f. Initial water level (h)

Water levels in the aquifers shown in Fig. 4-13, which were obtained based on the results of water level observation in June, 1988, were used as initial water levels in the aquifers.

g. Water level in unconfined aquifer (H)

Water levels in unconfined aquifer, which overlays the confine aquifer, were assumed to be five meters below ground level.

h. Groundwater abstraction (Q)

Groundwater abstraction in the study area was estimated in the section 4-7-3 based on the investigation carried out by F D W R since the estimated abstraction was based on borehole records in 1981, present (1990) abstraction was estimated under the assumption that the increase rate of groundwater abstraction is equivalent to the growing rate of the population in Sokoto State. The growing rate is 2.5% according to the study on socio-economic framework (see 1-5). Therefore, present (1990) groundwater abstraction becomes :

Table 7-8 Predicted Present Groundwater Abstraction

Aquifer	1981	1990
Gwandu aquifer	12600 m^3/day	15800
Kalambaina aquifer	4300	5300
Rima aquifer	8600	10800
Gundumi aquifer	8300	10300
Total in the sedimentary area	33800	42200

Distribution of the abstraction by aquifer and area is shown in Fig. 7-9.

(D) Model calibration

Steady state groundwater levels for the aquifers were computed by use of the quasi 3-D multi-aquifer model. Distributions of computed groundwater levels were compared to actual distributions of groundwater levels. Transmissibility and leakance for each grid were adjusted on a trial and error basis until computed groundwater levels and actual groundwater levels gave reasonable agreement.

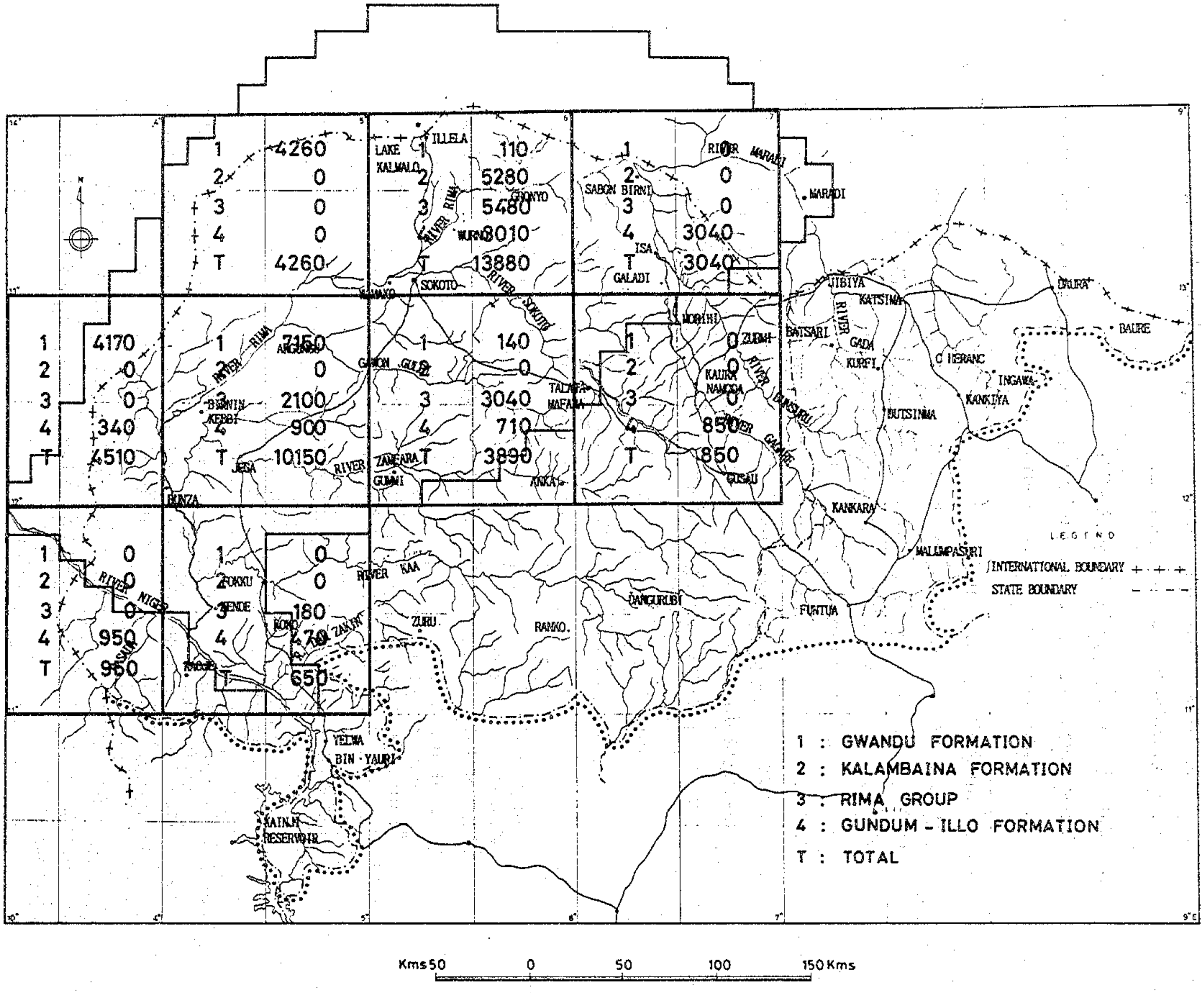


Fig. 7-9 Distribution of Groundwater Abstraction

The final calibration match between the distribution of computed groundwater levels and that of actual groundwater levels in each aquifer are shown in Fig. 7-10.

7-3-3 Prediction of future groundwater level under estimated pumping conditions

After calibration, the quasi 3-D aquifer model was used to predict future groundwater movement by future pumping schemes.

It should be emphasized that results of simulation are subject to various uncertainties arising from assumptions inherent in the modeling process, simplifications made in conceptualizing the natural system, and limited data available for model calibration. Thus, simulations of future groundwater behavior should be regarded as estimates based on currently available data and technology.

The computed steady state groundwater levels which were the final result of the calibration were used as the initial condition for each of these predictions.

(1) Future pumping scheme

According to the study on socio-economics (see 1-5), the growing rate of the population in Sokoto State is 2.5%. Assuming that pumping rate increases in proportion with the growth of population, future abstraction in Sokoto State is estimated as population presented in Table 2-1.

Table 7-9 Present and future pumping rate in the sedimentary area (m^3/day)

Present	Years after pumping started					
	5 years	10 years	15 years	20 years	25 years	30 years
42200	47700	54000	61100	69100	78200	88500

Based on the predicted pumping rate increase, two scenarios for pumping schemes were established.

a. Case 1

This case assumes that pumping rate increases equally at all places and aquifers.

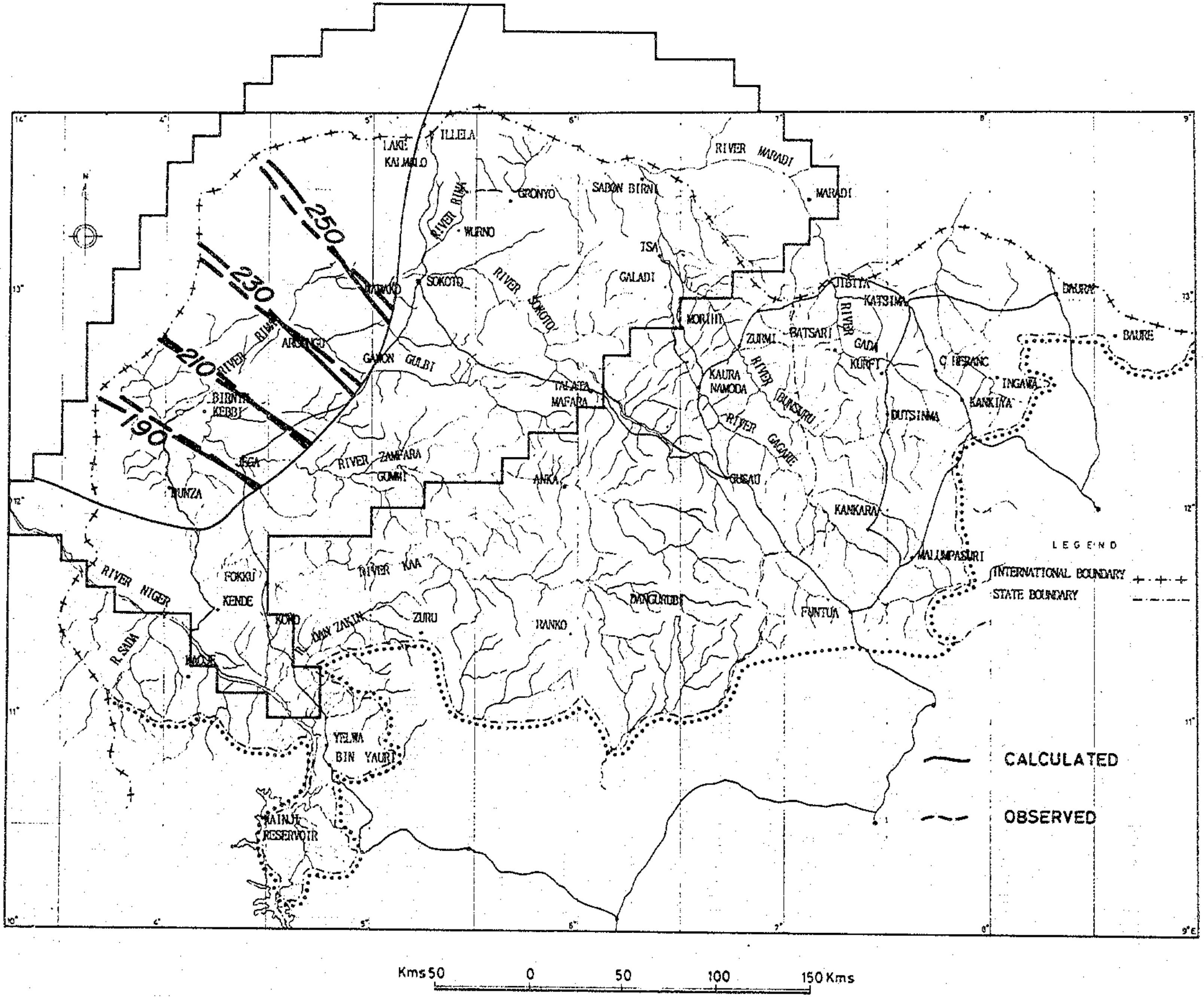
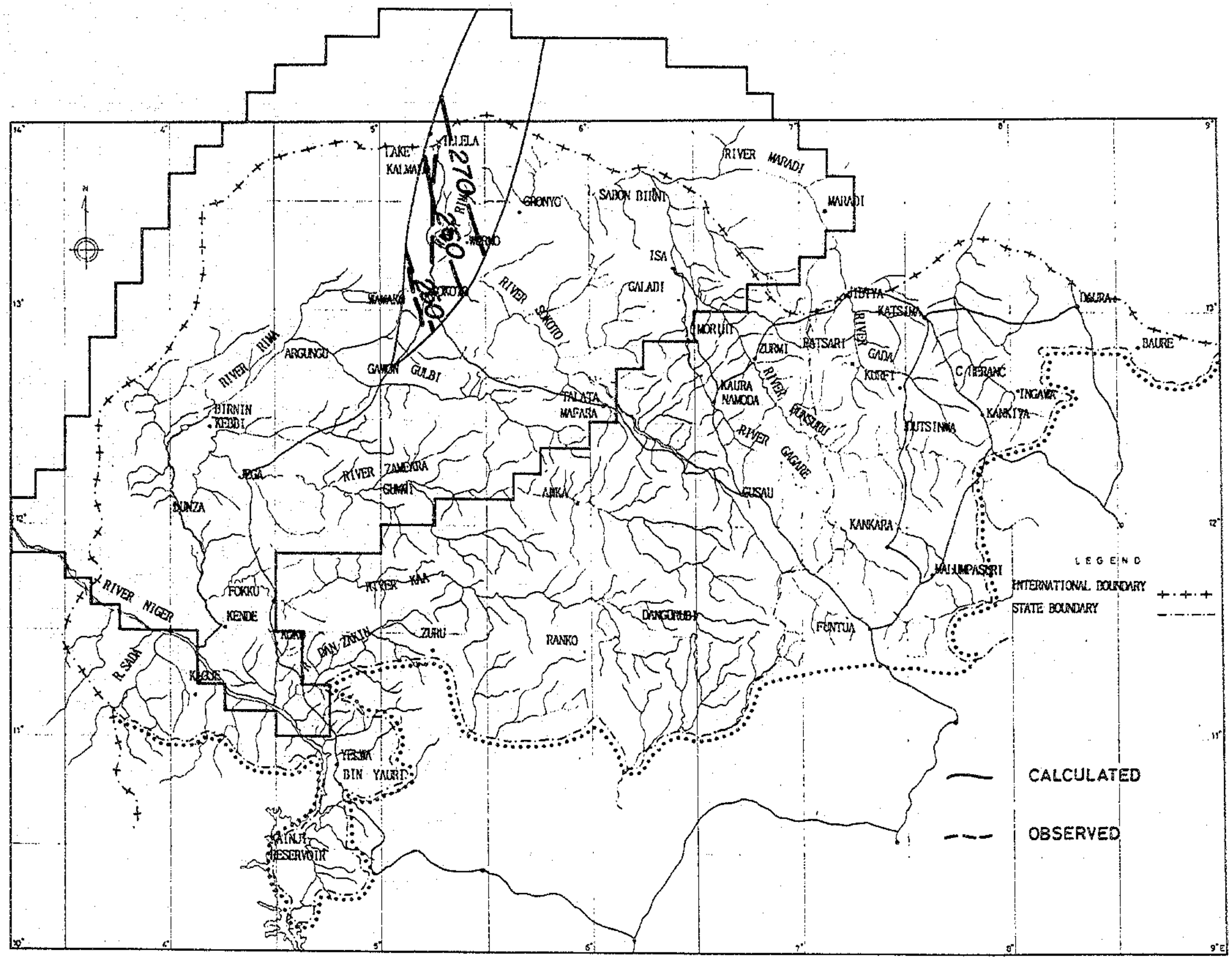


Fig.7-10(1) Comparison of Simulated and Actual GroundwaterLlevel - Gwandu Formation -



Kms 50 0 50 100 150 Kms

Fig.7-10(2) Comparison of Simulated and Actual Groundwater Level - Kalambaina Formation -

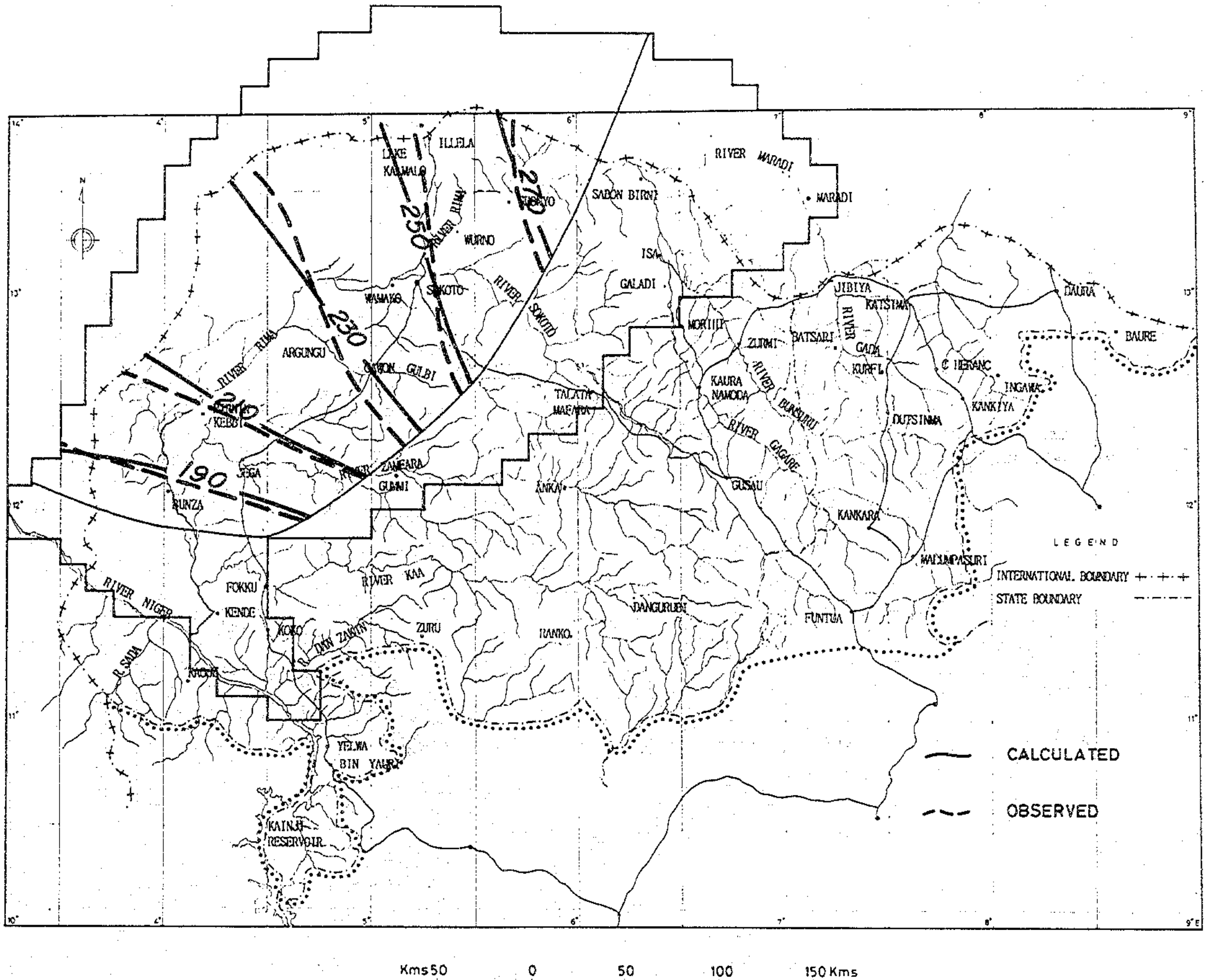


Fig.7-10(3) Comparison of Simulated and Actual Groundwater Level - Rima Group -

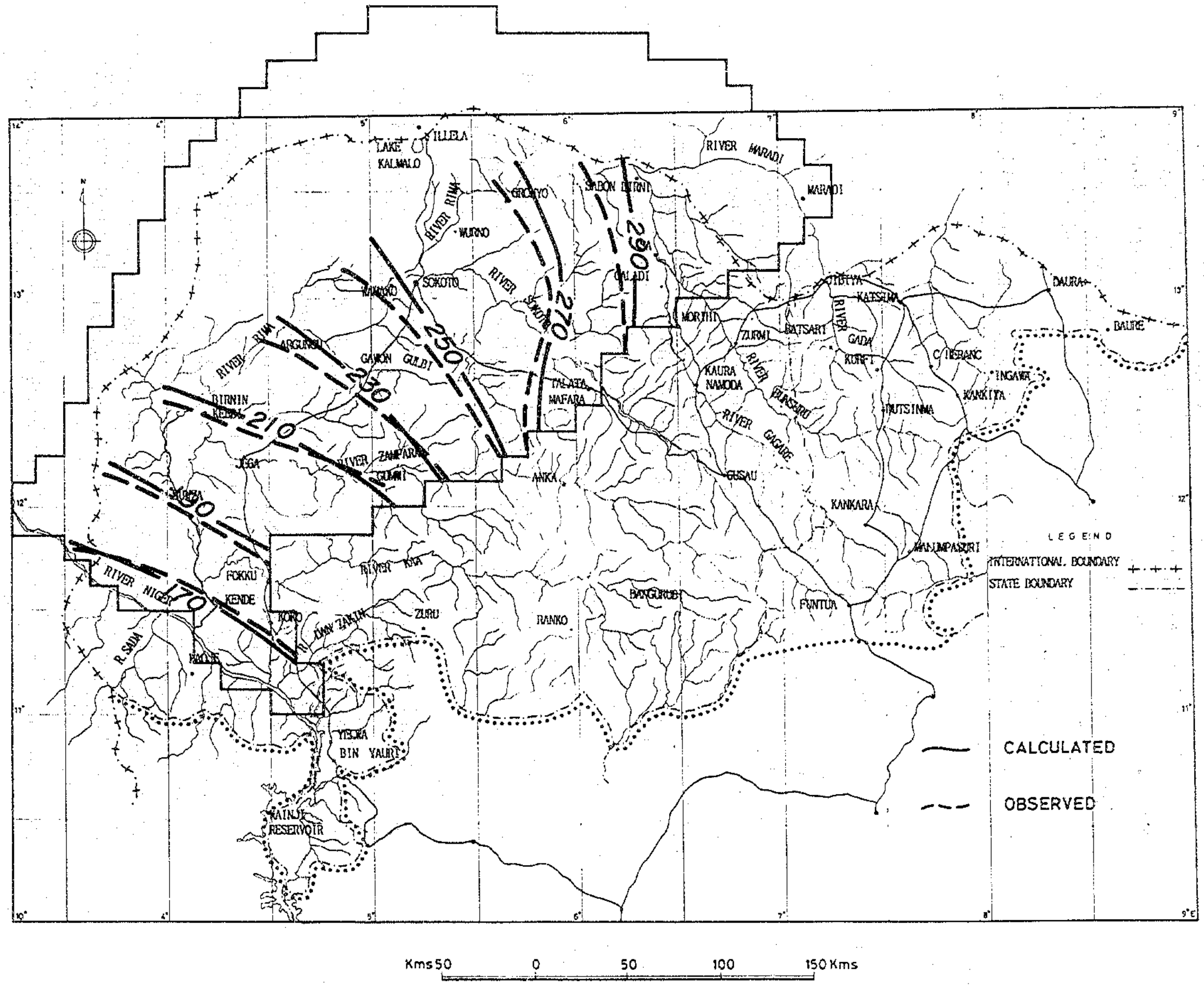


Fig.7-10(4) Comparison of Simulated and Actual Groundwater Level - Gundumi Formation -

b. Case 2

This case assumes that the present pumping rate from the Kalambaina aquifer is kept constant in future regardless with population growth. In order to keep the increase in total pumping rate corresponding to the population growth, shortage in pumping rate caused by the constant pumping rate in the Kalambaina aquifer is to be covered by additional abstraction from the Rima aquifer.

