13 BASIC CONCEPT OF WATER RESOURCES MANAGEMENT

13.1 Objectives of Water Resources Management

The goal of the water resources management is sustainable water use.

In order to achieve the effective and sustainable water resources management, items which shall be required for the proper monitoring, evaluating and controlling works are summarized as follows;

a) Water quantity
b) Water quality
c) Hydro-meteorological and hydro-geological network
d) Drought management
   (Reservoir operation/ Water diversion)
e) Watershed management
   (Drainage water regulation/Forest protection/Land conservation)
f) Facilities maintenance

The basic concept for the water resources management had been studied and established already by the Cote d'lvoire Government and as a result the document on "National Policy and Strategies for Integrated Management of Water Resources was prepared in 1999. In addition the document on "National Program of Hydraulics 2000 – 2015 related to the water resources management was prepared in 1999.

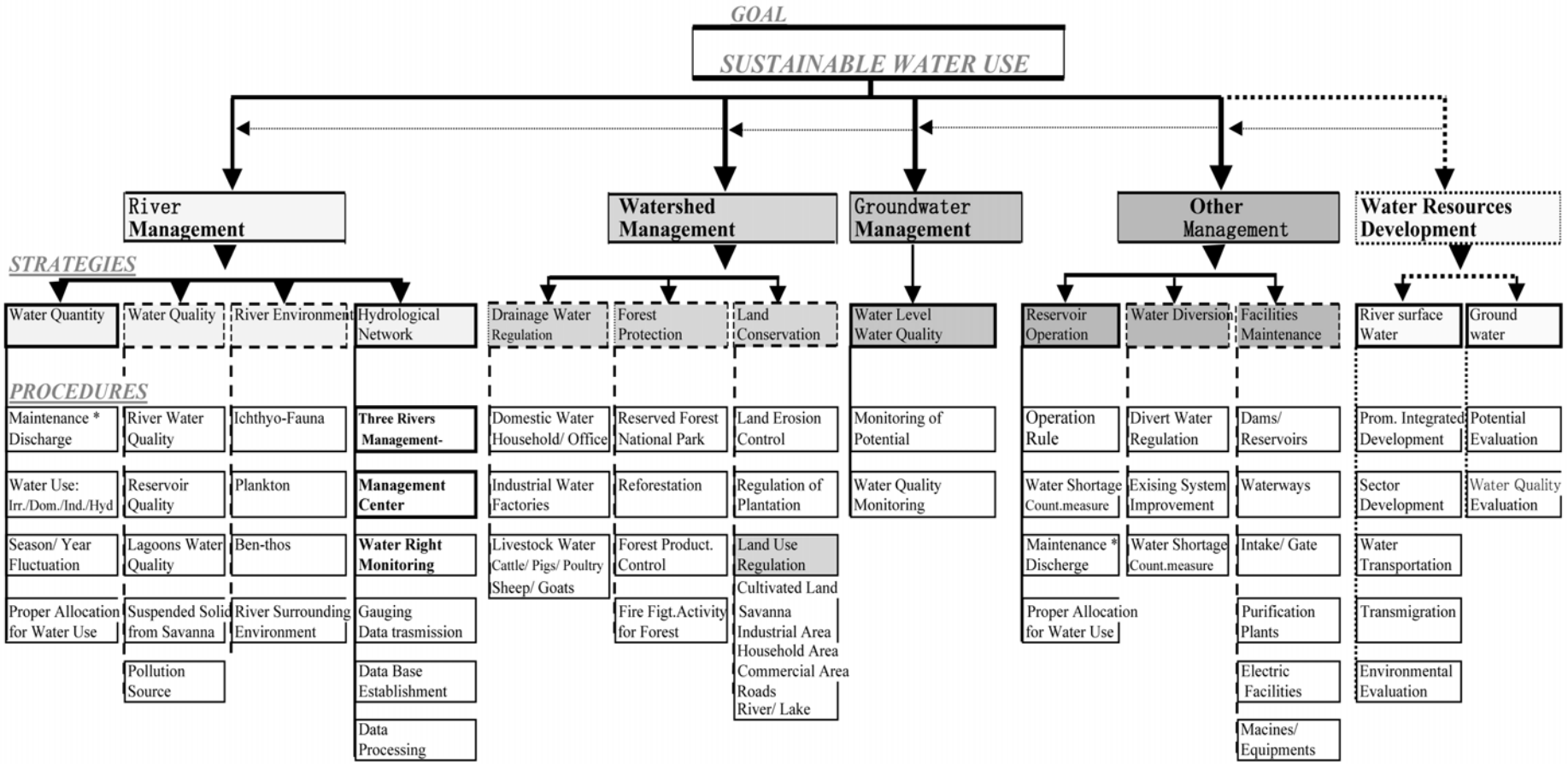
It is judged that the contents described in both documents cover completely and sufficiently the important items related to the water resources management. It is recommendable accordingly that the integrated water resources management in the country will be performed based on those documents.

13.2 Framework of Water Resources Management

The framework of strategies of water resources management is as shown in Figure 13-1.

The each strategies would be executed based on procedures items.

Figure 13-1 FRAMEWORK OF WATER RESOURCES MANAGEMENT



* Maintenance Discharge
The discharge which has been stipulated to be maintained even at the time of low flow, upon overall consideration of *boat transportation/ fishing/ picturesque scenery/ prevention of salt injury/ prevention of blocking of estuary/ protection of river control facilities/ maintenance of groundwater level/ protection of plants・animals/ maintenance of clearance of river flow.*

14 WATER USE QUANTITY CONTROL

14.1 Necessity and Objectives of Water Use Quantity Control

Available river surface water and groundwater resources in every river basin are limited by rainfall pattern and watershed conditions, while the water use quantity will increase toward 2015 in accordance with promotion of the water resources development in response to increasing various water demands.

Objectives of the water use quantity management are to evaluate the available water resources for the water use in the existing and proposed new project sites and the water use quantity for various water demands and as a result to control the water supply taking into account the balance between available water and water use quantity. The water use quantity management is necessary for effective and sustainable water uses under the limited and fluctuated available water resources.

The issues to be studied and implemented to achieve the proper and smooth water use quantity management are summarized as follows;

a) Establishment of the control points to monitor the water level and discharge.

b) Evaluation of the water balance between available water resources and the water use quantity and the water allocation quantity.

c) Establishment of the rule for the reservoir operation and the diversion water of the river.

d) Establishment of the water use right

14.2 Issues for Water Resources Management

(1) Evaluation on Water Demand and Supply Balance and the Issues

The water demand and supply balance and issues in the Comoe, Bandama, Sassandra and surrounding rivers Management Basins are as shown in Tables 14-1 to 14-3.

(2) Issues on River Management

a) Criteria and Manual for River Works

Preparation of criteria and manual for river works ; The criteria and manual consists of three parts such as Survey/ Planning/ Design and the contents could be used as a completed text book for river works.

b) Manual for Water Right

Preparation of manual for the water right evaluation ; The major items are standard year/ maintenance water/ control point/ safety factor/ existing water right/ high water right/ water storage at out of watershed etc. and those items consist of issues and the countermeasure respectively.

c) Hydro-Meteorological Network System

Establishment of hydrological network system (data observation/ data transmission/ data processing) ; The network system is essential matter for monitoring of water right.

d) Preparation of the River Ledger

Preparation of the river ledger and flow diagram along the river system showing a catchment area, river length, river slope, river flow regime on average and dry years, and sediment etc.

Table 14-1 Water Demand/Supply Balance & Issues in COMOE Management Basin Area : 2015 Year Target

Item	Unit	Water Demand			Water Supply					
		Comoe Main River	Agneby River	Bia Area	Comoe Main River		Agneby River		Bia Area	
					Source	Quantity	Source	Quantity	Source	Quantity
Domestic water										
A・Urban water										
1) Abidjan city	m^3/day		**570,000**				**Underground**	**380,000**		
2) Agneby other cities(Ⅸ-C1/C2/C4)	m^3/day		58,600				River+Ground	58600?		
3) Comoe main river (Ⅲ-C1):Cities in Comoe	m^3/day	124,000			River+Ground	124,000				
4) Bia (Ⅷ-C1) : Cities in Bia	m^3/day			27,900					River+Ground	27900?
B・Rural water	m^3/day	8,400	2,800	2,700	Underground	8,400	Underground	2,800	Underground	2,700
Agricultural water										
1) Comoe river (Ⅲ-C1) : Total area	mm	7			River-1/5*0.2	7				
2) Come upstream (Ⅲ-C3) : Up-Daukr	mm	8					River-1/5*0.2	6		
3) Agneby (Ⅸ-C1/C2/C4)	mm	11					River-1/5*0.2	40		
4) Bia (Ⅷ-C1)	mm	10							River-1/5*0.2	20
Hydroelectric Power	1) Ayame-1	Planning HWL : 90 m Planning Head : 25m			Reservoir capacity 900 MCM				Actual HWL:88-90m Actual power production;as same as planning	
	2)Ayame-2	Planning HWL : 69 m Planning Head : 30m			Reservoir capacity 69 MCM					

Issues

1) Domestic water	①・For time being, the domestic water supply of Abidjan city is carried out by the underground water.(About 220,000m3/day) ・The water demand in 2015 would be estimated to be 570,000m3/day based on a consuming water per-capita of 100 l/day and a population growth rate of 3.9%. ・Besides, since the available maximum underground water supply would be estimated to be 380,000m3/day, a water supply shortage of about 190,000m3/day will be probably generated. ・Although above estimation is executed based on 100 l/day per-capita,as a matter of fact, it's more than 300 l/day at major cities in foreing countries. Therefore, in case of 300 l/day the water supply shortage will be estimated to be more than 1.3 million. It is very serious condition on water supply and it also wolud be generating a big social problem. ② It is difficult to supply the steady water for other cities in dry season. Because, the big amount of underground water couldn't be supplied in northern area. Therefore, the shortage of urban water supply in local cities on the Comoe river upstream would be generated in the future. ③ The rural water supply could be possible by underground water in case of the water demand of 25 l/day per-capita.
2) Agricultural water	④ The water use rate in the Comoe river is about 20% of 1/5 year probablity runoff and it is low percentage compared to Bandama river. ⑤ Since the rainfall in the coastal area is abundant, there is adequate surface water as potential, but the rainfall in dry season is very small, therefore, it wolud make difficult conditions for water supply and agricultural production would be limited.
3) Hydroelectric power	⑥ The Ayame No.1 and No.2 dams are constructed on two steps and the controled water by No.1 dam is using effectively by No.2 power station, moreover threre is a remain head of about 30m, therefore the reconstruction in downstream of No.2 dam would be recommended.
4) Flood Inundation	⑦ Inundation in Agboville city caused by flooding in the Agneby river is habitual and serious.

