600    1150.000       8.000
   3.300
>           .00000
 CONSTRAINT NO                8
   -.900      -.300   -100 000       .500        .310       6.770        000        2.000
   1.000
>           .00000
 CONSTRAINT NO.               9
    .900      -.100    -70.000       .500        .220       8.150        .000       3.000
   1.000
>           .00000
 CONSTRAINT NO.              10
   -.900      -.440    -60.000       .000        .000        .450        .000        .000
    .000
            .00000
 CONSTRAINT NO.              11
    .000       .000       .000       .500        .220       8.150        .000       3.000
   1.000
=          1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -.064417

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1          2          3          4          5          6          7
 SOL. VALU.      .0000      .0000      .0009      .0000      .0000      .1227      .000
0

 VAR.  NO.          8          9
 SOL. VALU.      .0000      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1          2          3          4          5          6          7
 SOL. VALU.      .1601      .1963      .4859      .2371      .4779      .0589      9.337
4

 VAR.  NO.          8          9         10         11
 SOL. VALU.      .7387      .9356      .0000      .0000
```

RUN 3: TRADITIONAL PIT LATRINE PROJECT

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                              SIMPL-X
                          ----------------
                      A program for solving
                     linear programming problems

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 THE PROBLEM HAS   11 CONSTRAINTS AND   9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    -.900      .440   -60.000     .000       .000       .000       .000       .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    .000
 CONSTRAINT NO.                1
    -.970     -.800  -150.000     .600       .730      2.430     479.000     6.000
    2.000
             .00000
 CONSTRAINT NO.                2
    -.780     -.500   -80.000     .650       .950      2.200     450.000     6.000
    .000
             .00000
 CONSTRAINT NO.                3
    -.350     -.400   -80.000     .600       .970      4.560    1000.000     7.000
    .000
             .00000
 CONSTRAINT NO.                4
    -.350     -.400    -5.000     .720       .950      1.970      72.000     5.000
    .000
             .00000
 CONSTRAINT NO.                5
    [illegible] [illegible] [illegible] .840   .990      4.420      66.000     6.000
    .000
             .00000
 CONSTRAINT NO.                6
    [illegible] .900   -60.000     .440       .540       .930       .000       .000
    .000
             .00000
 CONSTRAINT NO.                7
    -.900     -.200   200.000     .460       .880     77.600    1150.000     8.000
    3.300
             .00000
 CONSTRAINT NO.                8
    .900       .300  -100.000     .500       .310      6.770       .000      2.000
    1.000
             .00000
 CONSTRAINT NO.                9
    -.900     -.100   -70.000     .540       .220      8.150       .000      3.000
    1.000
             .00000
 CONSTRAINT NO.               10
    -.900     -.440   -60.000     .000       .000       .450       .000       .000
    .000
             .00000
 CONSTRAINT NO.               11
    .000       .000      .000     .000       .000       .450       .000       .000
    .000
=            1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -1.000000

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1          2          3          4          5          6          7
 SOL. VALU.      .0000      .0000      .0167      .0000      .0000     2.2222      .000
0

 VAR.  NO.          8          9
 SOL. VALU.      .0000      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1          2          3          4          5          6          7
 SOL. VALU.     2.9000     3.5556     8.8000     4.2944     8.6556     1.0667   169.111
2

 VAR.  NO.          8          9         10         11
 SOL. VALU.    13.3778    16.9444      .0000      .0000
```