Pumping rate at present and thirty years hence from the aquifers are shown in Table 7-10.

Tab. 7-10 Pumping rate after 30 years

Aquifer	Present	Estimated after 30 years	
		Case 1	Case 2
Gwandu aquifer	15800	33100	33100
Kalambaina aquifer	5300	11100	5300
Rima aquifer	10800	22700	28500
Gundumi aquifer	10300	21600	21600
Total in the are	42200	88500	88500

(m^3/day)

(2) Results of the prediction

Groundwater levels 30 years hence were predicted by use of the simulation model under the condition of abstraction established as case 1 and case 2.

a. Case 1

Predicted changes in groundwater levels at Sokoto and Birnin-Kebbi are given in Fig. 7-11. Configuration maps of predicted declines in groundwater levels from the present levels are given in Fig.7-12.

Water level declines in the Gwandu aquifer are generally less than one meter over the entire area except around Birnin-Kebbi and Argungu where a mound of water level decline of more than one meter is formed.

A water level decline of 2.2m is predicted to occur in the Kalambaina aquifer at Sokoto city.

Water level declines in the Rima aquifer are generally less than 1.0m. However, a mound of high water level decline of more than 2.0m is formed around Sokoto city.

Water level declines in the Gundumi-Illo aquifer are generally to be less

FIG. 7-11(1) PREDICTED CHANGE IN GROUNDWATER LEVEL AT SOKOTO

CASE 1

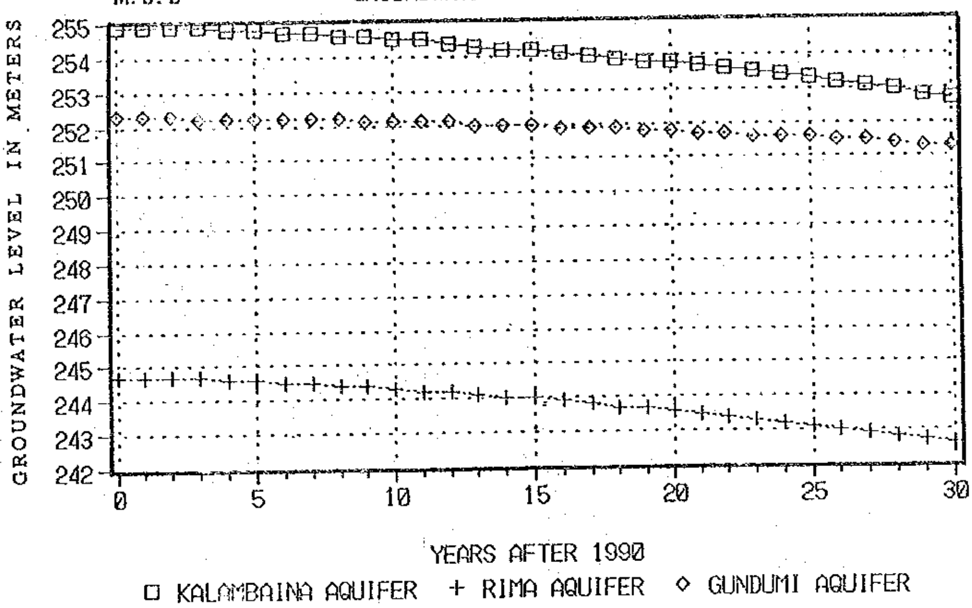
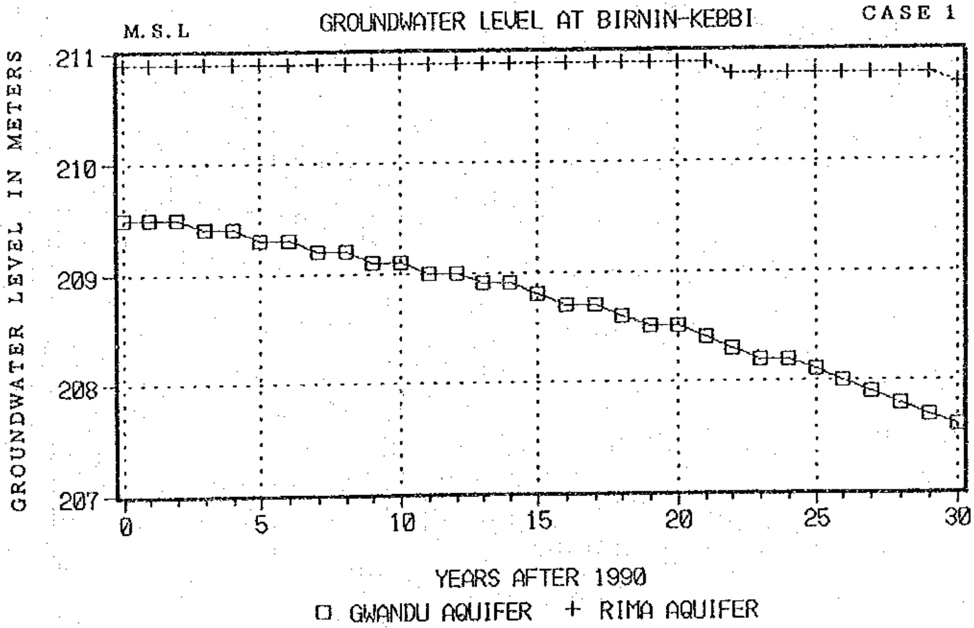


FIG. 7-11 (2) PREDICTED CHANGE IN GROUNDWATER LEVEL AT BIRNIN-KEBBI

CASE 1



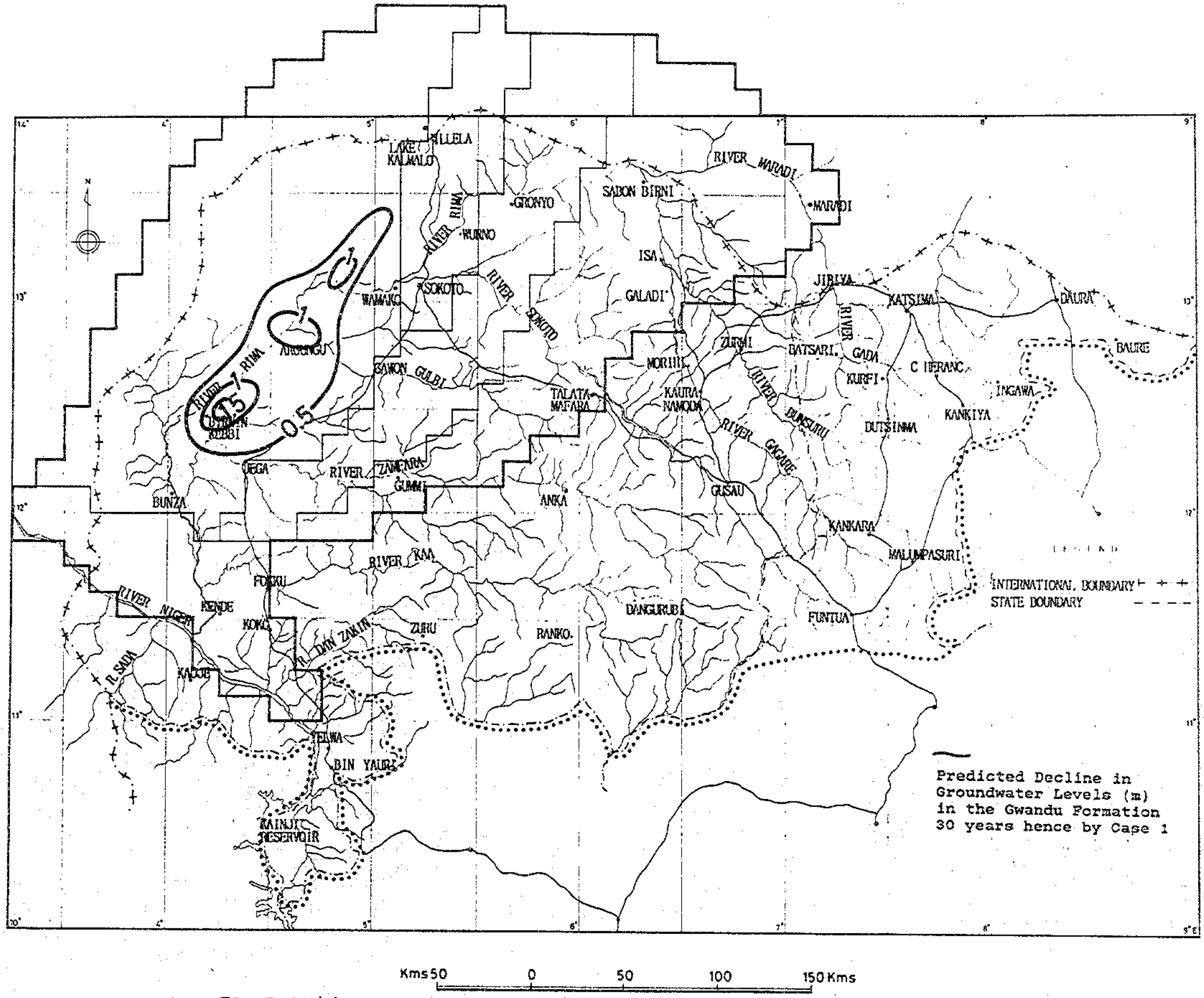


Fig. 7-12 (1) Predicted Decline in Groundwater Level in 30 years after
-Gwandu Formation- (case 1)

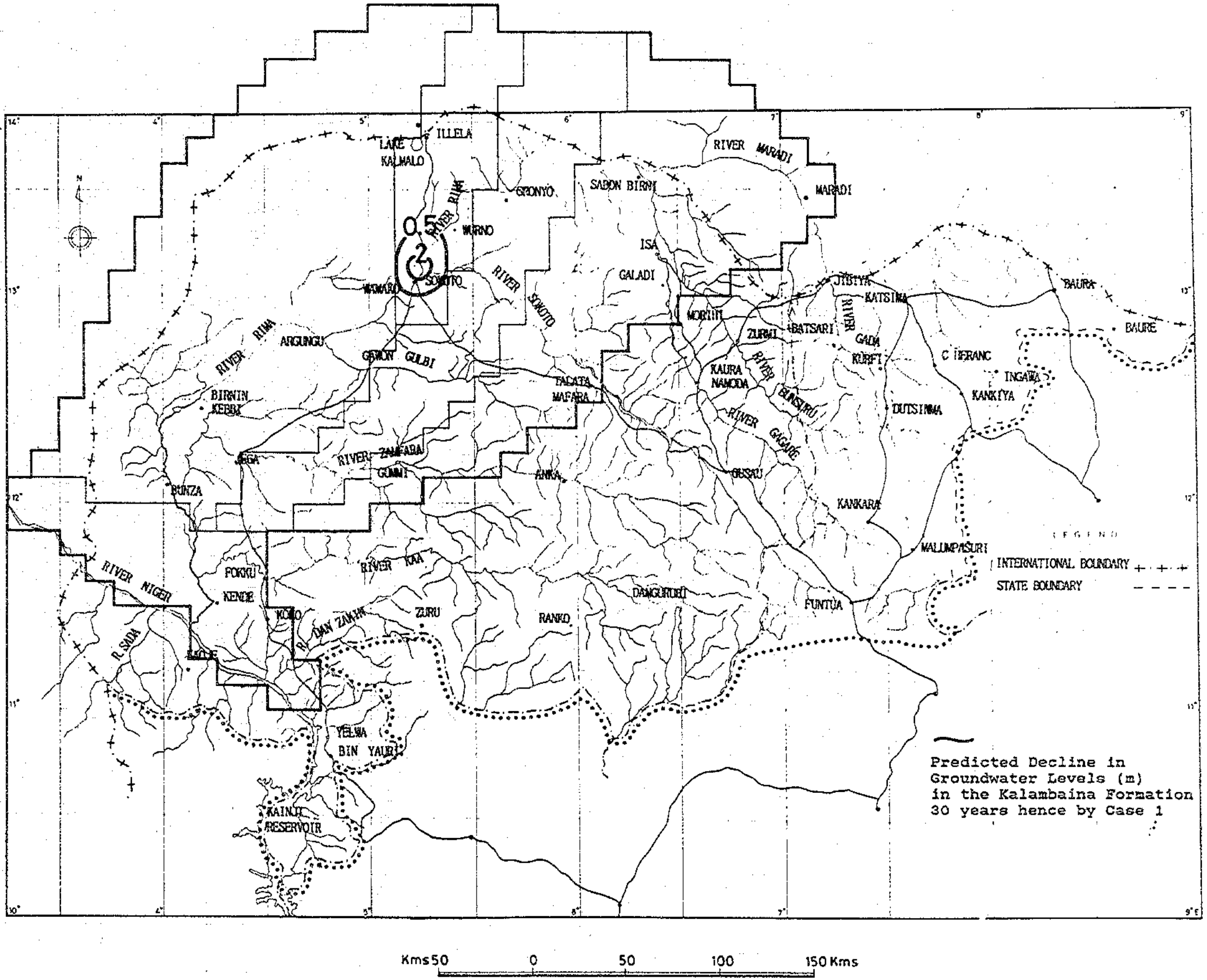


Fig. 7-12(2) Predicted Decline in Groundwater Level in 30 years after -Kalambaina Formation- (case 1)

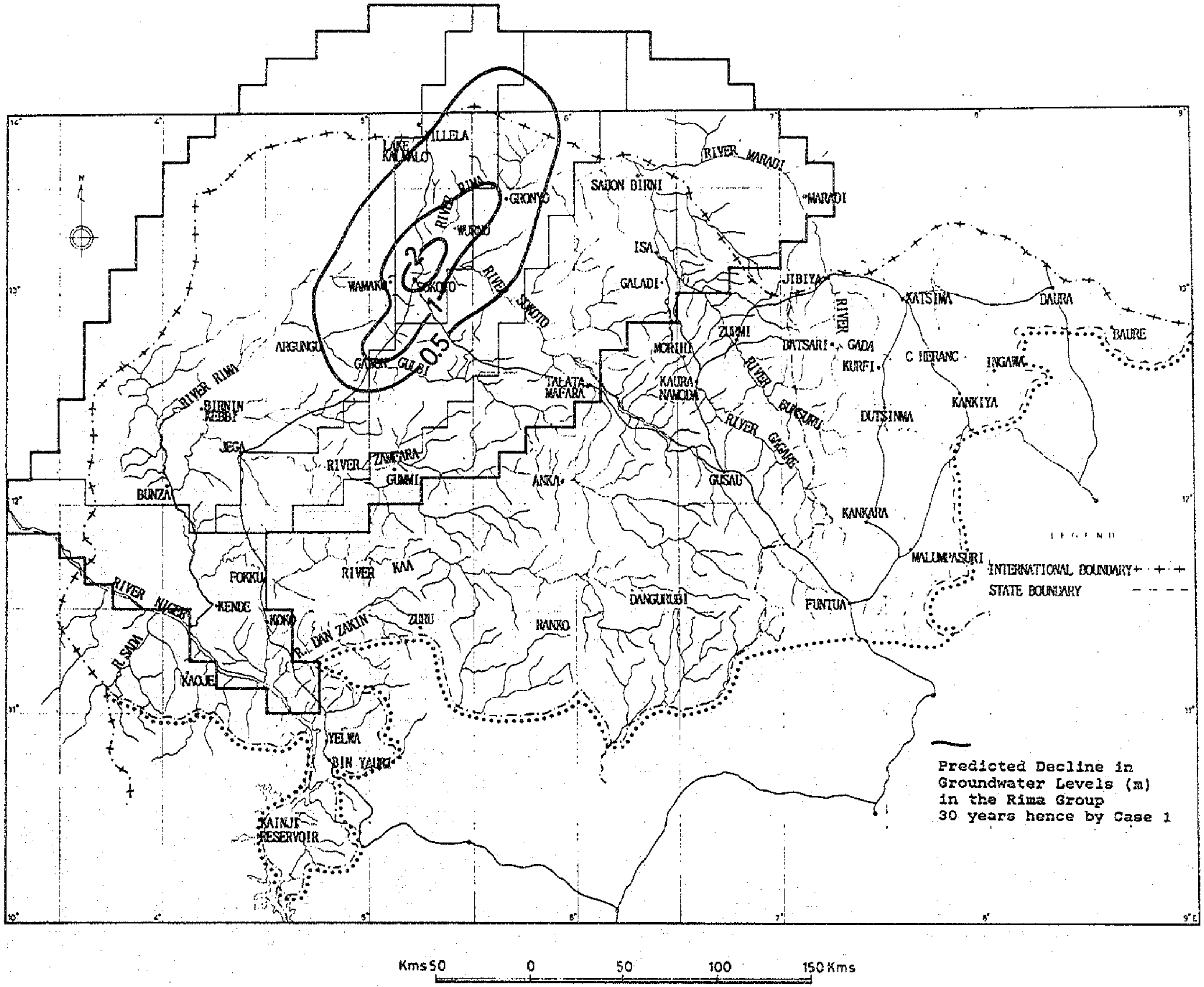


Fig. 7-12 (3) Predicted Decline in Groundwater Level in 30 years after -Rima Group- (case 1)

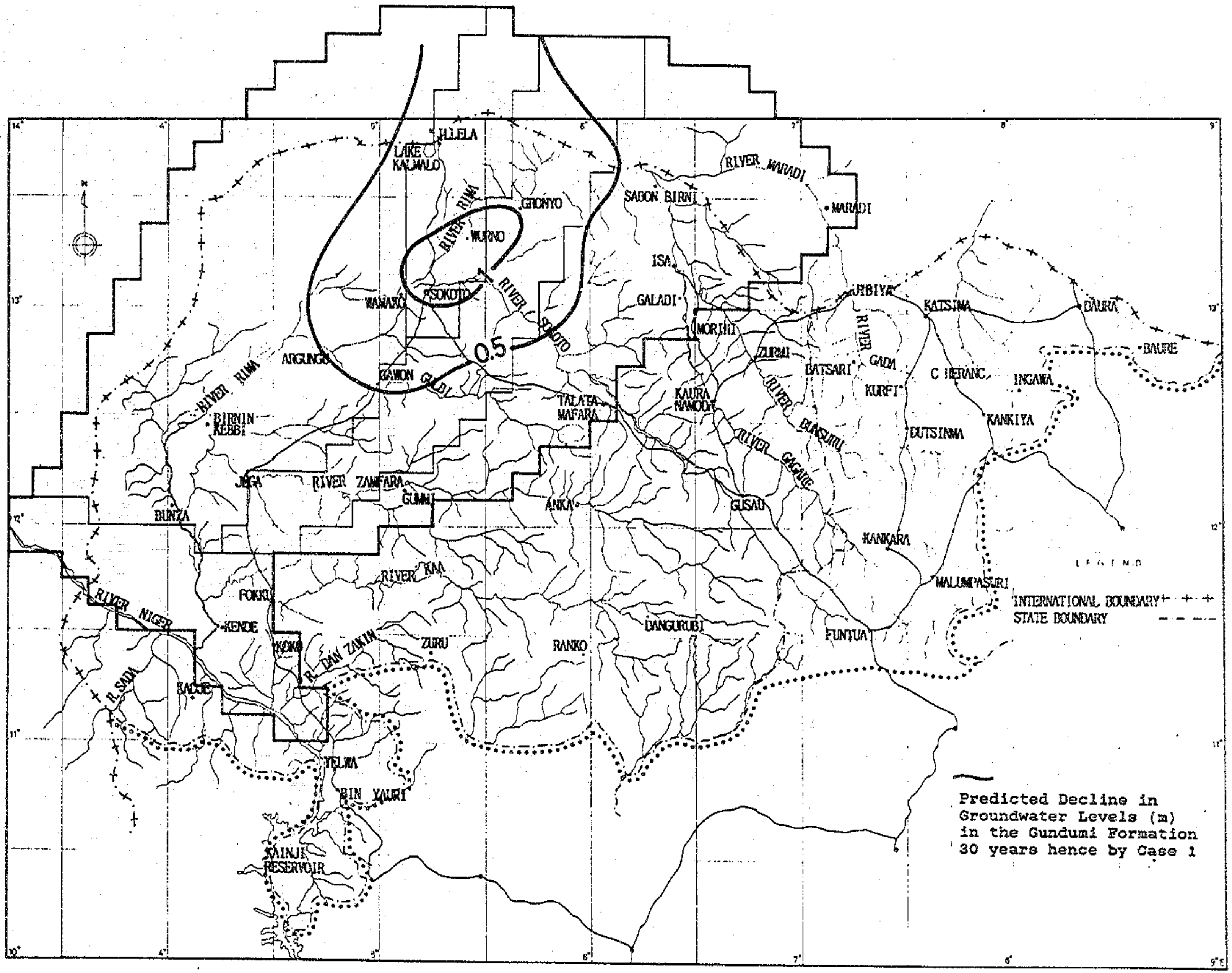


Fig. 7-12(4) Predicted Decline in Groundwater Level in 30 years after -Gundumi Formation- (case 1) than one meter over the entire area except around Sokoto city, where a mound of water level decline of more than one meter is formed.

b. Case 2

Predicted change in groundwater levels at Sokoto is given in Fig. 7-13. Configuration maps of predicted declines in groundwater levels in the Kalambaina aquifers is given in Fig. 7-14.

Water level declines in the Kalambaina aquifer is predicted to be very small or water levels in the aquifer are almost same as those of present.

To the contrary, high decline in water levels of more than 2.0m is predicted in the Rima aquifer around Sokoto city.

The highest decline of 6.8m is predicted to occur in the aquifer on Sokoto city.

