development is dealt with in subsection 7.5.1 under Water Supply and Sanitation Development. Rehabilitation of sewerage works in other towns is touched on in subsection 7.5.3 under Water Quality Control.

7.4.2 Rural water supply

(1) Target of water supply

As early as in 1970, Kenyan Government set a target of 100% population coverage in water supply by the year 2000. Complying with the goal of the International Drinking Water Supply and Sanitation Decade (1981-1990), it was declared that the target or water supply population coverage to be achieved by 1990 is 100% in urban areas and 75% in rural areas (ref.17).

Water supply coverage, here, may include different levels: individual house connection, stand post as a communal water point, protection or improvement of a traditional source such as wells or springs, and roof catchment of individual houses. The government commitment is to bring "potable water within reasonable reach" of all citizens by the year 2000. In achieving this ambitious target, the definition of "the reasonable reach" may become an issue. At present, it is understood that the reasonable reach is 1 to 2 km from a citizen's house to a potable water point.

National Development Plan (ref.43) specifically points out the Government policy of water service pricing. That is, everybody will pay for water service and the pricing will be such that the water rates would cover direct operation and maintenance costs for the rural water supply schemes.

(2) Basic strategy of rural water supply

As stated in a previous section the estimate of rural population coverage by piped water supply (including communal water) is 5 to 10%. This small percentage achieved through more than 20 years efforts since the independence indicates that the government target of 100% coverage by 2000 for rural population will not be realized by the same method of water supply schemes of the past 20 years. It is generally recognized by MOWD officials that the water supply service standard in the past has not been appropriate. Alternatively, attention is now being turned to groundwater development with the use of boreholes, wells, springs, and particularly of handpumps.

In the Lake basin, the same recognition stated above may be obtained by the following simple calculation. It is anticipated that available development investment capital will be approximately K£ 2,700 million (Kshs.54 billion) for the next 20 years in the Lake basin (Master Plan Report). The past records of the Kenyan Government expenditure show budget allocations to various ministries and development programs (ref.42) . Such allocations may be used to estimate future allocations to water supply development. Assuming 9% of Kshs.54 billion will be available for MOWD and 60% of the MOWD allocation could be spent on rural water supply (including self-help programmes), Kshs.2.9 billion may be used for rural water supply development.

Past experiences show that per capita cost of piped rural water supply is Kshs.1,500 on the average for surface water and Kshs.250 for a handpump well, assuming approximately 200 people served by a well. Rural population in the Lake basin has been estimated as 14 million in 2005 in this Master Plan study. Out of this population, 83% of rural population can be provided by handpump wells if only groundwater resource is developed or 14% with surface water if only surface water is developed, assuming the capital of Kshs. 2.9 billion will be available for rural water supply in the next 20 years. Such a simple calculation gives an implication of rural population coverage by different modes of water supply for the two extreme cases, i.e., groundwater with a handpump or surface water with a piped water supply system.

The extreme cases, however, will not be the true case. As the demand projection in a previous section shows, the true case will be a combination of surface water and groundwater use depending on where water is available. It should be stressed here, again, that the strategy of rural water supply must invoke groundwater development with handpump use in order to achieve maximum water supply coverage for rural population by the year 2000.

(3) Advantages in handpump well

In addition to the economic advantage stated above, use of handpump wells has the following advantages. Water quality is generally better for groundwater and it is not necessary to treat water for drinking use, while water treatment is always necessary for surface water and it causes a health problem when a treatment facility breaks down. Such a breakdown has been happening sometimes.

Reliability of operation is much higher in handpump operation. A failure of existing large surface water piped system was caused by the lack of fuel and shortage in spare parts. Even a theft of parts seems to be interrupting the operation several times a year and for tens of thousands of people are affected at a time. Although mechanical failures are probable with handpumps, people can repair them in a short time; and approximately only 200 people are affected by failure, and those people can find operational handpumps nearby. It should be noted, however, that the repair of handpump depends on the types of pumps, availability of spare parts and mechanics.

Flexibility of water supply is another advantage of handpump wells. The operation of each handpump well can be started immediately after it is completed, and if the water demand of an area turns to be higher than forecast, constructing another well can solve the water shortages. A large piped system takes long time to complete and to start service, and it also requires a large investment to augment the capacity. Participation from a community can be more easily obtained for handpump wells because such a technology already exists and available at a village level. People's participation has been proved to be an important aspect as explained in a previous section in order to make consumers accept a water supply facility of their own.

There are, however, advantages in a piped water supply in terms of service level, although they are not considered to be of critical importance unlike the advantages of handpump wells. The advantages of a piped water supply are: walking distance to a water point is

none or shorter for a piped water supply; it is much easier to use a water tap rather than to use muscle energy needed for operating a handpump; a piped water generally provides more water per capita than a handpump well. Urban water supplies can take such advantages of piped water supply, while rural water supplies should take advantages of groundwater development.

(4) Community involvement

The most important problem associated with rural water supply is a maintenance of facilities. Traditionally, domestic water is fetched by women from a stream or springs, free of charge. A water supply facility initiated and constructed by the government appears to belong to the government; therefore, people do not care much the facilities and consider water as a gift. There is a big gap between traditional way of water use and recent rural water supply schemes, i.e., a change from a free gift to a commodity. Realizing this fact, a policy of rural water supply project has now become clear: to involve people as much as possible from the beginning of a project, to make people responsible for maintenance cost, and to start construction only after people collect the maintenance cost in order to assure people's participation.

7.4.3 Irrigation

Kenyan irrigation experiences to date were reflected in a statement of the current Fifth Development Plan. This plan has stipulated that "a low cost approach to irrigation will be emphasized" and that "preference will be given to rehabilitation of existing schemes and to encouragement of small-scale projects where water is available through gravity flow." In line with this basic strategy, the following three irrigation development programmes are currently operated in the LBDA region under the management of PIU Nyanza: Small-scale Irrigation Development Program, Smallholder Rice Rehabilitation Programme, and Kisii Valley Bottom Development Programme.

Considering the national policy of irrigation and the present irrigation development condition, the basic irrigation development strategy is to promote the presently on-going programmes, to rehabilitate existing schemes and expand area for increasing yield of crops, and to develop small scale irrigation scheme using gravity flow of water.

Presently proposed irrigation development projects such as Yala Swamp Agricultural Development Project, Kano Plain Irrigation Project, and small-scale pumped irrigation projects are all important irrigation schemes for the Region.

7.4.4 Flood control

(1) Priority area

The Fifth Kenyan National Development Plan states "flood protection activities will be centred in and around the Kano Plain in Nyanza Province." Although a flood protection activity in Kano Plain started in 1985 by the MOWD, it is expected to take 20 years to

complete with an anticipated financial resource availability. Moreover, the Kano Plain flood control project is considered as the only major flood control undertaking for the next 20 years or so in the LBDA region, although there would be other minor flood protection projects in the Region. The present study conceives, therefore, the Kano Plain is the priority area of flood control to be dealt with in the water plan.

The Kano Plain is considered as the priority area because of the magnitude and frequency of the flood damages as discussed in a previous section and also of its agricultural land potential. The present study includes the area as one of major area development schemes, i.e., Integrated Kano Plain Development (Master Plan Report). Flood control is an inherent component of the Kano Plain development, which also justifies the selection of Kano Plain as the priority area for flood control.

In addition to the Nyando River, there exist many small rivers in the Kano Plain which require flood protection works. Considering the fact that government has already started the embankment on the Nyando and also that damages caused by a flood from the Nyando are greater than those from other small rivers, the Nyando River flood protection should hold the first priority to be implemented as compared with other small rivers in the Kano Plain.

(2) Integrated approach to Kano Plain flood control

In general, flood control alternatives fall into two categories: viz. structural and non-structural. Structural alternatives include reservoirs, levees, channel improvement, diversion, and other structures. Non-structural alternatives include flood-proofing, relocation, flood plain zoning, flood insurance, flood warning systems, flood plain acquisition, and watershed management. A flood control plan may combine two or more of these measures.