Note: ・River-1/5*0.2= Controled ration (Reservoir capacity / river runoff) of 20% for the river surface water with probability 1/5 ・?=Question for supply possibility
・River+Ground=River surface water+ underground

Table 14-2 Water Demand/Supply Balance & Issues in BANDAMA Management Basin Area

Item	Unit	Water Demand			Water Supply					
		Bandama Main River	Nzi River	Boubo Area	Bandama Main River		Nzi River		Boubo Area	
					Source	Quantity	Source	Quantity	Source	Quantity
Domestic water										
A・Urban water										
1) Korhogo・Ferke・Yamoussoukro	m^3/day	51,500			Dam-Reservoir	49,800				
2) Bandama main river other cities	m^3/day	162,300			River+Ground	162,300				
3) Nzi (Ⅱ-C8):Cities in Nzi river	m^3/day		137,900				River+Ground	137,900 ?		
4) Boubo (X-C2):Cities in Boubo	m^3/day			40,300					River	40,300
B・Rural water	m^3/day	12,500	2,700	6,300	Ground water	15,200	Ground water	2,700	Ground water	6,300
Agricultural water										
1) Bandama upstream (Ⅱ-C5)	mm	52			River-1/5*0.5	32				
2) Marahoue (Ⅱ-C12):Up-Biouafle	mm	12			River-1/5*0.5	11				
3) Nzi (Ⅱ-C8):Up-Confluence	mm	14			River-1/5*0.5	12				
4) Boubo (X-C2):Up-Grand Lahou	mm	10							River-1/5*0.5	6
Hydroelectric Power	1) Kossou	Planning average inflow:152m^3/s Planning HWL:196 m			Actual average inflow:about 80-90 m^3/s Actual HWL:about 185-187m					
	2)Taabo	Planning average inflow:154m^3/s Planning HWL:124m			Actual average inflow:190-196 m^3/s Actual HWL:122-124 m					
Issues										
1) Domestic water	① Urban water supply for Korhogo/Ferke/Yamoussoukro cities could be carring out by controled water of dams. ② It is verry difficult to supply the steady water for other cities in dry season. Because, the big amount of underground water couldn't be supplied in northern area. Therefore, the big amount shortage of urban water supply in local cities would be generated in the future. ③ The rural water supply could be possible by underground water in case of the water demand of 25 l/day per-capit.									
2) Agricultural water	④ Even if the controled ration (reservoir capacity/Inflow) of 50% with adequate dams construction could be keeped, the big amount of shortage of agricultural water supply would be generated in the future.									
3) Hydroelectric power	⑤ The power production of Kossou power station is considerably small compared to the planning due to small inflow in to the dam.									

Note: River-1/5*0.5= Controled ration (Reservoir capacity / river runoff) of 50% for the river surface water with probability 1/5

・?= Question for suuply posibility

Table 14-3 Water Demand/Supply Balance & Issues in SASSANDRA Management Basin Area : 2015 Year Target

Item	Unit	Water Demand			Water Supply					
		Sassandra River	San Pedro River	Bani-Niger Area	Sassandr River		San Pedro River		Bani-Niger	
					Source	Quantity	Source	Quantity	Source	Quantity
Domestic water										
A・Urban water					Weir intake	Dry season (Year average)				
1) Man (I -C8)	m^3/day	17,000			River-1/10	1,300(31,000)				
2) San Pedro (X I -C1)	m^3/day		37,000				Dam-Reservoir	2,580,000		
3) Sassandra river other cities (I -C1)	m^3/day	340,000			River+Ground	20,000,000				
4) Bani-Niger (VI-C1/C3/C4/C5)	m^3/day			52,000					River+Ground	52,000
B・Rural water	m^3/day	45,000	4,700	600	Underground	45,000	Underground	4,700	Underground	600
Agricultural water						Dry season (Year average)				
1) Sassandra river (I -C1)	mm	18			River-1/5	76(152)		Dry season (Year average)		
2) San Pedro (X-C1/C2/C3)	mm	15					River-1/5	140(400)	Dam-Reservoir	Dry (Year)
4) Bani-Niger (VI-C1/C3/C4/C5)	mm	20							River-1/5	10(120)
Hydroelectric Power	1) Buyo	Planning HWL :200 Reservoir capacity 8,300 MCM Planning Head : 36 m						Actual energy production:As same as planning		

Issues

1) Domestic water

① The domestic water of Man city is suppied from a river surface water, but since the river runoff in dry season is less than 1/10 of the planning supply water, the storage facilities are essencial for the steady water supply.

② Although the domestic water in other local cities are supplied from underground water and river surface water in rainy seasons, it seams to be no problem in sassandra basin since the river is plenty of surface water.

③ The rural water supply could be possible by underground water in case of the water demand of 25 l/day per-capit.

2) Agricultural water

④ ・Although the rivers are plenty of surface water, since the surface water in dry season is about half of average. Therefore,the agriculture are limited products such as cacao, banana etc which are low water consumption.

・To promote the rural electrification

3) Hydroelectric power

⑤ The controled water by Buyo dam is not using effectivelly in down stream, therefore it is recommended to construct new dams which is also a re-regulation dam in down stream.

Note: River-1/5=River surface water with probability of 1/5

14.3 Use of Control Points

The control points will be mainly used for following purpose related to water use control :

a) To execute the hydrological analysis /water balance calculation and the monitoring of water quantity/quality at the control points

b) To grasp the flow regime in the basins by observing of water level - discharge

c) To judge of water supply quantities by observing of water level - discharge

d) To be monitoring the river maintenance discharge

14.4 Water Use Right

(1) Water Safety Factor

The water safety factor in Cote d'Ivoire shall be basically decided on the basis of design drought having a return period of 10 years taking "The Drought management" into consideration.

(2) River Maintenance Discharge

The river maintenance discharge could be defined as "The discharge which has been stipulated to be maintained even at the time of low flow, upon overall consideration of boat transportation / fishing / picturesque scenery / prevention of salt injury / prevention of blocking of estuary / protection of river control facilities / maintenance of ground water level / protection of plants animals / maintenance of clearance of river flow".

It could be recommended to decide the maintenance discharge based on 9 items study as above-mentioned and it is realistically for Cote d'Ivoire to use as a standard figure "The monthly average the lowest discharge"

(3) Decision of Development Discharge

The development discharge should be decided based on studies of the above-mentioned water safety factor on water planning.

In case of insufficient water safety factor, following countermeasure should be studied.

a) To divert water from tributaries (Inter-basin diversion plan).

b) To divert water from out of the basin (Wide area diversion plan)

c) To down the scale of development

d) To study alternative plans

(4) Design Drought Year

As above mentioned, "Design Drought Year" shall be basically decided on the basis of design drought having a return period of 5 or 10 years taking "The Drought Management" into consideration**.** Besides, in Cote d'Ivoire, projects concerning water resources are planning based on a drought year of 1983. We have studied the relation between the probable drought discharge and discharge in 1983 and as a result of the studies, it could be considered that the return period of 1983 is equivalent to a return period of approximately 20 years.

In case of reservoir's capacity which would be controlled for one year period and weir's intake, the development discharge at proposed development sites could be calculated by following formula using adjustment factor for return period 1/10 years vs. development discharge in 1983.

$Q_{1/10}$=Adjustment factor $\times Q_{1983}$

$Q_{1/10}$=Development discharge for return period 1/10 years

Q_{1983}=Development discharge calculated based on discharge in 1983

Moreover, the actual water balance calculation with big capacity reservoirs which would be controlled by carrying over for several years should be executed for 5～10 years terms including 1983 year.

(5) Other Criteria

a) Water Supply Diffusion Rate

The supply rate is assumed to be 100 % by target year.

b) Food Self-Supply Rate

The self-supply rate in a national level will be estimated. The study on possibility of import reduction and export increase to reach to a satisfactory level will be made.

c) Water Quality of Water Source

The preliminary study are made about the water quality at the control points. According to the study, although no serious problem in big rivers which have plenty water, there are rivers showing slightly high value of suspended solids (SS), electrical conductivity (EC) and chemical oxygen demand (COD) in the dry season water. While the high turbidity in the wet season water caused by soil erosion in devastated watershed.

Those phenomenon of the water quality pollution should be taking care in the water resource development and management plan.

The criteria of the water quality is using for time being the criteria of WHO. The New criteria for Cote d'voire is under preparation by SIAPOL.

14.5 Reservoir Operation Rules in Dry Year

It is necessary to set up operation rules based on the save water utilization of the reservoir in order to be carrying out effective operation and to be minimizing the damage in dry year-season.

It is a practical method to prepare the operation rule by "Probability DP(Dynamic Program) Method" etc. (these method could be obtained by probability analysis and trial /error based on past hydrological data) and we are expecting that it will be possible to estimate the future rainfall based on long-term meteorological forecast in near future.

15 WATER RESOURCE DEVELOPMENT PLANS

15.1 Necessity and Objectives of Water Resources Development Plans

It is essential matter to study including development plans in the water resources management, in order to improve the present water use condition, to increase the useful water quantity and to get the sustainable stabile water use; and we have to recognize that although the present water use condition will be improved by better management, the quantity will not be increasing without the developments/ the investments.

15.2 Countermeasure for Issues on Water Demand and Supply Balance and Proposed Projects

The countermeasure for issues on water demand and supply balance and the proposed development projects are shown in Table 15-1 (1) & (2).

The priority projects are defined by mean of projects which would be expected the execution up to 2015 year.