(2) Conclusion

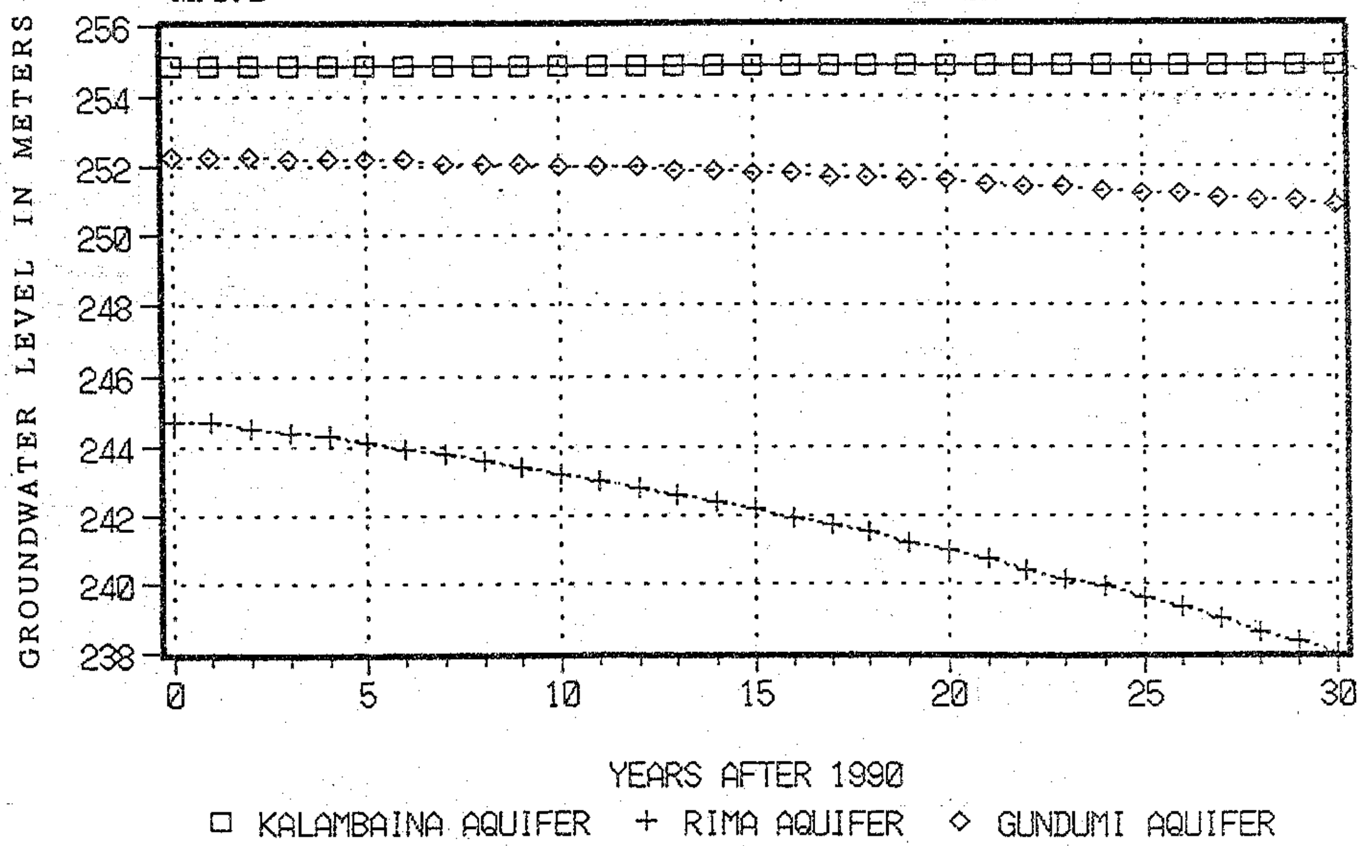
According to the results of water level predictions based on the assumption that the growing rate of groundwater abstraction is 2.5%/year, which is equivalent to that of population, water levels thirty years later in the aquifers in the sedimentary area were predicted as :

a. The Gundumi-Illo aquifer
   Present pumping rate from the aquifer is estimated to be $10,300m^3$/day. Pumpping rate 30 years hence is estimated to be $21,600m^3$/day.
   Water level declines in the aquifer are predicted to be generally less than 1.0m.

b. The Rima aquifer
   Present pumping rate from the aquifer is estimated to be $10,800m^3$/day. Pumping rate 30 years hence is estimated to be $22,700m^3$/day.
   In case abstraction from the aquifer around Sokoto city increases drastically with exhaustion of the upper Kalambaina aquifer, water level decline in the aquifer will be as high as 6.8 m.

FIG. 7-13 PREDICTED CHANGE IN
GROUNDWATER LEVEL AT SOKOTO

M.S.L CASE 2



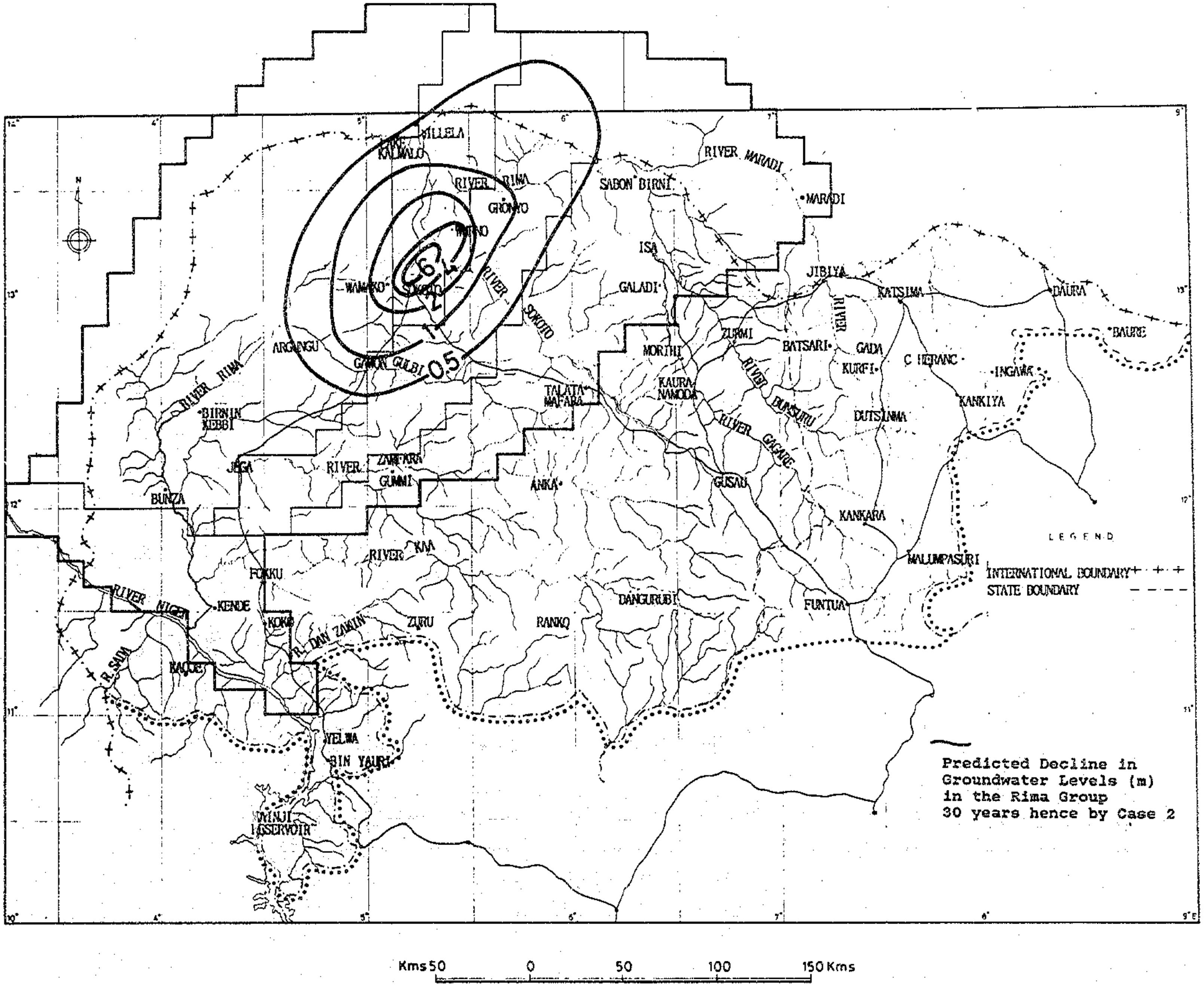


Fig.7-14 Predicted Decline in Groundwater Level in 30 years after -Rima Group- (case 2)

c. The Kalambaina aquifer

Present pumping rate from the aquifer is estimated to be 5,300m^3/day. Pumping rate 30 years hence is estimated to be 11,100m^3/day.

Water level decline in the aquifer around Sokoto city is predicted to be 2.2m provided that abstraction from the aquifer increases at the same rate as the population growth.

Considering the fact that many boreholes tapping the aquifer have been dried up due to decline in water levels, future increase in groundwater abstraction will result in other dried-up boreholes.

d. The Gwandu aquifer

Present pumping rate from the aquifer is estimated to be 15,800m^3/day. Pumping rate 30 years hence is estimated to be 33,100m^3/day.

Declines in water levels are predicted generally less than one meter, However, an area of water level decline of more than one meter will be formed around Brinin-Kebbi and Argungu.

We should note again that the future pumping schemes were established based on the assumptions as follows :

① Present state of groundwater abstraction will not change in future except for pumping rate.

② Boreholes are used for drinking water

③ Increase in abstraction is in proportion to the rate of population growth.

If conditions of groundwater abstraction change significantly, new water level decline will occur at places subject to concentrated abstraction. Therefore, in designing a water use scheme with high groundwater abstraction, simulation by the established model with a corresponding pumping rate should be carried out to predict the future decline in water level.

7-4 The Basin Yield of Basement Rock Area

7-4-1 Hydrogeological characteristics and recharge

In the basement rock area, discharge into the rivers occurs in the rainy season at the time of the heavy rains. However, at other times, the rivers are intermittent. In other words, in the hard exposed basement rock area and surface weathering zones, rainfall does not infiltrate but runs off. The only place where infiltration occurs is areas where the surface weathering layer is thick. Therefore, the storage in the basin is extremely low. In addition, most of the water stored in the basin is lost to evapotranspiration.

Nevertheless, though quantitatively it is very low compared with the total rainfall amount, rainfall infiltrates in the weathering and fractured zones and becomes groundwater in the basement rock area. In particular, basin-shaped weathered zones, formed by geological structure, such as faults, fractured zones and dykes distribute in the basement rock area form small-scale groundwater basins.

According to water balance calculations, the recharge volume of the basement rock area is estimated as 154 mm/year. This volume multiplied by the groundwater basin area gives the recharge volume of the entire groundwater basin. However, as described in 7-2-3, these values are not directly equivalent to actual recharge volume. Assuming that one third of above, approximatly 50 mm/years of recharge can be obtained. This value would be more reliable considering the evapotranspiration of the area.

The area of the distribution of small-scale groundwater basins in the entire basement rock area cannot be estimated. However, taking the basin-shapped weathered zones over 10m in depth in the candidate villages identified in the detailed study, as the groundwater basin area of approximately 1km^2 would result in a daily 140 m^3/day in the recharge. If the groundwater basin is any smaller than this, the recharge also decreases.

The groundwater in the basement rock area is unconfined or confined, and from the perspective of water quality, it is thought to be of rapid circulation and renewable. Consequently, if the pumping rate exceeds the recharge rate the groundwater level declines annually. However, in the areas of thick weathered zones, the aquifer is sufficiently thick, thus drying up does not occur.

7-4-2 Evaluation of the yield

According to the borehole data drilled by SARDA, histogram of pumping rate in the basement rock area is shown as Figure 7-15.
As observed easily, pumping rate of most boreholes ranges 20~50 ℓ/min (28~70 m^3/day). This may indicate that above estimation of the recharge of 140 m^3/day/km is reasonable and groundwater can be pumped if plural borehole were drilled at more depth.

One of economic risks resulting from a decline in the groundwater level is an increase in pumping costs. However, considering the water usage in the basement rock area, there is a problem preceding that of the increase in pumping costs as that of who will bear responsibility of the operation and maintenance fees, if there is no other potential water resources. Even if the groundwater is mined, groundwater pumping must be allowed.

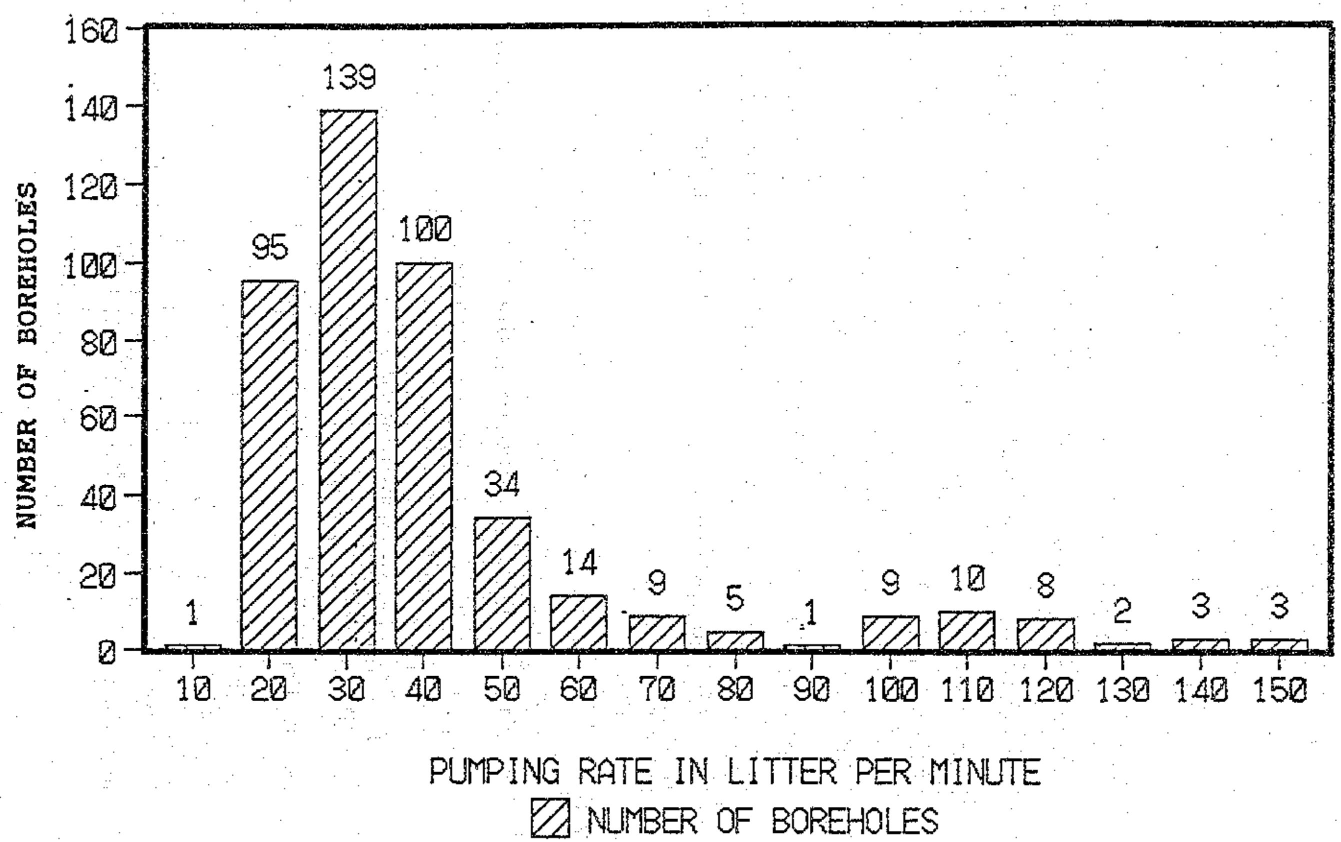
In saying this, groundwater should be used perennially as much as possible. In order to realize this, it is important to establish a suitable scale of development for each small groundwater basin in taking the recharge rate as a criterion for the yield.

7-5 The Basin Yield of Sedimentary Rock Area

7-5-1 Hydrogeological structures and flow characteristics

In the sedimentary rock area, underlain by the basement rock, Gundumi formation, Rima group, Kalambaina formation and Gwandu formation in ascending order form a multi-aquifer system. The groundwater of each aquifer is unconfined in the exposed zones, however in the area covered by the other layer, it is confined. The groundwater in each aquifer forms a wide, generally NE-SW regional flow system. However, hydraulic small gradient of groundwater indicates that the groundwater basin is still under virgin conditions.

FIG. 7-15 NUMBER OF BOREHOLES IN THE BASEMENT AREA CONSTRUCTED BY SARDA



In general terms, a groundwater basin can artificially be uncorked, in that in drilling boreholes, and flow is begun when the groundwater is pumped.

Clearly, the groundwater basin in Sokoto State is not completely closed. Thus there is natural groundwater discharge. In areas of confined groundwater, a local flow system is formed and the discharge of groundwater into rivers creates a base flow in the rivers. The regional flow heads towards the Niger River.

7-5-2 Evaluation of the yield.

(1) Criteria for evaluation

Most of the recharged water in the unconfined aquifer in the sedimentary rock area either becomes local groundwater flow and then discharges into rivers, or is lost to evapotranspiration. A portion of the recharge can added to the confined aquifer, however this volume is unknown at present. In any case, the recharge volume into confined groundwater does not exceed the total recharge to the basin. If the pumping of groundwater in confined aquifers is increased and the groundwater level declines, leakage results from the shallow to deep aquifers. If pumping is maintained to be constant, the pumping amount and the vertical leakage and lateral supplemental flow amounts achieve a balance, and the confined groundwater level achieves a secondary equilibrium. However, if a balance cannot be found with the supplemental flow, the groundwater level does not achieve an equilibrium and gradually begins to decline. At this level, due to an increase in the leakage amount from the unconfined to the confined groundwater, the unconfined groundwater level may decline and the flow system may be changed.

The circulation in shallow unconfined groundwater is rapid, however the deep confined groundwater circulation is slow.

Though the storage capacity is large, the non-renewal factors in groundwater are considered in the evaluation. Therefore, importance must be placed more on the economic risks involved in groundwater than on water balance conditions. In other words, in the Sokoto groundwater basin, the basin yield is evaluated as mining yield.

(2) Economic factors

An increase in the pumping lift results an increase in the pumping cost. If the pumping lift increases, the necessary water volume in pumping cannot be achieved, due to the surpassing of the capacity of the initially installed pump. The pumping of water is abandoned in some cases. In addition, even in the instance where there is surplus in the pump capacity, the operation cost increases.

Judging from the results of the groundwater simulation, when the pumping amount for the entire Sokoto groundwater basin is approximately 88,500m^3/day, the groundwater level achieves secondary equilibrium 30 years later. Maximum decline in the groundwater level is 1.5m in Gwandu aquifer. In the calculation of pumping lift, this declining in the water level is added to the drawdown of the well.

According to the results from the pumping tests in the Gwandu aquifer, the decline in water level (s_1) by aquifer loss with pumping rate at 300 ℓ/min is calculated by Thiem's formula and is shown in the following.

$$s_1 = (2.30 \log R/r)\ 2\pi T$$

where, s_1 : drawdown

Q : pumping rate

R : radius of influence circle

r : radius of well

T : transmissivity

and R = 500m, r = 0.1m, T = 141 m^2/day at Kukakogo

we obtain $s_1 = 4.1$ m

In addition, the well loss (s_2) is assumed as 30% of the aquifer loss (s_1). The groundwater level in the Gwandu aquifer, according to the results of the existing borehole study, ranges between several to 30m. Consequently, taking the maximum value here as 30m, the borehole dynamic water level (s_W) is :

$$s_W = s_1 + s_2 + 30$$
$$= 35.3 \text{ m}$$

If the maximum decline in the water level of 1.5m of the Gwandu formation predicted in the simulation is added to this, it becomes 36.8 m. The head loss in the ground must be added to the pumping lift. However only judging from this numerical value, it is within the range of the lift and operation cost of the pump which is initially designed.

Consequently, in considering the socio-economic condition, development of the pumping rate of 33,100 m^3/day which was input in the simulation model related to the Gwandu aquifer is thought to be possible and this could tentatively taken as the yield.

In addition, the groundwater level in the Kalambaina aquifer, the Rima aquifer and the Gundumi aquifer is within a range of several m and 35m. Therefore, pumping lift of these aquifers is basically the same as that of the Gwandu aquifer. Thus, the pumping rates which were input into these aquifers in the model are considered possible to develop. Total amount of pumping becomes about 88,500 m^3/day in entire basin.

On the other hand, groundwater is pumped from the Rima group in the vicinity of Sokoto city. Groundwater level in the existing boreholes declined to below 50m in some places and anarea of below 80m is also found. Consequently, it is difficult to increase the groundwater withdrawal from the Rima group in the vicinity of Sokoto city.

7-6 Necessity of Groundwater Basin Management

The Sokoto groundwater basin is said to still be under virgin conditions and problems such as decrease in the pumping rate due to the decline in the groundwater level, drying up of the wells and deterioration of water quality may occur, if development takes place without proper planning. Consequently, it is necessary to initially carry out planned groundwater basin management, and to conserve this precious water resource.

The basis of groundwater basin management is the control of the information related to groundwater. For this, the collection of the data and the observation of the water level should be continuously carried out. The data relating to groundwater should be accumulated into the database system established in this study.

1) Collection of borehole data

   Geological columnar section, well log, pumping test results and water quality analysis results

2) Groundwater level observation

   a. Continuous observation by the water level recorders installed in this study.

   b. Simultaneous groundwater observation at existing boreholes

In addition, in the future, it will be necessary to carry out a legal and institutional investigation relating to the management of the groundwater.