The Kano Plain flood control, in particular, will require several of these alternatives and some more additional measures. In the past studies of Italconsult and Lotti, levees along the Nyando River are considered necessary in addition to other rivers' levees, drainage canals, channel improvement, and a diversion. In order to solve the bottleneck in flow capacity at Ahero, an improvement of Ahero bridge is another structural measure to be undertaken. Constructing many more culverts along Kisumu-Ahero-Kisii road will also be required.

A land use control should also be exercised. First, for the levee construction, existing structures inside or along the course of levees have to be removed and further construction has to be controlled especially in the populated areas at Ahero. Second, for a possible flooding, even after the levee construction has been completed, an urban expansion has to be controlled; otherwise flood damages will be more serious after the levee construction than before. Such a necessity of land use control cannot be over-emphasized. An agricultural extension service should be so conducted that farmers select a cropping pattern where crop damages would be minimum when a flood occurs.

A watershed (or catchment) management is also a necessary measure for the Kano Plain flood control considering a relatively high suspended sediment load of Nyando River and other small rivers, which is one of the major causes of impeded drainage. Upper reaches of Nyando River flow through forest areas, i.e., Tinderet and Mau Forest; however, a further

afforestation should be encouraged at upper catchment areas where possible. In the middle and lower reaches, the Nyando River flows through developed agricultural areas, which are believed to be an origin of the most of suspended sediment. Therefore, soil erosion control measures should be exercised along the middle reaches by contour cultivation, on farm tree planting and other methods.

A flood warning system may be found to be effective for the Kano Plain flood protection. Such a system is useful to save human lives and livestocks by evacuation from flood-prone areas to higher areas. A simple communication utilizing a radio or telephones between upstream local people and the LBDA headquarters followed by a flood warning to people around the lower reach may be a good start of such a flood warning practice rather than a network of telemetering system of rainfall and river gauging stations, which is liable to break down.

Water supply and sanitation development is important to prevent expanding disaster after a heavy flood, particularly for low-lying areas of the Kano Plain where stagnant water could stay for a prolonged period of time. Roof catchment water supply for an individual house may be an appropriate mode of supplying drinking water if piped water supply system is not economically feasible for such areas.

As discussed above, flood protection and control require many different measures ranging from a catchment-wide approach and agricultural practice to people's basic needs of water supply. Among those measures, dike construction would be the first step. The flood protection of Kano Plain has started and the MOWD's work on Nyando River should be continued with great endeavor.

(3) Community involvement

Traditionally, people in a Kano Plain flood-affected area have been living by adopting a flood proof life style such as raising banks around their houses and lands, building houses on higher grounds or raised floors, and coordinating works for river bank construction and evacuation at a flood time to higher safe grounds by village chiefs. The government sponsored flood protection work should not encourage people to forget such traditions and customs; rather the government should encourage people to inherit those traditions and ask people to participate the government effort by reinforcing a tradition of constructing dikes coordinated by village chiefs. Such a participation will result in a good maintenance of river dikes by local people after a completion of the government sponsored dike construction. This aspect can not be over emphasized.

In order to lessen damages of a flood, which will inevitably occur, people should expect a flood to occur sometime in their life and adopt a flood proof life style or a land use. If people do not expect a flood to occur and they live without consciousness to a flood, damages will be undoubtedly more serious.

(4) Role of LBDA

The flood control and protection of the Kano Plain will require an integrated approach combining many activities. It necessitates various efforts of many concerned agencies, local

governments, and ministries. The related areas of flood control and protection are large and beyond the territory of many local governments and ministerial activities tend to be single-purpose oriented. LBDA being located in the problem area is, therefore, in the best position to exercise its major role of coordinating various activities of the Kano Plain flood protection and related area development and enhancement. The major activity of flood protection such as a levee construction will probably be performed by MOWD considering the Ministry's manpower, experiences, and a legislative authority. However, LBDA should participate in the flood control activities and take an initiative in coordination and implementation, simply because of its assigned role.

LBDA did start its commitment to the implementation of Kano Plain flood protection by taking an initiative to form the Interministerial Committee on Flood Control on Nyando River Basin (the first meeting held on 31st May, 1985). LBDA also formed the Technical Committee on Nyando River Flood Control (the first meeting held on 16th October, 1985). The Technical Committee should be responsible to the Interministerial Committee in technical aspects. It is necessary that the two committees involve MOWD as much as possible so that any modifications or recommendations will be reflected in the implementation of the Kano Plain flood protection.

7.4.5 Water quality control

The water of Winam Gulf is found to be polluted as discussed in Section 7.2. However, it is very difficult to predict the future condition of water quality in the Gulf since mechanism of water pollution is not well known . It is not proper to hold such a stance that all the development activities should be suspended until water quality of the Gulf improves. The Master Plan takes a position to implement development activities in a manner to minimize pollution effects to the Lake or Gulf and to monitor their effects and then to strengthen pollution control measures if necessary, rather than to stop all the development activities. Needless to say, pollution control activities deemed necessary at present time must be implemented as soon as possible. Those activities include improvement of treatment of urban sewage and factory effluents.

Most important strategy and urgently required actions are to rehabilitate existing waste-water treatment facilities for both municipal sewage and factory effluent, to make sure existing wastewater treatment facilities are properly operated continuously, and to enforce law and regulations of effluent standards to those who violate them.

In order to back up this strategy, it is necessary to update laws such as Water Act to enable government agencies to enforce such laws. Coordination among concerned agencies, e.g., MOWD, Water Apportionment Board, LBDA, and local governments have to be strengthened.

7.5 Water Resources Development and Management Plan

Based on the strategies stated in Section 7.4 and in line with the Master Plan, water resources development and management plan has been formulated and presented in this section.

7.5.1 Water supply and sanitation development

(1) Rural and urban water supply

Rural and urban water supply programmes

The rural and urban water supply programmes for the Region are proposed based on the present conditions of water supply explained in Section 7.2, domestic water demand projection of Section 7.3, and some planning assumptions. Basic strategies are high priority on handpump well development and rehabilitation and augmentation of existing piped water supply facilities.

Rural and urban water supply programmes have been formulated in such a way that 100% of the Lake basin population will be provided with improved water by 2005 in order to achieve the national target. Table 7.19 summarizes various water supply programmes proposed by this Master Plan study. The table includes the type (rural or urban), source of water, kind of programme, estimated present population coverage, target 2005 population coverage, and investment capital under each programme. As described in Section 7.3, percentages of groundwater dependent populations were assumed for different subbasins. The groundwater dependent rural population of all subbasins amounts to 9,568 thousand people which is approximately 65% of the total Lake basin rural population. Other modes of groundwater utilization such as private wells and protected springs are assumed to be 10% and 5%, respectively. Therefore, the population coverage for the handpump well programme is assumed as 50% of the Lake basin rural population as a whole.

The remaining 35% of rural population will utilize surface water. Rehabilitation and augmentation of existing piped water supply will provide water for 10% of rural population, improvement of traditional sources for 5% and roof catchment for 20%. In the following, each water supply programme is described with assumptions and rationales.

Handpump well rural water supply programme

The use of handpump wells is a basic strategy. Service areas are mainly rural, but some of service centres such as rural centres and market centres currently without safe water supply should be included and given higher priority. The present population coverage by hand pump wells is not precisely known but it should be a few percent at most. The target population coverage of 2005 is set at 50% of the Lake basin rural population.

Past experiences of well development shows that a per capita cost is Kshs.250 for a hand-dug well and Kshs.500 for a drilled well (refs.33 and 55). Since a part of the Lake basin

requires drilled wells, the per capita cost of Kshs.300 is assumed. The total capital investment for the population coverage amounts to Kshs.2,208 million until the year 2005.

Private wells assistance programme

An estimate of existing private wells in the whole Lake basin is not available, although it should be less than a few percent of rural population (ref.34). The target is set at 10% of total rural population in the year 2005. Under this programme, it is recommended that the government should provide a technical extension service and invite owners of private wells to an education programme in order to improve private wells and even to construct new private wells.

There is no public capital investment incurred under this programme. The extension and education service could be performed as a part of service required for other programmes. The population coverage could be more than 10% if the government assistance is successful enough, which brings less burden on the government investment for other water supply programmes.