Table 15-1(1) The Countermeasure for the Isuues and Proposed Projects

(1/2)

Basin	No	Issues	Countermeasure & Proposed Project
COMOE Management Basin	①	Abidjan urban water supply	·Short term countermeasure-1): The Agneby river integrated development : Q = 120,000m ^{3}/day. ·Short term countermeasure-2): The river mouth lake development of lagoue (under study by MIE): : Q ≒ 120,000m^3/day ·Short term countermeasure-3): underground water development (Uper limit : 380,000m^3/d). ·Long term countermeasure.: Comoe river integrated developmnt: : Q=110m^3/s(about 9.5milion m^3/day)
	②	The urban water supply in local cities on Comoe river up-stream	·It is necessary to investigate the underground water development and reservoir developmentin of the each local cities.
	③	Rural water supply	·To contenue the underground development for un-development area of water supply.
	④	**To improve the low water use rate of Comoe riv**	·Comoe river integrated development : Q = 110 m^3/s (100%water use rate) Maximum power output = 224.5 MW // Annual power production: 815 GWH **(61% of existing total hydropower energy)**
	⑤	Water supply shortage in coastal area	·The issue could be solved by the Comoe river integrated development (tow time harvest in one year possible).
	⑥	**To use the controled water by Ayame-1**	·Aboiso hydro-power development(downstream of Ayame-No.2): P = 6,400 KW
	⑦	**Flood inundation in Agboville city**	·Agneby river integrated development : Peak cut of flood = 330→100m^3/s

Table 15-1(2) The Countermeasure for the Isuues and Proposed Projects

(2/2)

Basin	No	Issues	Countermeasure & Proposed Project
BANDAMA Management Basin	①	Urban water supply in Kohrogo/Yamoussoukro	・To prepare the reservoir operation rules of the existing dams・reservoir.
	②	The urban water supply in local cities on Bandama river up-stream	・Marhoue river integrated development：Steady urban water supply for Bouafle etc. local cities are possible. ・Integrated rural development in the middle valley of Nzi river as below mentioned：Multipurpose development with agriculture.
	③	Rural water supply	・To contenue the underground development for un-development area of water supply.
	④	Agricultural water large shortage	・Integrated rural development in the middle valley of Nzi river (M'Bahiakro/Bocanda and 13 dams construction)
	⑤	**Inflow shortage into Kossou dam**	・Marahoue river integrated development：Increased inflow into Kossou dam Q = 34m ^{3}/s(Increased 40%) Increased power production：99 GWH (%Increased)
SASSANDRA Management Basin	①	**Urban water supply of Man cityin**	・Reservoir facilities of Man city water supply.
	②	The urban water supply in local cities on Sassandra river up-stream	・It is recommended to investigate the detailed water balance and water source of each local cities.
	③	Rural water supply	・To contenue the underground development for un-development area of water supply.
	④	**Agricultural water shortage in dry seas and to promote the rural elctrification**	・Dounou river integrted development：Q = 0.70m ^{3}/s(700ha)//Small hydro power：P = 34KW(0.3 GWH) ・To promote the agricultural products which are low water consumption in dry season
	⑤	**To use effectively the controled water by Bu**	・Soubre hydro-power development(downstream of Buyo dam)：P = 27,000 KW(218 GWH) ・Louga **hydro-power development(downstream of Soubre dam)：P = 30,000 KW(239GWH)**

16 WATER QUALITY CONTROL

16.1 Necessity and Objectives

Objective of water quality management is to supply the clean and safe surface and groundwater to the domestic water uses of urban and rural inhabitant and the drinking water of livestock and fishes at the overall river basin, to eradicate the hydrous diseases such as typhoid fever, schistosomiasis, malaria, etc. infecting in the water bodies such as reservoir and swamp.

In order to achieve the above objectives in the water quality management, the following test and survey works and countermeasures shall be carried out for the river water, reservoir water, groundwater, polluted water, etc.

a) Periodical water quality tests for the surface and groundwater

b) Survey for watershed and river courses being suffered from a large sediment load and high turbid water

c) Survey for reservoir and swamp in the dry season generating aquatic weed and animal, as well as the hydrous diseases.

d) Provision of sewerage for the life wasted water in the urban area and the treatment plant for industrial effluent in factories. Periodical inspection of the above untreated water.

e) Provision of trash treatment places near urban area.

16.2 Water Quality Control Practices

(1) River Water

There are existing 28 national observation network stations to monitor the surface water quality in the rivers of Sassandra, Bandama and Comoe. It is anxious that the water quality at tributaries will become worse in the future by promoting of agricultural and urban development. The water pollution caused by the following issues shall be cared in the future development.

a) Decreasing of dry season water in many tributaries by expansion of irrigated agriculture

b) Increasing agricultural chemical uses and expansion of livestock breeding

c) Life and industrial wasted water

(2) Reservoir and Swamp Water

The reservoir and swamp water are originally supplied by the river and has no serious water pollution problem, except the reservoir and swamp under the following condition:

a) Reservoir and swamp being formed with shallows water depth and poor river flow will loose easily the stored water during dry season and may change its water quality by development and accumulation of aquatic weed

b) Reservoir and swamp being located in the devastated river will suffer from the inflow with the high turbidity and deposit of many sludge in the reservoir

c) Some hydrous diseases will be generated at the reservoir and swamp with a shallow water depth

(3) Groundwater

The groundwater in Abidjan area has faced the saline water problem recently by sea water invasion due to the lowering of its water level. It's necessary in Abidjan's groundwater to control the withdrawn quantity from wells to reservoir the groundwater level by providing sufficient monitoring wells.

(4) Lagoon Water

The water quality of the lagoon Ebrie has been polluted considerably by the life wasted water and wasted trash of Abidjan city and industrial effluent without any treatment along the lagoon shore. Since the lagoon has only a small outlet to connect sea side and small inflow from the upper river basin, its water pollution will be accelerated year by year. The particular countermeasures to control and treat the wasted water shall be urgently required to improve the water quality in the lagoon. It will be also necessary to dredge out sledge accumulated and polluted at the bottom of lagoon.

16.3 Proposal for Water Quality Control

At the present, there are 28 national observation network stations to monitor the water quality in the main rivers and 9 stations of littoral area. And, there are 10 national observation network stations in the central lagoon of Ebrie. Therefore, it should be monitoring continuously by these points.

The measurement items are as follows:

1) Water temperature, 2) pH, 3) Dissolved oxygen, 4) Electric conductivity, 5) Salinity
6) Nitrate nitrogen, 7) Nitrite nitrogen, 8) Phosphorus ion, 9) Ammonium nitrogen
10) Heavy metals, 11) Chlorophyll, 12) Pheopigments, 13) E. coli, 14) Streptococcus
15) Chemical oxygen demand, 16) Biochemical oxygen demand

It's proposed to establish following machinery and material with guard reinforcement of water quality because of raise of analysis efficiency.

a) Water Quality Analyzer

b) Water Quality Checker to measure quickly in the field

c) Chemical Oxygen Demand Analyzer (COD)

d) Automatic Biochemical Oxygen Demand Analyzer with incubator (BOD)

17 Watershed Management

17.1 Necessity and Objectives of Watershed Management

(1) Issues on Water Resources

a) The runoff coefficient is quite low, except the western rivers. That is, the mean runoff coefficient is 0.26 in the Cavally River and 0.13 in Sassandra, but only 0.05 in the Bandama River and 0.045 in the Comoe River.

b) The discharge during the dry season is remarkably decreased and the total rainfall in the dry season becomes less than 20 % of the annual rainfall in most basins.

c) The water resources potential, especially for the surface water, is much different by river/region. The specific discharge of the Cavally River (0.7 ~ 1.7 m3/s/100km2) is more than 10 times of that of the Comoe River (0.13 ~ 0.14 m3/s/100km2).

(2) Functions on Watershed Management

a) To increase the natural storage function without structural measures. That is, the runoff in the flood time could be decreased and the runoff during the dry season increased.

b) To prevent the climate change caused by human activities. The long-term climate change in Cote d'Ivoire is not so definite. However, there is a tendency of slight decline of rainfall in some regions.

c) To reduce the water quality contamination of runoff to rivers or to the other surface waters.

d) To decrease the soil erosion caused by human activities.

e) To increase the infiltration of rainwater to the ground and keep the stable groundwater supply potential.

The effects of watershed management generally may not be visible definitely in a short period. It will take a certain period of time to recognize the effects of the expected functions/objectives listed above.

17.2 Proposed Watershed Management

For achieving the objectives of watershed management, it may be common knowledge that the increase of forest area with the quality improvement is most effective. And in many cases, the forest management has the common meaning to the watershed management, as the forest has almost all the functions required for the watershed management.

The increase of forest area may be the most effective measure for the land use management and also for the control of land-surface erosion.

In other words, the government already has been making effort for the forest management since 10 or 15 years ago, when the country recognized the significant loss of forest in the past and the necessity of forest recovery measures at the same time.

Based on the review of the reports and information concerned and the present conditions and issues described in the previous Section 17.1, it is decided to select the proposed practical measures for the watershed management from the overall viewpoints are as shown in Figure 17-1.