8. GROUNDWATER DEVELOPMENT PLANNING

As stated in the previous sections the basement rock area in Sokoto State is thought to be a "difficult area" for groundwater development. Even in this area, according to proper groundwater exploration in a borehole of a 90 - 130 m depth and a 100 mm diameter, groundwater pumping at 70 - 140 ℓ/min is possible. This amount is in no way large, however it is suitable for development as potable water.

In addition, in the sedimentary rock area, in a borehole of a 100 - 150 m depth and a 150 mm diameter, groundwater pumping at 300 ℓ/min per well is possible. This amount is thought to be sufficient for development as potable water. In this section, based on the consideration for the yield of the entire groundwater basin and the hydrogeological conditions, groundwater development plans are established for both the basement rock area and the sedimentary rock area, with the objective being potable water supply.

8-1 Groundwater Development in the Basement Rock Area

(1) Aquifer

Aquifer is composed of basin-shaped or valley-shaped weathering zones along fractured zones and large-scale faults. Narrowing down of the field of investigation from a wide area to a local area, based on the guidelines proposed, is carried out. Then, geophysical prospecting is carried out and the distribution and thickness of the aquifer are estimated. The locations of the boreholes are determined based on these detailed surveys.

(2) Development scale

Considering the recharge, a standard yield is set up as 140 m^3/day/km^2. However, the area of villages in the basement rock area is some 10 - 100 ha, and the area of aquifer distribution does not always correspond with the area of villages. In the case of water distribution to the villages, it becomes uneconomical to place the boreholes at distances from the dwellings. Consequently, even in the case of large-scale scattered villages, the number of boreholes equipped with submersible pumps is limited to 3 locations. Judging from the aquifer distribution, there may be a possibility of increase in the withdrawal and distribution of water. However, basically an increase of the number of boreholes with hand pumps is desirable. The pumping capacity of boreholes with hand pumps depends on the efficiency of the pumps. Therefore, a pumping rate of more than 10 m^3/day is difficult.

(3) Standard design of wells

The standard design of the hand pumped well for the basement rock area is shown in Figure 8-1.

1) Target depth

The thickness of the weathering zone is studied through electrical prospecting and the depth is decided, however the target depth of 90 - 130 m is tentatively planned here.

2) Logging

In order to identify the aquifer and decide on the screen position and length, spontaneous logging, resistivity and natural gamma ray logging is carried out after the drilling.

3) Casing

The materials and the diameter of the casing for the submersible pump borehole is a 6" steel pipe, and that for the hand pump borehole is 4" PVC pipe.

4) Screen

The standard used is a Johnson-type or stainless screen similar to it, with a ratio of openings of 15 % and a slot size of 0.5 - 1.0 mm. A total screen length is designed as 15 m, and screen positions are set at multiple layers.

5) Gravel packing

It is not always necessary to carry out a sieve analysis for the selection of packing gravel. At the test wells in this study, gravel of a grain size of 2 - 3 mm was used. Moreover, as shown in Figure 8-2, at many test wells, packer was installed in the middle of the hole, and deeper than that was

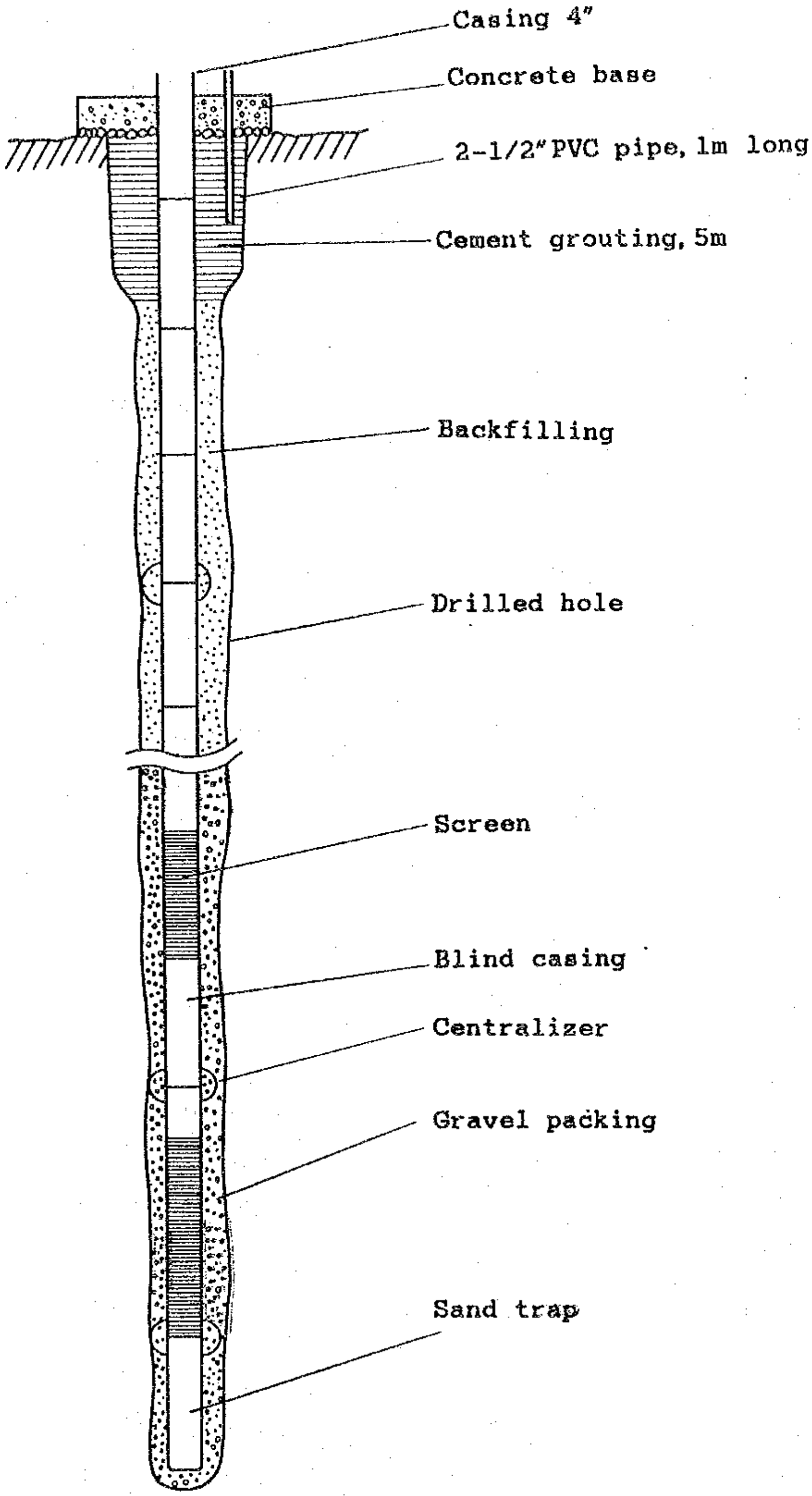


Fig. 8-1 Standard Well Design for Hand Pump Well

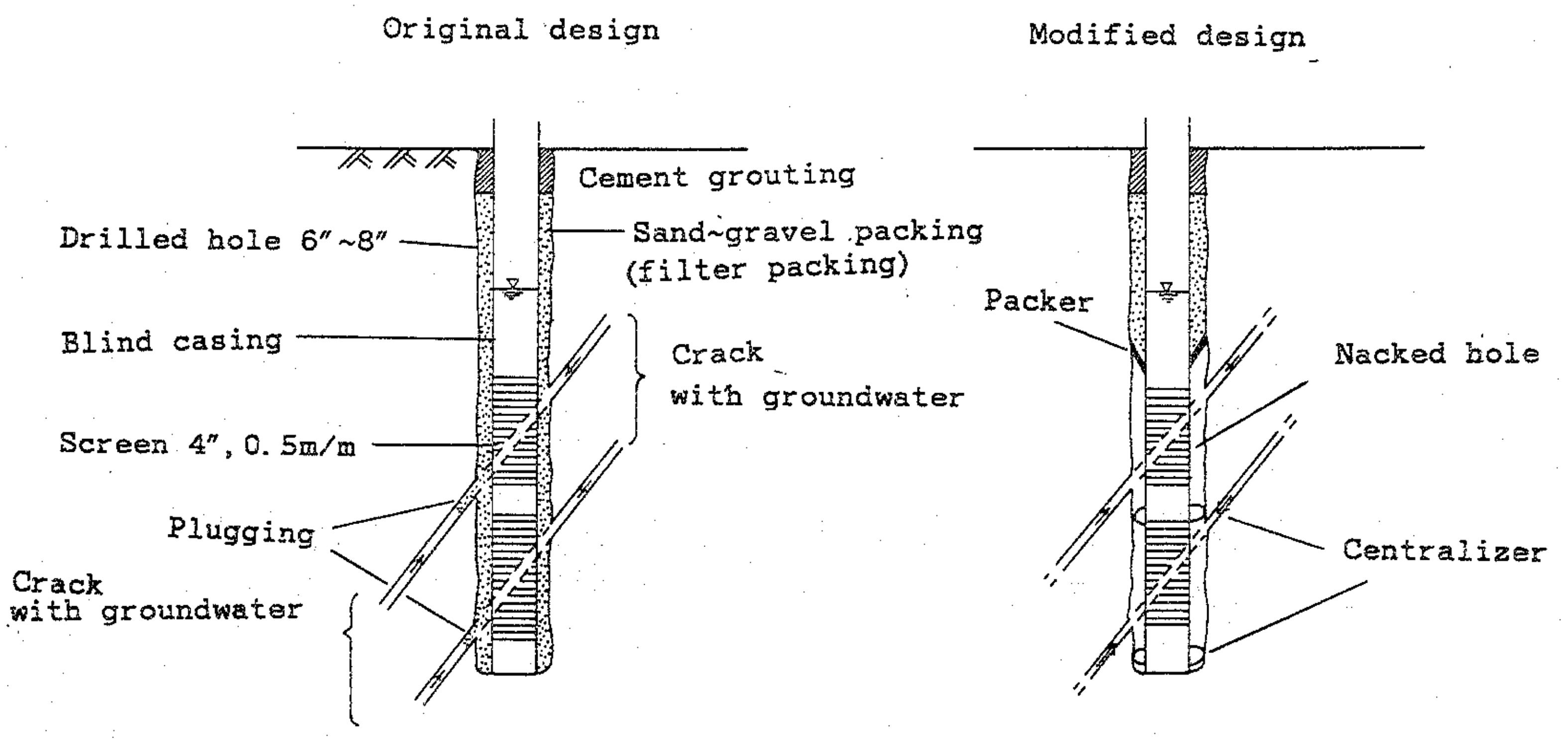


Fig. 8-2 Proposed Modification of the Well Design in the Basement Rock Area

left as a naked hole. In the existence of cracks, the withdrawal could be larger from a naked hole. Based on the evaluation of the results, proper design change is carried out.

6) Well completion

In the completion of the filter-packed well, except for the screen area, the annuls of the well between the borehole wall and the casing is backfilled by drill cuttings. Moreover, within 5 m from the surface of the ground, cement grout is placed for prevention of contamination.

8-2 Groundwater Development in the Sedimentary Area

(1) Aquifer

Judging from the groundwater contour map in the sedimentary rock area (Figure 4-4), the groundwater level of the Gundumi formation and the Rima group aquifers is recognized as below 70 - 80 m in some areas. These areas are that which extends from the northern portion of Sokoto city to the national border and that which lies on the inside of the line connecting Gummi, Jega and Yabo. Groundwater development in these areas is not impossible. However, since the pumping lift increases, it is inefficient.

Excluding these areas, groundwater development is focused on the Gwandu formation, the Taloka formation of the Rima group, the Gundumi formation and Illo formation, as they are good aquifers in medium degree, judging from the specific capacity map.

(2) Development scale

A pumping capacity per well of over 300 ℓ/min can be expected. In the village water supply plan, it is possible for all of the boreholes to be those equipped with submersible pumps. Consequently, in the plan for village water supply, the number of wells responding to the necessary water amount can be decided, however these wells must be properly placed in order to avoid decrease in the withdrawal due to interference.

From the results of the pumping test, the radius of influence was calculated by the Theis's formula when the pumping capacity is at 300 ℓ/min. This is shown in the following.

$$s = Q\,W(u)/4\pi T$$
$$u = r^2 S/4tT$$

Where,	s	:	drawdown
	Q	:	pumping rate
	W (u)	:	well function
	r	:	radius of influence
	S	:	coefficient of storage
	t	:	time since pumping started
	T	:	coefficient of transmissivity

From the pumping results at Horo Birni, in determining the radius of influence r at s=0.1 m, assuming S=0.05, and Q=300 ℓ/min, t=8 hours, $T=5.4\times10^{-2}$ m^3/min/m, then $W(u)=2.26\times10^{-5}$. According to the table of function, u becomes 8.58, then we obtain r=216 m.

From these calculation results, it is understood that the well spacing has to be at least 430 m distance. As regards the detailed design, proper well spacing is designed upon consideration of the hydrogeology, topography and village distribution in the study area.

(3) Standard well design

The standard well design of the motor pumped well for the sedimentary rock area is shown in Figure 8-3.

1) Target depth

In this study, the test well depth for the sedimentary rock area was 150 m in all cases, however the screen was placed at 50 - 80 m. In Soro, water is not taken from the lower Kalambaina limestone. In addition, in Horo Birni, it is estimated that the lower part of the Taloka formation is muddy and that the water quality is unfavorable. In Kukakogo as well, the muddy portion of the Illo formation was avoided when the screen was placed.

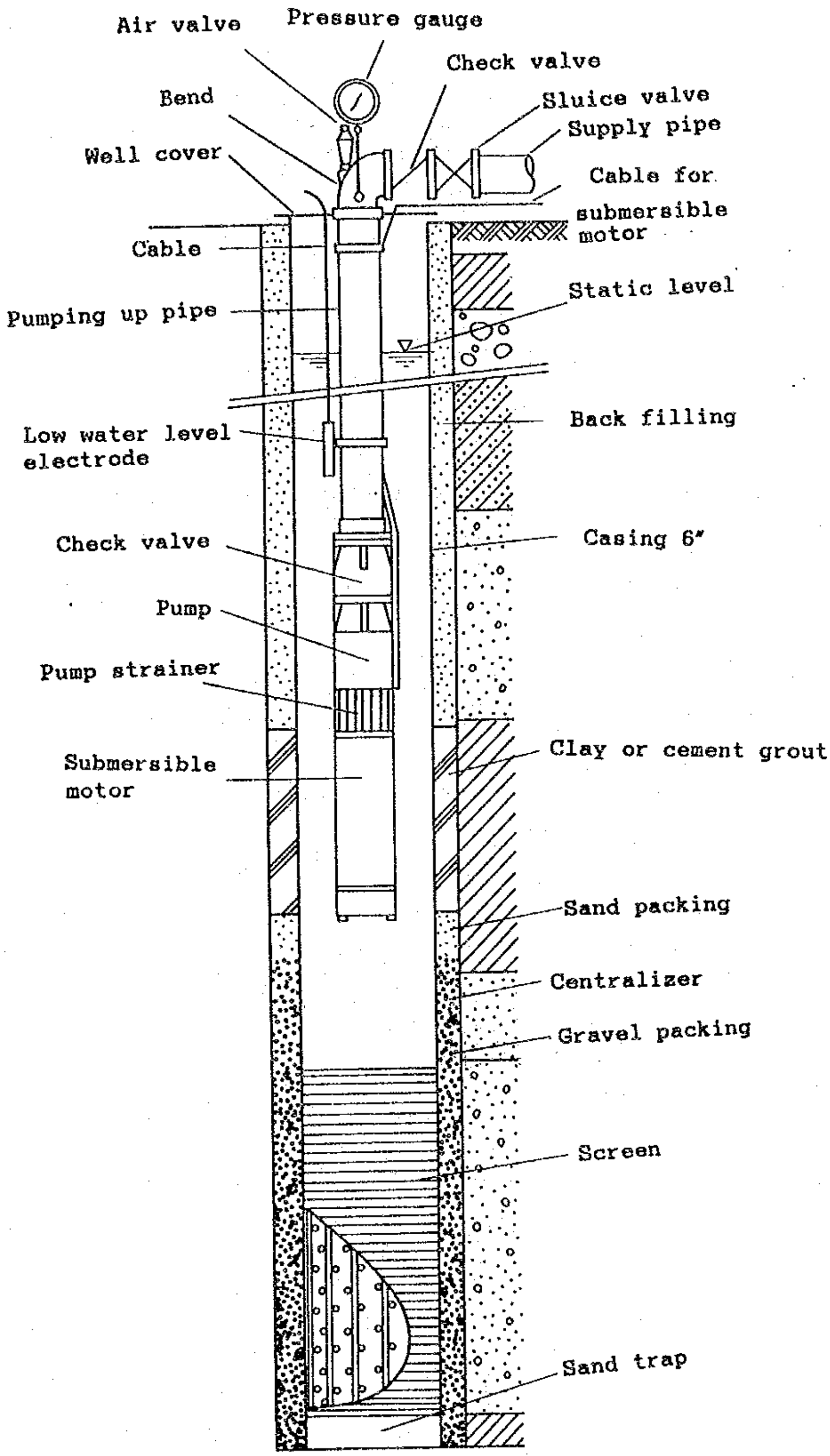


Fig. 8-3 Standard Well Design for Motor Pumped Well

Based on these experiences, the target depth for the boreholes was decided suitable at 100 m.

2) Logging

After drilling, the aquifers were identified based on electric logging and natural gamma ray logging, and then the screen position was decided.

3) Casing

The casing pipe chosen was a 6" steel pipe.

4) Screen

Just as in the basement rock area, the screen chosen is either a Johnson type or a stainless type similar to it, with the ratio of openings at 15 % and the slot size at 0.25 - 0.5 mm. With the screen length at 10 - 15 m, water is taken from a single aquifer.

5) Filter packing

Around the screen, 1 - 2 mm gravel is empirically used as filter.

6) Well completion

In the completion of a filter-packed well, except for the screen area, the casing and the annuls of the well between the borehole wall and the casing is backfilled by drill cuttings. Moreover, within 5 m-deep from the surface of the ground, cement grout is placed for prevention of contamination.

9. WATER SUPPLY PROGRAM FOR MIDDLE TO LARGE SCALE VILLAGES

9-1 Present Status of Water Supply Program

9-1-1 National Policy

The problems of water supply include an inadequate supply and distribution network as well as the low quality of the water itself. In order to solve these problems, the Federal Government announced the following intentions in 4th National Development Plan for 1981, (National Economic Planning Office).

a. The strengthening of the established State Water Boards and the pursuance of a vigorous cost recovery policy based on reasonable user charges.

b. The identification of additional sources of raw water and their exploitation through the activities of the River Basin Development Authorities and the State Water Boards.

c. The expansion of the school for the training of assistant works superintendents in Kaduna.

d. The mounting of an educational campaign, especially in the rural areas, to underscore the value of boiling water.

e. The intensification of hydrological investigations in order to collect adequate data for the further expansion of water resources in the country.

f. The encouragement of the various State Water Boards to set up water quality control laboratories to monitor the quality of water supplied to consumers.

At the same time, the Federal Government outlined the following responsibilities:

a. Federal Government

- The exploitation of groundwater resources would be undertaken by the Federal Ministry of Water Resources.

- The design and construction of five storage reservoirs per state would be undertaken.

b. State Government

- The main objective of the various state government water supply programs would be to bring immediate relief to areas of the states which have been without adequate water for a great length of time.

- Construction of new water supply schemes and expansion of existing schemes in the major urban areas would be undertaken, such as the damming of rivers and streams and the construction of water treatment plants, pumping facilities, reservoirs, and pipe distribution networks.

- For rural water supply schemes, access to safe drinking water would be extended to increasing numbers of rural dwellers. This would be accomplished in part by drilling boreholes and damming rivers and streams.

c. Local Government

Boreholes would be drilled in villages at a distant from existing pipelines.

9-1-2 Organization

The water supply schemes in Sokoto State are categorized into three main categories: urban, semi-urban, and rural water supply schemes. The present organization is shown in Figure 9-1. This figure makes clear that the SSWB holds the responsibility for water supply in urban and semi-urban areas, and that the SARDA is responsible for rural areas. In contrast, the main function of the SRRBDA is large-scale irrigation, though the SRRBDA sometimes drills boreholes in order to supply drinking water for those dwelling in rural areas.

Figure 9-2 shows the transition of the organization concerning water supply in Sokoto State. The present organization was established in 1982.

