7C. 2 Problems and Needs on Control Works

7C. 2. 1 Existing Control Works and Post-Control Maintenance

Numbers of existing and proposed erosion control projects on state basis, recorded by JICA-NWRIS, are listed in Table 4. 1 and 4. 2. However, the data are still insufficient to properly assess each project.

Problems observed in the course of JICA-NWRIS can be summarized as follows;

1. Lack of consideration for geology, hydrology and hydraulics in planning and design.
2. Inadequate budget allocation for construction works.
3. Improper construction schedule, particularly with respect to timing of types of work for the dry and the wet seasons.
4. Lack of consideration for material selection and distribution systems.
5. Inadequate procedures and budget provisions for OM.
6. Lack of agronomic consideration for revegetation.

Problems of selected projects are described below with some details.

a. Ankpa Erosion Site (Kogi)

The Ankpa Antierosion Project, in the State of Kogi, commenced in 1980 and the first phase of the erosion protection programme was completed in 1985. Gullies were developed along roads with a finger-like pattern between houses. The first phase programme included construction of two 2 m-high check dams, followed by protection works against rainfall runoff covering sediment filled gullies, with cobbles and concrete. The protection works appear to be functioning at the present time since progress of the gullies has not been observed. The second phase of the project was started in 1985 and is still continuing, comprising drain installation and plantation for protecting the existing protection structures. The present problems observed or anticipated are;

1. The check dams are being damaged and require repair before the damage progresses.
2. Slit drains which have been installed at the foots of the check dams to reduce groundwater pressure do not appear to have a sufficient capacity for draining groundwater during peak periods, which may lead to destruction of the check dams.
3. The entire protection structures appear to have been poorly maintained. It is observed that rills have already started forming along the newly installed drains.
4. Top soils are hardened due to agglutination as a result of weathering process under the tropical humid climatic conditions and are unsuitable for plants to take root.

b. Madonna Erosion Site (Anambra)

The Madonna Project, in the State of Anambra, comprises a sizable check dam, 8 m high and 15 m wide, to trap sediments washed out from a large gully. However, the foot of the check dam was scoured away by rainfall runoff flowing over sediments that had filled the dam. The damage was apparently caused by the poor design lacking consideration for hydrological and hydraulic conditions. A serious defect is observed in the design of the drainage system, in particular, it has insufficient capacity for draining rainfall runoff. A plan to construct a new check dam, has been suspended and is being completely reviewed.

c. Umuchima Erosion Site (Imo)

Large gullies, with sizes of some 20 m in width and around 3 m in depth, initiated along a road beside the Ferdinand Group Company's rubber factory in Imo State in 1982, and expanded widely within a short period in 1987 when a drain under the road collapsed. The ground consists of Cretaceous Sedimentary rocks vulnerable to erosion. Three drains were installed after the collapse of the previous drain but without taking account of the required capacity for draining rainfall runoff. Accordingly, these drains collapsed again in 1988 and the gullies further widened and deepened, threatening the foundation of the factory.

d. Apara Town Erosion Site

A landslide, with dimensions of 140 m in length, 80 m in width and 40 m in thickness, occurred on a slope beside a road in the central part of the town of Apara in the State of Abia on an occasion of heavy rainfall in September, 1992. The surface of the landslide, consisting of tropical red soils with a significant amount of silt, was covered by gmelia trees for protection after the incident. A protection work program is planned and is now being implemented, comprising terracing, revegetation and protection wall construction in order of the work procedure. However, the program appears to be inadequate for the following reasons; (1) the protection walls should be constructed prior to the revegetation, (2) the terraces should be slightly tilted so as to make rainfall runoff flow easily over the terrace surface and to prevent it from infiltrating into ground as much as possible and (3) bore-hole drains should be installed to drain groundwater in order to prevent the landslide mass from further movement.

e. Eben Erosion Site (Abia)

Excessive rainfall runoff overflowing from the drainage system of the town of Eben in the State of Abia, has formed, a gigantic active gully with the present size of 30 m in width, 16 m in depth and more than 3 km in length, opening its mouth to the Mmugi River. The ground is covered by brown, fine grained soils. An erosion control project has been planned and is now being implemented, consisting of (1) installation of an adequate drainage system in the town, (2) covering up the gully with earth after installation of drains at its bottom, (3) construction of a check dam at its mouth. The installation of the drainage system has been completed. However, the construction of the check dam has been suspended due to budget constraint during installation of the drains. The installed drains are at risk of collapse, being left without care. Although the progress of the gully appears to have been slowed in its upstream reach in the proximity of the town, it is still expanding in its downstream reach. If the project is left as it is, the present situation will worsen, which may require a complete revision of the project.

f. Enugu-Ukwu Erosion Site (Enugu)

A gully with a size of 30 m in width, 35 m in depth and several kilometers in length, is protected by seven 8m-high check dams and a number of groundsels at an interval of 300 m, at the Enugu-Ukwu Gully Erosion Site in the State of Enugu. However, the side walls have been left unprotected and are providing a considerable amount of sand which has almost filled up the dams. The entire protection system appear to be loosing its proper function, and is in need of review.

g. Obollo-Afor/Iken Erosion Site (Enugu)

A gully, 10 m wide and 6 m deep, has evolved over a distance of some 3 km for the last two years at the Obollo-Afor/Iken Erosion Site in the State of Enugu, due to the inadequacy of side drains installed along the road. An erosion control project is planned and is being implemented by the Anambra-Imo RBDA, comprising (1) terracing of the gully bottom, (2) installation of drains along the road and the gully bottom with a sufficient capacity for draining runoff, (3) plantation of trees and grass over the terraced surface and (4) construction of eight check dams. Various hydrologic, hydraulic and geologic conditions have been taken into account for the design concept, which was though appropriate at the time of planning. Unfortunately, however, the gully changed its form considerably due to heavy rainfall during the wet season prior to the commencement of construction. As a result, a drastic change in the design of the structures was required. The actual construction cost is likely to overrun the project budget initially estimated at about six million Naira.