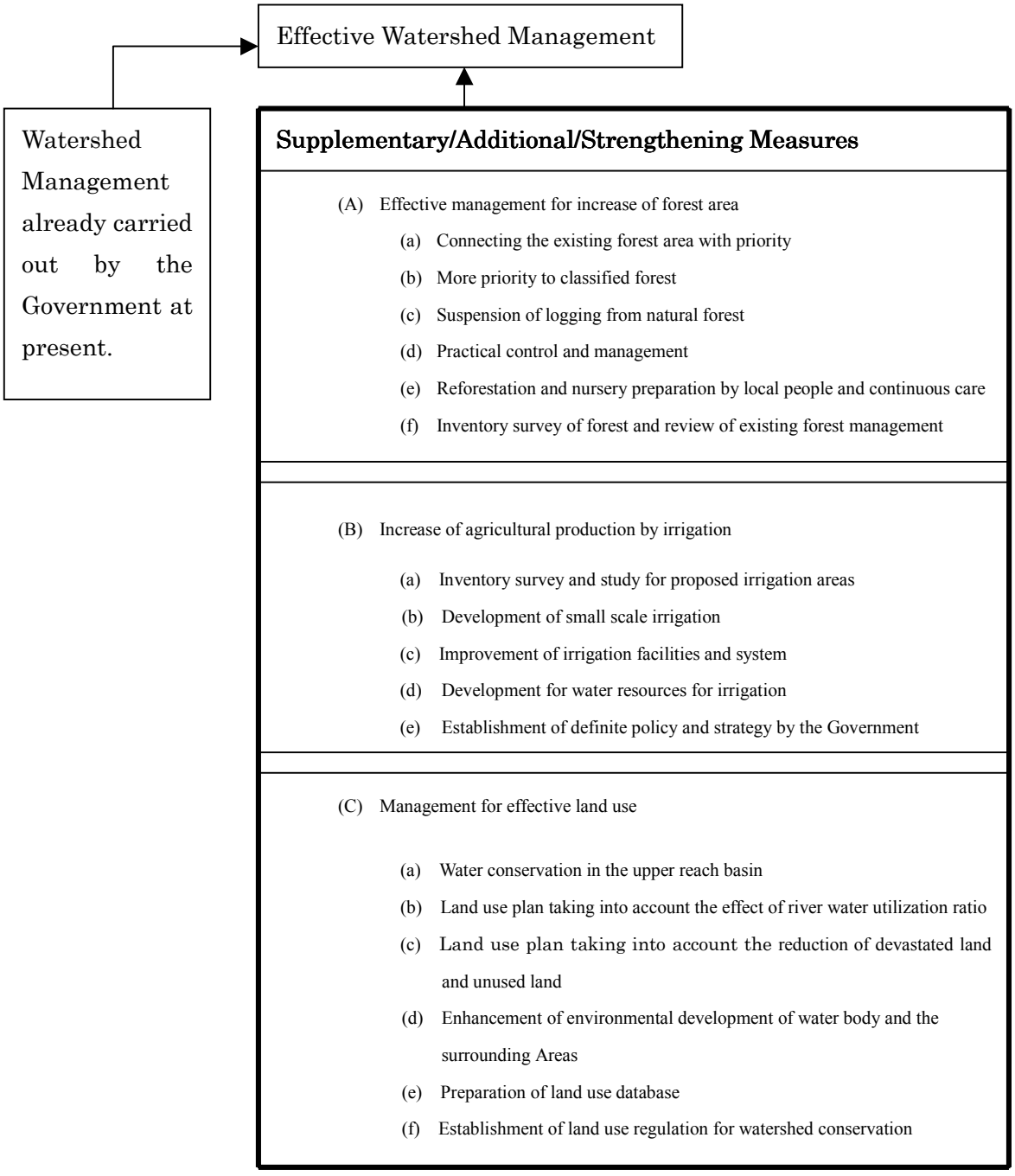


Figure 17-1 Summary of Proposed Measures for Watershed Management

18 OPERATION AND MAINTENANCE OF WATER CONTROL FACILITIES

18.1 Necessity and Objectives for Effective O&M of Water Control Facilities

Effective O&M is one of necessary measures for increasing the water supply capacity against the increase of water demand.

The O&M activities of facilities are done by their related organizations. The territory of water supply and O & M activities organizations is generally demarcated as follows:

a) Agricultural water supply: Company/Private person/Farmer's association (with guidance by PNR of Ministry of Agriculture and Animal Resources, ANADER, etc.)

b) Rural water supply : Rural Water Supply Section of Ministry of Infrastructure

c) Urban water supply : SODECI (Private company under Urban Water Supply Section of Ministry of Infrastructure)

d) Hydro-Electric power : CIE (Private company under Ministry of Mine and Energy)

In general, the private companies carry out efficient and reliable O & M of their facilities, although there are some issues for the further improvement of effective water uses. On the other hand, the O & M for rural water supply and agricultural uses have various issues for further improvement, mainly due to the following reasons:

a) Relatively small scale and many locations

b) No income from the operation

c) Shortage of budget for repair and maintenance for users

d) Shortage of knowledge for operation (Users are actual operators.)

The operation and maintenance of structures/facilities is carried out to ensure the achievement of their purposes. It includes the management of facility as well as the observation, control and operation for respective purpose such as flood control and water supply.

18.2 Proposed Operation and Maintenance of Water Control Facilities

Water control facilities are generally located in or along a water body. They are dam, weir, dike/levee, groundsill, sluice gate, etc., which contribute for the public benefit by water/discharge for the demand and/or remove or mitigate environmental issues especially for water quality.

Water control facilities can be classified generally by the following different viewpoints:

a) Irrigation
b) Hydro-electric power
c) Fishery
d) Transportation/navigation
e) Water supply
f) Flood control
g) Recreation
h) Environmental conservation/improvement (water quality improvement, etc.)

These proposed measures and plans for effective O&M are summarized in Figure 18-1.

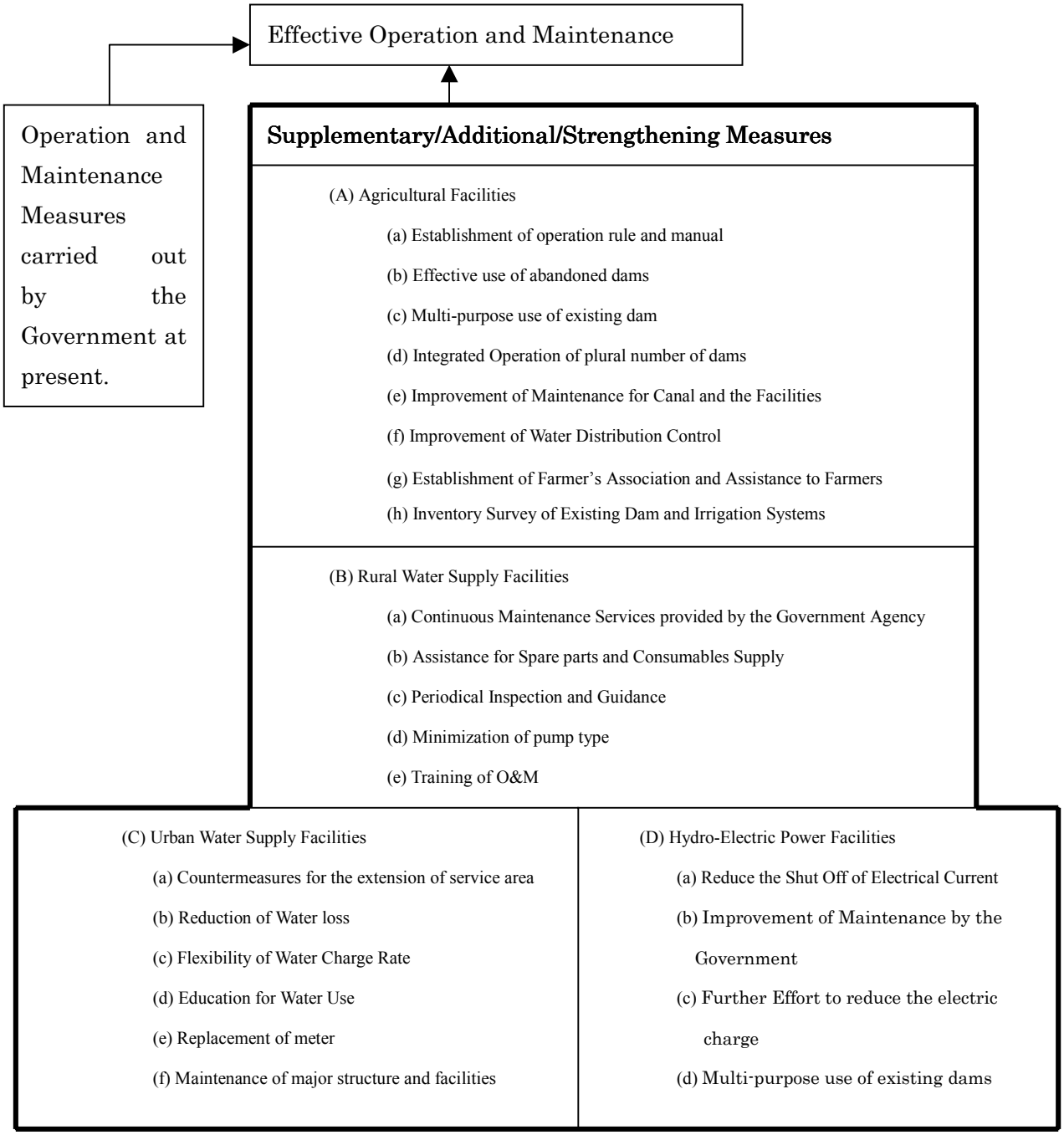


Figure 18-1 Proposed Measures for Effective O&M for Water Control Facilities

19 HYDRO-METEOROLOGICAL AND HYDRO-GEOLOGICAL NETWORK MANAGEMENT

19.1 Hydro-meteorological Network Management

(1) Necessity and Objectives of Hydro-meteorological Network Management

Existing meteorological and hydrological data network are respectively controlled under SODEXAM and Water Director. To integrate the management, improve the data reliability and collect the real-time digital data, therefore, a management on the hydro-meteorological network, which can meet with the requirements and cope with the intricateness, shall be newly established (see Figure 19-1). This modern network will consist of the twenty three (23) main control points.

The main objective for establishment of the hydro-meteorological network is in order to monitor the water use right and the actual works can be summarized as below;

- To collect the real-time data on rainfall, water level/discharge
- To monitor the surface water volume utilized by the users
- To monitor the surface water quality within certain criteria
- To monitor the sediment load
- To reduce the artificial observation error

(2) Installment of Observation and Measurement Facilities

a) Radar Rain Gauges Water Level Recorder

Radar rain-gauges shall be newly installed at the upper reach of the twenty three (23) main control points to grasp the real-time rainfall information.

To grasp the real-time water level and discharge, raider type water level recorder shall be newly installed at the site near to the main control points (23).

b) Automatic Water Level Recorders and Staff-Gauges

For other gauging stations, automatic water level recorders shall be installed.

It is indispensable that the observation of the water level by staff gauges shall also be carried out in order to check and verify the data through the water level recorder each other, and also countermeasure the case of trouble caused by water-level recorder or an electrical failure.

c) Water Samplers

To grasp and monitor the water quality (COD, DO and pH) and suspended load, any facilities shall be equipped with water samplers for the various objectives.

(3) Data Processing and Management

The objective is to process the collected data in accordance with the user's needs, and to transfer these processed data and other collected information to the data safekeeping system. Data processing system will be respectively stated as below.

- Rainfall
- Water-level and discharge
- Water quality
- Sediment load

a) Data banking and database (Data process safekeeping system)

Information held by Abidjan Headquarters should be systematically compiled into a database. As for the original data, processed data and other information shall be registered with numbering and kept in Abidjan Headquarters annually. Original data and information will be kept into the storage. The processed data will be kept by database. Furthermore, CR-DOM or MO (magneto optical disk) will be utilized to backup the data mentioned above.

b) Geographic Information System (GIS)

All data and information held by Abidjan Headquarters related to water –resources management would be established by Geographic Information System (GIS) and they should be opened to the public. As for data furnishing, adoption by year -book, floppy disk, CD-ROM, MO and duplication is desirable.

(4) Role of Abidjan Headquarter and Management Office

a) Abidjan Headquarters

Abidjan Headquarters should be established to fulfill the following functions, and act as an overall center. Of curse, it is need to be equipped with data communication control facilities, data bank facilities, computers for data display, computers for high flow forecast, data display panel, graphic display panel, telephone and facsimile, and radio communication equipment etc.