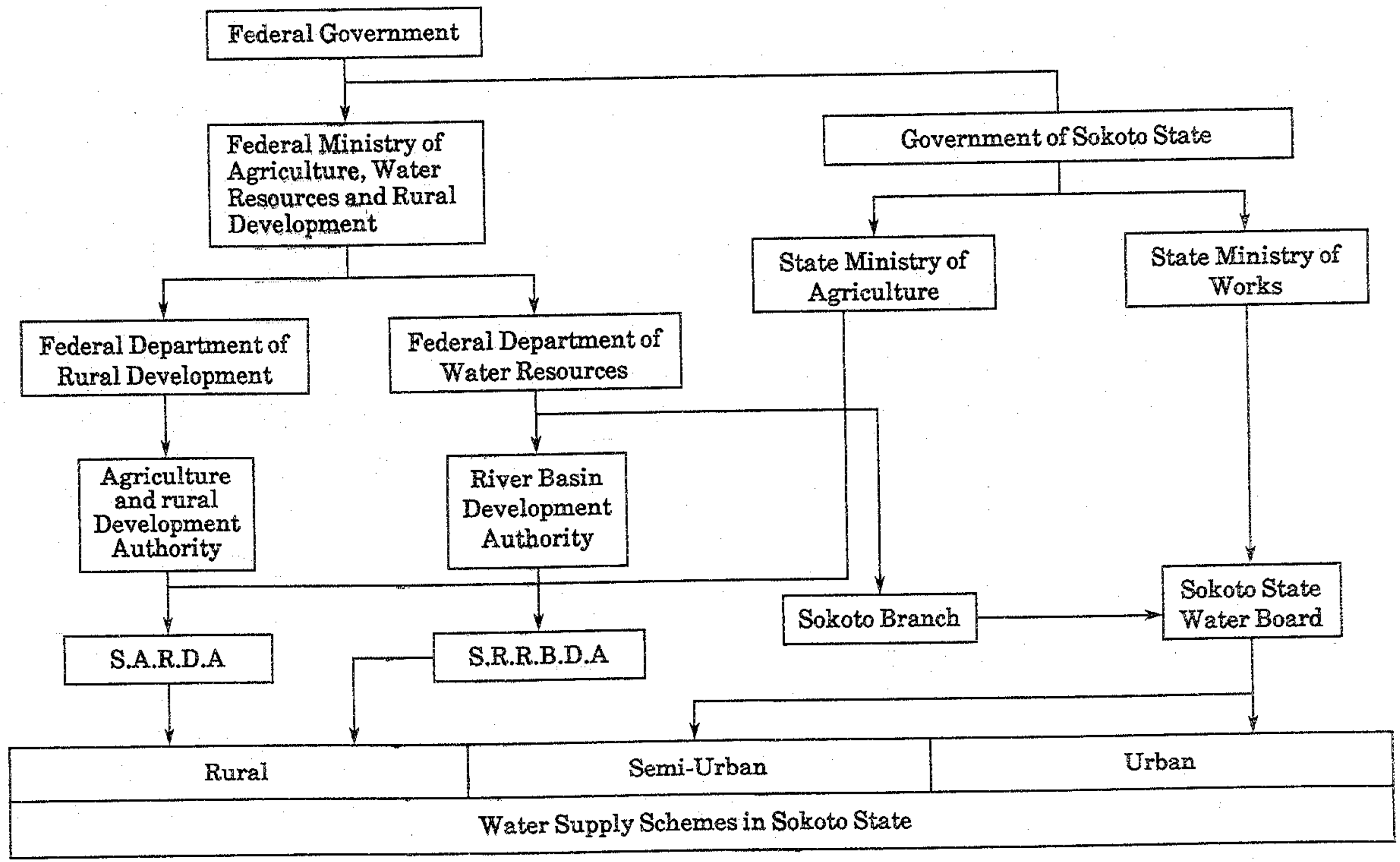


Figure 9-1 Organization of Water Supply in Sokoto State

Table 9-1 Capital Expenditure on Water Supply by Scheme

(Unit: 1000 NAIRA)

		Actual 1981	Actual 1982	Actual 1983	Actual 1984	Actual 1985	Revised 1986	Estimated 1987
Urban Scheme from Water Supply		8,656	5,080	6,164	269	22,600	40,800	47,200
Semi-Urban Scheme	from Water Supply	407	564	–	–	–	–	–
	from Agriculture	–	1,878	–	–	–	–	–
Rural Scheme	from Agriculture	10,319	5,754	–	–	–	–	–
	from World Bank	–	–	5,010	8,625	7,177	1,645	1,078
Total		19,382	13,277	11,174	8,894	29,777	42,445	48,278

Note: Capital Expenditures by the World Bank are all actual and based on the Stage I 1983 - 1987

Source: (1) Recurrent and Capital Estimates of the Government of Sokoto State of Nigeria 1987
(2) Verbal reports from SARDA.

Urban Schemes	Sokoto Water Board	Ministry of Water & Electrical Supply	Sokoto State Water Board
Semi-Urban Schemes	Sokoto Water Board	Ministry of Rural Development & Cooperation	Sokoto State Water Board
Rural Schemes	Sokoto Water Board	Ministry of Rural Development & cooperation	SARDA

1979 1982 1989

Figure 9-2 Transition of Water Supply Organization in Sokoto State

9-1-3 Finance

The capital expenditures of each scheme are shown in Table 9-1. It is indicated that the water supply projects in urban and rural areas have been undertaken continuously by the SSWB and the SARDA. However, no capital expenditures have been made in semi-urban areas since 1983.

9-1-4 Development Activities

The number of boreholes drilled from 1982 to 1985 are shown in Table 9-2 by scheme.

a. Urban Scheme

The total potable water supply in the urban areas of Sokoto State during the year 1985 was 18.98 million gallons of water per day, out of which 13.50 million gallons per day were from treated surface water supply and 5.48 million gallons per day were from treated boreholes supply.

The difference between supply and capacity during 1985 was 5.31 million gallons per day. This gap was caused by reasons such as generator breakdown, power failure, and inadequate distribution networks.

b. Semi-Urban Scheme

The water supplied to dwellers in semi-urban areas is from boreholes. However, the amount of water is obviously inadequate.

c. Rural Scheme

The drilling of boreholes and wells has been implemented aggressively by the SARDA, The Directorate for Food, Road and Rural Infrastructure (DFRRI) and the local governments. The SARDA and the DFRRI now carry full responsibility for water supply development in rural areas.

Table 9-2 Additional Number of Boreholes Drilled in Sokoto State by Scheme

		Additional Boreholes Drilled				Total Boreholes in Area
		1982	1983	1984	1985	Dec. 1985
Urban Scheme (by SSWB)		9 (0.77)	2 (0.10)	1 (0.14)	15 (1.44)	101 (10.79)
Semi-Urban Scheme (by SSWB)		17 (0.05)	12 (0.02)	0 (0)	3 (0.01)	*
Rural Scheme	by L.G.A. & M.R.D.	424	312	315	211	*
	by SARDA	(0)	236	784	387	*

Note: (1) Figure in "( )" shows a capacity. Unit is MGD.
(2) MGD = Million Gallons per Day
(3) L.G.A. = Local Government Authority, M.R.D. = Ministry of Rural Development and Cooperation
(4) * means no statistics

Source: Sokoto State Water Electricity Statistics 1985

The SARDA's activities have been in villages of about 500 or fewer people, where it has drilled boreholes with a depth of 50 to 80 m and provided handpumps for these boreholes. These activities have been financed, 98.5 %, by the World Bank and, 1.5 %, by Sokoto State.

Table 9-3 SARDA Drilling Activity

Phase 1 (1983 - 1987)

1,401 boreholes (1,200 planned)

1983	1984	1985	1986	1987	Total
5,010	8,625	7,177	1,645	1,078	23,535 (1,000 Naira)

Phase 2 (1988 - 1989)

2,200 boreholes (1,500 planned)

1988	1989	Total
66,362	60,000	126,362 (1,000 Naira)

The history and cost of this activity is presented in Table 9-3.

Consequently, it is concluded:

The SSWB is responsible for the improvement of water supply conditions in urban and semi-urban areas using the state budget. The SARDA is promoting water supply development in rural areas utilizing a contribution from the World Bank.

The SSWB has acute shortage of funds to adequately fulfill its obligations. According to the 4th National Development Plan, only half of the capital budgeted for 1976 to 1980 was available. There is an urgent need for adequate water supply in the semi-urban areas, which the SSWB can satisfy only with financial resources provided by foreign sources.

9-2 Water Supply Plan

Investigation of water supply schemes by groundwater in medium- to large-scale villages, of populations of 3,000 - 20,000 was carried out.

9-2-1 Basic plan

(1) Villages for water supply schemes

Twenty-one villages were subject to detailed investigation regarding water supply schemes. As for the candidate villages, there were 47 for all of Sokoto State, however by the preliminary survey, the following villages were excluded: 8 villages of below 3,000 in population; 13 villages of extremely poor road access conditions; 2 villages of already existing boreholes with pumps or in the planning process of having them; 2 villages of scant possibility for groundwater existence; 1 village for other reasons. This resulted in 26 being excluded from the detailed survey. The water supply execution potential in these villages will require future investigation.

In Horo Birni, one of the chosen villages, as mentioned below, a water supply facility model was constructed, thus bringing the number of investigated villages to 20. The name and location of each village are shown in Table 9-10 and Figure 9-3.

(2) Water supply population

The population of Sokoto State, according to a supposed 2.5 % growth rate, rose form 4,530,000 recorded in the 1963 census, to 8,200,000 in 1987. The population breakdown in each administrative district could be researched, however population totals for medium- to large-scale villages don't exist. Consequently, the population in the area of the planned water supply was learned by on-site verbal survey. In addition, the population of those served by water supply in the year 2000 was estimated by applying a growth rate of 2.5 % to the present population. The population for these 20 villages concerned in the water supply scheme is 147,700 (Table 9-10).

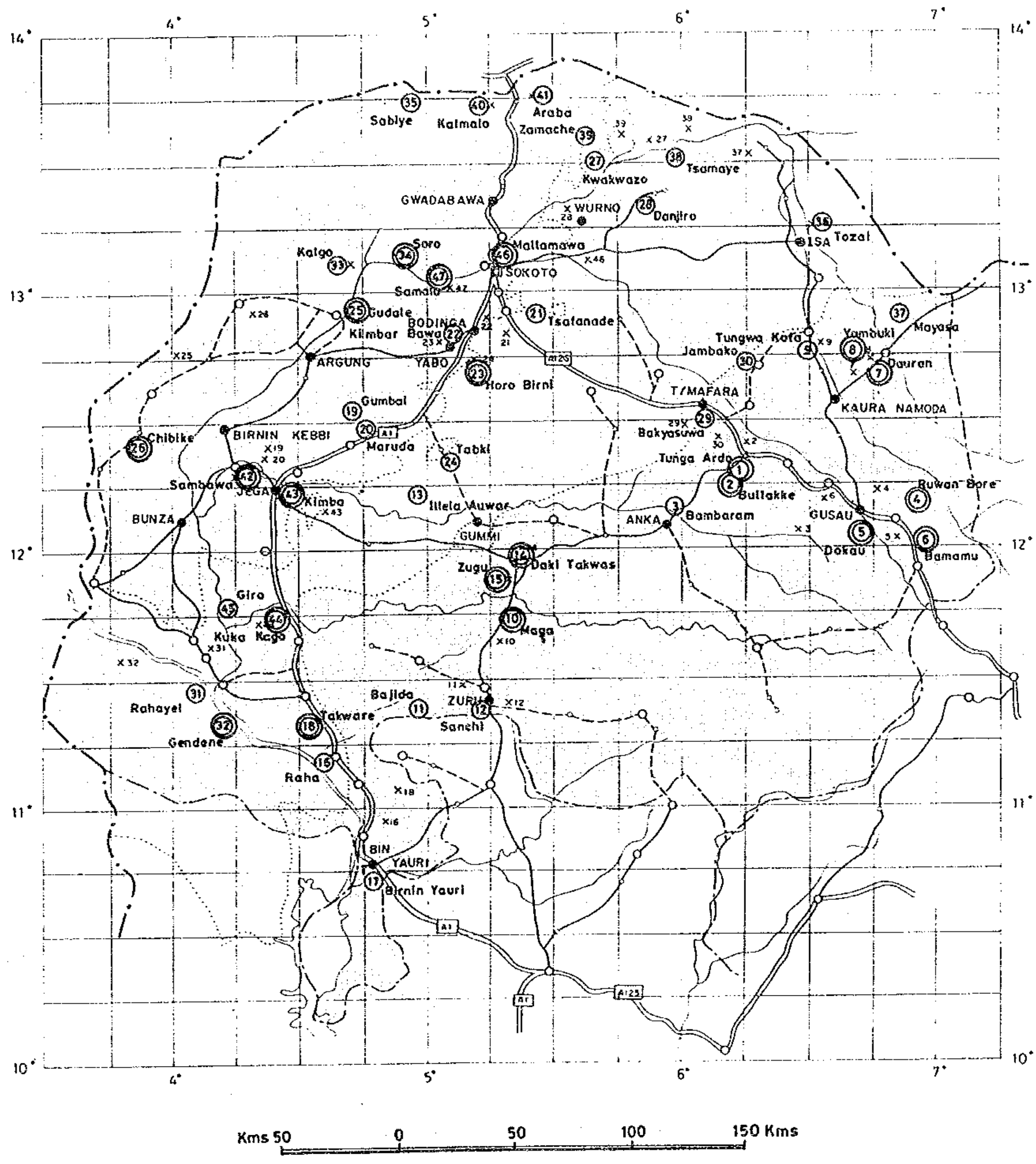


Fig. 9-3 **Location Map of Candidate Villages for Water Supply Schemes**

◎ Selected villages for the sites of detailed survey

Sedimentary rock area

Basement rock area

(3) Designed water supply amount

1) Standard consumption rate for water

Tables 9-4, 9-5 shows the most widely used WHO standards for water consumption amount for small-scale water systems in developing countries at present. In addition, the FDWR in Table 9-6 shows a proposed ideal water supply and water consumption rates. However, if the present situation of water use is taken into consideration, it would not be very practical to base the design standards on the above standard values nor the proposed values as they are. Because of this, suitable consumption values are proposed in Table 9-7, based on the scale of the villages, present water supply and hydrogeological conditions for this study. It is thought very important for future designs that they take into account the conditions in each village in establishing consumption amounts. In addition, as stated below, basing the investigation on the actual amount of water used in the model water supply system in Horo Birni, the consumption amount is 27 ℓ/c/d.

2) Designed daily average water demand

The designed daily average water demand (Qn) is found by the following formula.

$$Qn = Ct \times r$$

Where, Ct : Total water consumption
r : loss coefficient by

$$Ct = P \times C$$

Where, P : water supply population
C : water consumption (ℓ/c/d).

A water consumption amount corresponding to the village conditions was established, as presented in Table 9-10 and the designed daily average water demand for each village was determined at r = 1.2.

Table 9-4 Typical Domestic Water Usage

Typical Water Supply	Water Consumption	Range
A. Communal water point	1 /c/d	1/c/d
- at medium distance (>100m)	7	5 - 10
- at medium distance (300m-1000)m	12	10 - 15
B. Village well - walking distance <250m	20	15 - 25
C. Communal standpipe - walking distance <250m	30	20 - 50
D. Yard connection - tap placed in house yard	40	20 - 80
E. House connection		
- single tap	50	30 - 60
- multiple tap	150	70 - 250

Table 9-5 Various Water Requirements

Typical water supply	Consumption
- School (day school)	15 - 30 ℓ/day per pupil
- Hospital (with laundry)	220 - 300 ℓ/day per bed
- Hotels	80 - 120 ℓ/day per resident
- Restaurant	65 - 90 ℓ/day per seat
- Mosques	25 - 40 ℓ/day per worshipper
- Livestock (goat or sheep)	15 - 25 ℓ/day per head

Table 9-6 The Ideal Water Supply and Consumption Proposal by FDWR

	Present average	Objective
Urban area	50 ℓ/c/d	120 ℓ/c/d
Semi Urban area	40 ℓ/c/d	90 ℓ/c/d
Rural area	40 ℓ/c/d	60 ℓ/c/d

Table 9-7 Recommended Water Consumption

Village condition	Water Consumption (ℓ/c/d)
Geology	
Basement Area	15 ~ 20
Sedimentary Area	20 ~ 50
Scale of Village	
Rural Type (<1000)	15 ~ 20
(1,000~10,000)	20 ~ 30
Semi Urban Type (> 10,000)	30 ~ 50
Existing Water Source	
Occasionally available	15 ~ 20
Always available	20 ~ 50

Table 9-8 Designed Standard for Velocity and Head Loss

Diameter (mm)	Velocity (m/sec)
40-75	0.6-0.8
75-150	0.7-1.0
200-300	0.8-1.2

<Calculation of head losses>

The Hagen-William's formula is commonly used in calculating the head loss:

$$Oij = 0.27583.C.Dij^{2.63} \left(\frac{hi - hj}{Lij}\right)^{0.54}$$

Where,

Oij : quantity of water flow between (i) and (j)
Dij : diameter of pipeline between (i) and (j)
Lij : length of pipeline between (i) and (j)
hi : dynamic hydraulic pressure at (i)
hj : dynamic hydraulic pressure at (j)
C : pipes coefficient
C=110-120 for steel pipes

3) Designed maximum daily water demand

The designed maximum daily water demand (Qmax) is found by the following formula.

$$Qmax = Qn \times kd$$

Where, the peak factor "kd" which is generally 1.1 - 1.3.

However, as there is no data on the monthly fluctuations in supply amount for Sokoto State, the peak coefficient will be assumed at 1.2.

The estimated results for each village are shown in Table 9-10.

4) Designed hourly maximum water demand

The designed hourly maximum water demand (Qhmax) is found by the following formula.

$$Qhmax = Qmax \times kh$$

Here, "kh" is the hourly peak coefficient. This coefficient should also be established in regards to the actual use of the model water supply facilities, however, as a general value, 1.5 is used.

(4) Water resources and water quality

1) Water resources

In Sokoto State, as explained in detail in Section 8, groundwater development is possible in both the basement rock area and in the sedimentary rock area. Consequently, with the water resources being groundwater, borehole drilling and pumping are carried out.

2) Water quality

The desired water quality standards for potable water, according to WHO, are shown in Table 4-6. In this study, the results from the water quality analysis conducted for the existing and the drilling test wells show that there is possibility for use as potable water. Although the total hardness is very high in some of the drilling test wells, it is below the highest value within the WHO permissible standards.

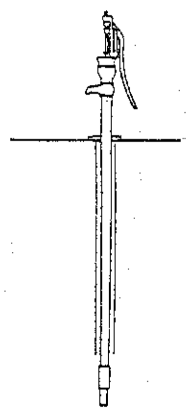
9-2-2 Facilities planning

(1) Facilities design

Three types of water supply facilities designs are shown in Figure 9-4. These are based on the scale, present water supply conditions and the hydrogeological conditions of the villages.

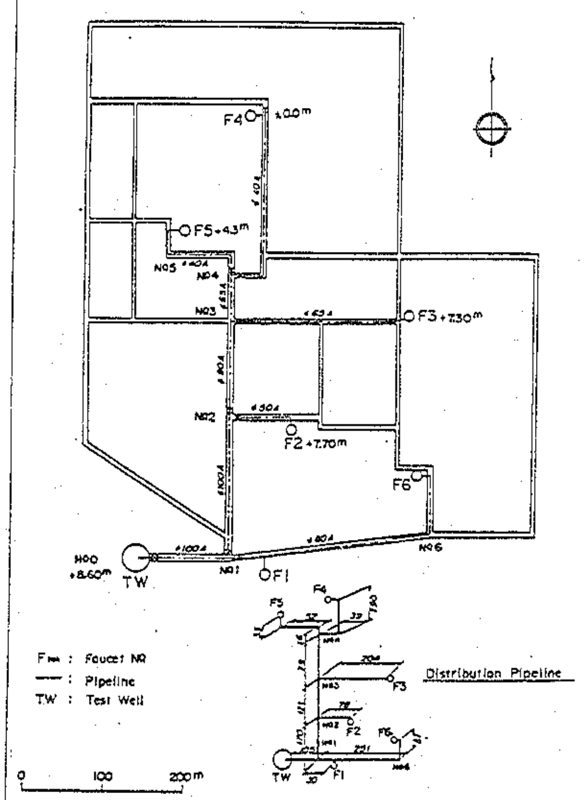
Figur 9-4 Water Supply System Design

Hand Pump System

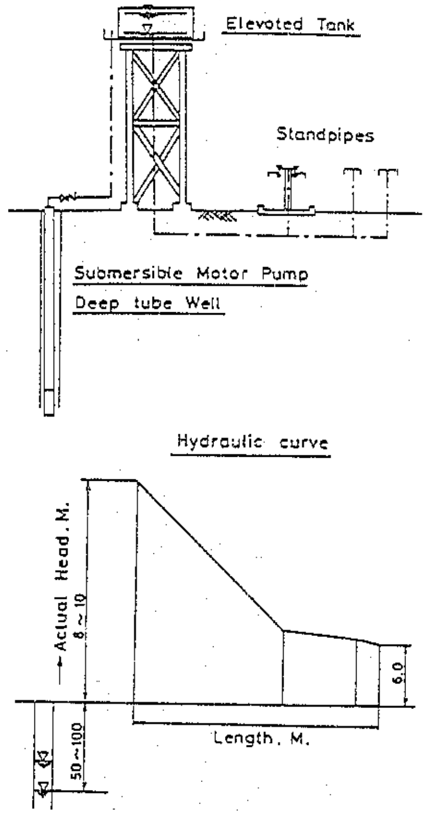


Piped Water System for Rural Area

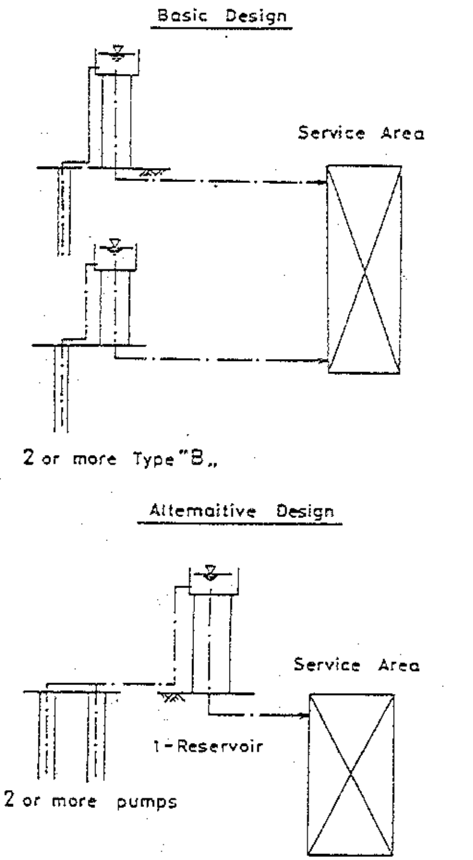
Distribution Pipeline



Case Study for Village



Pipe Water System for Semi Urban.



Type "A"

(1) Facilities

One or more handpumps

(2) Classification

A-B Handpumps for Basement Area

A-S Handpumps for Sedimentary Area

Type "B"

(1) Facilities

1) Deep tube well, 2) Subme sible Motor Pump, 3) Elevated Tank

4) Distribution pipe 5) Standpipes.