Spring protection programme

Springs are widely used as a traditional source of domestic water particularly in wet areas. An estimate of the population percentage using this traditional source of water is 16% to 33% in the Region (see Section 7.2). Some springs may be intermittent and some may have sanitary problems, and therefore, it may not be worth providing protections for those by structural measures. The target population is set at 5% of rural population although the coverage could be increased. The unit per capita cost was estimated as Kshs. 120 from a report (ref.33). The total investment amounts to Kshs. 88 million.

Rural water supply system rehabilitation programme

The existing piped water supply sources are either surface or groundwater but major and majority of supplies utilize surface water. Data obtained from districts show that all the urban centres have piped water supplies, all or some (depending on a district) of rural centres have piped water supplies, and some of market centres have water supplies of some sort (Table 7.13).

It has been found that most of rural water supply facilities run by county councils or by the MOWD require a major rehabilitation work; therefore, the Rural Water Supply System Rehabilitation Programme, a major rehabilitation of the facilities, is proposed in order to fully utilize the existing water supply facilities, which is in line with the basic strategy stated in Section 7.4.

As estimated in Section 7.2, rural piped water supply seems to cover 5% to 10% of rural population. The objective of rehabilitation work is to recover the system up to a design capacity and to serve design population. Since the population in such service centres are expected to increase, augmentation works will be necessary. Assuming average population of 5,000 people per service center in 2005, 231 service centers in the Region will constitute

8% of the total rural population. Taking these into consideration, the target 2005 population coverage is set at 10% for this programme.

Data obtained from districts show that most of the piped water supply require capacity augmentation and that water availabilities at raw water sources are sufficient for the augmentation. This implies smaller cost requirement because a new water source development will not be needed. From past experiences, a minor rehabilitation may cost some dozens of shillings per capita but a major rehabilitation work costs more or less Kshs.200 per capita (ref.34). The latter is assumed as a per capita cost for this programme. The total required capital investment up to 2005 is estimated at Kshs.294 million under the programme.

Traditional water source improvement programme

Traditional surface water sources such as a small dam and reservoir can be rehabilitated and improved for drinking water, provided that it is equipped with a filter or fetched water is used after boiling and serve as a communal water point. Currently, the MOWD is working on a dam rehabilitation under a water conservation programme in drier areas of Kenya. The population coverage is assumed to be 5% of total rural population. Unit cost per capita is difficult to estimate and not given here, and so is the investment capital for this programme. This programme may be implemented under a water conservation programme.

Roof catchment rural water supply programme

Roof catchment is utilized as a source of water supply on an individual basis and invested accordingly by those people who have houses with an improved roofing. Although its per capita cost is more than a handpump well, it is very useful where rainfall pattern is favourable, groundwater source is scarce near or on the top of a hill, groundwater quality is not suitable for drinking as in a part of the Lake shore and the Kano plain, and wells can be easily polluted, for example, by periodical floodings.

It is assumed 20% of rural population may be covered by this mode of water supply. Since roof catchment is used individually, required investment capital is not given here. However, the government can provide an assistance to rural population in the form of a loan with a higher priority to those who live in areas where other modes of water supply are not economically feasible.

This programme can also cover peri-urban areas if the same conditions hold in such areas. The population coverage in urban or peri-urban areas is assumed as 10% of urban population, including population who depend on private wells.

Urban water supply rehabilitation and expansion programme

Urban areas include municipalities and some of urban centres. Those urban areas, at present, have piped water supply, although actual population coverage is less by about 50% than the design population of the served area. The resulting population coverage was estimated at 30% to 40% on the average of each urban area. There is more urban population

outside the presently served area and the water supply system needs to be expanded to cover the growing urban area and population .

Excluding 10% of peri-urban population for other water supplies such as roof catchment and wells, 90% of total urban population was assumed to be provided with piped water by 2005. In order to cover growing urban area and population, per capita cost of Kshs.700 is assumed for major expansion. The total investment cost amounts to Kshs.1,247 million.

Completion of piped water supplies

There are many piped water supply projects which are currently under implementation as presented in Table 7.14. Excluding the projects still in the design stage, all the projects under construction are shown to be completed by 1990 at the latest. The cost of completing the remaining works are not known for all the districts in the Region; therefore, it is estimated roughly as Kshs. 500 million from the information of Table 7.14.

Groundwater investigation and development programme in Rift Valley Province

Many areas of Rift Valley Province are drier than other areas in the Region. Most of areas in the Western Province and Nyanza Province should be covered by the on-going rural water supply projects, but not in the Rift Valley Province. Population density in the Rift Valley Province is generally lower than other provinces in the Region, which indicates the advantage of developing communal point sources of water particularly by handpump wells. Water related district needs found in District Development Plans presented in Section 7.2 indicate the importance of groundwater development in the Province. Accordingly, the groundwater investigation and development programme is proposed to comply with those needs.

The programme is to investigate groundwater potential by assessing existing groundwater data and wells as well as field soundings in the Province and to identify high groundwater potential areas. Then, target areas can be specified with consideration of groundwater potential and development needs. Some particular areas are indicated in the Table 7.12 of water related district needs. After the area specification, a pilot phase can be performed searching an optimal scheme of groundwater development for domestic water. On-going projects in other provinces will provide a good model for this programme. Handpump wells should be the primal mode of the development where possible, which is in line with the basic strategy stated in this water plan.

Achievement of the government target

Various water supply programmes have been formulated to achieve the government target. The total capital requirement of those government sponsored programmes amounts to approximately Kshs.4.3 billion. Utilizing the past records of government expenditure and budget allocations, an order of magnitude estimate of capital availability for rural and urban water supply has roughly been made (ref.42). The anticipated investment capital for the next 20 years in the Lake basin is Kshs.54 billion, of which 9% may be available to MOWD and 2% to MOLG. Assuming 73% of the MOWD allocation will be available for rural and urban water supply development and 25% of the MOLG allocation will be

available for local governments to spend on urban water supply, the total amount of Kshs.3.8 billion may be available against the requirement of Kshs.4.3 billion. This indicates that 88% of the total Lake basin population can be provided with improved water by the year 2005 and this implies that 100% of the government target may be achieved if the government expenditure is increased to Kshs. 4.3 billion.

If more investment capital is available than anticipated, the rural population depending on roof catchment can be reduced and groundwater can be provided, or more piped water supply may be found to be an appropriate mode of water supply for some areas. However, a new piped water supply scheme should not take a high priority unless socially and technically favorable conditions are obtained. This statement is simply based on the past and present experiences of water supply in the Lake basin region.

The existing rural and urban water supply systems require operation and maintenance cost, which may have to be withdrawn from the anticipated investment capital. This implies less capital may be available than anticipated for the future investment. However, it was assumed in the above discussion that such operation and maintenance cost will be covered by the revenue from water sold. This may not be realistic for many water supplies at present, but such is the government policy. Alternative solutions are indicated later as "rationalization of water supply management".

Screening criteria for target areas

Since capital availability could be less than the total requirement, it will be useful to indicate a screening criteria to identify target areas for rural water supply. The following may be adopted as the criteria to identify target or priority areas. Hinterland of development areas such as Kisumu-Eldoret dual core or other growth centres, proposed in the Master Plan, should take a higher priority in order to support particular area development (Master Plan Report).

The designated service centres such as urban centres, rural centres, and market centres should be given a higher priority in order to support bottom-up development. In the Region, the service centres include 29 urban centres, 58 rural centres, and 144 market centres. The present conditions of water supply in service centers are presented in Table 7.13.

Those areas where self-help efforts are active should also take a higher priority. It is also necessary to consider in priority making a proper design or costing in those self-help projects as well as a management aspect. A water supply facility will be useless without proper management. Needless to say, a priority determined in a district development committee would be most important.

Three points described above constitute the screening criteria to decide target areas. Putting them together, target areas are those service centers, located in areas of particular area development schemes, where a self-help and management effort is appreciable.

In selecting urban water supply rehabilitation and expansion schemes from existing piped water supplies, financial management in the operation of water supply is an important

consideration. A water supply where operation cost is covered by the revenue of water sold can assume higher priority for the selection. This policy will help the government to reduce the financial burden in operation of water supply after the scheme is completed. This aspect can not be overemphasized.