- Collection of data transmitted;
- Processing of collected data;
- Data banking;
- Monitoring of the operation of facilities;
- Forecast of high flow, information, data and warning transmission to the agencies concerned; and
- Display of the situation

b) Management Offices

Besides Abidjan Headquarters, another three Integrated Management Offices at Man, Bouake, and Boundoukou should be respectively established. Equipping with telephone, facsimile, radio communication equipment and computer, therefore, the following functions can be fulfilled.

- Observation of rainfall and water-level;
- Transmission of observed data to Abidjan Headquarters:
- Operation and monitoring of facilities;

19.2 Hydrogeological Data Network Management

(1) Necessity and Objectives of Hydrogeological Data Network Management

Most important issue for groundwater resources management of the country is management and protection of general aquifer for resources of domestic water supply of Abidjan city.

On some boreholes for urban domestic water supply of provincial cities and town located mainly on discontinuous aquifer area have problems of decrease of extraction from aquifer caused by continuous draw down of water level by over pumping. This is basically caused by small capacity of discontinuous aquifer but also by concentration of boreholes. Therefore, monitoring for groundwater level and quality are required.

It is necessary to accumulate long term data of groundwater level fluctuation to analyze relationship between rainfall, groundwater and runoff of rivers and to monitor future change of groundwater resources.

(2) Required Observation System

To solve above mentioned problems preparation of observation system will be required (see Table 19-1).

Table 19-1 Required Observation System

Item		Interval	Country Level	Urban	Water	Long-term QWL Data	Remarks
				Abidjan Area	Provincial Urban		
Borehole inventory			18,190	72	318	17,800	AD 1999
Groundwater exploitation			506	72	318	116	
Observation borehole							
	New construction			10	10	16	
	Rehabilitation			50	0	0	
	sub-total			60	10	16	
Groundwater level							
	Recording gauge			16	10	10	
	Pumping station	1/month		40	0	0	
	Whole basin	2/year		100	0	0	
	Sub-total			156	10	10	
Water quality							
	Conductivity profile	1/month		120			
	Periodical measurement	3/year		27			
	Lagoon conductivity	3/year		10			
	River water quality	1/month		4			
	Full item SODECI	1/year			220		
	Main item rural water supply	1/year				16	

(3) Data Processing and Monitoring System

It is required to update borehole inventory for rural water supply projects and to install into GIS system. And also, it is necessary to manage comprehensively every borehole data including urban water supply projects.

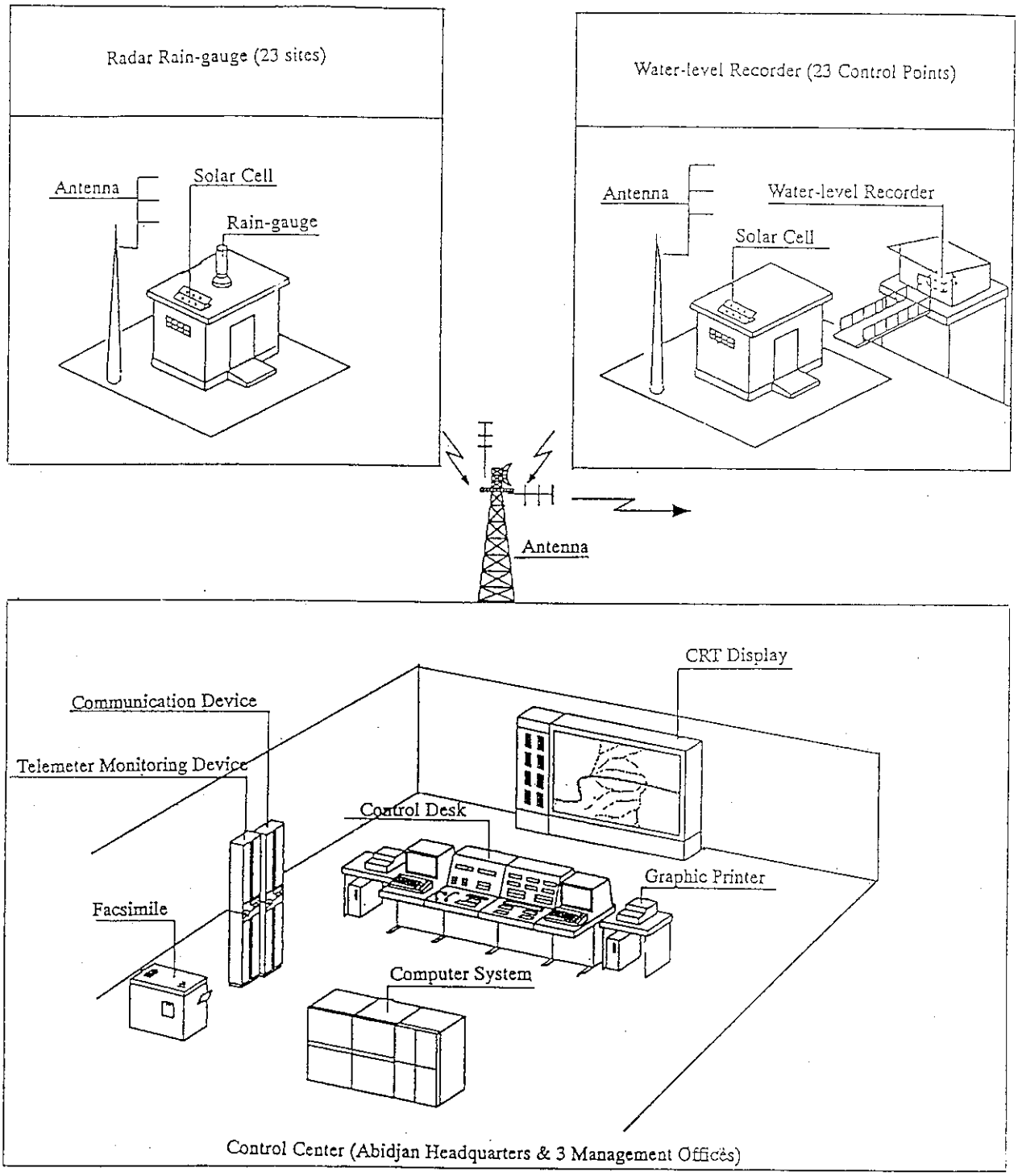


Figure 19-1 Hydrological Network Management System

20 ESTABLISHMENT OF DATA BASE FOR RIVERS

20.1 Necessity and Objectives of Establishment of Data Base for Rivers

In Cote d'Ivoire, it was found to be difficult to collect the necessary data for the rivers and river basins from the following points:

a) The survey data for rivers and river basins are very limited. For example, the fundamental data such as river profile and cross-sections do not exist.

b) Many data/files including the study reports of projects are disappeared or lost.

c) Most existing data are owned by individual organizations only for their field in charge.

d) The reliability of accuracy for some essential data seems to be not sufficiently high.

e) Some organizations are reluctant to provide some essential engineering data, which do not seem to be a kind of confidential data or rather should be used more effectively for the engineering studies.

f) Some fundamental data to be published, especially maps, are out of stock.

g) The survey data and analyses, which are compiled in a report, are generally old and most of them are not updated.

It would be significant and a "Must" to establish the integrated database for rivers and river basins for the effective water resources management. The database will be effectively utilized for the following:

a) Rivers and water resources management

b) Water resources development plans

c) National/Regional development plans

d) Education and training

e) Publication of information and data

The establishment of the database for rivers and river basins will diagnoses the conditions of multi-sectors and it may contribute to more harmonious and effective management and development of the limited water resources.

20.2 Preparation of River Ledger

The River ledger is a database for rivers and river basins, which contains the basic information and data for water resources management. In consideration of the wide-range of data and the conveniences of file management, it is decided to categorize the ledger as follows:

a) River basin

   (Main river, Tributary)

b) River system

   (Administration, Name of river system, River length, Catchment area, Region/Prefecture

   Basic flood/Design flood for river, River planning, Flow regime)

c) River facilities

   (Water Resources, Development Facilities: Dam, Weirs etc)

d) Water right

   (Hydropower, domestic water/Industrial water, Irrigation and other)

e) Meteorology and hydrology

   (Rainfall, Temperature and Water Level/Discharge)

f) River environment

   (Water Quality, Land Erosion, Sand, Soil Outflow)

The contents of each category may include some common data for the convenience of effective utilization.

An example of ledger (summary sheet) for river system is shown in Table 20-1.

Table 20-1 Example of River Legder (Summary Sheet) for River System

Description	Unit	Features	Reference No. and Name	Remarks
Basin No.	N.A.	II-T1		Largest tributary of Bandama
River No.	N.A.	II-T1		
River Name	N.A.	N'Zi		
Primary River No. (Main stream)	N.A.	II		99,700 km2
Primary River Name (Main stream)	N.A.	Bandama		
Confluence point	km	? Km from the river mouth		
River Class	N.A.	A		
Name and No. of major tributaries	N.A.	See attachment	Reference No.1	
Location (Administration)	N.A.	See attachment	Reference No.2	5 regions and ? Departments
Location map	N.A.	See attachment	Reference No.3	
Basin area	km^2	35,500		All the area is in Cote d'Ivoire
River length	Km	725		
River profile	N.A.	See attachment	Reference No.4	Not detail. Mean gradient : 1/2000
River cross sections	N.A.	No survey data		Expected to be carried out within 5 years.
Change of river course in the past	N.A.	No survey data		
Scouring condition and location	N.A.	No survey data		
River water source	N.A.	South Ferkessedougou		peak at El. 643m
River mouth condition	N.A.	Join to Bandama		
River bed materials	N.A.	No survey data		
River structures/facilities	N.A.	See attachment	Reference No.5	
Control points	N.A.	See attachment	Reference No.6	4 Control points in the basin
River system map	N.A.	See attachment	Reference No.7	1/200,000 1/50,000
River system diagram	N.A.	See attachment	Reference No.8	
Flow discharge data	N.A.	See attachment	Reference No.9	4 Stream gauging stations in the basin.
River maintenance flow	N.A.	Not established yet		
Water use right	N.A.	Not established yet		
Annual mean discharge	m^3/s	48.1		At Zienoa station, 1980-1996 records
Annual mean specific discharge	$m^3/s/100km^2$	0.14		
Month of max. mean monthly discharge	N.A.	October		
Max. mean monthly discharge	m^3/s	200.2		
Month of mini. mean monthly discharge	N.A.	February, March		
Mini. mean monthly discharge	m^3/s	0.4		
Reference documents/reports	N.A.	See attachment	Reference No.10	
Other information and data	N.A.	See attachment	Reference No.11	Agency/office or person to contact, etc.