Agronomic works, such as plantation of trees and grass, are required to protect erosion control structures but have been unsuccessful in most cases in Nigeria, because Nigerian soils are, under the tropical humid climatic conditions, very poor in nutrition content and often have surface crusts too hard for plants to take root.

h. Nnewi 100 Feet Road Erosion Site (Enugu)

A gully, 30 m wide and 200 m long, has developed at the Nnewi 100 Feet Road Erosion Site in the State of Enugu due to excessive runoff from the drainage system of the town of Nnewi. An erosion control project, which was supposed to be completed by 1991, is still continuing and comprises (1) scraping the side walls of the gully to make the slopes gentler and planting bamboos to protect the walls against collapse, (2) installation of a drainage system in the town with a sufficient capacity for draining rainfall runoff and (3) construction of a check dam at the end of the gully. In the first trial of the plantation, bamboo failed to take root and withered during the dry season. The second trial is planned, with watering of the bamboo during the entire period of the dry season.

i. Secondary School Erosion Site (Abuja FCT)

Gullies are developed in the close proximity of a secondary school in the southern part of Abuja FCT, where sheet erosion is also serious. Erosion protection works commenced five years ago. Drain construction and turfing have been completed to date. The drains have a sufficient capacity to drain rainfall runoff. The turf has successfully taken root even in tropical red soils with sufficient watering during the dry season. Maintenance of the protection structure appears to be carried out satisfactorily. As a consequence, no notable damage has been reported recently.

j. Akwdo Erosion Site (Imo)

Many gully erosion control facilities in Nigeria are not functioning satisfactorily due to inadequate OM. An erosion control project was completed for a gully near the Akwdo Secondary Technical School in the State of Imo, three years ago. The control works include installation of side drains for a road near the school, filling the gully with earth and plantation of gmelina trees for protection. The design of the control works seems to be adequate. However, maintenance has been neglected since the completion of the construction, since no organization responsible for the maintenance has been decided. At the present time, sediments accumulating in the side drains are left undredged. As a results, new gullies have been formed at the edges of the drains and require immediate protection works against their expansion.

7C. 2. 2 Procedures of Planning, Design and Control Works

(1) Lack of Initial Action

Most erosion control works have been carried out to prevent medium sized gullies from further expansion. It is almost impossible to restore those gullies with such extraordinary size as observed in the States of Imo and Anambra. Therefore, it is important to take appropriate countermeasures against expansion of gullies at their initial state. The earlier the stage of gully erosion is, the easier is the protection against its advance. As repeatedly mentioned, gully erosion is mostly caused by regional and urban infrastructure development lacking adequate consideration for soil degradation. At the present time, neither precaution against initiation of gully erosion nor prevention of its expansion at an early stage is taken, unless its adverse effect or damage becomes apparent.

It is necessary to assess the country's susceptibility to gully erosion and to recognize the present status of existing gully erosion sites on the same standards, in order to plan and design appropriate gully erosion control works.

(2) Engineering Factors for Planning and Design

The following basic information is required to plan and design gully erosion control works in general;

1. Hourly rainfall intensity records.
2. Precise topographic maps.
3. Hydrologic, hydraulic and geologic characteristics.
4. Nature of top soils and vegetation.
5. Availability of appropriate plants for revegetation.
6. Availability of construction materials.
7. Present life style and land uses of inhabitants.
8. Future plans for infrastructure development.

It is essential for the design of a drainage system with an adequate draining capacity to estimate the maximum runoff rate based on the peak rainfall intensity for a certain duration within an appropriate return period and on the catchment area concerned with the gully erosion site. One of the problems is that sufficient rainfall intensity records may not be always available in the proximity of the project site.

The hydrologic, hydraulic and geologic characteristics of the terrain are necessary to determine structures of erosion control facilities. The amount of groundwater is dependent on permeability of top soils and underlying rocks, and also on water retention and transpiration of surface vegetation. Plants for revegetation to protect the structures are selected according to the nature of top soils, so as to be able to firmly take root.

It will be an advantage in reducing construction costs, if construction materials such as aggregates are available locally. It is also desirable for the entire erosion control program to take account of the present life style and land uses of the local residents and the future requirement for the infrastructures.

7C. 3 NWRMP

7C. 3. 1 Gully Erosion Restoration Works

(1) Inter-Government Coordination

Causes of gully erosion are rather complex but are largely attributable to soil and vegetation deterioration, and other surface land disturbance due to inadequate regional or urban infrastructure development. Therefore, various Federal Ministries such as the FMWRRD, the FMANR and the FMWH and the State agencies are concerned with restoration of gully erosion sites. The Department of Soil Erosion and Flood Control in the FMWRRD is responsible for the coordination of gully erosion control in terms of civil engineering works, and it is urgently required for this Department to establish appropriate technical guidelines and criteria for gully erosion control and restoration works in cooperation with the relevant Departments in FMWRRD which has the mandatory responsibility to enforce the 1993 Water Resources Decree. It may be recommended that the gully erosion protection, control and protection should come under a central unit in the FEPA which may be called the Federal Gully Control Coordination Unit and should take the part of a technical secretariat to the Sub-Committee on Erosion and Flood Control of the National Committee on Ecological Problems.

Gully erosion is the immediate concern of local residents and hence of State Governments or LGAs, creating regionally hazardous problems. Urgent action should be taken by State and LG Governments in order to restore existing gully erosion sites under proper instruction and surveillance of the FEPA. Execution of actual restoration works may be commissioned to RDBAs including the feasibility study, detailed design and construction supervision.

(2) Improvement of Gully Erosion Control Technology

Construction of an adequate drainage system is one of the fundamental works not only to protect existing gullies but also to prevent occurrence of gully erosion in association with roads and other surface structures.

It is observed in many drainage systems in Nigeria that their capacities are either insufficient or unnecessarily oversized for draining surface water runoff. If a drainage system is found to be insufficient in its capacity, the system is reconstructed accordingly. An oversized drainage system is, as a matter of course, uneconomic.

Also observed in Nigeria are a number of drainage systems without proper foundations. In some cases, no foundations have been installed, simply because of unavailability of construction materials such as aggregates. Naturally, such systems last only for a short period.

As mentioned in the last paragraph of the previous section (7C. 2. 2(2)), fundamental hydrologic parameters which are required for design of a drainage systems are the peak rainfall intensity and the catchment area concerned with the system. Therefore, a long term rainfall record and a precise topographic map are indispensable. Information with respect to physiographic, hydraulic and geologic characteristics of the terrain and nature of the top soils and the vegetation are also necessary to determine or estimate the total capacity of the drainage system, number, dimensions, shapes and arrangement of individual drains, foundations and other accessory facilities, and amounts and kinds of necessary construction materials. Details of a design procedure for a drain are described in Appendix 7C-1.

Another major work for gully erosion control is construction of check dams or 'Sabo' dams. The same parameters as for a drainage system should be taken into account for design of check dams and associated facilities. Side walls of a gully require protection against collapse or mass-movement such as landslide. Groundwater drains or weep holes should be installed at the bottoms of the check dams or the protected side walls according to an estimated amount of groundwater based on the total rainfall of a single event and the permeabilities of top soils, underlying rocks and sediments filling the gully.