Rationalization of water supply management

The existing water supply facilities are deteriorating due to insufficient operation and maintenance works and funds for those. The recurrent budget of MOWD has been far below the requirement of the MOWD's operation and maintenance cost of existing facilities. Since the water supply systems are increasing, such budget requirement should also be increasing, but budget allocation for the operation and maintenance cannot increase as water supply systems increase.

The government policy is that the operation and maintenance cost should be paid by the revenue of sold water, which has not been realized yet for many of the MOWD operated water supply schemes. Such a dilemma of more water supplies needed while budget deficit increasing has to be rectified.

There have been several proposals to solve such a problem: a market study need to be strengthened in a feasibility or design stage; role of operation and maintenance work should be decentralized from MOWD to a more local level; water tariffs need to be adjusted so that the revenue will cover the recurrent cost; more effort to reduce the difference between the amount billed and collected needs to be made; and so forth.

Public education and information service for water supply and sanitation

It is proposed that projects involving water supply and sanitation should include education and information services. The rural and urban water supply programmes proposed in the water plan must be implemented together with such services.

The information to be offered varies for different programmes and projects. Needs of safe water with regard to water related diseases, an advertisement of safe water to become available by a project, government services in water connections and loans, maximum utilizations of safe water, an advertisement of early payment of water charges are the important information for a piped water supply project. A self-help project will require information such as how to initiate a self-help project, to form a group, and to obtain a government assistance and among others the importance of self-reliance. A handpump well project should offer its own education and information service such as the formation of a well committee, by-laws and behaviour at well site, parts of handpumps, and mode of function and failure.

The methods of offering education and information are mass communications utilizing radio, TV programmes, and newspapers and grassroots movement in markets, schools, and public gatherings by mobile cinema, for example.

It will be more effective if extension workers from the Ministry of Health, the Ministry of Social Services, and the Ministries of Agriculture and Livestock Development, and school

teachers are involved, adopting an integrated approach. Considering wide and large impacts of a water project and a large number of people to be involved, such an integrated approach will be necessary and effective. The on-going rural water supply project in Western Province will offer an example for a community involvement at virtually all levels.

(2) Rural sanitation

Sanitation in rural areas will be undertaken primarily by individuals. Government agencies should provide services on public health education to rural populations. Such education may be offered together with the education programme of rural water supply mentioned previously.

A demonstration project on sanitation by constructing pit latrines and septic tanks will be effective if it is implemented in conjunction with the public health education. Government projects of rural sanitation are on-going in Western Province by KENAFYA (cooperation of Kenyan and Finnish governments) and in Nyanza Province by LBDA (cooperation of Kenyan and Dutch governments). It is expected that these projects will serve as cores to disseminate sanitation facilities to rural areas.

(3) Municipal water supply and sanitation

Kisumu

The municipality of Kisumu is planned to grow as a service oriented commercial center, an institutional center, and an industrial center according to the Master Plan. The present guidelines to the future expansion are the Draft Structure Plan issued in 1984, the Development Plan for the New Kanyakwar Area issued in 1983, and the Part Development Plans for parts of the Kanyakwar area issued in 1985. It is planned that the future expansion of the municipality will take place northwards and eastwards into Kanyakwar and subsequently into Warthorego.

A sound industrial development can be attained with such basic services as water supply and wastewater disposal facilities; particularly a wastewater disposal system will be of paramount importance for protecting water quality of Winam Gulf. Therefore, water supply and waste water disposal systems should be strengthened and extended, north and eastward into the New Kanyakwar Area, Warthorego, and the Kibos Industrial Estate by 1995 and westward so as to encompass Otonglo and the Airport industrial estate by 2005.

Augmentation of Kisumu water supply consists of emergency works project, immediate works project, stage I project, and stage II project, (ref.23). The rehabilitation work has started in 1986 and the immediate work is planned to start in 1987. The augmentation plan is summarized in Table 7.20. The required investment capital is a part of capital requirement under the urban water supply rehabilitation and expansion programme of the water plan.

The source of water up to stage I project will be Winam Gulf. The Kisumu Water Supply and Sanitation Study compares water source alternatives of Winam Gulf, Kibos River and Yala River for the stage II project (ref.23); it does not make a definite conclusion of the optimal alternative although use of Yala River or Kibos River was found to be more

expensive. Since it is planned to divert Yala River water to Kano Plain for a multipurpose use around 1995, Yala River water may be utilized for the stage II project. The benefit of hydropower and irrigation development from Yala River diversion is high, and it could pay the most of the water diversion cost. Only a gravity pipeline of approximately 35 km may be required for the water supply if the multipurpose Yala River development is implemented. This scheme is further dealt with in a subsection on Integrated Kano Plain Development.

According to Kisumu Water Supply and Sanitation Study, the municipal sewerage system is expected to carry total sewage flows of 9,900m^3/day in 1985, 23,200m^3/day in 1995, and 35,400m^3/day in 2005 (ref.23). For these estimates, it is assumed that industrial, commercial, institutional, and medium density residential areas will be served with the municipal water borne sewerage facilities; low density areas shall use septic tanks; and residential areas with water consumption less than 150 l/capita/day will use group septic tanks or pit latrines.

The study proposes the following sewerage expansions. Immediate works are proposed aiming at improvement within the existing sewerage system, and also limited extensions into areas that are currently being developed such as the new Kanyakwar areas and Kibos Industrial Estate. Stage I extension should be completed by 1990; stage IA should be completed before 1995. Stage II will further extend service areas and should be completed before 2005, exact implementating schedule depending on the speed of urbanization.

Rehabilitation and expansion of sewage treatment works were also proposed by the study. The emergency and immediate stage is to upgrade existing treatment works for producing final effluent to the requisite standard. Stage I is to expand treatment capacity of 1995 sewage flow by upgrading the conventional sewage treatment works and constructing Otonglo water stabilization pond. Stage II is to upgrade the three treatment works, i.e., the conventional treatment works, Nyalenda and Otonglo stabilization ponds to the sewage flow of 2005.

The staging of sewage treatment works and associated capital investment costs are summarized in Table 7.20.

Eldoret

As explained in Section 7.2, the phase I of the Eldoret water supply project was completed and the implementation of phase II is expected. Among several alternative plans, New Two Rivers Dam scheme should be recommended by the following reasons. This scheme is in accordance with the recommendation of Eldoret Water Supply Study Phase II (ref. 21); the unit construction cost is deemed much less than those for other alternatives (a hearing from a JICA expert in the MOWD); and the distance between water source and the town is short, i.e., only 5 km to the existing treatment plant while the Moyben scheme requires a pipeline of 47 km. The New Two Rivers Dam will augment low flow of Sosiani River, which will improve its deteriorating water quality. The New Two Rivers Dam scheme will cost Kshs.361 million including the new dam, treatment works and reticulation systems. The total supply capacity will amount to approximately 70,000 m^3/day against the projected water demand of 77,000 m^3/day in 2005 (ref.21).

In order to implement the phase II Eldoret water supply project with the New Two River Dam scheme, a feasibility study and detail design will be necessary. The demand projection needs to be looked into and revised if necessary. Since a preliminary study was finished, the feasibility study should include updating financial evaluation. The study and detail design are estimated to cost approximately Kshs.15 million and 5 to 6 months (MOWD, JICA experts).

Other towns

Plans of water supply in other towns such as Bungoma, Kitale and others should be implemented according to their demand increases. Studies for other towns have been made and can be found in many reports (refs.22,25,27,30, and 36). Improvements of water supplies in these towns should be implemented under the proposed Urban Water Supply Rehabilitation and Expansion Programme; details of the improvement plans are beyond the scope of this study. Sewerage facilities have to be rehabilitated first in most of towns particularly at Kakamega and Bungoma. Descriptions with regard to sewage can be found in the sections of water quality control of this report.

7.5.2 Multipurpose Water Resources Development

(1) Preliminary assessment of water resources development project

This subsection presents structural measures to develop water resources in the Region in order to meet the projected water demands given in Section 7.3.