(2) Classification

B-B Piped Water for Rural Basement Area

B-S Piped Water for Rural Sedimentary Area

Type "C"

(1) Facilities

Type"C" consists of two or more of Type"B"

(2) Classification

C-B Piped Water for Semi Urban Basement Area

C-S Piped Water for Semi Urban Sedimentary Area

1) Hand-pump system (Type A)

This system is suitable for use in villages of which the groundwater development potential amount is not very large. The number of people suppliable for one borehole equipped with a hand-pump depends on the water use amount and the pump capacity. In general, the number of people is 300 - 800, thus the location of the borehole and the amount are based on the layout of the village, the population and the hydrogeological conditions.

2) Pipe water supply system (Type B, Type C)

The Type B system is composed of a borehole equipped with one powered pump, an elevated water tank, a distribution pipe and a communal faucet. The Type C is made up of many boreholes and elevated water tanks.

This system is suitable for use in villages of which there is some level of potential amount for groundwater development. The combination of boreholes and elevated water tanks, the amount and the location depend on the layout of the village, the population and the hydrogeological conditions. These results are shown in Table 9-10.

(2) Intake facilities

Intake facilities are composed of boreholes equipped with hand pumps or boreholes equipped with submersible pumps.

1) Boreholes

For boreholes, the depth is 90 - 120 m, the casing diameter is 6 inches (submersible pump well) and 4 inches (hand pump well).

2) Hand pump

A pump with a submersible cylinder for deep wells is used. The head is over 50 m and the discharge is over 15 ℓ/min.

3) Submersible pump

A deep well submersible pump is installed and the capacity of this pump is designed based on the following formula.

$$P = 0.163 \cdot Q \cdot H / yp$$

where,
- P : pump drive power (kw)
- Q : discharge corresponding to the planned daily maximum water demand (m^3 / min)
- H : overall pumping head, being: $H = H1 + H2 + H3$ (m)

where,
- H1 : dynamic water level
- H2 : head loss due to friction
- H3 : height of elevated water tank
- yp : efficiency of pump

The pump horse power (Pm) is shown by

$$Pm = P(1 + A) / y$$

where,
- A : safety rate (generally 15 %)
- y : motor drive efficiency (generally 60 %)

(3) Water distribution facilities

These facilities are composed of an elevated water tank and a distribution pipe.

1) Elevated water tank

This is installed in order to maintain a balance between the constant supply for the storage tank from the intake pump and the fluctuations in the water demand in the distribution area. It is necessary to make the storage volume large enough to enable adjustment of the accumulation of the difference between the pump amount and the demand for water. This accumulation of the difference is 20 - 40 % of the total daily maximum water demand. Assuming that the pump is in operation for 6 hours, the volume of the storage tank must be 40 % of the daily maximum water demand.

The elevated water storage tanks in Sokoto State are generally made of steel panel, however from the point of durability and safety, GRP (glassfiber-reinforced plastic), stainless steel and concrete should be looked into.

The tower for the elevated water tanks distribute water within the zone, and should be as tall as to meet with the water level in the storage tank, in order to ensure maintenance of at least a 6 m water head at the ends of the distribution pipes. The actual water level should be established in consideration of the head loss of the distribution pipe and the elevation differences in the surroundings of the site.

2) Distribution pipe

The distribution pipe system is usually one of the two following types.

a) branch system

b) loop-network system

The branch system is generally appropriate for small-scale villages, and the loop-network system is appropriate for large-scale villages or for semi-urban villages.

The velocity in the pipes and the head loss are examined as designed standards in Table 9-8. In addition, it is necessary to investigate the type of pipe, the depth of the pipe laying and the installation of the valves at the detailed designing stage.

(4) Water supply facilities

These are composed of a communal faucet and service pipe. The end of the distribution pipe joins up with the service pipe which connects to the communal faucet. The number of faucets is determined based on the location of the dwellings and the population.

(5) Other facilities

Small generator houses and material storehouses will be set up. These facilities should be used for the storage of a generator (including a spare), fuel and repair materials.

9-2-3 Estimated project costs

A summarized facilities planning was carried out for the 21 candidate villages. The construction costs necessary for the planning were estimated and shown in a model for Horo Birni (sedimentary rock area) and Ruwanbore (basement rock area) (Table 9-9).

As for the Horo Birni water supply model, test execution within this study period was carried out, therefore excluding this, the estimated construction costs for other 20 villages is tabulated in Table 9-10.

In addition to the construction costs, equipment costs and design and supervision costs were estimated.

Equipment costs includes cost of vehicles and equipments for construction work and groundwater investigation. Design and supervision costs is an expense of the consultancy service for detailed design and supervision on the construction. The estimated project costs are as in the following,

(1) Estimation conditions

1) Estimated period — January 1990

2) Foreign currency exchange rate

1 U$ = Yen (¥) 140
= Naira (N) 7.4
1 (N) = ¥ 18.9

3) Construction period — 30 months

4) Contractors — Foreign contractors for well drilling and water supply works

Table9-9 Cost Estimate of the Model Construction

No.	Village Name	Design System	Facilities		Intake: Deep Well	Intake: Pump & Generator	Intake: Pump House and Fitting	Intake: Total ①	Elevated Water Tank: Reservoir Tank (GRP)	Elevated Water Tank: Tower (Steel)	Elevated Water Tank: Total ②	Pipeline: Pipe & valve Faucet	Pipeline: Total ③	Grand Total: ¥×1000 ④	Grand Total: $
4	RUWAN BORE Basement Area Service Population P=8,000 Water Daily Maximum Q=230m³/d	(B)−B	Specification		Dia. 6" Depth 90m Quantity 160 ℓ/min	50 ϕ 5.5 kw 17.5 kVA	Brook Concrete 3.0×8.0×3.0		98 m³ 7.0×7.0×2.0ᴴ	392 m³ 7.0×7.0×8.0ᴴ		80A 120ᵐ 50A 240 40A 240 25A 60 Total 660ᵐ			
			Number		1	2 (1-spare)	1		1	1					
			Cost ¥ ×1000	Material	—	6,600		6,600	5,782	6,272	12,054	2,300	2,300	20,954	149.6
				Installation	5,400	—	3,000	8,400	1,862		1,862	1,978	1,978	12,240	87.4
				Administration	2,160	—	1,200	3,360	744		744	791	791	4,895	35.0
				Total	7,560	6,600	4,200	18,360	14,660		14,660	5,069	5,069	38,089	272.00
			%	① ~ ③/④				48 %			39 %		13 %	100 %	
23	HORO BIRNI Sediment Area Service Population P=8,000 Water Daily Maximum Q=345 m³/d	(B)−S	Specification		ϕ 6" D 110 m Q 300 ℓ/min	60 ϕ 7.5 kw 17.5 kVA	3.0×8.0×3.0		128 m³ 8.0×8.0×2.0ᴴ	480 m³ 8.0×8.0×7.5ᴴ		100A 330ᵐ 80A 540 65A 340 40A 350 25A 90 Total 1745ᵐ			
			Number		1	2	1		1	1					
			Cost ¥ ×1000	Material	—	8,281		8,281	7,540	7,710	15,250	3,360	3,360	26,891	192.1
				Installation	6,600	—	3,085	9,685	2,403		2,403	2,897	2,897	14,985	107.0
				Administration	2,640	—	1,234	3,874	961		961	1,158	1,158	5,993	42.8
				Total	9,240	8,281	4,319	21,840	18,614		18,614	7,415	7,415	47,869	341.9
			%	① ~ ③/④				46 %			39 %		15 %	100 %	

Note: RUWAN BORE (B)−B Unit cost 38,089,000 ¥/230 m³/d = 165,600 ¥/m³/d = 1,180 $/m³/d
HORO BIRNI (B)−S Unit cost 47,869,000 ¥/345m³/d = 138,000 ¥/m³/d = 1,000 $/m³/d

Facilities unit cost:
- Deep well 60,000 ¥/m depth
- Reservoir Tank 54,000 ¥/volume m³
- Tower 16,000 ¥/Air volume m³
- Pipeline & Faucet 10,000 ¥/m³/d

Hand pump 25,000 ¥/1 unit
Borehole pump & Generater 600,000 ¥/pump kw

Table 9-10 Cost Estimation for W/Supply System (1/3)

No.	Village Name (Local Gov.)	Population (Service population)	Hydro-geological Feature	Water Consumption ℓ/c/d	Water Demand m³/d Average (ℓ/min)	Water Demand m³/d Daily Maximum (ℓ/min)	Result of Test Drilling	System Design: System	System Design: Preminary Design	Estimate Construction Cost 1000¥: Intake	Elevated Tank	Distribution Pipeline	Total 1000¥	Total $	Estimate Operation & Maintenance Cost N/Month (N/p/Month)
1	Tunga Ardo (Anka)	30,000 (3,000)	Basement	15	54 (90)	65 (108)	T/W 80 m 17 ℓ/min	A	6 Deep Well 50 m, 18 ℓ/min 6 Hand Pumps	27,300	–	–	27,300	195,000	1,300 (0.43)
2	Bullake (Anka)	10,500 (5,000)	Basement	15	90 (150)	108 (180)		A	10 Deep Well 50 m, 18 ℓ/min 10 Hand Pumps	45,500	–	–	45,500	325,000	2,160 (0.43)
4	Ruwan Bore (Gusau)	11,500 (8,000)	Basement	20	192 (133)	230 (160)	T/D 84 m 49 ℓ/min T/W 90 m 84 - 168 ℓ/min	B	1 Deep Well (90 m) 160 ℓ/min 1 Unit Water Supply System	18,360	14,660	5,069	33,089	272,064	1,500 (0.18)
5	Dokau (Gusau)	10,000 (10,000)	Basement	20	240 (166)	288 (200)		C	2 Deep Well 90 m, 100 ℓ/min 2 Unit Water Supply System	36,720	14,960	6,346	58,026	414,471	2,250 (0.22)
6	Bamamu (Gusau)	10,000 (4,000)	Basement	15	72 (120)	86 (144)		A	8 Deep Well 50 m, 18 ℓ/min 8 Hand Pump	36,400	–	–	36,400	260,000	1,728 (0.43)
7	Dauran (Kaura Namoda)	23,500 (23,500)	Basement	20	564 (391)	676 (470)	T/W 84 m 110 ℓ/min~ 210 ℓ/min	C	3 Deep Well 90 m, 160 ℓ/min 3 Unit Water Supply System	47,520	43,982	14,898	106,400	760,000	3,579 (0.15)
8	Yambuki (Kaura Namoda)	25,000 (12,000)	Basement	20	288 (200)	345 (200)	T/D 80 m 50 ℓ/min T/W 100 m 80 ℓ/min	C	3 Deep Well 100 m, 80 ℓ/min 3 Unit Water Supply System	49,200	22,440	9,884	81,524	582,314	3,579 (0.29)

Table 9-10 Cost Estimation for W/Supply System (2/3)

No.	Village Name (Local Gov.)	Population (Service population)	Hydro-geological Feature	Water Consumption ℓ/c/d	Water Demand m³/d: Average (ℓ/min)	Water Demand m³/d: Daily Maximum (ℓ/min)	Result of Test Drilling	System Design: System	System Design: Preminary Design	Estimate Construction Cost 1000 ¥: Intake	Estimate Construction Cost 1000 ¥: Elevated Tank	Estimate Construction Cost 1000 ¥: Distribution Pipeline	Total: 1000 ¥	Total: $	Estimate Operation & Maintenance Cost N/Month (N/p-Month)
10	Maga (Zuru)	4,000 (4,000)	Basement	20	96 (66)	115 (80)	T/D 80 m 5 ℓ/min-20 ℓ/min T/W 130 m 120 ~ 200 ℓ/min	B	1 Deep Well 100 =, 80 ℓ/min 1 Unit	10,800	7,480	2,599	20,879	149,136	1,500 (0.37)
14	Daki Takwas (Gummi)	20,000 (5,000)	Basement	15	90 (150)	108 (180)		A	10 Deep Well 50 =, 18 ℓ/min 10 Hand Pumps	45,500	-	-	45,500	325,000	2160 (0.43)
15	Zugu (Gummi)	4,000 (4,000)	Basement	20	96 (66)	115 (80)		B	1 Deep Well 120 =, 80 ℓ/min 1 Unit	10,800	7,480	2,534	20,814	148,671	1,500 (0.37)
18	Takware (Yauri)	10,000 (10,000)	Sedimentary	30	360 (250)	432 (300)		B	1 Deep Well 90 =, 300 ℓ/min 1 Unit	20,760	24,487	9,521	54,768	391,200	1,500 (0.15)
23	Horo Birni (Yabo)	8,000 (8,000)	Sedimentary	30	288 (200)	345 (240)	T/D 150 m 200 ℓ/min T/W 110 m 380 ℓ/min	B	1 Deep Well 110 =, 240 ℓ/min 1 Unit						
25	Gudale (Argungu)	11,000 (11,000)	Sedimentary	30	396 (275)	475 (330)		B	1 Deep Well 110 =, 330 ℓ/min 1 Unit	26,640	24,487	13,540	64,667	461,907	1,500 (0.13)
26	Chibike (Argungu)	5,000 (5,000)	Sedimentary	30	180 (125)	216 (150)		B	1 Deep Well 60 =, 150 ℓ/min 1 Unit	15,840	14,660	4,790	35,290	252,071	1,500 (0.30)

Table 9-10 Cost Estimation for W/Supply System (3/3)

No.	Village Name (Local Gov.)	Population (Service population)	Hydro-geological Feature	Water Consumption ℓ/c/d	Water Demand m³/d Average (ℓ/min)	Water Demand m³/d Daily Maximum (ℓ/min)	Result of Test Drilling	System Design: System	System Design: Preminary Design	Estimate Construction Cost 1000¥: Intake	Elevated Tank	Distribution Pipeline	Total 1000¥	Total $	Estimate Operation & Maintenance Cost N/Month (N/p/Month)
32	Gendene (Bagudo)	3,500 (3,500)	Sedimentary	30	126 (87)	151 (105)		B	1 Deep Well 80 m, 105 ℓ/min 1 Unit	14,604	10,771	3,327	28,702	205,014	1,500 (0.42)
34	Soro (Silame)	4,500 (4,500)	Sedimentary	30	162 (112)	194 (135)	T/W 150 m 900 ℓ/min	B	1 Deep Well 60 m, 135 ℓ/min 1 Unit	7,884	10,771	4,275	22,930	163,786	1,500 (0.33)
42	Sambawa (Jega)	8,000 (8,000)	Sedimentary	30	288 (200)	345 (240)		B	1 Deep Well 130 m, 240 ℓ/min 1 Unit	21,720	19,148	7,603	48,471	346,221	1,500 (0.18)
43	Kimba (Jega)	6,200 (6,200)	Sedimentary	30	223 (155)	267 (186)		B	1 Deep Well 80 m, 190 ℓ/min 1 Unit	17,520	14,660	5,884	38,064	271,885	1,500 (0.24)
44	Kuka Kogo (Jega)	3,500 (3,500)	Sedimentary	30	126 (155)	151 (105)	T/W 110 m 800 ℓ/min	B	1 Deep Well 90 m, 105 ℓ/min 1 Unit	5,643	10,896	3,327	19,866	141,900	1,500 (0.42)
46	Mailamawa (Sokoto)	10,000 (5,000)	Sedimentary	15	90 (150)	108 (180)		A	10 Deep Well 50 m, 18 ℓ/min 10 Hand Pump	45,500	–	–	45,500	325,000	2,160 (0.43)
47	Samalu (Sokoto)	4,500 (4,500)	Sedimentary	30	162 (112)	194 (135)		B	1 Deep Well 80 m, 135 ℓ/min 1 Unit	15,360	10,081	4,275	29,716	212,257	1,500 (0.33)
										519,571	250,963	97,872	868,406	6,202,897	

(2) Estimated project costs (20 villages)

	×10³ yen
1) Construction cost	¥ 868,406
	($ 6,202,900)
2) Equipments & vehicles cost	¥ 104,900
	($ 749,300)
3) Design & supervision cost	¥ 97,331
	($ 695,200)
Total	¥ 1,070,637
	($ 7,647,400)

The local portion of the construction costs is estimated as about 10% (N 4.65 million).

9-3 Project Implementation Planning

9-3-1 Organization of the implementation

The principal implementing body for this project is the Sokoto State Water Board (SSWB). The SSWB follows the policies related to the Nigerian National Water Supply Plan, and in this project works together with the Federated Department Water Resources (FDWR), and the Sokoto-Rima River Basin Development Authority (SRRBDA). Other than the above-mentioned government-related agencies, Figure 9-5 shows an organization of the work made up of the Consultants and Contractors.

Detailed information on the SSWB, the major implementation agency is described as in the following. Principle services of the SSWB are:

① Supply of potable drinking water to urban and rural areas in Sokoto State

② Development of surface and groundwater for the above purpose.

③ Maintenance and operation of urban and rural water supply schemes

④ Collection of water rates in urban areas

⑤ Consultancy services to other governmental agencies in water-related projects

This project aims at achieving the former two services.

As a department in the organization, the SSWB belongs to the State Ministry of Works and Transport and consists of the 6 sections following:

① Hydrology

② Project & Design

③ Rural Water Supply

④ Operation & Maintenance

⑤ Accounts

⑥ Administration

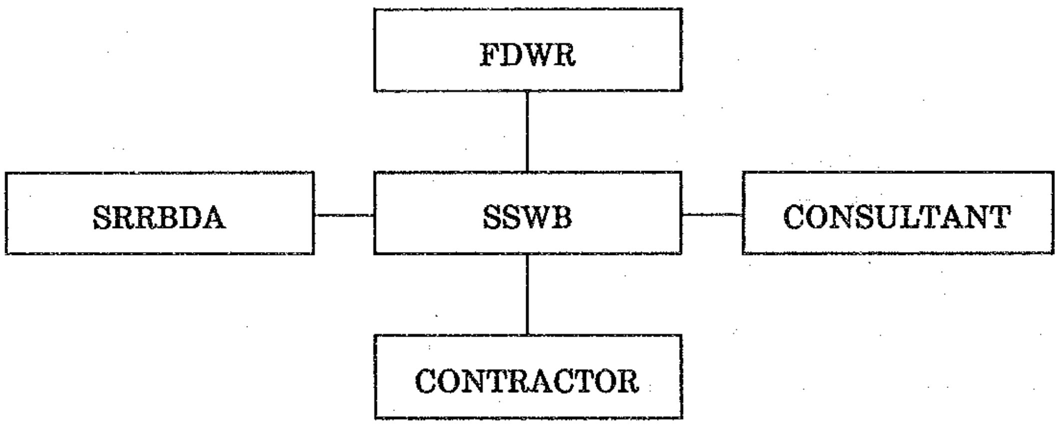


Figure 9-5 Organization for Implementation

The Rural Water Supply section consists of 4 area offices. Both the Project & Design section and the Rural Water Supply section are to take charge of construction in the project. In addition, the Rural Water Supply section is to take charge of operation. The accounts section is to take charge of collection, and a uniform fee of 10 naira per month per household will be issued, which indicates that the rate is not determined by water consumption. Ratio of collection in 1988 was reported at about 65 %. Thus, the SSWB has carried out many projects, with regards to following:

① Development of water resources and construction of water supply equipment

② Operation and maintenance of existing equipment

But on account of a lack of skilled engineers and a lack of budget for water supply, progress is slow.

(1) SSWB

The SSWB carries all the responsibility for the execution of this work of this project. It manages the budget, as well as, with the cooperation of the consultant overseas and guides the contractors in regards to the construction of the water supply facilities. In addition, after the construction of the facilities, it guides in the operations and maintenance of the resulting the community water association set up in each village.

(2) FDWR

The FDWR assists the SSWB in its works, responding when necessary in dispatching hydrogeologists and hydrologists.

(3) SRRBDA

The SRRBDA assists the SSWB in technical areas, responding when necessary in dispatching hydrogeologists and hydrologists.

(4) Consultant

The Consultant is responsible for the planning related to the procurement of the equipments and the materials, the preparation of the tender document, the execution of the tendering session, the analysis and evaluation of the bids, the meeting and the advice for contract negotiations with the chosen bidder and the supervision of the construction and the procurement of the equipment and materials.

(5) Contractor

The Contractor is responsible for the procurement of the equipment and execution of the water supply facilities construction work.

9-3-2 Implementation planning

(1) General condition

There are only a handful of private firms technologically capable of executing water supply facilities construction work, and all of these firms are based in Lagos. All of them are supported by foreign investment and all have qualified engineers on the staff. The private firms in Sokoto State are both financially and technologically weak, but as they understand the local situation, one should be used as a Sub-contractor.

The equipment, including the submersible pump, the generator and the distribution pipe can be domestically obtained, however there are limitations concerning type, quality and size. It is thus necessary to import foreign equipment. Materials including concrete and iron, on the other hand, can be relatively easy to obtain.

(2) Procedure and content of the execution

This project is for water supply through groundwater resource, and the content depends largely on the success of the well drilling. Consequently, the work involving well drilling and test pumping should be separate from that including other facility construction. This procedure is outlined in the flow chart shown in Figure 9-6.

9-3-3 Schedule

A detailed construction schedule will be prepared in the detailed design study. Described below is just a tentative consideration for the construction schedule.

1) The duration of the detailed design study for the siting of the boreholes, designing of the facilities, preparation of tender documents and tendering requires 4 months.

2) The procurement of contractor, equipments and materials and their transportation them to Nigeria. This requires at least 6 months.