As indicated in an example at the Akuwado gully erosion site (para. 7C. 2.2), lack of adequate maintenance leads to occurrence of new gullies and destruction of erosion control facilities, even though planning, design and construction have been carried out satisfactorily. Improvement of the present maintenance practices for gully erosion control facilities should be approached from the following two aspects; one is to make clear an organization or institute responsible for the maintenance and the other, to establish civil engineering standards and codes for maintenance procedures. It is understood in Nigeria that the maintenance of erosion control facilities is the responsibility of state governments or LGAs. However, the maintenance is neglected, in most cases, due to inadequate budget provisions. There are certainly no appropriate civil engineering standards and codes for maintenance in Nigeria at the present time. Minor defects in the facilities or minor gullies can be identified at an initial stage by periodic surveillance of the facilities on the basis of the appropriate civil engineering standards and codes, and can be easily repaired or restored with minimal cost.

As aforementioned (para. 7A. 2.2), gully erosion and landslide (a type of mass-movement) are different in mechanism of their causes and require different approaches for prevention or protection against their occurrence. However, advanced gullies, particularly with steep side walls, are vulnerable to landslide as well, depending upon hydrologic, geomorphologic, and geologic characteristics of the terrain. The combination of gully erosion and landslide expands gullies rapidly and ultimately forms gigantic gullies as observed in the States of Anambra and Imo. Once a gully grows to an extra-ordinary size, it becomes almost impossible to prevent its further expansion. In addition, as a gully grows larger, sediments produced by erosion increase and are carried downstream in river channels which deteriorate as a consequence. Therefore, it is important to prevent a gully against its expansion at an early stage.

As above explained, various problems are involved in technological improvement for gully erosion control works as practiced in Nigeria at the present time. All the existing and proposed gully erosion control projects should be reviewed on the basis of the above-mentioned technological aspects.

(3) Guidelines and Criteria for Planning, Design, Construction and Surveillance of Control Works

Site investigation is indispensable to collect necessary information for planning, design and construction of gully erosion control works. Data for the following items should be collected in the course of the site investigation;

1. Gully Characteristics:

   Plan area

   Length, depth and width

   Density of rills

   Associated landslides, if any, their lengths, thicknesses and widths

   Detailed topographic map of the gully and its immediate vicinity (1 to 2,000 or larger as necessary)

   Nature of sediments filling the gully. (Sizes and kinds of fragments, amount of clay, particle size distribution)

2. Catchment Area Characteristics:

   Plan area

   Peak rainfall intensity and seasonal fluctuation of rainfall and temperature (records for at least five years)

   Vegetations and land uses (types of plants or crops, are covered by vegetation and land uses).

   Detailed topographic map (1 to 5,000 or larger as necessary)

   Surface streams and springs (runoff rates, water quality)

3. Top Soil Characteristics:

   Type

   Hardness or degree of agglutination

   Particle size distribution

   Thickness

   Relation with plant species

   Permeability

4. Bed Rock Geology:

   Lithology

   Macrostructure (stratification, faults, their attitude and nature)

Microstructure (joints, fractures, their attitudes, density and nature)

Degree of consolidation

Compressive strength

Intensity of weathering (amounts and kinds of clay minerals)

Geotectonic map of the catchment area (scale corresponding to the topographic map).

5. Geographic Characteristics:

Location of roads, residences and other surface structures (distances from the periphery of the gully)

6. Others:

Timing of initiation of the gully

Timing and damage intensity of past incidents such as landslide

Location of construction material sources (aggregate quarries)

Plan for infrastructure development in immediate future (roads, highways, power lines, reservoir dams and other surface structures)

Based on the data collected as above, the following principal civil engineering parameters can be decided for plan and design of gully erosion facilities;

1. Types of work required; excavation, back-filling, sandbag piling fencing, drainage systems, check dams, hillside works, terracing, plantation and other auxiliary works.
2. Drainage System: types, cross-section areas, length, configuration, foundation works, construction materials (kinds and amounts) and other necessary factors.
3. Check Dams: type (gabion, concrete, or others), numbers, dimensions (length, height, width), shapes, slit drains (numbers, length, diameter, intervals), construction materials (kinds and amounts) and other necessary factors.
4. Hillside Works: slope gradient, length and height, construction materials (kinds and amounts), groundwater drains (numbers, intervals, lengths and diameters of boreholes) and other necessary factors.
5. Terracing: areas and heights of terraces, number of steps, configuration, types of terrace retaining wall (wooden, concrete,

rubbles or others), construction materials (kinds and amounts) and other factors.

6. Plantation: Species of plants, types of plantation (spray nursery bed, turning or others), areas of plantation, soil improvement and other necessary factors.

A construction schedule should be carefully prepared, taking account of (1) numbers and kinds of required engineers and laborers, (2) duration of each type of works, (3) critical paths (4) availability of equipment and materials, (5) climatic and terrain conditions, and so forth. The climatic conditions are sometimes very critical in Nigeria, because heavy rainfall during the wet season may considerably alter the shape and other characteristics of a gully. It is advisable to monitor the gully for any change in its state, before the commencement of and during the progress of the construction, so that modification of the design and the construction schedule can be made whenever necessary. In execution of the construction, the critical path is the most important aspect for insuring smooth progress and saving unnecessary expenditure.

The construction cost can be estimated according to the above civil engineering parameters and construction schedule. If the construction affects the surrounding residences or infrastructures, costs for relocation or indemnity may be necessary to be included as a provision. The construction cost must be, once established, authorized and secured as a budget for a LGA or state government concerned. Suspension of the construction work due to an inadequacy of budget, as cases for some instances, will result in worsening gully erosion situation.

After the completion of the construction, it is, as a matter of course, necessary to monitor the gully for the change of its shape and characteristics and also to maintain the erosion control facilities in appropriate condition. Particularly, in case that a gully is still at an early stage and requires as only minor control works, using gabions, wire sausages or other light structures, surveillance of the facilities is important to identify damage to the facilities at its initial stage and to repair it without delay because these light control works are temporary in nature and are easily damaged by ordinary erosion agents. However, it is noteworthy that thorough surveillance is effective to keep the control facilities in appropriate conditions for a satisfactory period and to minimize maintenance. Regardless of whether the facility is temporary or permanent, careless surveillance will lead not only to destruction of the facility but also to acceleration of the progress of the gully. As aforementioned, it is essential for satisfactory surveillance and maintenance, to establish appropriate civil engineering standards and codes.

(4) Plan Implementation Program

JICA-NWRIS has reported a total of 618 gully erosion sites as shown in Table 7-3. However, neither numbers of nor areas affected by gullies are indicated for States, such as Sokoto, Kebbi, Kaduna, Niger, Lagos and Rivers, where gully erosion is apparent. The total number of gully erosion sites may well come close to 1,000. Severity of damage by or urgency for restoration of each gully has not been well documented except for the notorious ones in the State of Anambra.