RUN 4: ACCRA-TEMA WATER SUPPLY PROJECT

```
                              SIMPL-X
                          ---------------
                     A program for solving.
                      linear programming problems

                   (C) COPYRIGHT 1986 SGF SOFTWARE

THE PROBLEM HAS    7 CONSTRAINTS AND    9 VARIABLES
THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    -.970      -.800  -150.000      .000       .000       .000       .000       COO
THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    .000
CONSTRAINT NO.              1
    -.970      -.800  -150.000      .600       .730      2.430    479.000      6.C 0
    2.000
              .00000
CONSTRAINT NO.              2
    -.780      -.500   -80.000      .650      -.950      2.200    450.000      6.000
    .000
              .00000
CONSTRAINT NO.              3
    -.930      -.400   -80.000      .600       .970      4.560   1000.000      7.000
    .000
              .00000
CONSTRAINT NO.              4
    .830       .400     5.000       .720      -.950      1.970     72.000      5.C 0
    .C0
              .0 0C0
CONSTRAINT NO.              5
    .400      -.300   -70.000       .840       .990      4.420     o6.000      6.000
    .C00
              .00000
CONSTRAINT NO.              6
    -.980      -.900   -60.000      .440       .540       .930       .000       .000
    .000
              .00000
CONSTRAINT NO.              7
    .000       .000      .000       .600       .730      4.170    479.000      6.C 0
    2.COC
=            1.00000
AN OPTIMAL SOLUTION HAS BEEN LOCATED

THE MINIMUM OF THE OBJECTIVE FUNCTION IS           -1.000000

THE SOLUTION VALUES FOR THE VARIABLES ARE
VAR.  NO.          1         2         3         4         5         6         7
SOL.  VALU       C000     .0000     .0067     .5676     .2782     .0000     .C 1
0

VAR.  NO.          8         9
SOL.  VALU.     .0000     .0000

THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
VAR.  NO.          1         2         3         4         5         6         7
SOL.  VALU.     .0000     .0000    1.0298     .1796     .3485     .0000     .000
0
```

RUN 4: BOREHOLE WATER SUPPLY PROJECT

```
                              SIMPL-X
                           ------------
                      A program for solving
                     linear programming problems

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 THE PROBLEM HAS    7 CONSTRAINTS AND    9 VARIABLES
  THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
      .780     -.500    -80.000      .000      .000      .000      .000      .0 0
  THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
      .000
  CONSTRAINT NO.               1
     -.970     -.800    150.000      .600      .730     2.400   479.000     6.000
     2.000
 >            .00000
  CONSTRAINT NO.               2
     -.780     -.500    -80.000      .650      .950     2.200   450.000     6.000
      .000
              .00000
  CONSTRAINT NO.               3
     -.330     -.400    -80.000      .600      .970     4.560  1000.000     7. 0
      000
              00000
  CONSTRAINT NO.               4
      8 0       400     -5.000      .720      .950     1.970    72.000     5.000
      0 [illegible]
              .[illegible]
  CONSTRAINT NO.               5
     -.400      .300    -70.000      .840      .990     4.42[illegible]  [illegible].000     6.000
      .000
              .00000
  CONSTRAINT NO.               6
     -.980     -.900    -60.000      .440      .540      .930      .000      .0 0
      .000
              .00000
  CONSTRAINT NO.               7
      .000      .000       .000      .650      .950     2.200   450.000     6.000
      .000
 =           1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS           -.902564

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR. NO.         1         2         3         4         5         6         7
 SOL. VALU.    .0000     .0000     .0113    1.5385     .0000     .0000      .000
0

 VAR. NO.         8         9
 SOL. VALU.    .0000     .3846

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR. NO.         1         2         3         4         5         6         7
 SOL. VALU.  . .0000     .0974     .0205    1.0515     .5025     .0000      .0 0
0
```

RUN 4: PACKAGE PLANT WATER SUPPLY PROJECT

```
                               SIMPL-X
                          ----------------
                        A program for solving
                       linear programming problems

                     (C) COPYRIGHT 1986 BGF SOFTWARE

/THE PROBLEM HAS    7 CONSTRAINTS AND    9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.330     -.400   -80.000      .000      .000      .000      .000      .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
      .000
 CONSTRAINT NO.                 1
     -.970     -.800  -150.000      .600      .730     2.430   479.000     6.000
     2.000
>              .00000
 CONSTRAINT NO.                 2
     -.780     -.500   -80.000      .650      .950     2.200   450.000     6.000
      .000
               .00000
 CONSTRAINT NO.                 3
     -.330     -.400   -80.000      .600      .970     4.560  1000.000     7.000
      .000
               .00000
 CONSTRAINT NO.                 4
     -.830      .400    -5.000      .720      .950     1.970    72.000     5.000
      .000
               .00000
 CONSTRAINT NO.                 5
      .400      .330    70.000      .840      .990     4.420    66.000     6.000
      .000
               .00000
 CONSTRAINT NO.                 6
      .980     -.900   -60.000      .440      .540      .930      .000      .000
      .000
>              .00000
 CONSTRAINT NO.                 7
      .000      .000      .000      .600      .970     4.560  1000.000     7.000
      .000
=             1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS           -.977778

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR. NO.          1         2         3         4         5         6         7
 SOL. VALU.    .0000     .0000     .0122    1.6667     .0000     .0000     .000
0

 VAR. NO.          8         9
 SOL. VALU.    .0000     .4157

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR. NO.          1         2         3         4         5         6         7
 SOL. VALU.    .0000     .1056     .0222    1.1389     .5444     .0000     .000
```