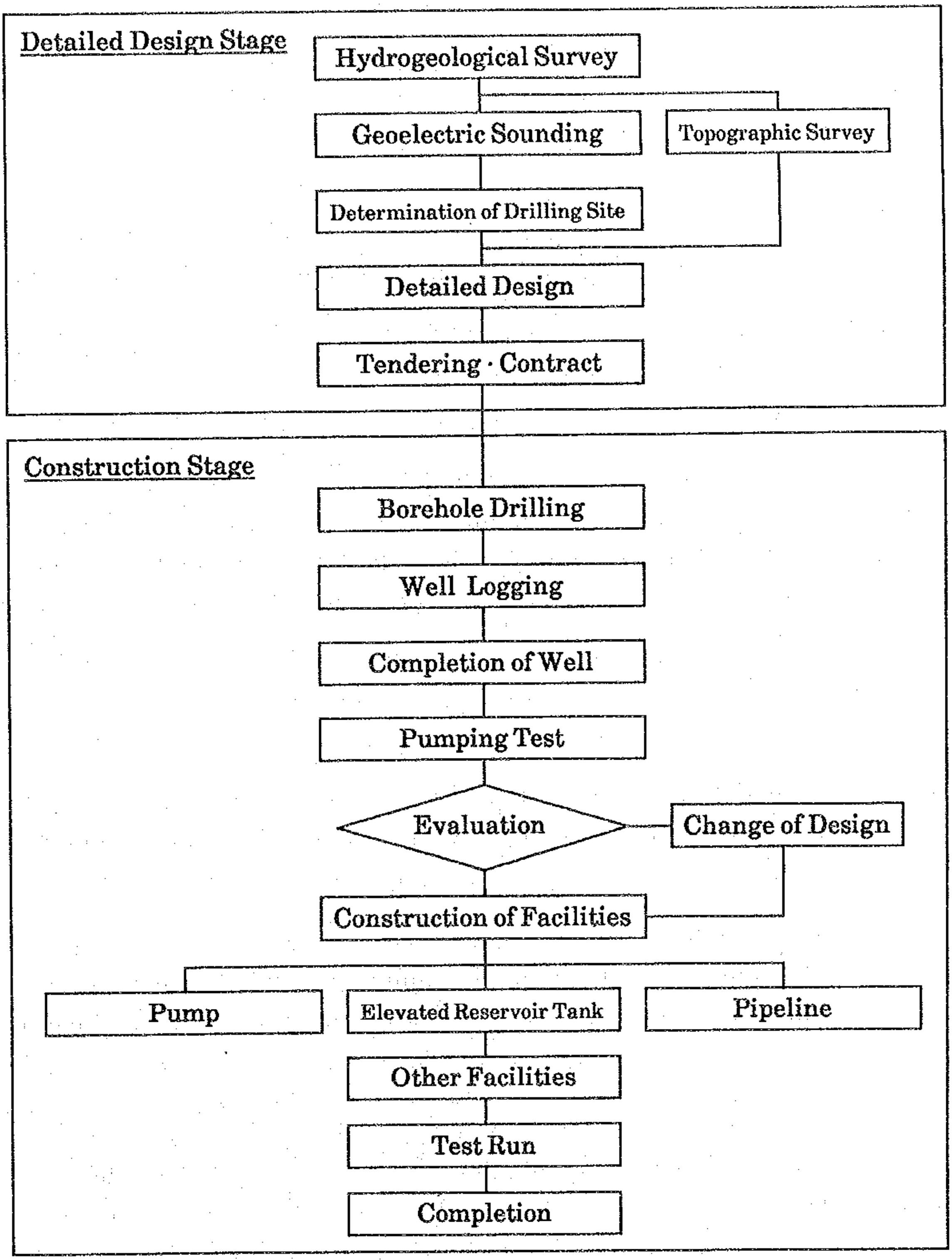


Fig. 9-6 Summarized Procedure of Construction

3) The well drilling work and the water supply system construction work can be executed simultaneously. The duration of the construction is estimated as 20 months.

Tentative implementation schedule of the project mentioned above is shown as Fig. 9- 7.

9-3-4 Operation and maintenance

In national regional water supply projects, state water boards and local governments execute everything from the construction of facilities to the operations and maintenance. In other words, everything is governmentally executed, leaving the users with no responsibility for the operation and maintenance of the water supply facilities.

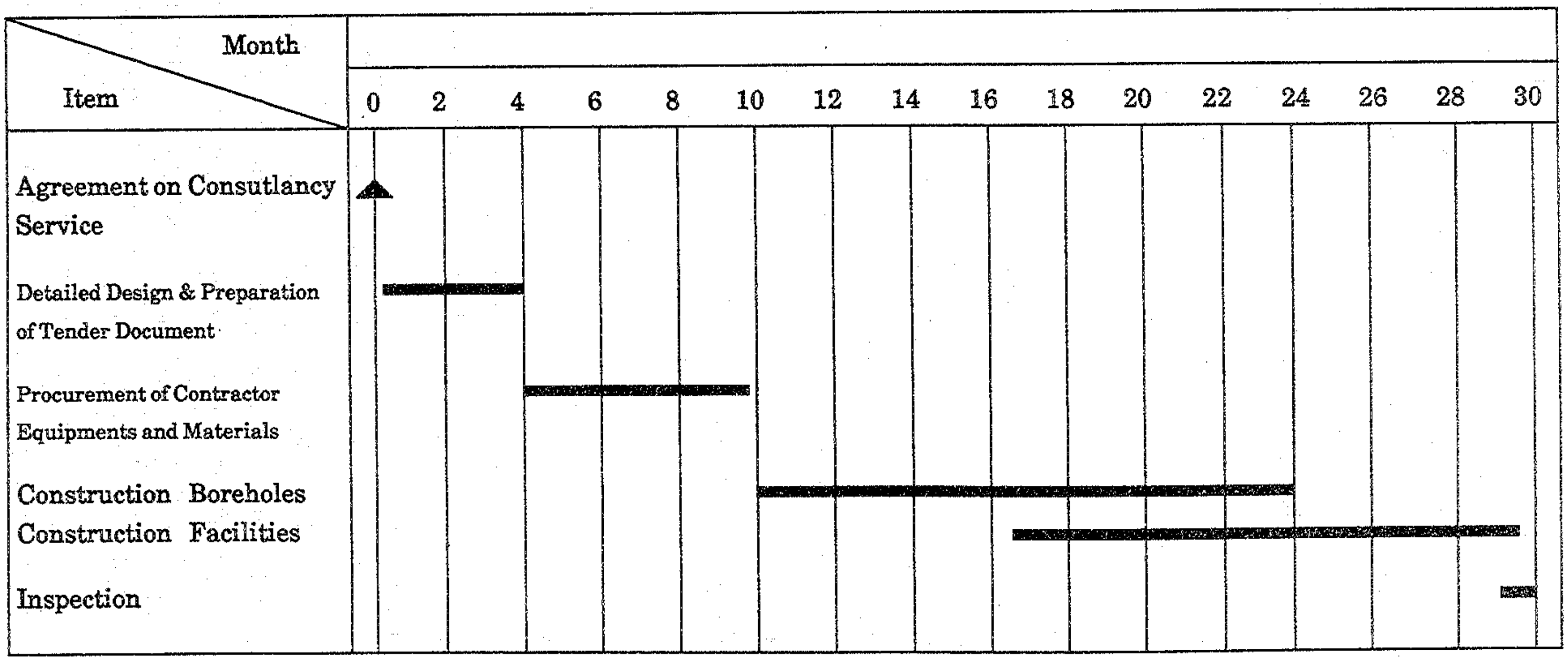
It is also said that there is legislation stating that the federal government and the state governments are responsible for the operation and maintenance incurred in rural water supply. (The user is obliged to pay water usage fees in the urban water supply projects.) However, judging from the present conditions, due to an insufficient budget, there is little done in terms of construction of new facilities, nor of the maintenance of existing ones.

During this study, there were seen several villages where simple water facilities were constructed, however none of these functioned normally.

Due to a generally lack of regional funds, a small break in the generator or the inability to pay for fuel has caused all of the facilities to stop functioning, and then to be abandoned.

Where improvement lacks in the establishment of a budget for governmental regional water supply, the only means of paying for water supply facility construction is to seek foreign financial assistance. In addition, even if facilities are constructed by foreign funds, it is still impossible at present for the government to carry on with their operations and management. Consequently, it is necessary from this point on to change the customs regarding water usage and to introduce regulations for the users to bear the cost of operations and maintenance.

Figure-9-7 Tentative Implementation Schedule



This study attempts to make a case study out of the model water supply system constructed in Horo Birni, and to propose the creation of a water association composed of by the people for operations and maintenance. The essence of this self-run system by the people is that the daily operations and maintenance of the facilities are handled by a village water association composed of community inhabitants, and the SSWB is responsible for the instruction and management concerning the facilities, which means that the fuel and maintenance fees are the responsibility of the people.

In the case of the model water supply system in Horo Birni (B type), the operation and management fee is calculated as follows :

Fuel and parts	511 Naira / month
Personal expenses	725
Reserve found for repairs	247
Total	1483 Naira / month

This shows about 1.5 Naira / month / family, when the number of the households is 1,000 in proportion to the population of 8,000 in this village.
Judging from the existing conditions, 1.5-4 Naira / month / family is feasible.

The SSWB is supposed to guide the water association and maintain the major facilities such as the pump, the generator and the pipeline. The elevated tower and tank are semipermanently usable. However, the submersible pump and the generator should be repaired every 5-7 years. In order to repair the facilities, a reserve fund must be prepared by the SSWB. This fund is estimated at about 3,700 / Naira / system / year.

Judging from the capability shown in the course of the model construction, the SSWB is able to maintain the facilities in terms of technical ability and organization.

9-4 Model Water Supply Facilities in Horo Birni

From among that 21 candidate villages covered in the detailed study, one was selected for experimental construction of model water supply facilities. The purpose of experimental construction is to understand the various problems which could result in actual construction and to be able to refer to the information learned in instances of future execution planning. In addition, another important objective is to obtain data for the establishment of more realistic design standards, in monitoring the water usage situation following the completion of the facilities. The proposal for the creation of a water association, self-run by the people, for the operation and maintenance of the facilities, was made and experimentation of this concept was carried out.

9-4-1 System design

The construction of the model water supply facilities was chosen for Horo Birni, a medium-scale village in the sedimentary rock area in the vicinity of Sokoto City. Horo Birni is located 50 minutes by car from the center of Sokoto city, with very good access from the trunk road. Already in the detailed study drilling had been carried out (120 m depth, 6" diameter), and a screen had been installed in the Taroka formation.

The water supply facilities other than boreholes were designed based on the following standards (Figure 9-8).

(1) Water supply population (P)

From what was heard during the detailed study, the population is estimated to be approximately 9,500, however the investigation prior to the experimental execution found a total of 5,627. The year 2000 water supply population, with a growth rate of 2.5 %, would be:

$$P = 7{,}200$$

(2) Average daily water demand (Qn)

With the consumption capacity (C) at 30 ℓ/c/d and the loss coefficient (r) at 1.2,

$$\begin{aligned} Qn &= P \times C \times r \\ &= 7{,}200 \times 30 \times 1.2 \\ &= 260 \text{ m}^3\text{/day} \end{aligned}$$

(3) Maximum daily water demand (Qmax)

With the peak coefficient (kd) at 1.2,

$$
\begin{aligned}
Qmax &= Qn \times kd \\
&= 260 \times 1.2 \\
&= 312\ m^3/day = 216\ \ell/min
\end{aligned}
$$

(4) Maximum hourly water demand (Qmaxh)

With the hourly peak coefficient (kh) at 1.5,

$$
\begin{aligned}
Qmax &= Qmax \times kh \\
&= 312 \times 1.5 \\
&= 468\ m^3/day = 325\ \ell/min
\end{aligned}
$$

(5) Pump and generator

Submersible pump : 2 (1 spare), 7.5kw, d. cap. 240 ℓ/min, p cap. 75 m

Generator : 2 (1 spare), 17.5 kvA

(6) Elevated reservoir tank

The elevated reservoir tank was designed for an effective capacity of 115 m^3, based on the maximum daily water demand for an 8-hour retention period.

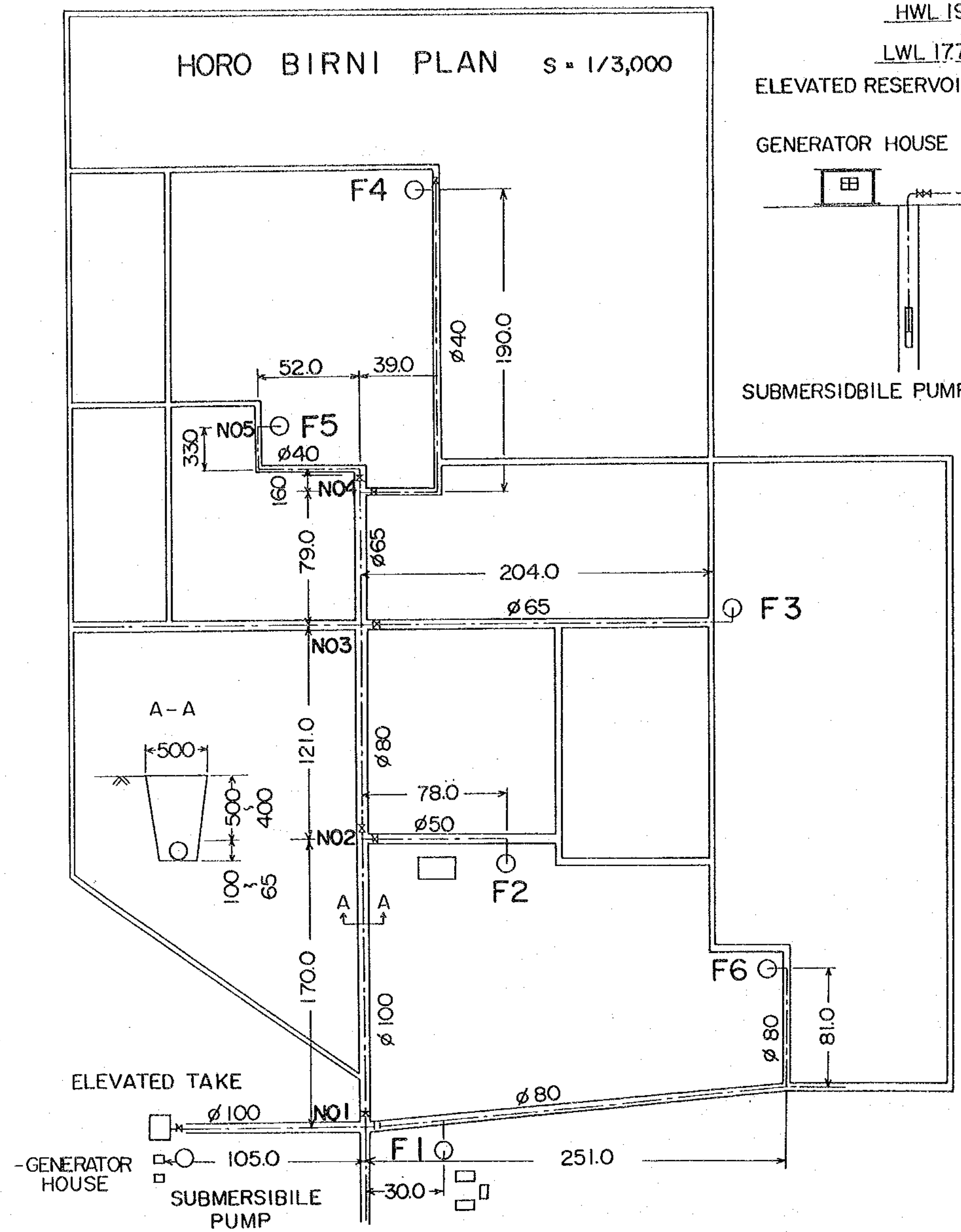
In addition, the material used to construct the tank was panel-type GRP (glassfiber-reinforced plastic) because of its ease in maintenance and long life.

(7) Distribution pipes

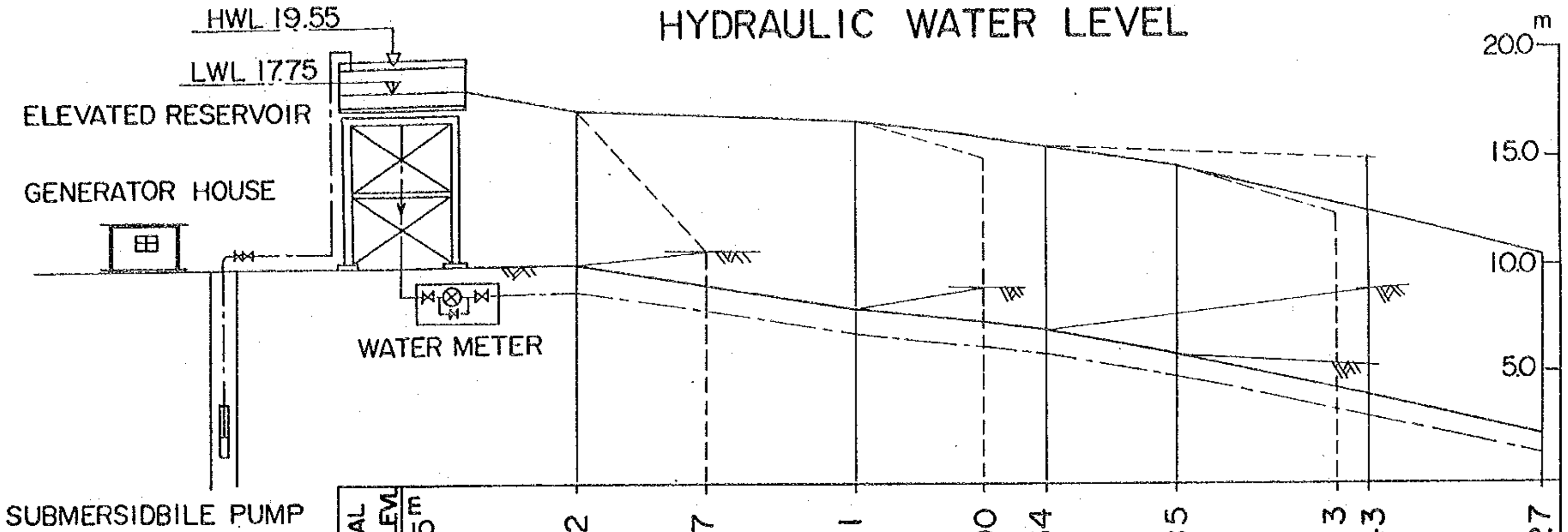
The distribution pipes were designed based on the standards shown in Section 9-2 and upon consideration of the water supply population, the flow capacity and flow pressure. The faucet of steel pipes, and water meters are attached to the main pipes and the faucet pipes.

These water meters are for the monitoring of the water usage situation following the completion of the facilities, therefore effective for an understanding of the water consumption patterns of a medium-scale village.

A detailed design was carried out for the model water supply facilities, and in order to place and order for the construction company, a contract, a sheet of



HYDRAULIC WATER LEVEL



NO	0	1	F6	2	F2	3	4	F5	F3	F4
TOTAI LENGHI	0 m	105		275		396	475			704
HIDRAULIC LEVEL	17.75 m	17.12	16.69	16.61	15.10	15.64	14.85	12.83	15.13	10.27
GROUND LEVEL	10.00 m	10.00	10.60	8.00	9.10	7.00	6.00	5.70	8.70	2.00
ACTUAL WATERLEVEL	7.75 m	7.12	6.07	8.61	6.00	8.64	8.85	7.13	6.43	8.27

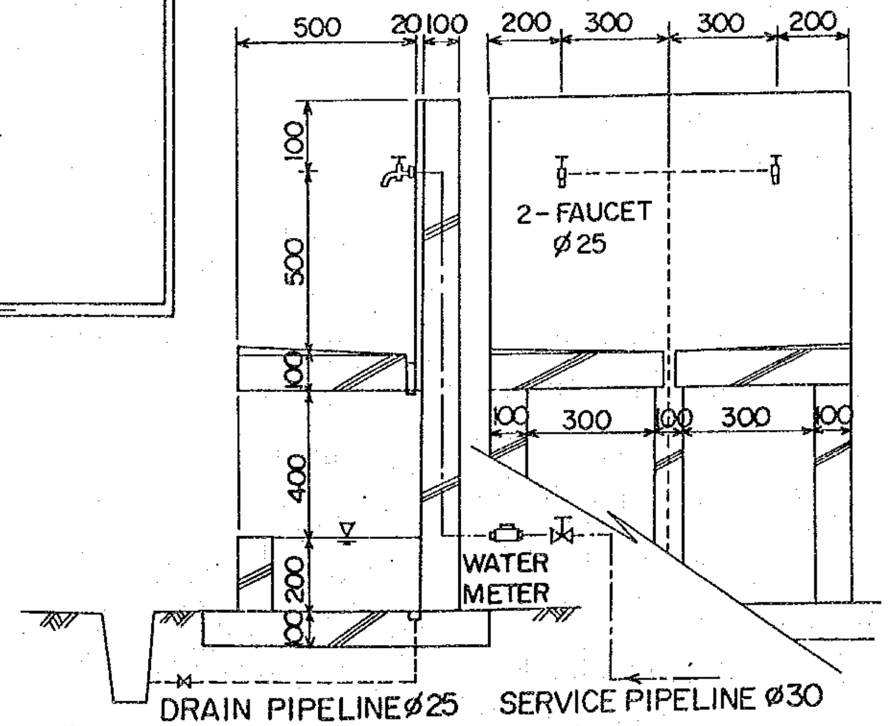


Fig. 9-8 Distribution Pipeline and Communal Faucet (F1-F6, S=1/200)

The Study on Groundwater Development in Sokoto State	
A Model Water Supply System. Construction in Horo Birni	
Distribution Pipeline and Faucet	
June, 1989	Fig. No. 9-8
JICA Study team (Japan International cooperation Agency)	

specifications, a bill of quantity and drawings were prepared. These are attached to the Supplementary Report 1.

9-4-2 Process of construction

A contract was given to one of the local contractors for construction of the model water supply system. The contract was comprised of a) supply of all necessary materials except the reservoir tank and the well-related materials b) construction of the whole system designed by the JICA Study Team except for the work involving the well-drilling, and c) a test run of the system.

The borehole well, as a source of water for the water supply system, had been constructed under a different contract during Phase 1 of Stage II of the Study. It was constructed as a test well to study the hydrogeological features of the area, and it was decided to be converted to a production well when Horo Birni was selected as the site for the model system construction.

A reservoir made of special material was proposed by the JICA Study Team, and another contract was given to the supplier to import the material from Japan. The material is panel-type GRP which has the characteristics of long life and simple maintenance needs.