(A) Storage and hydropower development

A preliminary assessment of water resources development in the Region is presented here. Reviewing past study reports, 18 projects as given in Figure 7.12 have been identified for the purposes of water supply, irrigated agriculture, hydropower and flood control in the Region (refs. 7,11,14,20,31,32,39, 40 and 54). In order to make an assessment of these identified projects, a preliminary plan has been worked out for the dam and hydraulic structures such as spillway, headrace tunnel, surge tank, penstock and diversion tunnel with the topographic map of 1 to 50,000 scale. Construction costs were estimated based on the preliminary plan.

Flows at each project site have been estimated using the monthly flow record of a stream gauge station in the same river by adjusting drainage area and rainfall (Table 7.4). The area-storage curve has been prepared at each reservoir site as given in Figure 7.13.

The results of preliminary project assessment are presented in Table 7.22. The table shows name of project, location, structural features, construction cost, and cost performance in terms of power capacity and regulated flow. Besides the 16 projects in the table, Rambula project on Nzoia River and Ol Ngabor on Migori River were assessed but found that active storage would not be secured due to sedimentation. Brief discussions of each project are given in the following.

Nzoia River

The Teremi is a hydropower project of run-of-river type with an installed capacity of 2 MW. Since its feasibility study has been completed with indication of viability, early implementation is recommended for rural electrification (ref. 20).

The Webuye Falls is also a run-of-river type hydropower project with a 4 MW installed capacity. A large scale development combining with the upstream reservoir, Rongai or Lungari, was evaluated for this project, but no promising index for the project was obtained.

The Hemsted's Bridge project can generate 233 million m^3 of regulated annual flow and 66 GWh/year electricity. It was first planned as an intra-basin project, but the viability was found marginal. An alternative to this project is water transfer to Kerio Valley through Elgeyo Escarpment, creating a net generation head of about 700 m with a 60 km-long water conveyance. Installed capacity could be 75MW. Such a long conveyance tunnel would, however, be technically difficult although it may not be impossible. This aspect has to be looked into before economic feasibility is investigated.

Yala River

The Nandi Forest is a project to transfer the Yala River water to Kano Plain. The water transfer by a 15 km long-tunnel not only makes possible the power generation of 45 MW utilizing 500 m head, but also furnishes water with 183 million m^3 for irrigation in Kano Plain and possibly for municipal water supply of Kisumu as well. Since the Nandi Forest is a hydropower project to share a part of power demand in the nation and is a core project to develop Kano Plain, further discussions will be given in a subsequent section of Integrated Kano Plain Development as well as in Sector Report of Energy (Chapter 9).

The Mushangumbo exhibits high cost performance in terms of an unit construction cost of regulated flow and thus favourable for flow regulation. This project will have a role to augment river flow for the beneficiaries in the downstream reaches if water demand in the downstream grows more than currently expected. The water balance for 2005, however, does not indicate water deficit in the downstream requiring a major storage.

Gongo project does not show any promising cost performance in both power generation and regulated flow.

Nyando River

The projects of Koru, Awasi, and Twin Bridge in the Nyando River do not show a promising index particularly for hydropower development. Considering the advantage of the Nyando River flowing through the Kano Plain, a development centre in the lowlands, it should not be excluded at this time from the list of development candidates. A past study indicates viability of the Awasi project to serve for irrigation in Kano Plain (ref. 7). The possibility to develop these projects is discussed in a subsequent section of Integrated Kano Plain Development.

Londiani dam is planned for water supply serving the Greater Nakuru area.

Sondu River

The Sondu/Miriu and Magwagwa are conceived as a combined project, the Sondu/Miriu for a water transfer function from the Sondu River to Kano Plain and the Magwagwa for flow regulation. The power generation from both schemes is firm energy of 514 GWh a year with 144 MW, and regulated flow of 760 million m^3/year will make possible the irrigated agriculture development in the large area of Kano Plain, (25,600 ha) and Nyakach plan. Further discussions to utilize the potential of the Sondu/Miriu and Magwagwa are given in a subsequent section on Integrated Kano Plain Development and Sector Report of Energy(Chapter 9).

The Orokiet project shows only marginal viability, and thus this project is not recommended for implementation.

Kuja/Migori River

The Kuja originating from the Kisii highlands with abundant rainfall is characterized as a river with ample flow. Although there is an existing reservoir at Gogo for power generation, it is not sufficient to regulate the Kuja River. On the other hand, there exists a potential reservoir site at Namba Kodero of the Migori River flowing through relatively dry area, where topography allows a diversion of the Kuja River flow with an open channel. The Namba Kodero is therefore contemplated as a project to regulate flow of the Kuja as well as the Migori. The cost performance index, however, has been found small for both power generation and regulation. Considering the potential irrigation areas extending at the downstream end of the Kuja/Migori, further investigation of the Namba Kodero project is needed for a multipurpose scheme.

Tenwek of Mara River

There is a potential site at Mau Forest Falls in Tenwek of the Mara River. This site is not listed in Table 7.22. This project is currently being developed by a mission for the exclusive use of Tenwek hospital. The development of 320 kW of the first stage with another 320 kW as the second stage has been determined. For further development of the project, it is recommended that governments and agencies concerned be involved in order to efficiently utilize limited water resources.

Conclusions

The preliminary assessment of projects as listed in Table 7.22 indicates that the Teremi and Webuye Falls in the Nzoia and the Nandi Forest in the Yala are promising projects besides the Sondu/Miriu and Magwagwa. Implementation of these projects is highly recommended. The Sondu/Miriu, Magwagwa and Nandi Forest projects are earmarked as the Master Plan projects. Teremi and Webuye Falls projects are expected to contribute to rural electrification. Other projects may be implemented with lower priority depending on realization of water demands projected in Section 7.3.

Hydropower potential from 15 projects was calculated to be some 290 MW, yielding 1,570 GWh/year of average energy and a firm output of 1,130 GWh/year. Lay-out plans for Webuye, Nandi Forest and Namba Kodero projects are illustrated in Figures 7.14, 7.15 and 7.16.

Environmental impacts of the water projects have not been evaluated in this preliminary assessment. The past study such as Sondu River Multipurpose Development Project or the study of Multipurpose Yala Reservoir should provide information on environmental impacts of water projects.

(B) Irrigation development

There are seven major irrigation projects identified in the Region as shown in Figure 7.12. Five irrigation projects are large scale irrigation schemes with an area of more than 5,000 ha, i.e., Upper Nzoia, Lower Nzoia, Yala Swamp and Kano Plain irrigation projects. Three projects are complex irrigation schemes consisting of small scale irrigation, i.e., PIU Western, Lower Kuja, and Lake shore irrigation projects. Irrigation areas of each small scheme range from 10 to 300 ha. The irrigation areas and project features are briefly described in the following.

Upper Nzoia Irrigation Project

The area of 9,440 ha (6,420 ha in net) are located along the upper Nzoia River and its tributaries (ref.32). Since the natural flow of Nzoia is not sufficient to satisfy the irrigation requirements, an effective reservoir capacity of 63 million m^3 is required to regulate the flow. Hemsted's Bridge reservoir will be used for this purpose. The total water requirement is about 69 million m^3/year. The sprinkler irrigation is proposed due to rather steep slope with 5 to 10% gradient on the average. Fruits, vegetable and maize are the proposed crops.

Lower Nzoia Irrigation Project

This project area, 10,490 ha (7,130 ha in net; including PIU Western project) lies on the lower Nzoia near Bunyala Irrigation Scheme (ref. 32). Intake weir is proposed at about 35 km upstream from the river mouth near Nzoia village. About 20 km flood protection bank along the river and 5km main drainage canal are also proposed. Excess water needs to be drained by pump. This project area is overlapping with PIU Western project.

PIU Western Project of Lower Nzoia

This project consists of irrigation and many small drainage projects along the Nzoia River. The irrigation project is located on both sides of the river banks and about 10 km upstream from the river mouth. About 24 million m^3 of river water needs to be pumped from Nzoia River for irrigation of 2,100 ha in net through 45 km canals. Rice, maize and cotton are proposed irrigation crops. Drainage projects lie scattering along the valley bottom of small tributaries. Total drainage area is about 12,400 ha (ref. 50).