RUN 4: 2500 DRILLED WELLS WATER SUPPLY PROJECT

```
                              SIMPL-X
                        -------------------
                      A program for solving
                     linear programming problems

                  (C) COPYRIGHT 1986 SGF SOFTWARE

/THE PROBLEM HAS    7 CONSTRAINTS AND   9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.850      .400    -5.000      .000      .000      .000      .000      .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     .000
 CONSTRAINT NO.               1
    -.970     -.800  -150.000      .600      .730     2.430   479.000     6.000
    2.000
               .00000
 CONSTRAINT NO                2
    .780      -.500   -80.000      .650      .950     2.200   450.000     6.C 0
    .00
               . [illegible]
 CONSTRAINT NO.               3
    .330       .100    80.C00      .600      .970     4.560  1000.000     7.000
    [illegible]
               [illegible]
 CONSTRAINT NO.               4
    .650       [illegible]   5.000      .720      .950     1.970    72.000     5.000
    .000
               .000 0
 CONSTRAINT NO.               5
    -.400     -.300   -70.000      .840      .990     4.420    66.000     6.C 0
    .000
               .00000
 CONSTRAINT NO.               6
    -.980     -.900   -60.000      .440      .540      .930      .000      .000
    .000
               .00000
 CONSTRAINT NO.               7
    .000       .000      .000      .720      .950     1.970    72.000     5.000
    .000
=              1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS         -.530045

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.        1         2         3         4         5         6         7
 SOL. VALU.    .6236     .0000     .0000    1.3889     .0000     .0000     .000
0

 VAR.  NO.        8         9
 SOL. VALU.    .0000     .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.        1         2         3         4         5         6         7
 SOL. VALU.    .2285     .4164     .6276     .4700     .9172     .0000     .000
0
```

RUN 4: 3000 DRILLED WELLS WATER SUPPLY PROJECT

```
                                  SIMPL-X
                              ---------------
                          A program for solving
                         linear programming problems

                       (C) COPYRIGHT 1986 SGF SOFTWARE

/THE PROBLEM HAS     7 CONSTRAINTS AND    9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    -.400      .300   -70.000      .000      .000      .000      .000      .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    .000
 CONSTRAINT NO.             1
    -.970     -.800  -150.000      .600      .730     2.430   479.000     6.000
    2.000
              .00000
 CONSTRAINT NO.             2
    .730      -.500   -80.000      .650      .950     2.200   450.000     6.0 )
    .000
              .00000
 CONSTRAINT NO.             3
    -.330     -.400   -80.000      .600      .970     4.560  1000.000     7.000
    .000
              .00000
 CONSTRAINT NO.             4
    -.850      .400     5.000      .720      .950     1.970    72.000     5.000
    .000
              00000
 CONSTRAINT NO.             5
    .400       .300   -70.000      .840      .990     4.420    66.000     6.0 )
    .000
              .00000
 CONSTRAINT NO.             6
    -.780     -.900   -60.000      .440      .540      .930      .000      .000
    .000
              .00000
 CONSTRAINT NO.             7
    .000       .000      .000      .840      .990     4.420    66.000     6.000
    .000
=          1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS            -.636364

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6         7
 SOL.  ALU.       .0000     .0000     .0091     .0000    1.0101     .0000     .000
0

 VAR.  NO.          8         9
 SOL. VALU.       .0000     .3131

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.          1         2         3         4         5         6
 SOL. VALU.       .0000     .2323     .2525     .9141     .3636     .0000     .000
0
```