Therefore, the first step is to identify and characterize each gully erosion site for its severity of damage and urgency for restoration, including anticipated areas, number of residents and extents of infrastructures affected by the gully. Restoration and erosion control works should be planned and designed according to the results of the identification and characterization. Some gullies of extraordinary size may be impossible to be restored immediately or controlled and may require evacuation of residents and relocation of infrastructures depending on the degree of their severity and urgency.

Types and amounts of restoration and erosion control works are dependent on the nature of gullies. From a civil engineering point of view, gullies can be classed into six ranks as follows;

Rank 1. Simple excavation and plantation.

Rank 2. Piling sand bags or rocks, or fencing at the mouths of gullies, Installation of drain, Plantation.

Rank 3. Piling sand bags or rocks, or fencing at the mouths of gullies, Filling gullies with sands, Installation of Drains, Plantation.

Rank 4. Installation of Drains, Construction of Check Dams, Plantation.

Rank 5. Installation of Drains, Construction of Check Dams, Hillside Works, Plantation.

Rank 6. Installation of drains, Construction of Check Dams, Hillside Works, terracing, Plantation.

All the parameters as mentioned in the previous paragraph (7C. 3.1 (3)) are necessary to estimate the cost of the civil engineering works for restoration of gullies of the above ranks.

However, an order-of-magnitude cost estimation has been made with arbitrary assumptions of civil engineering parameters and unit costs based on average consumer prices and salary-wage rates of the year 1989 as shown in the table on the following page. Meanwhile the inflation rates of the years 1990, 1991, 1992 and 1993 have been estimated at 7.4, 13.0, 44.6, and 57.7% respectively on the basis of the average all-items consumer price indices (1985 = 100) according to the Federal Office of Statistics (FOS). Taking account of these inflation rates, the unit costs of the table have been multiplied by 2.77 to estimate the civil engineering costs as of January, 1994. Ten percent of the total cost has been added as allowance for the miscellaneous works. The results of the cost estimation for each rank are as follows:

Rank 1.

Excavation	13,850	Naira/ha	1 ha	13,850
Plantation	1,385,000	Naira/ha	0.02 ha	27,700
Miscellaneous Works				4,155
Total (Naira)				45,705

Rank 2.

Sandbag Piling/Fencing	5,540	Naira/m	5 m	27,700
Drain Construction	1,108,000	Naira/km	0.5 km	554,000
Plantation	1,385,000	Naira/ha	0.05 ha	69,250
Miscellaneous Works				65,095
Total (Naira)				716,045

Rank 3.

Sandbag Piling Fencing	5,540	Naira/m	8 m	44,320
Gully Filling Works	139	Naira/m^3	1,200 m^3	166,800
Drain Construction	1,385,000	Naira/km	1 km	1,385,000

Plantation	1,385.000 Naira/ha	0.1 ha	138,500
Miscellaneous Works			173,462
Total (Naira)			1,908,082

Assumed Civil Engineering Parameters and Construction Costs

Rank	1	2	3	4	5	6
Civil Engineering Parameters (Naira)						
Cross-section Area of Gully (m^2)	3	4	6	10	20	40
Length of Gully (m)	50	100	200	500	1,000	2,000
Length of Sandbig-piling/Fencing (m)		5	8			
Area of Excavation (ha)	1					
Volume of Back-fill (m^3)			1,200			
Cross-seciton Area of Drain (m^2)		0.5	1	2	4	8
Length of Drain (km)		0	1	5	10	20
Number of Check Dam (dam)				3	5	8
Dimension of Check Dam (H*W*L,m)				3*1*5	5*2*10	10*4*20
Area of Hillside Works (ha)					10	20
Area of Terracing (ha)						20
Area of Plantation (ha)	0.02	0.05	0.1	0.2	0.5	1
Unit Cost (Naira) as of 1989						
Excavation (1 ha)	5,000					
Sandbag-piling/Fencing (1 m)		2,000	2,000			
Gully-filling Works (1 m3)			50			
Drain Construction (1 km)		400,000	500,000	600,000	700,000	800,000
Check Dam Construction (1 dam)				250,000	320,000	500,000
Hillside Works (1 ha)					200,000	200,000
Terracing (1 ha)						60,000
Plantation (1 ha)	500,000	500,000	500,000	500,000	500,000	500,000

Rank 4

Drain Construction	1,662,000 Naira/km	5 km	8,310,000
Check Dam Construction	692,500 Naira/dam	3 dams	2,077,500
Plantation	1,385,000 Naira/ha	0.2 ha	277,000
Miscellaneous Works			1,066,450
Total (Naira)			11,730,950

Rank 5

Drain Construction	1,939,000	Naira/km	10 km	19,390,000
Check Dam Construction	886,400	Naira/dam	5 dams	4,432,000
Hillside Works	554,000	Naira/ha	10 ha	5,540,000
Plantation	1,385,000	Naira/ha	0.5 ha	692,500
Miscellaneous Works				3,005,450
Total (Naira)				33,059,950

Rank 6

Drain Construction	2,216,000	Naira/km	20 km	44,320,000
Check Dam Construction	1,385,000	Naira/m	8 dams	11,080,000
Hillside Works	554,000	Naira/m^3	20 ha	11,080,000
Terracing	166,200	Naira/km	20 ha	3,324,000
Plantation	1,385,000	naira/ha	1 ha	1,385,000
Miscellaneous Works				7,118,900
Total (Naira)				78,307,900

In addition to the above construction costs, the investigation costs for one gully erosion site should be provisioned as follows;

Rank 1	300,000	Naira
Rank 2	400,000	Naira
Rank 3	500,000	Naira
Rank 4	1,650,000	Naira
Rank 5	3,500,000	Naira
Rank 6	8,500,000	Naira

In order to estimate an order-of-magnitude cost for investigation and restoration of all the gullies in Nigeria, the total number of gully erosion sites in Nigeria has been assumed on the basis of Table 3 and other published information as follows;

	Total	Region					
		NW	NE	CW	CE	SW	SE
Rank 1	Numerous	-	-	-	-	-	-
Rank 2	350	5	5	10	50	60	230
Rank 3	350	-	10	10	40	40	250
Rank 4	300	-	5	-	35	40	220
Rank 5	30	-	-	-	-	-	30
Rank 6	15	-	-	-	-	-	15

Since the restoration and site investigation costs are minimal for Rank 1, it is assumed that these costs can be provided by the ordinary operating budget of each LGA and have been consequently excluded from the cost estimation. The results of the cost estimation are shown in table on the following page.