Lower Kuja Irrigation Project

This project consists of a number of small schemes with 200 to 300 ha each (ref. 7). Each scheme needs one diesel driven pump and an independent irrigation and drainage system. Total development area is 3,150 ha (net 1,900 ha). Crops of maize, groundnuts, pulses, cotton, vegetables etc, are proposed.

The Namba Kodero multipurpose project mentioned previously regulates flows of Kuja and Migori Rivers. The irrigable land could be expanded by the Namba Kodero project and such a possibility deserve a further investigation.

Lake Shore Irrigation Projects

This project area is extending along the Lake Victoria within a belt of 20 km to the inland from the Lake. In this strip of land, a number of small irrigation schemes are proposed. The irrigation water for each scheme is either pumped from the Lake or diverted from small rivers. Some existing schemes are managed by PIU Nyanza. Total irrigation area of existing schemes is about 1,400 ha and the total of 8,000 ha consisting of 21 schemes is proposed. This project is found to be one of the high priority irrigation projects in the LBDA region based on the basic development strategy, and has been studied in more details to promote its early implementation (Chapter 1, Report on Preparatory Study).

Yala Swamp Agricultural Development Project

This project covers a total area of 17,500 ha consisting of three areas: Area I (2,300 ha), Area II (9,200 ha) and Area III (6,000 ha). Area I has been reclaimed and is under cultivation. Area II is proposed to be irrigated by gravity flow with a diversion of Yala River, which is envisaged for implementation in the near future with the aid from Netherlands. Area III would require empoldering and pump drainage as the land level is below the average Lake water surface. This area would also require a review of feasibility for the environmental effects of reclaiming the swamp, project cost and technical problems.

Kano Plain Irrigation Project

A number of studies were carried out and projects were evaluated, as the Kano Plain is the most promising area for irrigation development in the Region. Crops proposed in this area are rice, maize, groundnuts, cotton, etc. There are four alternative water sources for irrigation: viz. Lake Victoria, Nyando River, Sondu River, and Yala River.

Lake Victoria: One pumping station is proposed at Nyakach bay with capacity of 13.5 m^3/sec (ref.32). Some booster pumps are also proposed to irrigate higher lands. The total area is 17,500 ha (14,000 ha in net). One third of the area is for rice and two thirds for other crops. Flood protection dikes for the Nyando, the Kibos and the Lielango Rivers are required. This scheme is not recommended since it is found infeasible (ref.32).

Nyando River: Awasi reservoir is required to irrigate 13,000 ha (9,750 ha in net) of rice and other crops (ref.7). Whole irrigation area is on the right bank of the Nyando. Flood protection dikes are also required.

Sondu River: Without any seasonal regulating reservoir, the Sondu River can irrigate some 14,000 ha (8,500 ha in net) in Kano Plain (ref.11). A high dam and reservoir is proposed at Magwagwa village. The capacity of Magwagwa reservoir is about 600 million m^3, which will provide water for 25,600 ha in net in Kano Plain (ref.11). The area includes existing Ahero and West Kano schemes, proposed South Kano scheme and PIU schemes.

The water for irrigation is taken from tailrace of power station near Apondo village. The water is conveyed to the north-west by open canals. The irrigation canals extend to the Nyando River to supply the water for lowland area. The lowlands require flood protection dikes. Proposed crops are rice, cotton, groundnuts, maize, etc.

Yala River: Nandi Forest reservoir is required to irrigate approximately 15,000 ha of sugarcane out of the existing Nyanza sugar belt. The yield of sugarcane is expected to increase approximately from 35 to 80 tons cane/ha/year (ref.56).

Conclusions

It is recommended to implement, with the highest priority, the small scale irrigation projects of PIU Western, Lower Kuja and Lake shore (PIU Nyanza). This is in line with the basic strategy stated in Section 7.4. As a part of the multipurpose river development of Sondu and Yala Rivers, the Kano Plain irrigation project should also be implemented with high priority during the plan period of 20 years. Other projects may be implemented depending on economic viability and social needs.

(2) Integrated Kano Plain Development

Integrated Kano Plain Development is highlighted here as it is one of eight area development schemes listed in the Master Plan and its major component projects are water resources and related land development. In the following, alternative development schemes of multipurpose river development are presented. Next, alternatives for Kano Plain flood control are examined and a recommended scheme for the flood control is presented. The Kano Plain flood control is considered as a prerequisite to the Kano Plain development on a full scale.

(A) Alternative development schemes

Development components

Water and related land development which can be implemented in and near the Kano Plain are hydropower, water supply and irrigation. Hydropower and irrigation projects including those of Kano Plain are listed in a previous section for a preliminary assessment of water resources projects (Table 7.22). Major water and related land development projects in and near the Kano Plain are listed below. These are the project components of Integrated Kano Plain Development constituting development alternatives.

(a) Magwagwa reservoir and hydropower;
(b) Sondu/Miriu diversion and run-of-river hydropower;
(c) Londiani water supply reservoir;

(d) Awasi reservoir and hydropower: Awasi dam is considered instead of Koru dam since Awasi is more viable than Koru according to the preliminary assessment (Table 7.22);
(e) Nandi Forest reservoir and hydropower;
(f) Irrigation of Nyando River left bank : area of 15,600 ha is considered as irrigable land;
(g) Irrigation of Nyando River right bank : area of 25,000 ha including existing 15,000 ha sugarcane field is considered as irrigable land;
(h) Irrigation of Yala Swamp: area of 17,500 ha is considered as reclaimable and irrigable land; and
(i) Kisumu municipal water supply : water demand of 2 m^3/second is assumed.

Locations and relations of these development components are schematically shown in Figure 7.17. For more detail and precise locations, past study reports (refs. 7 and 11) should be refferred to.

Project screening

Water development at sources of Sondu/Miriu, Nyando and Yala Rivers can serve to a varying degree for hydropower, irrigation and water supply, and development of all the schemes may not be necessary to satisfy water requirements at different sites and for different purposes. Therefore, it is necessary to find out which sources of water should be developed and where water should be allocated for various water users, or what combination of water development projects and water supply projects should be chosen. This task has been done in the following project screening.

Screening many projects by different amounts of available investment capital would provide useful information with regard to selecting projects for an available budget during the next 20 years and also clarifying project priorities among many projects. These are the objectives of the project screening.

A project screening has been performed by maximizing net benefit from whole water and related development projects in the Kano Plain, i.e., development components listed previously from (a) to (i) were so selected and combined that the total system will produce maximum net benefit.

Net benefit is computed as the value of discounted benefits minus discounted costs of projects. An evaluation period is set to be 50 years; a build-up period is assumed as five years for an irrigation project; construction periods are assumed to be five years for irrigation, dam and power projects. The benefits arise from power generation, irrigation, and municipal water supply, and the costs are incurred for facilities such as reservoirs, power plants, weirs, canals, pumps, pipelines and treatment plants as well as on-farm development.

A mathematical optimization method was employed as a tool for finding out an optimal solution, i.e., maximum net benefit, from practically all possible combinations of component projects with a constraint of available investment capital. Various amounts of

available investment capital were assumed to obtain optimal combinations of projects for different levels of investment budget.

The data used for cost and benefit computation were taken from a previous section (a preliminary assessment of water resources development project), a past study (ref.11) and Design Manual for Water Supply (ref.26).

Results of project screening: alternative development schemes

The results of project screening are summarized in Table 7.23. Different development components were selected with five different amounts of investment capital cost. The table indicates the following. The development of Lake water solely for irrigation is not viable since river water can be developed both for irrigation and hydropower. Awasi dam with hydropower is not selected with any amount of available capital since other sources of river water provide sufficient amount of water at smaller cost. Lake Victoria water supply is selected always as a source of Kisumu water supply.

Since use of the Lake water may cause operational problems (due to pumping and degraded Lake water quality) which may be interpreted as an intangible cost and cannot be included as monetary cost, another project screening was conducted with the condition of excluding the use of Lake water. Then, the Yala River is selected as the source of Kisumu municipal water.