Note:This example is not a complete one and prepared only for reference of the river ledger to be prepared in the future.

21 GIS PREPARED BY JICA STUDY TEAM

GIS can store both spatial information and non-spatial information in the same environment, so that it might be helpful to see the useful information visually and briefly and to minimize the time taken for decision making process. The information for water resources management varies widely from natural items such as geology, topography and hydrology to social items such as population and administration system.

There are two basic categories of GIS information as follows:

a) Spatial information shown by polygons, lines and points
   (Natural condition, Administration, Roads, City/Town, Village name)

b) Attribute information shown by tables, which are associated with spatial information
   (Hydro-Meteorology, Development plan, Production, Population, Administration System)

All the water resources related data whatever could be collected were listed to input into the GIS database. The lists of these information and data so prepared by the JICA Study Team, are presented in Tables 21-1 and 21-2.

Table 21-1 List of Spatial GIS Database Prepared by the Study Team

Spatial Information	Feature	Scale
Administration Boundary		
Country with part of Neighbors	Polygon	1:500,000
Region Boundary	Polygon	1:500,000
Department Boundary	Polygon	1:500,000
Sub-prefecture Boundary	Polygon	1:500,000
Administration Point Data		
Regional Capital	Point	1:500,000
Department Capital	Point	1:500,000
Sub-prefecture Capital	Point	1:500,000
Village	Point	1:500,000
Basin Data		
Main Basin Boundary	Polygon	1:500,000
Sub-basin Boundary	Polygon	1:500,000
Sub-basin Boundary for Control Point	Polygon	1:500,000
Water Body	Polygon	1:500,000
River System (Cote d'Ivoire)	Line	1:500,000
River System (Part of Neighboring Countries)	Line	1:2,000,000
Major Road/Railway Network	Line	1:500,000
Navigation Data		
Ferry	Point	1:1,000,000
Lagoon Transport Route	Line	1:500,000
Lagoon Transport Stations	Point	1:500,000
Vegetation	Polygon	1:1,000,000
Forest	Polygon	1:500,000
Protected Area	Polygon	1:500,000
Hydro-geology Data		
Lithological Classification	Polygon	1:1,000,000
Main Fault	Line	1:1,000,000
Remarkable Fractured Zone	Polygon	1:1,000,000
Isohyetal Line of Annual Mean Effective Rainfall	Line	1:1,000,000
Renewable Ground Potential Map	Polygon	1:1,000,000
Climate Zone	Polygon	1:4,000,000
Meteorological Point	Point	1:1,000,000
Well Location	Point	1:500,000
Dam/Barrage Location	Point	1:500,000
Irrigation Location	Point	1:500,000
Control Point Location	Point	1:500,000
General Aquifer Control Point Location	Point	1:500,000
Gauging Station Location	Point	1:500,000
Water Supply Location	Point	1:500,000
Water Quality Control Point Location	Point	1:500,000
Hydro Power Dam Location	Point	1:500,000
Contour Line	Line	40 meter Interval

Table 21-2 List of Tabular GIS Database Prepared by the Study Team

Tabular Information	Associate Map Information
Category Socio-Economy	
Inventory on GDP	Administration Boundary
Inventory on Population	Administration Boundary
Category Institution & Laws	
Inventory on Branch/Local Office	Administration Boundary
Category Topography, Geography & Hydro-geology	
Inventory on Borehole and Modern Dug Well	Administration Boundary
Category Meteorology & Hydrology	
Inventory on Rainfall	Meteorological Point
Inventory on Discharge	Control Point, Gauging Station
Category River and River Structure	
Inventory on Dam and reservoir	Dam Location
Category Land Use & Regional Development	
Inventory on Regional Development	Administration Boundary
Category Environment & Water Quality	
Inventory on Water Quality	Water Quality Control Point
Inventory on Agriculture	Administration Boundary
Inventory on Irrigation	Irrigated Area Location
Inventory on Livestock Production	Administration Boundary
Inventory on Fishery Production	Administration Boundary
Category Domestic & Industrial Water Supply	
Inventory on Urban Water Supply	Sub-prefecture Capital
Category Water Power & other Water Use	
Inventory on Water Power Station	Hydro Power Dam Location
Inventory on Other Water Use (Navigation)	Navigation Data
Category Water Demand & Potential	
Inventory on water Demand for Agriculture and Livestock	Sub-basin Boundary for Control Point
Inventory on Water Demand for Water Supply	Sub-basin Boundary for Control Point
Inventory on Surface Water Balance Present and Future (Yearly)	Control Point Location
Inventory on Surface Water Balance (Monthly)	Control Point Location
Inventory on Ground Water Balance	Control Point Location
Inventory on Ground Water Potential	Control Point Location
	General Aquifer Control Point Location

22 PROPOSED ORGANIZATIONS AND ITS OPERATION

22.1 Framework of Water Resources Management Organizations

The following can be deduced from the principles out of Water Law as the framework of water resources management organizations.

- Water Authority should be created.
- Basin Water Agency should be created at basins or groups of basins.
- All classes' representatives shall participate in water resources management.

Water Resources Management Plans were drawn up by the Study Team. The Plans describe necessary management tasks to manage water resources effectively and efficiently up to the aiming year 2015.

Basic principles are as follows :

- Data processing and management
- River ledger management
- Establishment of monitoring and evaluation system
- Effective use of GIS

22.2 Proposed Organizations at National Level

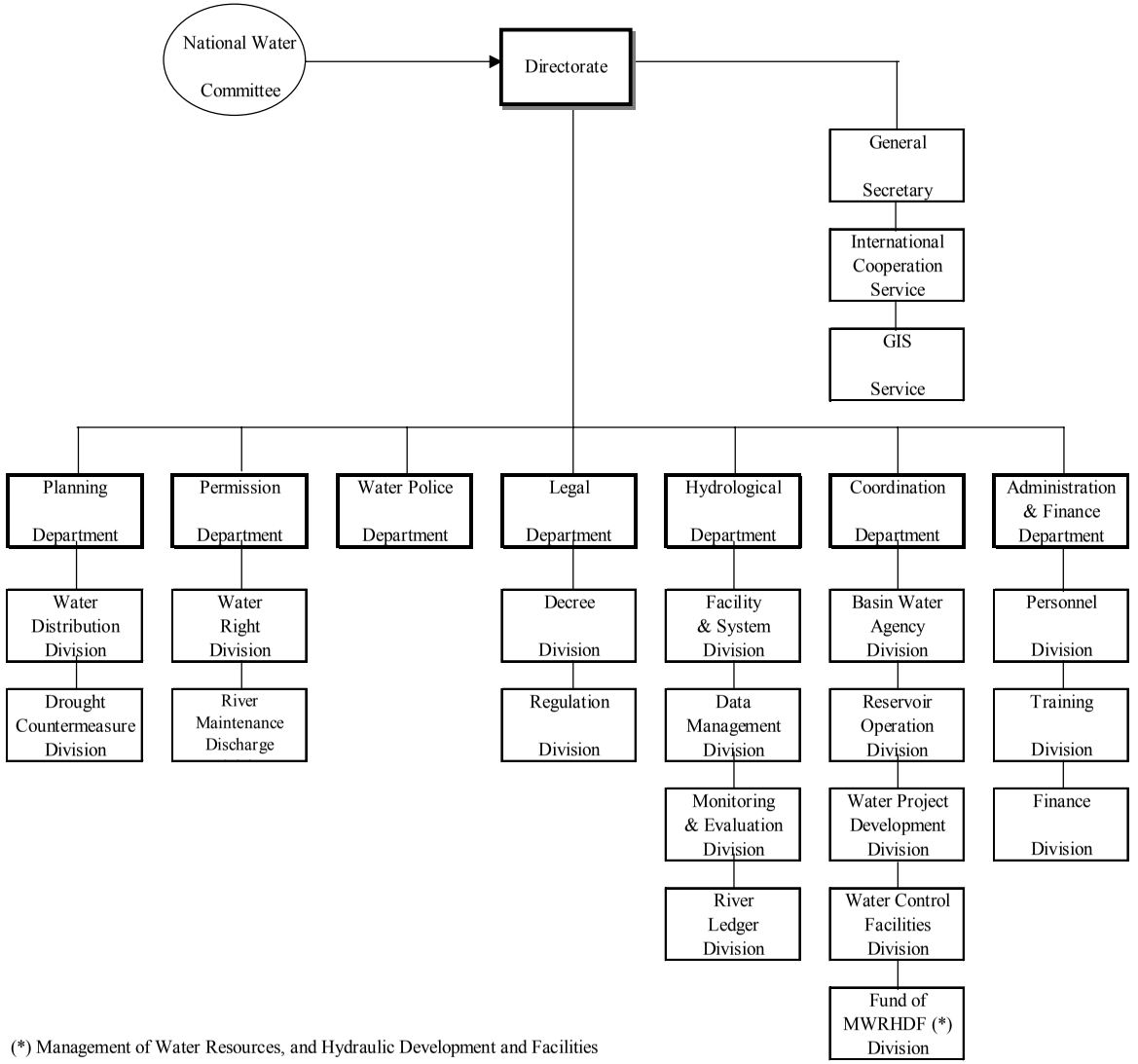
(1) Water Authority

The following shall be main assignments of Water Authority :

- To give users permission for utilization of water (water right) ;
- To collect, process and manage national hydrological data ;
- To exercise water police ;
- To make a national water distribution plan ;
- To make drafts of Presidential and Ministerial Decrees for due enforcement of Water Law
- To supervise Basin Water Agency ;

The proposed organization chart of Water Authority shall be as shown in Figure 22-1.

Figure 22-1 Proposed Organization Chart of Water Authority



(*) Management of Water Resources, and Hydraulic Development and Facilities

(2) National Water Committee

In accordance with the Water Law, creation of "National Water Committee" is recommended. Members of the committee shall be chosen from three (3) different fields, namely, ① planners, deciders and specialist (= government officers, members of national and local assemblies, professor, etc.), ② operator (=government officers, private companies staff, etc.) and ③ users (=personal users, corporate users, etc.).

(3) Inter – Ministries Committee

In order to discuss the water projects which shall have multiple purposes, creation of **"**Inter – Ministries Committee" is recommended. The Committee shall compose of the representatives from ministries implicated into water sector services.