A total of about seven thousand six million Naira will be required to investigate and restore all the gully erosion sites in Nigeria.

Cost of the Nation-Wide Gully Erosion Control Work

Unit: Million Naira

	Site Number	Site Investigation		Restoration		Total Cost
		Unit Cost	Total	Unit Cost	Total	
NW Region						
Rank 2	5	0.400	2.0	0.716	3.6	5.6
NE Region						
Rank 2	5	0.400	2.0	0.716	3.6	87.1
Rank 3	10	0.500	5.0	1.908	9.5	
Rank 4	5	1.650	8.3	11.731	58.7	
Sub-total			15.3		71.8	
CW Region						
Rank 2	10	0.400	4.0	0.716	7.1	
Rank 3	10	0.500	5.0	1.968	19.1	
Sub-total			9.0		26.3	35.3
CE Region						
Rank 2	50	0.400	20.0	0.716	35.8	
Rank 3	40	0.500	20.0	1.908	76.3	
Rank 4	35	1.650	57.8	11.731	410.6	
Sub-total			97.8		522.7	620.5
SW Region						
Rank 2	50	0.400	20.0	0.716	35.8	
Rank 3	40	0.500	20.0	1.908	76.3	
Rank 4	40	1.650	66.0	11.731	469.2	
Sub-total			106.0		581.3	687.3
SE Region						
Rank 2	230	0.400	92.0	0.716	164.7	
Rank 3	250	0.500	125.0	1.908	477.0	
Rank 4	220	1.650	363.0	11.731	2,580.9	
Rank 5	30	3.500	105.0	33.060	991.8	
Rank 6	15	8.500	127.5	78.308	1,174.6	
Sub-total			812.5		5,358.9	6,171.4
Grand Total			1,042.6		6,564.6	7,607.2

Appendix 7C-2 includes details of civil engineering and agronomic techniques for gully erosion control works, and two examples of conceptual plans for Ishiamigbo Village and Aguru Lake gully erosion sites.

7C. 3. 2 Gully Erosion Protection Measures

(1) Gully Erosion Hazard Mapping

Since gully erosion is one of the most hazardous elements in Nigeria from a water resources conservation point of view, it is important to assess lands for susceptibility to gully erosion. There are a number of approaches to prepare a hazard map with respect to erosion. In this report, a gully erosion hazard map has been prepared (Water Resources Data-Base Map No.26) in accordance with the procedure as explained hereunder.

A SHA or SSHA is given one point each for (1) bareland ratio exceeding 10% (Fig. 4), (2) vegetated ground ratio less than 80% (Fig. 6), (3) inclusion of urban areas larger than five square kilometers (Fig. 7), (4) valley density exceeding 0.05 km/sq.km (Fig. 5), and (5) hilly terrains occupying more than 50% of the total area (Fig. 8).

With the above assessment, each SHA or SSHA is classed into six ranks having points ranging from 0 to 5 in increasing order of susceptibility to gully erosion. The susceptibility ranks are further adjusted taking account of geologic and rainfall conditions as follows;

1. Geological Conditions (NWRMP Data-Base Map No.12)
   - 1-1 SHAs or SSHAs, consisting mainly of Quaternary lacustrine deposits are rated at 0 point regardless of the points acquired in the above assessment.
   - 1-2 SHAs or SSHAs, consisting mainly of Quaternary marine deposits or Pre-cambrian basement rocks loose one point from the points acquired in the above assessment.
   - 1-3 SHAs or SSHAs, consisting mainly of Cretaceous or Tertiary sedimentary rocks hold the point acquired in the above assessment.
2. Rainfall Conditions (NWRMP Data-Base Map No.6)
   - 2-1 SHAs or SSHAs, or which annual rainfalls are less than 600 mm, are rated at 0 point regardless of the points acquired in the above assessment.

2-2 SHAs or SSHAs, of which annual rainfalls range between 600 and 1,200 mm, loose one point from the adjusted points taking account of the geologic conditions.

2-3 SHAs and SSHAs, of which annual rainfalls exceed 1,200 mm, hold the adjusted points taking account of the geologic conditions.

Some SHAs or SSHAs which may be rated at less than 0 as a result of the above adjustment, are rated at 0 point.

The six ranks from 0 to 5 points correspond to very high, high, medium high, medium low, low and very low resistances to gully erosion respectively in the Gully Erosion Hazard Map (Water Resources Data-Base Map No.26).

Some observations in the Hazard Map are summarized as follows;

1) The States of Anambra, Imo and Enugu are most susceptible to gully erosion and are actually being subjected to serious damage.
2) The South-West and Central-West Regions are susceptible to gully erosion but are free from actual damage at the present time. However, future development of these Regions must be made with great care for preventing gully erosion.
3) The Abuja FCT and the Central Plateau are rated at modest in their susceptibility to gully erosion. In fact, however, damage due to gully erosion is becoming serious in the vicinity of urban areas or in association with abandoned open-cast mining sites.
4) The State of Kogi belongs to a moderate-to-high susceptibility zone. Though the present state of damage appears to be modest, it may become serious unless appropriate care is taken of existing gully erosion sites.
5) The susceptibility in the vicinity of the Kainji Dam Reservoir is rated moderate. Since modest damage due to gully erosion is reported in association with infrastructure development, existing gully erosion sites should be carefully investigated and protected against future expansion.

(2) Inter-Government Coordination

As aforementioned (7C. 3.1), the FEPA is the federal agency with the full responsibility for the gully erosion control as a whole, and should take the initiative for the gully erosion protection measures. It is required for the FEPA to prepare, in cooperation with the FMWRRD, a nationwide program for preventing gully erosion on a regional scale by assessing regional susceptibility to gully erosion based on a gully erosion hazard map such as the NWRMP Data-Base Map No.26. The FDF should also take a part in the preparation of the program, because the plantation to restore bare lands is one of the major protection measures against gully erosion.

Although gully erosion is regionally hazardous, for example, causing floods by accumulating a considerable amount of sediments in river channels, immediate concern stays with local residents and hence with the State Government or LGAs, because of its disastrous nature for local infrastructure. It is urgently required for State Governments or LGAs to assess existing urban infrastructures, forested and agricultural lands and residential areas for their susceptibility to gully erosion, and to prepare appropriate plans for preventative works under instruction and supervision of the FEPA. Execution of the preventative works is the responsibility of the State Governments or the LGAs concerned but may be commissioned to RBDAs or contracted to private consultants and/or contractors depending upon the nature of the works.

It is also necessary to establish standards and codes for rural and urban development work with a provision for gully erosion prevention. The FEPA should take the initiative for preparing the standards and codes in cooperation with the federal ministries or agencies such as the FMWRRD, the FMWH, the FDA, the and so forth.