Changes in a project combination of dams and hydropower with different amounts of available capital budget are found in the table. Alternative development schemes, with respect to combinations of hydropower projects are (1) Sondu/Miriu, Magwagwa and Nandi Forest (2) Sondu/Miriu and Magwagwa and finally (3) Sondu/Miriu only, with the corresponding reductions of available capital.

With the different combinations of dams and hydropower projects selected, irrigation development sites and areas also change as shown in Table 7.23. Irrigation project sites for each development alternative scheme are selected along with the upstream flow regulation facilities, i.e., dams and weirs. The selected irrigation development sites and areas are (1) whole Kano Plain (40,600 ha), (2) whole Kano Plain except sugarcane belt (25,600 ha), (3) Nyando left bank (10,000 ha) and Nyando right bank (15,000 ha), and (4) Nyando left bank (10,000 ha) and Nyando right bank (3,000 ha), with the corresponding reductions of available capital. Yala swamp development (17,500 ha) is always included.

(B) Flood control of Kano Plain

MOWD has started a construction of dike along the Nyando River as a first step of implementing the Kano Plain flood control and protection. However, various concerned agencies have not yet supported or agreed on the MOWD's plan. The MOWD's plan, as a whole, is based on the work of Italconsult. There exist now two alternatives for the Kano Plain flood control: Italconsult's plan (ref.32) and Lotti's plan (ref.7). The two alternatives are introduced for a comparison here with underlying considerations of their plans. The Kano Plain flood protection is focused on structural measures since they have a direct effect on flood protection and considered to be implemented as a first priority.

Italconsult's plan

Italconsult looks at the Kano Plain flood control as most urgent and absolute priority. The results of protecting lands from floods and draining them for reclamation are expected to be a decrease in harvest losses, an increase in yields, a shift in the farming patterns toward a more profitable combination of crop and livestock production activities, and an increase in cropped areas by approximately 4,500 ha. The improved dry farming conditions created by the Kano Plain flood control which is called as short-term measures in the Italconsult plan, are considered to enhance the area development. Therefore, it is clear that the objective of Italconsult plan of flood control (short term measures) is the resulting land enhancement rather than serving for a particular irrigation development project.

The long-term flood control measures of Italconsult plan is concerned with those parts of the Kano Plain lying below the elevation of 1,136m with embankments along the shores of Lake Victoria. It also proposes irrigation development of approximately 18,000 ha, including Nyando Swamp. Flood protection is designed against 50-year return period flood for all rivers.

Figure 7.18 shows short-term flood control and protection measures such as embankment, a diversion channel, and main drains. Table 7.24 shows the costs (in 1981 price) of various flood control and protection works.

Lotti's plan

The Lotti's plan for the Kano Plain flood control and protection is basically to serve for agricultural development project in the Kano Plain. Lotti presented a master plan for the drainage and irrigation of Kano Plain and the flood protection plan is a part of the master plan.

Flood protection works were examined separately for three different hydrological areas: the Nyando and Kibos, the water courses flowing into the Central Kano Swamp, and the rivers between the Nyando and the Nyakach Escarpment. The return period used for the plan is 50 years except for Nyando River, where 100 years is used. The delimitation of low-lying area of the Central Kano Swamp by means of embankments to be used as controlled retention storage and used also for supplying irrigation water is an unique feature of this plan.

The main consideration of the proposed solution is that the distance between the embankments should be as large as possible since it will cause smaller damages in the event of embankment failure and it will require smaller cost for constructing embankment.

Figure 7.19 shows the flood control and protection measures such as embankments, flood plain, reservoir, and main drains. Table 7.24 shows the costs (in 1983 price) of various flood control and protection works.

Comparison of the two alternatives

There are differences between the two alternatives in many respects ranging from differences in fundamental objectives of flood control to technical details. In the following, some notable differences are pointed out.

The objectives of flood control and protection are general land protection and enhancement and not for a particular irrigation project in the Italconsult plan, and a particular area protection for an irrigation project in the Lotti's.

The embankment on the Nyando left bank beyond the 1,136m contour extending to the east on the Lake shore for the long-term measures of Italconsult's plan should be compared with the embankment extending from the Nyando left bank to the north up to Ahero-Kisii road of the Lotti's. The latter is protecting the left bank areas of the Nyando but is excluding possible future reclamation of the Nyando Swamp.

A diversion channel from Oroba River to Nyando River is proposed to protect downstream areas of the Oroba beyond the Kisumu-Ahero road in Italconsult's plan; however, the creation of Oroba flood plain in conjunction with Lielango reservoir is proposed in Lotti's plan, which is intended to be used for irrigation as well.

Extensive secondary drains for 30,000 ha are proposed in Italconsult's plan which amount to as much as Ksh.510 millions; however such extensive drains are not proposed in Lotti's plan; and the results of the different drainage may not be compatible for the two plans. It is questionable that the lands will be drained from rain and upstream water without extensive secondary drains in such flat areas with the soil of low permeability. The effects of extensive drainage deserve a further study. Flood protection measures are more straight-forward in Itlaconsult's plan than in Lotti's plan, probably because of different intended objectives stated above.

Embankments are higher and distance between right and left banks is smaller in Italconsult's plan than in the Lotti's. This is partly because of higher design discharge in Italconsult's plan and also because of consideration in expected damages in the event of dike failure.

As found in Table 7.24, the cost of Italconsult's plan is Kshs.407 million without secondary drains and Kshs.308 million for Lottii's plan. However, it should be mentioned that the Italconsult's cost is in 1981 price and does not include engineering, contingencies, supervision and overheads, while the Lotti's cost is in 1983 price and include those additional costs. Major costs are incurred from embankment and excavation, and unit prices of those are Kshs. 50/m^3 and Kshs. 60/m^3 respectively for Italconsult and Kshs. 66/m^3 and Kshs. 30/m^3 for the Lotti's.

There is a notable point common to both of the plans. The two plans excluded a creation of flood protection storage on the Nyando River because the Koru dam, regarded as a potential site, has only a small effect on the control of floods. Therefore, the Koru dam cannot be justified for a Nyando flood protection purpose alone, although it may be justifiable for an irrigation purpose or multipurposes.

Recommended Kano Plain flood protection scheme

It is desired that the following proposed scheme will help settle technical issues among concerned agencies. It should be noted that the integrated approach, community involvement, and the role of LBDA described in Section 7.4 are important aspects of the flood control. Therefore, these should serve as a part of this scheme together with those of the following.

An approach adopted by the Italconsult seems to be more reasonable. First, flood protection of Kano Plain, followed by naturally induced land enhancement will bring interests in more agricultural production by irrigation practice later. Therefore, it is proposed that the Kano Plain flood protection shall be performed for land enhancement. The approach, however, can be flexible. Needless to say, an irrigation project can be started together with an area protection wherever physical and social condition supports such development.

Being an agricultural area, a flood protection against a flood of 50 years or a longer return period seems to be an over-protection, considering examples in other developed and developing countries. It is proposed to design flood protection measures against 20 to 25 years. This will reduce the cost of flood protection measures and facilitate an early completion of construction works. When the Kano Plain is developed further as a result of this level of flood protection, it may be found necessary to protect the area against a flood of a longer return period. Then, the area can be protected against such a flood by raising and strengthening the dikes. In order to reach an agreement on the design discharge among concerned agencies, a comprehensive survey and measurement of discharge have to be performed and it is necessary to come up with one rating curve.

A future or eventual land use pattern should be considered behind the flood protection measures and land enhancement so that further development will be smoothly induced. The eventual development in the Kano Plain will most likely be fully irrigated agricultural lands. Although it may take 20 or more years to realize such development, an eventual land use should be kept in mind. In view of the Sessional Paper No. 1 of 1986 regarding small-scale and large-scale irrigation, a further Kano Plain irrigation development should take place step by step from a small or medium scale to a large scale irrigation development. Reclamation of the Lake shore by embankments should be considered as a very long term option, since the cost of pumping would be prohibitive. However, such a possibility of land reclamation should not be excluded by any flood protection measure to be implemented.