22.3 Proposed Organizations at Basin Level

The Basin Water Agencies has proposed in three (3) basins as follows :

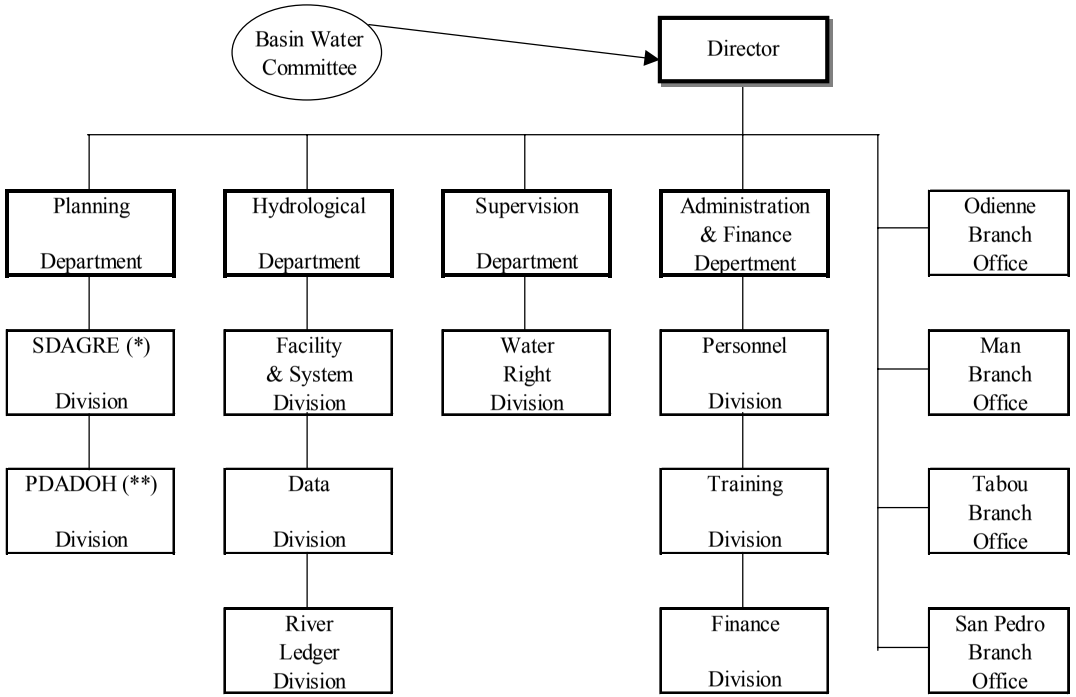
- Sassandra and Cavally (including Fae, Nuon and Niger) ;
- Bandama and Boubo ;
- Comoe and Agneby (including Bia and Volta).

The main assignments of Basin Water Agency might be as follows :

- To make General Principles for Improvement and Management of Water Resources by basins ;
- To establish observation and measurement system of meteo – hydrological network ;
- To establish data transmission system of meteo – hydrological network ;
- To supervise the observation of conditions of water right permission.

The proposed organization chart of Basin Water Agency shall be as shown in Figure 22-2.

Figure 22-2 Proposed Organization Chart of Sassandra Basin Water Agency



(*) General Principles for Development and Management of Water Resources
(**) Action Plans for Development and Management of Water Resources

23 ARRANGEMENT OF LAWS AND REGULATIONS

23.1 Presidential Decrees to be Arranged

Some articles of Water Law stipulate that the details of conditions, procedures, methods, organizations, standards, etc. shall be determined by Decrees, i.e. Presidential Decrees, approved by the Cabinet Meeting. Therefore, the creation of several Presidential Decrees are absolutely necessary for due enforcement of Water Law.

23.2 Ministerial Decrees to be Arranged

It may not be necessary to say that the full completion of President Decrees are not enough to enforce Water Law. More detailed regulation such as Ministerial Decree and Regulations within relevant organizations shall be required.

23.3 Legal Framework to be Arranged Surrounding Water Law

If the above mentioned presidential and ministerial decrees related to Water Law are completed, it seems necessary to arrange legal framework surrounding Water Law. The following may be main ones to be arranged.

(1) Environment

a) Law related to sewerage

b) Law related to industrial water and ground water

(2) Water use

a) Law related to water resources development promotion

b) Law related to multipurpose dam

c) Law related to electric power facilities development promotion

d) Law related to agricultural land improvement

e) Law related to dam or reservoir construction area's improvement

23.4 Establishment of Water Right

Among the management of water resources, the most important legal and administrative control's subject may be water right, i.e. right of water utilization, from economical aspect of water resources.

Water right shall difine the following items.

- Scope of public water
- Planning standard year
- Hydrological data accuracy
- Discharge necessary for maintaining normal function of river flow (River maintenance flow)
- Restricted Discharge (Intake, Storage)
- Design control point
- Temporary water right
- Water use safety factor
- Evaluation of existing water use
- High water right
- Water storage at out of watershed
- Criteria of standard drought discharge
- Criteria of river structure inspection
- Criteria of water use inspection
- Criteria of wide area water supply

24 FINANCIING AND IMPLEMENTATION PROGRAM

The required program for the period 2000 to 2015 takes into consideration the level of the investments reached during these last years, but it is normal for a master plan that magnifies the amounts necessary and goes beyond the only sub-sector of management, particularly for the projects on a “water resources development project”.

Globally, the situation would develop the following amounts.

Table 24-1 Financing and Implementation Program by Year Basis

(million FCFA)

year	water resources management	water resources development project	total
Year 2001	2,586	1,580	4,166
Year 2002	4,450	3,820	8,270
Year 2003	6,760	3,550	10,310
Year 2004	8,110	15,010	23,120
Year 2005	392	75,490	75,882
Year 2006	0	109,070	109,070
Year 2007		113,870	113,870
Year 2008		99,350	99,350
Year 2009		88,065	88,065
Year 2010		5,190	5,190
Year 2011		13,631	13,631
Year 2012		51,275	51,275
Year 2013		55,880	55,880
Year 2014		44,000	44,000
Total	22,298	679,781	702,079

Detailed program is shown in Table 24-2.

Table 24-2 Financing and Implementation Schedule

(million FCFA)

	Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
Water Resources Management Plan	**Study on Watershed Management**	**1,305**	**345**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1,650**
	Effective management for increase of forest area	515														515
	Increase of agricultural production by irrigation	330	345													675
	Management for effective land use	460														460
	O/M of water control facilities	**670**	**966**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1,636**
	Agricultural facilities	400	390													790
	Rural water supply facilities	270														270
	Urban water supply facilities		221													221
	Hydro-electric power facilities		355													355
	Establishment of data base for river	**0**	**0**	**480**	**588**	**392**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1,460**
	Study			480												480
	Preparation of river ledger				588	392										980
	Water quality control analyse's materials	**161**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**161**
	Establishment of hydro-meteorological network		**1,630**	**2,450**	**2,440**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6,520**
	Establishment of water authority	**0**	**609**	**2,030**	**3,732**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6,371**
	Construction		609	2,030	2,030											4,669
	Equipment				1,702											1,702
	Criteria and manuals	**450**	**900**	**1,800**	**1,350**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4,500**
	River works	450	900	900	450											2,700
	Establishment of water right			900	900											1,800
	Sub-Total	**2,586**	**4,450**	**6,760**	**8,110**	**392**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**22,298**
Water Resources Development Project	**Integrated development project**	**290**	**1,400**	**1,450**	**8,290**	**44,400**	**78,080**	**87,170**	**95,990**	**83,280**	**1,120**	**1,120**	**1,100**	**0**	**0**	**403,690**
	Agneby river	180	300	150	2,730	2,730	2,740									8,830
	Dounou river							40	80	40	1,120	1,120	1,100			3,500
	Marahoue river	110	200	200	100	12,670	12,670	12,680	12,670							51,300
	Comoe river		900	1,100	4,100	27,640	61,340	61,340	61,340	61,340						279,100
	N'Zi river				1,360	1,360	1,330	13,110	21,900	21,900						60,960
	Integrated rural development	**110**	**230**	**110**	**2,180**	**2,250**	**2,170**	**1,620**	**3,360**	**4,785**	**3,210**	**10,781**	**46,105**	**52,650**	**41,640**	**171,201**
	Sanpedro plain	110	230	110	2,110	2,110	2,100									6,770
	Karogou Womo									35	70	35	645	650	640	2,075
	Tiassale				70	140	70	1,250	1,250	1,220						4,000
	Rice irrigation in centre-north							370	750	750	360	9,326	11,000	11,000		33,556
	Marabadiassa sugarcane								500	1,050	1,050	550	13,650	15,000	15,000	46,800
	Serebou sugarcane								860	1,730	1,730	870	20,810	26,000	26,000	78,000
	Hydropower	**200**	**400**	**200**	**3,740**	**3,740**	**3,720**	**0**	**0**	**0**	**860**	**1,730**	**4,070**	**3,230**	**2,360**	**24,250**
	Aboisso	200	400	200	3,740	3,740	3,720									12,000
	Soubre										860	1,730	1,730	870		5,190
	Louga												2,340	2,360	2,360	7,060
	Abidjan water supply	**980**	**1,790**	**1,790**	**800**	**25,100**	**25,100**	**25,080**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**80,640**
	Sub-Total	**1,580**	**3,820**	**3,550**	**15,010**	**75,490**	**109,070**	**113,870**	**99,350**	**88,065**	**5,190**	**13,631**	**51,275**	**55,880**	**44,000**	**679,781**
Total		**4,166**	**8,270**	**10,310**	**23,120**	**75,882**	**109,070**	**113,870**	**99,350**	**88,065**	**5,190**	**13,631**	**51,275**	**55,880**	**44,000**	**702,079**

25 EVALUATION

(1) Economic Evaluation

As the study result, investments equivalent to about 22,300 FCFA million for the water resources management and 679,800 FCFA million for the water resources development are proposed by JICA study team as shown in Table 24-1 &-2. The investment for the water resources management of 22,300 FCFA million could be estimated as the minimum amount for all the studies related to water resources management which ranging 15 items as show in Table 24-2.