On-going and planned construction works for rural and urban development should be reviewed and reassessed with respect to the gully erosion protection measures by the FEPA in line with the standards and codes established as above. It is necessary to establish a legislative authority in order to enforce the FEPA's recommendation to executing agencies of the construction works.

(3) Forecasting and Warning Systems

Rainfall forecast is essential to cope with disaster in association with gully erosion sites due to heavy rainfall runoff. Local change in rainfall intensity within a short time is very critical for this purpose. Therefore, in addition to the regional meteorological stations, rainfall recorders should be located at appropriate intervals, particularly where active gullies exist. It is desirable that the rainfall records be transmitted to the district meteorological station concerned and to nearby LGAs on a real time basis. The meteorological station prepares or revises the local weather forecast according to received records and informs it to the LGAs. The LGAs, upon receipt of the latest weather forecast or with their own decision based on the records from the nearby recorders, issue warnings to local communities concerned with gully disasters. An information networks system of this kind is a fundamental requirement for protection against gully disaster. It is also necessary for LGAs to monitor all the active gullies at all times in order to cope with states of emergency without delay. Monitoring gullies will provide useful information with respect to forecasting landslides associated with gullies. Landslides occur instantaneously due to not only heavy rainfall but also cumulative rainfall during the wet season, and often cause more disastrous damage.

Local communities should appropriately respond to warnings issued by LGAs without delay. For this purpose, it is effective to organize disaster protection units comprising local residents under supervision of LGAs. LGAs should supply the protection units with necessary materials such as sand bags, timbers, waterproof sheets, scoops, hand-held radios and others. Periodic patrolling of gully erosion sites is the responsibility of the protection units to identify damage to erosion control facilities.

(4) Education ad Campaign Program

Many international organizations are implementing plantation or vegetation restoration projects in many countries in Asia and Africa to prevent losses of tropical rain forests or desertification. Many successful projects have been attributed to participation and cooperation by local residents. On the other hand, major reasons for unsuccessful projects are reportedly reluctance and ignorance of local residents or conflict of interest among them. Therefore, roles of local residents are essential factors for the success of environmental conservation projects and their education for environmental conservation is important.

At the present time in Nigeria, anti-erosion campaigns are carried out in many states mainly under the initiative of stages governments. For example, a campaign with a slogan "No Cut, No Excavate" is now under way in the State of Imo taking advantage of mass media such as TV and radio. Another example is the "No Burning Campaign" which is led by Abuja Environmental Conservation Office. However, all the movements are still in their infancy and are yet to spread through local residents. Many state governments in the South-East Region have produced video tapes demonstrating fears of gully erosion and necessity of its prevention, and are broadcasting them on TV. The video tapes are also rented out to schools and to the community as education material. Influence of TV is highly appreciated and many state governments have plans to produce anti-erosion campaign programs. Campaigns of this kind should be expanded and continued with leadership by state governments. Educational leaflets or posters which advocate the importance of gully erosion protection and proper land uses should be prepared and distributed. It will be effective to intensity the campaign just before the wet season.

According to the replies to the questionnaires by the resident of the State of Anambra (Tables 5.1 and 5.2), many are aware that the environment has become worse than ever and that investment is necessary to protect lands against erosion. They also attribute causes of gully erosion to insufficient professional advises, inadequate laws and regulations, and negligence of rules by residents. Therefore, it is very important to educate and instruct local resident so as to fully realize necessity of their cooperation for erosion control and for environmental conservation in general.

(5) Plan Implementation Program

Preparation of laws and regulations as well as establishment of a clear institutional framework is fundamental for promoting nation-wide environmental conservation activities including erosion control. It is necessary to review all the laws and regulation for construction of regional and urban infrastructures, land uses, resources development and any other activities concerned with land development, from an environmental conservation point of view. It is also essential to clarify roles and responsibilities of federal departments and institutes, state governments, LGAs, PBDAs and other agencies concerned. FEPA is, as aforementioned (Para. 7C. 3.1(1)), in principle responsible for gully erosion control in terms of civil engineering works. In reality, however, most gully erosion control works and post-control maintenance are left with responsibilities of state governments or LGAs. It is impossible to allocate adequate funds for gully erosion control works and post-contorl maintenance without the clarification of the roles and the responsibilities of the various governmental institutions and agencies.

The following measures should be implemented as early as possible;

1. Establish regulatory standards and codes for construction of regional and urban infrastructures, and development of land and resources.
2. Establish design standards and codes for construction of regional and urban infrastructures and development of land and resources, in accordance with terrain and climatic characteristics such as catchment areas, slope gradient, top soil nature rainfall intensity and so forth.
3. Establish design standards and codes for erosion control works, in accordance with civil engineering parameters and the same terrain and climatic characteristics as for the above item 2.

The above standards and codes should be prepared by relevant federal departments or institutes. FEPA is responsible for the item 3, particular.

In addition,

4. Prepare hazard maps
   - 4-1 Nation-wide hazard map at a scale of 1 to 1,000,000 by refining or revising the 'Gully Erosion Hazard Map' included in NWRMP.
   - 4-2 Large scale hazard maps at a scale of 1 to 250,000 for the States in the Central-East, the South-East and the South-West Regions.
5. Investigate and characterize existing gullies in details taking account of terrain and climatic characteristics, in priority order of urgency.

6. Review all the existing and proposed gully erosion control works for their design, taking account of terrain and climatic characteristics.
7. Plan and design erosion control works according to the results of the above item 5 and 6, in priority order of urgency.
8. Monitor existing gullies by periodic surveying.
9. Organize disaster protection units comprising local residents.
10. Install rainfall recorders at appropriate intervals and establish information network systems of short-term local weather forecast.
11. Make all the past weather records publicly available.

For the above eight items, involvement of state governments, LGAs and RBDAs are required.

It may be worthwhile to try a thorough erosion control works, including site investigation and characterization, plan and design, construction and installation of facilities, and monitoring for a selected gully erosion site in order to train civil engineers and to make them deeply understand gully erosion control works.