As stated previously in the strategy of Kano Plain flood control, Nyando flood protection is the first priority and it should be implemented at the earliest time possible. There exist some arguments regarding the use of heavy machinery or man power for the Nyando embankments. Heavy machinery have to be used for compaction to make embankments strong enough to last for centuries. Weak compactions and resulting erosion have been experienced in the Nzoia flood protection embankments on the left bank. Unless the embankments are made strong, the resulting maintenance costs will be very high and they will not last long as those previously built on the Nyando. However, manpower can be used wherever possible such as digging drains. Regarding the height of embankment and distance between the embankments, Lotti's plan should be supported: i.e. lower embankment and larger distance in between.

In this water plan, the cost of the Kano Plain flood protection is assumed as a lump sum of Kshs.200 millions. An adoption of 25-year recurrence interval will make embankments less costly than Kshs.150, millions of the main river flood control in Lotti's plan. However, more drainage works may be necessary as Italconsult proposed. Therefore, a half of the total may be spent on main rivers flood control and the rest on main and secondary drainage canals. Harambee may be utilized more for drainage works.

7.5.3 Water quality control

In order to conserve water environment in the Lake basin, concrete actions are definitely required. First, it is proposed that a comprehensive assessment study with regard to water quality and the effects of various human activities in the Lake basin needs to be made. The results of the assessment will show how to improve and control water quality or environment as a long-term project -- a water quality monitoring and control project.

(1) Water quality assessment and control study

This study project should investigate the effects of human activities on water quality of the rivers and the Lake, particularly the Winam Gulf. Human activities should include human settlement in rural and urban areas, agricultural activities, livestock production, and industrial activities. Present conditions and operation of facilities affecting water environment in the Lake basin such as sewerage works in towns and municipalities, sanitary facilities in rural areas, wastewater treatment facilities of various kinds of factories have to be evaluated. Effects of these facilities on the rivers and the Lake should be quantitatively evaluated. Effects of soil erosion in catchment areas on water quality of rivers and the Lake may be evaluated and target catchment areas should be identified. All the water quality data collected in the past has to be assembled and assessed, and new sample collection can be made to supplement the existing data. Such an assessment will help find the effects of human activities as quantitatively as possible.

The results of assessment will then be utilized to find out how to control the effects of such human activities. A requirement of urban sewage treatment standards will be shown and a preferable mode of rural sanitation can be found. In an agricultural activity, preferred kinds of fertilizers and pesticides from an environmental point of view will be recommended and preferred methods and levels of applying those agricultural chemicals to crop land should be recommended in order to minimize the chemical transport to water bodies. Farming practice to prevent soil erosion is important for reducing both suspended sediment and chemical transport. Similarly for livestock production and industrial activities, necessary recommendations should be indicated. Particular attention must be paid to various development activities proposed in the Master Plan and recommendations shall be made to alleviate any negative effects on environment especially on the Winam Gulf.

The assessment study needs to be extended to the past efforts of government control on water quality for various human activities and wastewater treatment facilities. Adequacy of laws such as Water Act and Public Health Act and a legal back-up to water controling government bodies such as MOWD and Water Apportionment Board have to be evaluated in

order to effectively enforce water quality control related laws (ref.46). A law amendment may be recommended as a result.

Manpower and facilities of water quality control bodies should be evaluated as well as methods to improve them. A proper way of coordinating various agencies, e.g., MOWD, Fishery Department and LBDA should be examined. Proposed recommendation and the plan of action in a past workshop are good guidelines for this study project and they need to be substantiated as they can be immediately implemented (ref.16). The costs and phasing of water quality control measures shall be proposed in this study.

(2) Water quality monitoring and control project

This project is an implementation of the proposed Water Quality Assessment and Control Study, and should be continued for a long period of time. The project must consist of water quality monitoring at necessary sites of the rivers and the Lake and effluent points of waste water treatment or pretreatment facilities, monitoring of various water quality affecting human activities and provision of guidances to improve such activities as most likely agricultural, livestock, and fishery law enforcement to violations probably of sewerage works and industries, and catchment conservations as well.

For the water quality control project, it is urgently needed to rehabilitate most of existing wastewater treatment facilities, particularly of Kisumu, Kakamega, and Bungoma, to make sure that existing wastewater treatment facilities of municipalities and factories are properly operated, and to enforce laws and regulations against those who violate them. Such rehabilitation and law enforcement shall be implemented as soon as possible without waiting the results of water quality assessment and control study, as it is an obvious necessity to conserve the environment.

7.5.4 Catchment conservation

(1) Objectives of catchment conservation

Catchment conservation is vital to effectively utilizing water and soil, the two basic resources for primary production activities. Objectives of catchment conservation are:

1) to minimize the productive top soil to be eroded,
2) to retard the flushing of flood water in order to prevent hazards downstream and at the same time to utilize the flood water, and more generally
3) to protect land and water environment.

(2) Factors affecting floods and soil erosion

Main factors affecting the occurrence of floods and soil erosion are rainfall patterns, land use, vegetation cover, soil characteristics and slope.

Not only the rainfall intensity but also the temporal distribution of rainfall affect soil erosion. Extended dry period may cause herbaceous cover to die out and make the erosion by

subsequent rainfall more serious. Erosion from actively cultivated areas depends on farming practice and crop types. Protective crop types include tea, sweet potatoes, bananas and sugarcane in different degrees. Coffee and citrus trees are also protective, if properly planted. Extensive grazing adversely affects the erodibility, and so is the high density of access roads and tracks in highly populated areas. Forest canopy in general is the best protection against soil erosion, and the effectiveness of bushes and grasses depend on the types and density of surface coverage. Soil characteristics are naturally the basic factor for determining soil erodibility. Slope length as well as slope gradient affect the erosion.

(3) Problem areas in the Region

Conditions affecting floods and soil erosion vary widely among different areas in the Region. An on-going study has identified at a preliminary level those areas in the Region which are more susceptible to erosion hazard, by applying basically the same factors enumerated above (LBDA, Lake Basin River Catchment Development -- Catchment Conservation and Rehabilitation; ref.57).

According to the study, about 40% of the LBDA region has a medium or high erosion hazard. The areas most at risk are most of Kakamega, Busia and Kisumu districts, much of Siaya and Bungoma districts, a substantial part of South Nyanza district, southern Kericho district and some part of Narok district.

High risk in Kakamega district is due primarily to high population density with a dense network of tracks and a high proportion of corrugated iron roofs which tend to concentrate run-offs and to topography especially in the southern part of the district with undulating terrains. Problems in Busia and Siaya are mainly caused by extended dry period followed by intense rainfall, which washes away soil on slope areas by sheet wash and rill formation. In Bungoma, the problem takes more often the form of extensive gullying. Erosion in Kisumu is associated with the extensive areas of the Kano Plain covered by highly erodible vertisols. In south Kericho, Narok and South Nyanza, serious erosion is caused by a mixture of factors including steep slope, extensive pastoralism, black cotton soil and the combination of dry spells and rainfall patterns.

(4) Measures

Most effective measures against flush floods and soil erosion differ, depending on the main factors causing these phenomena as outlined above. The following are recommended as general measures related to this Master Plan. More specific measures for each problem area should be determined following the results of the on-going study cited above. More detailed field investigation should be conducted first in the next phase as proposed by the study in order to assess the priority for implementing those measures.

Proper farming practice and adoption of protective crops are effective measures on cultivated areas. Deep ploughing and terracing will increase the water infiltration and retention on the farm land. A few crops promoted by the Master Plan are favourable for reducing erosion. They are tea, sugarcane, coffee and citrus fruits. Irrigated paddy fields are also effective for increasing water infiltration and retention.

On-farm tree planting is another effective measure. This is recommended also for increasing sustainable supply of woodfuel for households in rural areas (Chapter 9, Sector Report).

The Master Plan also advocates the expansion of area under managed pasture to increase livestock production (Chapters 2 and 10, Sector Report). Extensive grazing in the natural grassland should thus be minimized.

Corrugated iron roofs are increasingly adopted in rural houses as the income level increases. This tend to concentrate run-offs. This should be combined with the water supply by roof-catchment in rural areas as described in subsection 7.5.1.