Economic evaluations of the proposed water resources development projects are as follows;

Table 25-1 Economic Evaluations of the Proposed Water Resources Development Projects

Project Name	Cost (C) M. FCFA	Benefit (B) M. FCFA	B/C	Development Contents
MULTIPURPOSE				
Agneby river Integrated development	3,620	11,222	3.1	P_{max}=160KW Energy Prod.=1.3 M.kwh Urban water=170,000 m^3/day
Marahoue river Integrated development	3,200	7,255	2.3	P_{max}=1,700KW Energy Prod.=99 M.kwh Urban w.=23,000 m^3/day, Irrigation=4,900 ha
Comoe river Integrated development	11,800	67,649	5.7	P_{max}=30,00KW Energy Prod.=239 M.kwh Urban w.=200,000 m^3/day,Irrigation=98,000 ha
Dounou river Integrated development	175	413	2.4	P_{max}=34KW Irrigation = 700 ha
Integrated rural development in San Pedro plain	339	1086	3.2	Irrigation = 965 ha,
Nzi river Integrated rural development	3,048	5,218	1.7	Irrigation = 4,638 ha
IRRIGATION				
Tiassale Irrigation	175	340	2.0	Irrigation = 300 ha
Kaougou-Womo Irrigation	104	150	1.4	Irrigation = 133 ha
Rice irrigation in Centre/North	1,678	2,420	1.4	Irrigation = 2,151 ha
Marabadiassa Sugercane Irrigation	2,340	3,375	1.4	Irrigation = 3,000 ha
Serebou Sugercane Irrigation	3,900	5,625	1.4	Irrigation = 5,000 ha

HYDROPOWER				
Aboiso Hydropower	600	1,237	2.1	P_{max}=6,400KW Energy Prod.=27 M.kwh
Soubre Hydropower	3,900	9,480	2.4	P_{max}=27,00KW Energy Prod.=218 M.kwh
Louga Hydropower	5,300	10,400	2.0	P_{max}=30,00KW Energy Prod.=239 M.kwh

Note: 1) Urban water supply projects have been planned by MOI on another donor, but it was difficult to get the data during the study period Therefore the economic evaluation couldn't be executed.
2) Above mentioned benefits do not include the flood control and other benefits. Otherwise, higher B/C could be expected with these environmental benefits.

The economic evaluation is quantified in benefit-cost ratio method at a discount rate of 5%. According to the result, these projects could be economically evaluated since the B/C values of all the projects exceed 1.0. Especially, the Agneby and Comoe are identified as highly economical projects.

The highly economical Agneby and Comoe projects could be contributed to the water supply on Abidjan city which is on urgent issue and the Marahoue project could be contributed to the recovery of Kossou dam which has been kept under ineffcient operation due to inflow shortage and it is also an urgent matter in order to offset the energy supply shortage, thus these 3 projects should be given the highest priority.

The internal rate of return (IRR) of these priority 3 projects of Agneby, Marahoue and Comoe are 14%, 9% and 19% respectively. The IRRs of the Agneby and the Comoe projects are highly exceeding 10% and the IRR of the Marahoue project is also close to 10% so that these 3 projects can be evaluated economically appropreate.

As above-mentioned, it could be evaluated that all the proposed projects have been proved feasible especially the comprehensive projects with multipurpose dam are appropriate from the national economy viewpoint.

(2) Financial Evaluation

The financial situation of Cote d'Ivoire has been in serious condition, because the tax revenue has decreased due to price drop of cacao in international market and also to the fact that about 20% of the expenditure has to be spent on debt services. However, as shown in Table 25-2, since the income from water charges amounts to 10% or more of the national revenue, it constitutes an important source of income for Cote d'Ivoire. Therefore, the sectors related water have a place in the important issue of the national policy and as a matter of fact, the HCH had a fiscal budget of about 300 FCFA million/year with 20 or more permanent staffs.

Table 25-2 National Revenue and Charge Income Related Water Resources and the Budget of former-HCH

Item	Amount (FCFA billion)	Remark
Revenue (the General account) Tax revenue Non-tax revenue Project income (Grant) Total	1,328.1 (1,112.9) (215.2) 44.1 1,372.2	(Japanese yen about 270 billion) Expenditure ≒2,200 (450=debt's interest)
Charge income related water resources Charge income domestic water Hydropower income	136.7 (21.8) (114.9)	
former-HCH annual budget (staffs = 20 more)	0.3	

Almost all the development fund has to depend on bilateral and international organizations' assistance, but the salary and expenses for staffs of implementing organizations are counted in the recurrent budget of government. And the maintenance cost for urban water and hydropower water could be paid by the income from water charge and that for rural water / irrigation water could be covered by beneficiaries through community association under assistance and guidance of central government. Therefore, the sustainability for the water resources management have been guaranteed.

External supports are considered to be continuously required. Under such circumstances, the most important issue is to secure the support from donors such as international agencies, bilateral donor countries or credit suppliers. On the other hand, it is also very important to encourage own financial capacity by increasing production of exportable agricultural products such as coffee, sugar, bananas and pineapples as well as increasing export of electricity. It is also important to ensure water supply for Abidjan City from an aspect of stable growth of economy. It is, therefore, evaluated to be reasonable to establish water resources management system by 2006 and to focus its priority on the three integrated development projects, namely Agneby, Marahoue and Comoe, to encourage the foreign currency reserve and to ensure water for Abidjan City. The state can expect supports from donor countries concerned through such plan.

(3) Organizational Evaluation

In order to realize effective water resources management by integration, the study proposes "Water Authority" for water resources management in the national level, "Basin Water Agencies" for water

resources management at three major basins, and "National Water Committee" as a consultative organization for Water Authority, based on the Water Law as well as "Inter-Ministries Committee" for adjustment between different ministries to develop multiple water resources projects. Among these organizations, Water Authority is the key organization and proposed to be established by 2004. Although HCH which will be origin of Water Authority, was transferred from the Cabinet of Prime Minister to the Ministry of Development Planning at the last rearrangement of government. The functions of HCH are still effective and preparatory works for establishment of Water Authority are carried out steadily. Proposed organizations are judged to work effectively once they are established because the establishments are desired from an aspect of national necessity and preparatory works such as on human resources development and on legal and legislative preparation are steadily proceeding based on the Water Law.

Furthermore, the study proposed the arrangement of legal frameworks surrounding the Water Law, namely the environmental law and regulation such as on conservation of water quality and groundwater and the water use law and regulation such as on multipurpose water resources development for hydropower, irrigation and domestic water supply. These laws and regulations are very important for water resources management. These are as below:

1) Environment
   a) Law related to sewerage (Water quality conservation)
   b) Law related to industrial water and groundwater (Groundwater conservation)

2) Water use
   a) Law related to water resources development promotion (multipurpose development and rationalization of water use)
   b) Law related to multipurpose dam (Cost allocation among water use sectors)
   c) Law related to electric power facilities development promotion (Large scale development by particular capital investment)
   d) Law related to agricultural land improvement (Agricultural infrastructure development and productivity improvement)
   e) Law related to dam or reservoir construction area's improvement (Improvement of living conditions in the dam and reservoir construction areas)

(4) Technical Evaluation

This study has been carried out based on the sufficient data on the natural conditions such as hydrology and meteorology, and on socio-economic data such as population, economic and agricultural statistics. The study also examined the potentiality of water resources, the frameworks of population and socio-economy, water demand projection based on the frameworks,

water balance between potential and demand, extracted issues on water resources management and development, investigated priority and prepared the development plan through discussion with concerned ministries and agencies such as Ministry of Infrastructures, Ministry of Agriculture and Animal Resources and National Rice Project. Most necessary data have been collected and input into the GIS for the study. Discharge data, that are necessary for potential analysis, have been collected at most control points for a period from 1980 to 1996, and demand analysis is based on reliable data sources such as the 1998 Census Data, the Agricultural Master Plan 1992-2015 and the National Rice Development Plan 2005. These technical procedures are judged to be appropriate and the results of this procedure are evaluated to be technically appropriate. The results of this study, such as the potentiality of water resources, the GIS, the frameworks of population and socio-economics and the water demand prediction, are very useful not only for water resources development planning but also for planning land use, forest preservation, agriculture and regional development.

(5) Environmental Evaluation

The water resources management plans aim to preserve water resources and secure safe and fair use of water, so that more positive impacts can be expected. However, it may suffer from deterioration of water quality in reservoirs, increase in contamination, water-born diseases around reservoirs and wetlands. Eutrophication of reservoirs and lagoons may also occur as utilization of water resources increases. In order to conserve the water quality, this study proposes a water quality control system by establishing the water quality monitoring network in the country.

In the evaluation process the items which can pay attention are: 1) impact to biological and ecosystems with bio-diversity, 2) outflow of rock, sand and mud, 3) prevention of water quality deterioration in lakes and rivers, and preservation of wetlands, and 4) toxic wastes in cities. The Initial Environmental Examination was conducted in six (6) areas of 1) Kossou dam, 2) Buyo dam, 3) Comoe basin, 4) Upper basin of the Bandama river, 5) Central western region in the Sasandra river, and 6)Ebrie lagoon.

The results show that environmental impact should be expected in the study areas in the ways; 1) having negative impact to forest and bio-diversity for the reasons such as fragile soil conditions and loss of surface soil at inclined land, 2) outflow of rock, sand and mud, 3) water quality decline in lakes and rivers, and preservation of wetlands will also have negative impact and needs Environmental Impact Assessment, and 4) toxic wastes impact to the cities will not be induced by the Project.

(6) Social Evaluation

By the water resources management, it is expected to bring about various indirect social benefits in addition to direct benefits as explained above. Among such benefits, followings are considered as major evaluation on social benefits;

- Improvement of water safety enables to balance the regional development and to prevent development gaps between regions as well as extreme concentration of population.
- Safe and stable water resources development makes achieve economic development and improve living standard of people.
- Stable supply of safe domestic water decreases water-borne diseases.

26 RECOMMENDATIONS

Among the number of recommendations made in the Main Report, such important items as worthy to appear in the Summary have been extracted and presented as follows.

(1) The Government of Cote d'Ivoire is recommended to make financial arrangement for creation of Water Authority and three (3) Basin Water Agencies which aim at an integrated management of water resources to resolve the problems caused by sectarian management.

(2) Planning of water resources development project shall be carried out by Ministries concerned. But the Water Authority shall take the initiative in planning of multi-purpose water projects.

(3) It is recommended to prepare the criteria and manuals for river works and water right with priority.

(4) Improvement of existing hydro-meteorological network systems has the priority, and therefore early implementation is desired.

(5) Comprehensive groundwater data network management is required to manage measured data comprehensively by concerned organizations.

(6) It is recommended to prepare the river ledger (the database for rivers), which contains the basic information and data for water resources management.

(7) The studies for Agneby river integrated development project, Comoe river integrated development project, and Marahoue river integrated development project are recommended for water resources development with priority.

(8) It may be required to maintain the GIS system with occasional updating of the GIS database to function effectively.