TABLE 7-1 SOIL EROSION ON HA BASIS (Fig. 3)

EROSION TYPE	HA-I sq. km (%)	HA-II sq. km (%)	HA-III sq. km (%)	HA-IV sq. km (%)	HA-V sq. km (%)	HA-VI sq. km (%)	HA-VII sq. km (%)	HA-VIII sq. km (%)	TOTAL sq. km (%)
SLIGHT SHEET EROSION	1,520 (1.2)	11,870 (7.5)	8,070 (5.1)	2,440 (3.3)	1,100 (2.1)	0 (0)	5,840 (9.8)	8,640 (4.6)	39,470 (4.3)
MODERATE SHEET EROSION	3,510 (2.7)	210 (0.1)	1,760 (1.1)	15,720 (21.5)	16,240 (30.1)	17,720 (17.6)	23,940 (40.0)	3,350 (1.8)	82,450 (8.9)
SEVERE SHEET EROSION	0 (0)	870 (0.6)	22,510 (14.2)	10,080 (13.8)	15,070 (28.0)	12,190 (12.1)	26,530 (44.4)	7,960 (4.2)	95,210 (10.3)
SLIGHT GULLY EROSION	470 (0.4)	11,580 (7.3)	0 (0)	0 (0)	0 (0)	3,630 (3.6)	0 (0)	0 (0)	15,680 (1.7)
MODERATE GULLY EROSION	2,840 (2.2)	7,800 (4.9)	5,340 (3.4)	1,580 (2.2)	3,730 (6.9)	4,320 (4.3)	0 (0)	1,160 (0.6)	26,779 (2.9)
SEVERE GULLY EROSION	0 (0)	0 (0)	0 (0)	0 (0)	340 (0.6)	0 (0)	850 (1.4)	0 (0)	1,190 (0.1)
SLIGHT WIND EROSION	5,810 (4.4)	5,300 (3.4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	11,110 (1.2)
SEVERE WIND EROSION	16,530 (12.6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	53,630 (28.5)	70,160 (7.6)
EROSION UNSPECIFIED	0 (0)	0 (0)	6,240 (3.9)	1,150 (1.6)	0 (0)	0 (0)	0 (0)	0 (0)	7,390 (0.8)
COASTAL EROSION	0 (0)	0 (0)	0 (0)	0 (0)	14,570 (27.0)	7,290 (7.3)	2,160 (3.6)	0 (0)	24,020 (2.6)
TOTAL	3,680 (23.5)	37,630 (23.8)	43,920 (27.6)	30,970 (42.4)	51,050 (94.7)	45,150 (44.9)	59,320 (99.2)	74,730 (39.8)	373,450 (40.4)
NON EROSION AREA	100,920 (76.5)	120,470 (76.2)	114,980 (72.4)	42,030 (57.6)	2,850 (5.3)	55,350 (55.1)	480 (0.8)	113,270 (60.2)	550,350 (59.6)
AREA TOTAL	131,600 (100.00)	158,100 (100.00)	158,900 (100.00)	73,000 (100.00)	53,900 (100.00)	100,500 (100.00)	59,800 (100.00)	188,000 (100.00)	923,800 (100.00)

TABLE 7-2 REGIONAL DISTRIBUTION OF BARELAND BY SATELLITE IMAGE ANALYSIS

Hydrogical Area	-A- Bareland (sq. km)	Percentage to Total Bareland, A/Total A (R)	-B- Total Area (sq. km)	Percentage of Bareland to Area of HA, A/B (%)
I	10,330	13.0	131,600	7.9
II	2,065	2.6	158,100	1.3
III	21,615	27.3	158,900	13.6
IV	3,230	4.1	73,000	4.4
V	7,955	10.1	53,000	14.8
VI	900	1.1	100,500	0.9
VII	5,405	6.8	59,800	9.0
VIII	27,700	35.0	188,000	14.7
Total	79,200	100.0	923,800	8.6

TABLE 7-3 LAND DEGRADATION STATUS ON STATE BASIS

	Gully Erosion		Sheet Erosion		Wind Erosion		Coastal Erosion		Deforestation	
	No. of erosion sites	Area (ha)	No. of erosion sites	Area (ha)	No. of erosion sites	Area (ha)	No. of erosion sites	Area (ha)	No. of erosion sites	Area (ha)
North-West Region										
Kebbi 'Sokoto' katsinn	no document									
North-East Region										
Knno 'Jigowa' Borho	8 zones				8 zones					
Yobe	18				1	50				
Bauch	27									
Central West Region										
Niger 'Kwara' Kuduna	no document									
Kogi	9	3.03								
Abuja FCT	14									
Central East Region										
Adamnga	36		16		3	220	3			
Taraba	22	57.65	18	21.52						
Plateau 'Benue'	12		2							
South-West Region										
Oyo		12		0.75						6
Ogun		6.7		0.35				0.15		8.5
Osun		15		1.70						2
Lagos								16		1.3
Ondo		13.5		1.60				5		9.75
Edo		15	1	2						9.25
Delta		60	53	20				20		8.05
South-East Region										
Anambra	92	172.40		2.42						
Imo	41	46.63		56.33						
Rivers	no document									
Enugu	2	2.59								
Abia	207	200.14	12	11.26						
Akwa Ibon	88	333.37	16	248						
Cross River	52	65.67					17	21.62		

TABLE 7-4-1 EXISTING EROSION CONTROL PROJECTS ON STATE BASIS (1)

State	Engineering	Agronomy	Engin/Agro	Unknown	Total
North-West Region					
Kebbi				1	1
Sokoto				1	1
Subtotal				2	2
North-East Region					
Yobe	7				7
Bauchi			2		2
Subtotal	7		2		9
Central West Region					
Niger				1	1
Kwara		1			1
Kaduna	1		4		5
Kogi	10				10
Subtotal	11	1	4	1	17
Central East Region					
Adamawa	1	6	4	1	12
Taraba	1	4		1	6
Subtotal	2	10	4	2	18
South-West Region					
Oyo	1				1
Osun	5			1	6
Ondo	3				3
Edo			2	2	4
Subtotal	9		2	3	14
South-East Region					
Anambra	2		1		3
Imo	18		3		21
Rives	33		9		42
Enugu	4				4
Abia	1		4		5
Akkwa Ibon	7				7
Cross River	8				8
Subtotal	73		17		80
Total	102	11	29	8	150

TABLE 7-4-2 PROPOSED EROSION CONTROL PROJECTS ON STATE BASIS (2)

State	Engineering	Agronomy	Engin/Agro	Unknown	Total
North-West Region					
Kebbi				1	1
Sokoto				1	1
Subtotal				2	2
North-East Region					
Yobe	1		2		3
Bauchi			2		2
Subtotal	1		4		5
Central West Region					
Niger				1	1
Kwara		1			1
Kaduna	1		4		5
Kogi	4				4
Subtotal	5	1	4	1	11
Central East Region					
Adamawa		2	8		10
Taraba	1	2	5	1	9
Subtotal	1	4	13	1	19
South-West Region					
Ogun	5				5
Osun	7				7
Edo				5	5
Abia	4				4
Subtotal	16			5	21
South-East Region					
Anambra	8				8
Imo	4				4
Rives	5				5
Enugu	1				1
Subtotal	18				18
Total	41	5	21	9	76