RUN 4: HAND DUG WELL WATER SUPPLY PROJECT

```
                              SIMPL-X
                         ----------------
                       A program for solving
                     linear programming problems

                   (C) COPYRIGHT 1986 SGF SOFTWARE

/THE PROBLEM HAS    7 CONSTRAINTS AND   9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.980     -.900   -60.000      .000      .000      .000      .000      .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
      .000
 CONSTRAINT NO.              1
     -.970     -.800  -150.000      .600      .730     2.430   479.000     6.000
     2.000
              .00000
 CONSTRAINT NO.              2
     -.780      .500   -80.000      .650      .950     2.200   450.000     6.00
      .000
              .00000
 CONSTRAINT NO.              3
     -.230      .400   -80.000      .600      .970     4.560  1000.000     7.000
      .000
              .00000
 CONSTRAINT NO.              4
     -.850     -.400    -5.000      .720      .950     1.970    72.000     5.000
      .000
              .00000
 CONSTRAINT NO.              5
     -.400     -.300   -70.000      .840      .990     4.420    66.000     6.00
      000
              .00000
 CONSTRAINT NO.              6
     -.980     -.900   -60.000      .440      .540      .930      .000      .000
      .000
              .00000
 CONSTRAINT NO.              7
      .000      .000      .000      .440      .540      .930      .000      .000
      .000
=            1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -1.000000

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.         1         2         3         4         5         6         7
 SOL.  VALU.   .0000     .0000     .0167     .0000    1.8519     .0000      .000
0

 VAR.  NO.         8         9
 SOL.  VALU.   .0000     .5741

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.         1         2         3         4         5         6
 SOL.  VALU.   .0000     .4259     .4630    1.6759     .6667     .0000      .000
0
```

RUN 4: CENTRAL ACCRA SEWERAGE PROJECT

```
                              SIMPL-X
                          ----------------
                        A program for solving.
                       linear programming problems

                    (C) COPYRIGHT 1986 SGF SOFTWARE

/THE PROBLEM HAS    5 CONSTRAINTS AND   9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.900     -.200  -200.000     .000      .000      .000      .000      .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     .000
 CONSTRAINT NO.                1
     -.900     -.200  -200.000     .460      .880    77.600  1150.000     8.000
     3.300
             .00000
 CONSTRAINT NO.                2
     -.900     -.300  -100.000     .500      .310     6.770      .000     2.00
     1.000
             .00000
 CONSTRAINT NO.                3
     -.900     -.100   -70.000     .500      .220     8.150      .000     3.000
     1.000
             .00000
 CONSTRAINT NO.                4
      .900      .140   -60.000     .000      .000      .450      .000      .000
      .000
             .00000
 CONSTRAINT NO.                5
      .000      .900      .000     .460      .880    77.600  1150.000     8.00
     3.300
=          1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS           -.019330

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR.  NO.         1         2         3         4         5         6         7
 SOL. VALU.     .0000     .0000     .0001     .0000     .0000     .0129     .00
0

 VAR.  NO.         8         9
 SOL. VALU.     .0000     .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO.         1         2         3         4         5
 SOL. VALU.     .9807     .0776     .0983     .0000     .0000
```

RUN 4: URBAN K-VIP LATRINE PROJECT

```
                              SIMPL-X
                          ----------------
                        A program for solving
                       linear programming problems

                     (C) COPYRIGHT 1986 SGF SOFTWARE

 THE PROBLEM HAS     5 CONSTRAINTS AND    9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
      -.900      -.300   -100.000        .000        .000        .000        .000        .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
      .000
 CONSTRAINT NO.                   1
      -.900      -.200   -200.000        .460        .880      77.600    1150.000       8.000
      4.300
               .00000
 CONSTRAINT NO.                   2
       .900      -.300   -100.000        .500        .310       6.770        .000       2.000
      1.000
               .00000
 CONSTRAINT NO.                   3
       .900      -.100    -70.000        .500        .220       8.150        .000       3.000
      1.000
               .00000
 CONSTRAINT NO.                   4
       .000       .000     50.000        .000        .000        .450        .000        .000
       .000
               .0000
 CONSTRAINT NO.                   5
       .000       .000       .000        .500        .310       6.770        .000       2.000
      1.000
              1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS          -.110783

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR. NO.          1          2          3          4          5          6          7
 SOL. VALU.     .0000      .0000      .0011      .0000      .0000      .1477      .000
0

 VAR. NO.          8          9
 SOL. VALU.     .0000      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR. NO.          1          2          3          4          5
 SOL. VALU.   11.2408      .3892     1.1263      .0000      .0000
```