The agreement on the system construction work, which is attached to supplementary report 1 along with the technical specifications, was signed on the 18th of September, 1989, and the work began on the 20th of September with a target date for completion of November 20, 1989.

The construction work began with such civil works as ditch digging for pipe laying and excavation for the tank tower foundation. During the progression of these works, construction drawings of such major facilities as the generator house, the steel tower, the pipeline and the communal faucets were prepared by the Contractor for the approval of the Study Team. After both minor and drastic revision of the drawings, the supplying of material and the major construction works started at the beginning of October, under supervision of the cooperative body of the JICA Study Team and the Project Managing Office of SSWB.

The completion of the construction work was at the beginning of January, 1990. Completion was behind schedule about one month and a half, and the major reasons for the delay were;

a) a drastic revision of the construction plans for the steel structure, including replacement of the material which the contractor offered

b) delay in the arrival of tank material to the site, due to a mistake in the shipment by the supplier

Since the framing up of the tank on the steel tower was delayed for the above-mentioned reason, the test run of the supply system was begun by direct connection of the pump to the main distribution pipe before completion of the reservoir tank, and the whole system test run was finalized with the leakage test of the tank.

The completed model water supply system was handed over from JICA to the cooperative body of the community water association, the SSWB and the FDWR, in the middle of February, 1990, and operation and maintenance are being undertaken by the community and the SSWB.

9-4-3 Water Use

Since the design criteria concerning water use in the middle- to large-scale villages has not been clearly based on actual data thus far obtained in the northern part of Nigeria, a monitoring system for the model water supply system has been planned to establish the criteria for the future implementation scheme.

In order to monitor the water consumption for the model supply system, water meter were installed on the main distribution pipeline and at all of the communal faucets. In addition, the following activities were undertaken by the JICA team members and the staff of the SSWB during system construction,

a) formulation of the water association in the Horo Birni Community, not only for the operation of the system but also for the monitoring of water use

b) preparation of the data sheet for water consumption observation and technology transference concerning the keeping of the leg, to the staff of the water association, and

c) a detailed population census in the community, focusing on the population of water use by faucets

The monitoring method is as follows.

a) Hourly meter reading from 5:00 AM to 10:00 PM for 3 consecutive days, including Friday, in order to identify the hourly peak of water use and identify the average water consumption per capita per day.

b) Three one-week observation periods of the total water use of the day in three different seasons, in order to identify the seasonal variation, will be held in the cool dry season (January, 1990), in the hot dry season (April, 1990) and in the rainy season (August, 1990).

9-5 Project Evaluation

The implementation of a groundwater development project will have plenty of effects on residents in Nigeria and Sokoto State. In this section, we attempt to evaluate these effects based on the three following points of view, both quantitatively and qualitatively.

a) Cost-Benefits,

b) Economic Impact,

c) Social Impact

The Cost-Benefit Analysis is to measure investment efficiency, based on the project costs and benefits estimated. The IRR (Internal Rate of Return) is a most useful index for investment efficiency. The Economic Impact Analysis is to quantify the economic multiplier, using the capital costs of the project. The macro-economics and concepts of the input-output table are needed. The Social Impact Analysis is to list up the qualitative impact, from the perspective of improvement in life style for the residents in the project area, following the completion of the project.

9-5-1 Cost-Benefit Analysis

(1) Concept

In performing a cost-benefit analysis, firstly the costs and benefits concerning a project are estimated and secondly, the IRR is calculated, based on them. The investment efficiency resulting from a project is evaluated by the amount of the IRR.

For this project, the costs can be properly estimated, but the benefits, consisting of water charges to be paid by users, will be underestimated, as the price of water remains low due to government subsidies. So it will be concluded that this project is not feasible from the point of view of investment efficiency, because of the low IRR obtained. Then, the water charges, the main benefit from this projects, should be calculated based on the estimated project costs and the expected IRR. Other than this, the other benefits, gained from project indirectly, are ignored by reason of difficulty of their quantitative estimation.

(2) Methodology

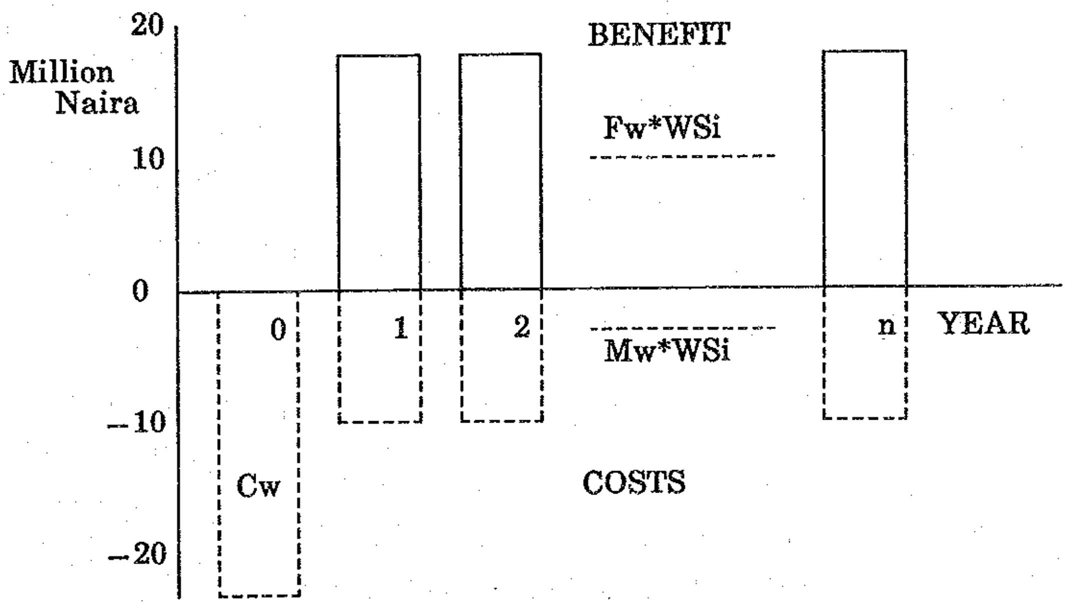
The equation, to calculate the water price (water charges are defined as the water consumption amount the water price) based on the project costs and the expected IRR, is as follows.

$$\sum_{i=1}^{n}(Fw*WSi - Mw*WSi)/(1+r)^{i-1} = Cw$$

Where,

Fw	:	Water Price	(Naira/m3)
Mw	:	Maintenance Cost	(Naira/m3)
WSi	:	Water Supply Volume as i year	(m3/Year)
Cw	:	Capital Costs	(Naira)
r	:	Expected IRR	(%/Year)
n	:	Project Life	(Years)

The following figure is to illustrate the structure of above equation.



In other words, this equation shows that a water price is found by the iteration method, given that the net present values of costs and benefits become nearly equal.

The calculation steps to solve the above equation are shown as follows:

① Set an initial water price

② Calculate water charges and maintenance costs

③ Calculate the IRR based on water charges, maintenance cost and capital cost

④ If this calculated IRR is almost the same as the expected IRR, the water price is accurately found.

⑤ If the calculated IRR is smaller than the expected IRR, increase the water price and jump to ②.

⑥ If the calculated IRR is larger then the expected IRR, decrease the water price and jump to ②.

(3) Expected IRR

The IRR indicates the time value of money and is related to the interest rates of savings accounts. It is reported that the current interest rates are approximately less than 10 %, for long term savings accounts, for periods over 5 years. Therefore, 3 % is assumed as the expected IRR for the cost-benefit analysis. This value would be suitable for public enterprises, like transportation (road), education, power supply and water supply.

(4) Case Study

Cost benefit analysis on this project is to be done with some preconditions. First, it assumes that project costs are consisted of construction cost, equipment & vehicle cost and design & supervising cost. Each cost could be estimated to be 6,200,000 US dollars, 750,000 US dollars and 700,000 US dollars respectively. So total costs sum up to 7,650,000 US dollars.

Furthermore, construction costs on every project area are shown on Table 9-11. Depending on the number of served population, project areas could be divided into large-sized villages with more than 10,000 people and middle-sized villages with not more than 10,000 people. With calculation of both average number of population and average amount of capital cost in each-sized villages, cost benefit analysis will be done for village with them. And equipment & vehicle cost and design & supervising cost assigns to every village equally.

Thus project costs on average of each-sized villages can be calculated below.

Middle sized 239,534 + (750,000 + 700,000) / 20 ≒ 312,000 (US dollars)

Large sized 521,978 + (750,000 + 700,000) / 20 ≒ 594,000 (US dollars)

And the other preconditions o f cost benefit analysis are shown as follows.

① Operations cost is 2 naira / home / month. (referring to Horobirni case)

② Maintenance cost consists of 1 % of construction costs / number of home / 12 months.

③ Persons per home are 10 persons.

④ Growth rate of population is 2.5 % annually.

⑤ One US dollar is as of 7.5 naira.

⑥ Project life is 15 years (from 1991 to 2005)

Result of cost benefit analysis based on these informations are summarized on Table 9-12 (the middle-sized) and Table 9-13 (the large-sized).

Table 9-11 Construction Costs of Each Candidate Site

Middle Village			Large Village		
Name	Served Population (Person)	Capital Costs (US$)	Name	Served Population (Person)	Capital Costs (US$)
1. Tunga Arde	3,000	195,000	1. Dokau	10,000	414,471
2. Bullake	5,000	325,000	2. Dauran	23,500	760,000
3. Ruwan Bore	8,000	272,064	3. Yambuki	12,000	582,314
4. Maga	4,000	149,136	4. Takware	10,000	391,200
5. Bamamu	4,000	260,000	5. Gudale	11,000	461,907
6. Zugu	4,000	148,671			
7. Chibike	5,000	252,071			
8. Daki Takwas	5,000	325,000			
9. Gendene	3,500	205,014			
10. Soro	4,500	163,786			
11. Sambawa	8,000	346,221			
12. Mallamawa	5,000	325,000			
13. Kimba	6,200	271,885			
14. Kuka Kogo	3,500	141,900			
15. Samalu	4,500	212,257			
TOTAL	73,200	3,593,005	TOTAL	66,500	2,609,892
Per Village	4,880	239,534	Per Village	13,300	521,978

Note: Exchange rate US$1 = ¥ 140 as of Jan. 1990.

Table 9-12 Water Charge Calculation in Middle Village

PREMISE :				
	Project Cost	:	2340.0	(1000 NAIRA)
	Operation Costs	:	6.00	(NAIRA/home/month)
	Population	:	4880	(persons/at year 2000)
	Project Life	:	15	(years)
	Expected IRR	:	3.00	(%/year)
Result :				
*****	Water Price	:	41.46	(NAIRA/home/month)

Table 9-13 Water Charge Calculation in Large Village

PREMISE :				
	Project cost	:	4455.0	(1000 NAIRA)
	Operation Cost	:	5.00	(NAIRA/home/month)
	Population	:	13300	(persons/at year 2000)
	Project Life	:	15	(years)
	Expected IRR	:	3.00	(%/year)
Result :				
*****	Water Price	:	29.76	(NAIRA/home/month)

(5) Evaluation

The calculation results are summarized as follows:

Items	Middle Case	Large Case
Water Price (naira/home, month)	40.45	29.26
Population (person)	4,880	13,300
Expected IRR (%/year)	3.0	3.0
Project Life (years)	15	15

It is understood from calculation results that residents in the project area will have to pay 29 ~ 41 Naira/home/month to obtain drinking water, if the SSWB implements without any foreign subsidies. However, the residents will pay only 5 ~ 6 Naira/home/month for maintenance cost, if the project is financed by Foreign aid. Accordingly, it is understood that each home in the project area will gain a profit of about 24 ~ 35 Naira/month. In addition, the total benefit per village gained from the project is estimated as follows.

Middle-size village:
35 Naira/home/month * 12 months * (488 homes)
* 15 years = 3,074,400 Naira/village

Large-size village:
24 Naira/home/month * 12 months * (1,330 homes)
* 15 years = 5,745,600 Naira/village

All villages in the project area:

middle-size	: 3,074,400 *	15	=	46,116,000 Naira
large-size	: 5,745,600 *	5	=	28,728,000 Naira
total	:			78,844,000 Naira

Note: 15 middle-size villages and 5 large-size villages are assumed referring to 9-12.

Investment efficiency of the project:
total capital cost : 2,340,000 * 15 + 4,458,000 * 5
= 57,375,000 Naira

investment efficiency : 74,844,000 / 57,375,000
= 1.3

It is concluded, therefore, that the project will produce a 30 % increased profit from its capital cost and that investment efficiency of the project is high, according to a cost-benefit analysis.

9-5-2 Economic Impact Analysis

This analysis is to study the economic impact of the implementation of the project. In order to implement the project, Nigerian funds will needed for an employment of the labor force, procurement of materials and purchase of equipment. The salary given to the labor force will be on a consumer scale. In addition, enterprise will require adequate funds for the purchase of manufacturing products for materials and equipment. Capital costs of the project will generate much new consumption in succession. The economic impact is defined as a summation of these consumptions induced by the original capital costs. This impact is also called an "Investment Multiplier", as defined below.

Investment Multiplier = (Summation of new consumption + Original capital costs) / Original capital costs

For example, according to the cost estimation of the construction of water supply facilities in the project area, the local currency portion, to be expensed in Nigeria, is planned at about a total of 4.65 million Naira (approximately 10 % of the construction costs). The investment multiplier resulting from the above 4.65 million naira, will be calculated as follows.

Where,

Y : GNP
C : consumption
I : investment
G : government expenditure
E : export
M : import

then, the following equation is defined.

$$Y = C + I + G + E - M \quad (a)$$

where,

$$C = c^* (Y - t^* Y)$$
$$M = m^* Y$$

c : marginal propensity to consume
t : marginal propensity to pay taxes
m: marginal propensity to import

then, equation (a) is transformed as follows.

$$Y = c^* (Y - t^* Y) + I + G + E - m^* Y$$

$$\therefore \; Y = \frac{I + G + E}{1 - c^* (1 - t) + m}$$

Now, if c, t and m are given roughly as follows, based on Nigeria economic data,

$$c = 0.75, \; t = 0.1, \; m = 0.2$$

the investment multiplier is calculated at about 1.9.

The economic impact resulting from the project is estimated finally at around 4.2 million Naira.
However, since the GNP components (C, I, E, M) are closely related, c, t, m fluctuate. Furthermore, the above equation doesn't consider the induced investment. Accordingly, the above value of economic impact is approximately underestimated.

9-5-3 Social Impact Analysis

After completion of the project, residents in the project area will enjoy the following qualitative benefits generated by obtaining potable drinking water easily.

(1) Health Improvements

On account of both bad climate conditions, such as scarcity of rainfall, and shortage in national budget assignment, people living in the project areas find difficult in obtaining potable drinking water. They are forced to drink dirty water. According to the National Policy, it is reported that the total amount of patients of water related diseases could not be ignored. For example, the rural infant mortality rate of 127 per 1000 is over two times 55 of the urban infant mortality rate. This difference partly arises from a lack of sanitary water. Thus improved water supply will reduce the mortality rate in the project areas. A disaster avoided is just as real a benefit as a gain in production. Consequently, this improvement is one of the qualitative benefits. Health improvements will also have indirect economic consequences, such as increase in labour productivity. Poor health can hold down production by making work impossible during periods of acute illness, by diminishing the productivity of a chronically infected worker, and by removing from the productive workforce those who have to care for the sick.

This may be very important if the main mortality associated with defective water supplies occurs at periods of peak labour demand in agriculture.

The direct measurement of the economic effects of health improvements will not usually be worthwhile in a modest evaluation. But if a health impact study indicates important health benefits, records of productivity might be obtained from local cooperatives or employers and checked to see if there has been a significant change.

(2) Time Savings

Time savings result from the provision of water closer to the home, reducing the cost of water in time spent by the consumer collecting it. These savings may be considered as a social benefit in themselves, however an additional economic benefit arises if the time saved is spent in economically productive activity.

The economic value of time savings can be considered in two principal ways. One is to estimate how much they contribute to an increase in production, which can be a very difficult without statistic research and analysis nor observation survey. The other is to calculate what value is implicitly given to people's time by the construction of water supply. This approach requires no field work, so we adopt this and calculate the time to be saved.

In the project areas, it takes a couple of hours in water collection. But a water supply would shorten the length by 30 minutes at best. Assuming that 1 person 10, engaged in collecting water, saves 1 hour per a day, a total amount of 182,500 hours are to be saved in the mid-sized village of 5,000 villagers, and 547,000 hours in the large-sized villages of 15,000.

Considering that the principal engagement in the project areas is agriculturally-related, we can clearly see contribution of this time saving to agricultural production.

Consequently, this also will be a major benefit for the people in project areas.

(3) Other Benefits

The construction of water supplies will have other economic consequences. For example, the presence of water supply in an area might encourage more people to move there. This could help to concentrate a previously scattered population into larger communities which can be more easily and more cheaply provided with other services such as schools and clinics. If there were a desire to live in an area with an improved water supply, it could also lead to industrial and commercial accumulation in the supplied area. Consequently, urbanization in such an area is supposed achievable.

Based on the analysis mentioned above, the following is concluded.

a. The investment efficiency according to the cost-benefit analysis is great.

b. The economic impact induced by the local currency portion of the project cost is not negligible.

c. The social benefits brought on from supplying safe drinking water to the inhabitants in the project area are considerably important.

In this way, the feasibility of this project is evident.

(4) Evaluation of organization, operation and maintenance

① Organization

The SSWB consists of 6 departments : Administration, Account, Design, Hydrology, Rural Water Supply, Operation and Maintenance. Number of employees is about 1,200. The SSWB mainly carried out the construction, operation and maintenance of the urban water supply systems using foreign assistance. As far as observed in the course of the field survey, it is understood that the SSWB has enough capacity to implement the project in terms of the ability of the engineers in the field of groundwater and water supply and their organization.

② Operation and maintenance

In this project, daily operation and maintenance is planned to be carried out by the water association composed of the inhabitants of the community. The SSWB is responsible for guidance of the management and repair of the major facilities. The amount of fee of daily operation by the inhabitants is thought to be payable considering the living standard of the village people.

Moreover, the SSWB intends to establish the water supply program in the middle to large scale villages (semi-urban area) throughout this project. Taking this willingness into consideration, this project has a validity in view of operation and maintenance.

(5) Overall evaluation

An increase in agricultural production and the activation of rural communities can be expected by the improvement of the health environment through the provision of sanitary and abundant water after the completion of the water supply system. The project will greatly contribute to Sokto State which is economically undevelopped due to its geographical condition. In addition, this project has a validity in terms of operation and maintenance.

It is judged that the project is highly effective and should be implemented immediately considering the severe natural environment surrounding these project sites.

10. CONCLUSION AND RECOMMENDATIONS

10.1 Conclusion

10.1.1 Groundwater Potential of Sokoto State

(1) Aquifers

Groundwater in Sokoto State exists in both the basement rock area and the sedimentary rock area. In the basement rock area, mainly weathering zones of metamorphic rock located along faults and fractured zones forms good aquifer. In the sedimentary rock area, sedimentary rock composed of sandstone, limestone and clay of Cretaceous to Tertiary ages forms a multi-layered groundwater basin. The alluvium deposit in fadama also contains unconfined groundwater.

(2) Groundwater development in the basement rock area

Considering the properties of the aquifer as a standard for the specific capacity, the range is 5 - 40 m^3/day/m in the basement rock area and 50 - 150 m^3/day/m in the sedimentary rock area. This might not actually be called excellent aquifer, however it has adequate potential for the potable water supply objective set up for groundwater development.

In addition, although groundwater development is considered difficult in the basement rock area, if drilling is carried out with respect to the distribution thickness of the weathering zone based on hydrogeological study, success is guaranteed. According to the results of test drillings, the pumping rate of 70-40 ℓ/min is possible at a well with 90-100m depth and 100mm in diameter.

The weathering zone of the basement rock area is of irregular distribution, and the scale of the groundwater basin is small. Perennial yield from the groundwater basin, estimating from the groundwater recharge, is 140 m^3/day/km^2. As regards the preparation of groundwater development plans, it is necessary to consider this value as the upper limit standard.

(3) Groundwater development in the sedimentary rock area

In the sedimentary rock area, with the exception of one zone where the groundwater level is low, groundwater development is possible in the entire area. According to the results of test drillings, the pumping rate of 300 ℓ/min is possible at a well with 100~150m depth and 150mm in diameter. The groundwater basin yield must be evaluated in regards to the mining yield, however, as the groundwater basin is still under virgin condition, it is possible to withdraw groundwater without producing any undesirable results by proper allotment of the wells based on the assessment of the decline in the water level due to pumping.

10.1.2 Water Supply Project for Middle to Large Scale Villages

(1) Water supply for preferential 20 villages

Classifying the groundwater potential, shortage of water, water related diseases and accessibility, a water supply project by means of groundwater development was planned for 21 villages. The project costs for 20 villages excluding Horo Birni where the model water supply system constructed is estimated 10.7 billion Japanese Yen (7.65million U$) and the duration of construction is 30 months.

(2) Project evaluation

This project intends to supply water to the inhabitants of the middle to large scale villages in Sokoto State. The improvemnt of health environment, time savings and the activation of the community are major effects of the project and greatly contributes to the socio-economy of the rural area. In addition, the project has a validity in terms of operation and maintenance.

(3) Water supply program for other 26 villages

A tentative schedule and project costs for 26 villages excluded from detailed survey were prepared based on the results of the preliminary site survey (Appendix). This program should be executed when circumstances such as village accessibility, improved.

10.2 Recommendations

10.2.1 Groundwater Development and Management

(1) Preservation of Data

Basic data for the evaluation of groundwater resources are meteorological data, hydrogeological data, groundwater level records and borehole data (geological maps, logging records, pumping test records, hydrological data). These data should be collected continuously in the future and be input into the data base system established at the FDWR Sokoto Branch Office. The cooperation and effort from the governmental and other agencies concerned