RUN 4: RURAL K-VIP LATRINE PROJECT

```
                    SIMPL-X
                ---------------
             A program for solving
           linear programming problems

        (C) COPYRIGHT 1986 SGF SOFTWARE

/THE PROBLEM HAS    5 CONSTRAINTS AND   9 VARIABLES
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     -.900      -.100    -70.000        .000        .000        .000        .000        .000
 THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
     .000
 CONSTRAINT NO.                1
     -.900       .200   -200.000        .460        .880      77.600    1150.000       8.000
     3.300
                .00000
 CONSTRAINT NO.                2
     -.900      -.300   -100.000        .500        .310       6.770        .000       2.000
     1.000
                .00000
 CONSTRAINT NO.                3
     -.900      -.100    -70.000        .500        .220       8.150        .000       3.000
     1.000
                .00000
 CONSTRAINT NO.                4
      900        140     60.000         .000        .000        .450        .000        .000
     . [illegible]
                .00000
 CONSTRAINT NO.                5
      000        .007       .000        .500        .220       8.150        .000       3.000
     1.0[illegible]
=               1.00000
 AN OPTIMAL SOLUTION HAS BEEN LOCATED

 THE MINIMUM OF THE OBJECTIVE FUNCTION IS              -.064417

 THE SOLUTION VALUES FOR THE VARIABLES ARE
 VAR  NO.          1          2          3          4          5          6          7
 SOL. VALU.     .0000      .0000      .0009      .0000      .0000      .1227      .000
0

 VAR.  NO.         8          9
 SOL. VALU.     .0000      .0000

 THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
 VAR.  NO          1          2          3          4          5
 SOL. VALU.    9.3374      .7387      .9356      .0000      .0000
```

RUN 4: TRADITIONAL PIT LATRINE PROJECT

```
                              SIMPL-X
                         -----------------
                      A program for solving
                     linear programming problems

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THE PROBLEM HAS    5 CONSTRAINTS AND   9 VARIABLES
THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    -.900     -.440   -60.000      .000      .000      .000      .000      .000
THE PARAMETERS OF THE OBJECTIVE FUNCTION ARE
    .000
CONSTRAINT NO.               1
    -.900     -.200  -200.000      .460      .880    77.600  1150.000     8.[illegible]
    3.300
             .00000
CONSTRAINT NO.               2
    -.900     -.300  -100.000      .500      .310     6.770      .000     2.000
    1.000
             .10000
CONSTRAINT NO.               3
    -.900     -.100   -70.000      .500      .220     8.150      .000     3.000
    1.000
             .00000
CONSTRAINT NO.               4
    .9[illegible]     -.4[illegible]0    60.000      .000      .000      .450      .000     .[illegible]
    .[illegible]
             .0000
CONSTRAINT NO.               5
    .000      .000      .000      .000      .000      .450      .000      .000
    .000
=            1.00000
AN OPTIMAL SOLUTION HAS BEEN LOCATED

THE MINIMUM OF THE OBJECTIVE FUNCTION IS         -1.000000

THE SOLUTION VALUES FOR THE VARIABLES ARE
VAR. NO.          1         2         3         4         5         6         7
SOL. VALU.    .0000      0000     .0167     .0000     .0000    2.2222      .000
0

VAR. NO.          8         9
SOL. VALU.    .0000     .0000

THE SOLUTION VALUES FOR THE SLACK VARIABLES ARE
VAR. NO           1         2         3         4         5
SOL. VALU.  169.1111   13.3778   16.9444     .0000     .0000
```