TABLE 7-5-1 QUESTIONNAIRE (1)

Adverse Effects of Erosion in Anambra State							
ITEMS		SITUATION BEFORE EROSION			SITUATION BEFORE EROSION		
		Good	Fair	Bad	Good	Fair	Bad
(a)	Amount of land available for use	71	18	5	15	43	40
(b)	Housing and residential areas	68	13	4	23	34	37
(c)	Roads and footpaths	57	25	5	2	22	73
(d)	Bridges and culverts	41	24	4	6	24	47
(e)	Transport	59	22	6	-	21	76
(f)	Crop farming	67	21	2	7	52	28
(g)	Livestock and livestock farming	59	15	2	12	33	20
(h)	Water supply	67	13	10	18	26	32
(i)	Availability of fuelwood	46	16	3	17	28	36
(j)	Wildlife	48	20	2	9	25	38
(k)	Availability of bushmeat	57	24	5	9	24	42
(l)	Loss of human lives	52	18	4	29	22	17
(m)	Migration of people	54	10	5	35	13	16
(n)	Other public infrastructure	54	17	4	23	29	40
(o)	Bushes and forests	58	9	3	15	30	30
(p)	Other income-earning activities	54	14	2	13	31	27
(q)	Other social activities	39	22	2	6	31	28
(r)	Expenditure on erosion control	33	31	4	5	18	49
(s)	Other negative effects	13	10	1	1	12	12
Average		52.5	18	3.8	12.9	27.3	36.3

Quotation from "The Raging WARI"

[The Government of Anambia State: 1993]

TABLE 7-5-2 QUESTIONNAIRE (1)

Relative Importance of Factors Constraining Erosion Control Efforts in Anambra State			
Problem		Number of Persons Mentioning Problem	Percentage of Total Mentions
(a)	Lack of Financial and other resources	17	18.7
(b)	Lack of expertise and expert advice	15	16.5
(c)	Negligence of refusal by individuals to abide by community rules on erosion control. Lack of agreement by members of the community on what is to be done.	14	18.7
(d)	Lack of Seriousness by communities in enforcing local regulations in erosion control.	11	12.1
(e)	Lack of equipment for erosion control work.	9	9.9
(f)	Failure by some communities to institute erosion control measures thereby jeopardizing the erosion control efforts of neighboring communities.	7	7.7
(g)	General lack of drainage facilities in the communities making erosion control more difficult.	6	6.6
(h)	Lack of, or inadequate, assistance from Government.	6	6.6
(i)	Ill-planned road and other construction works which either block the natural water-ways or do not make provisions for drainage.	3	3.3
(j)	Inadequate supply of planting materials for erosion control. Use of some of the plants for other purposes.	3	3.3

Quotation from "The Raging WARI"

[The Government of Anambia State: 1993]

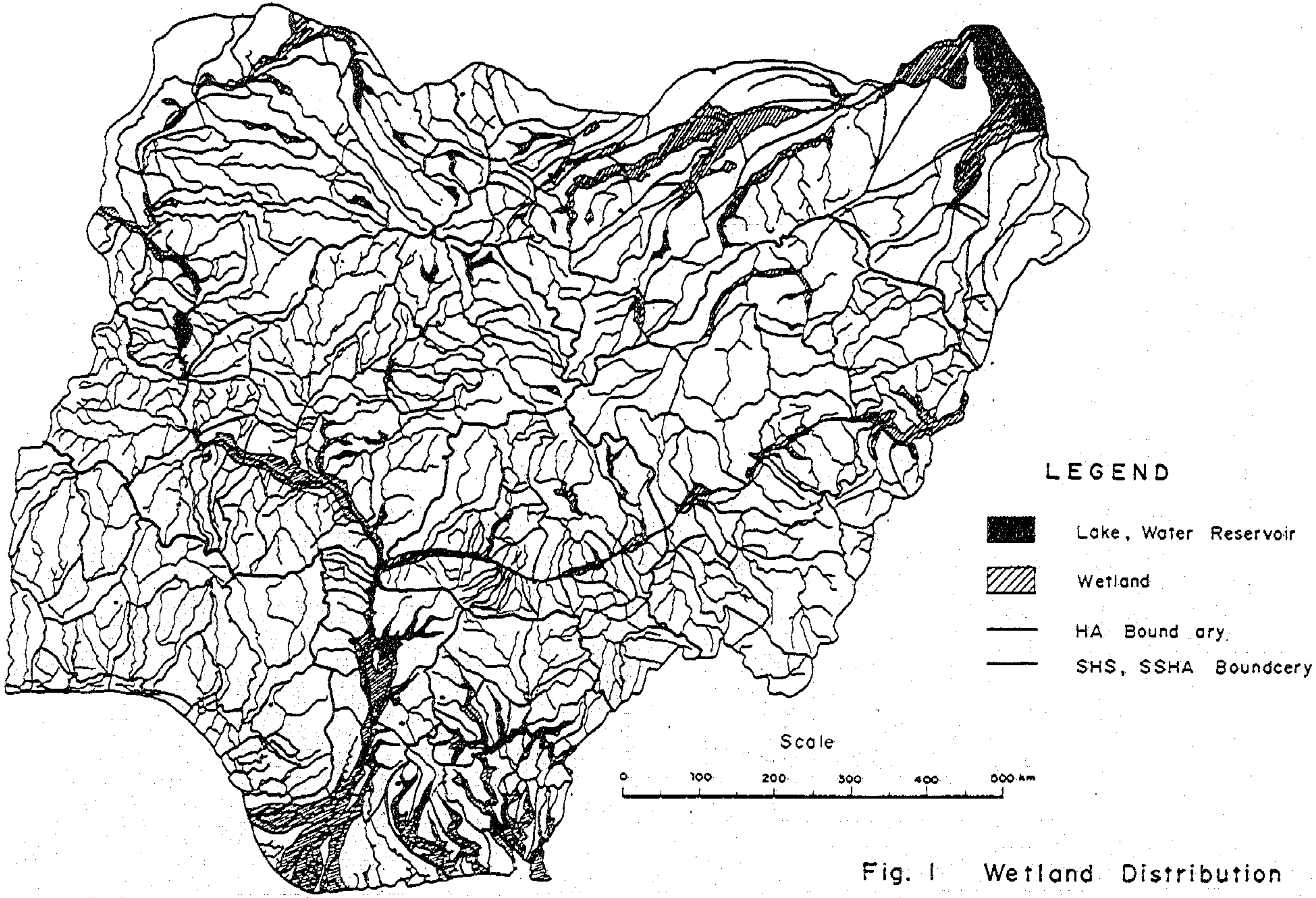


Fig. I Wetland Distribution

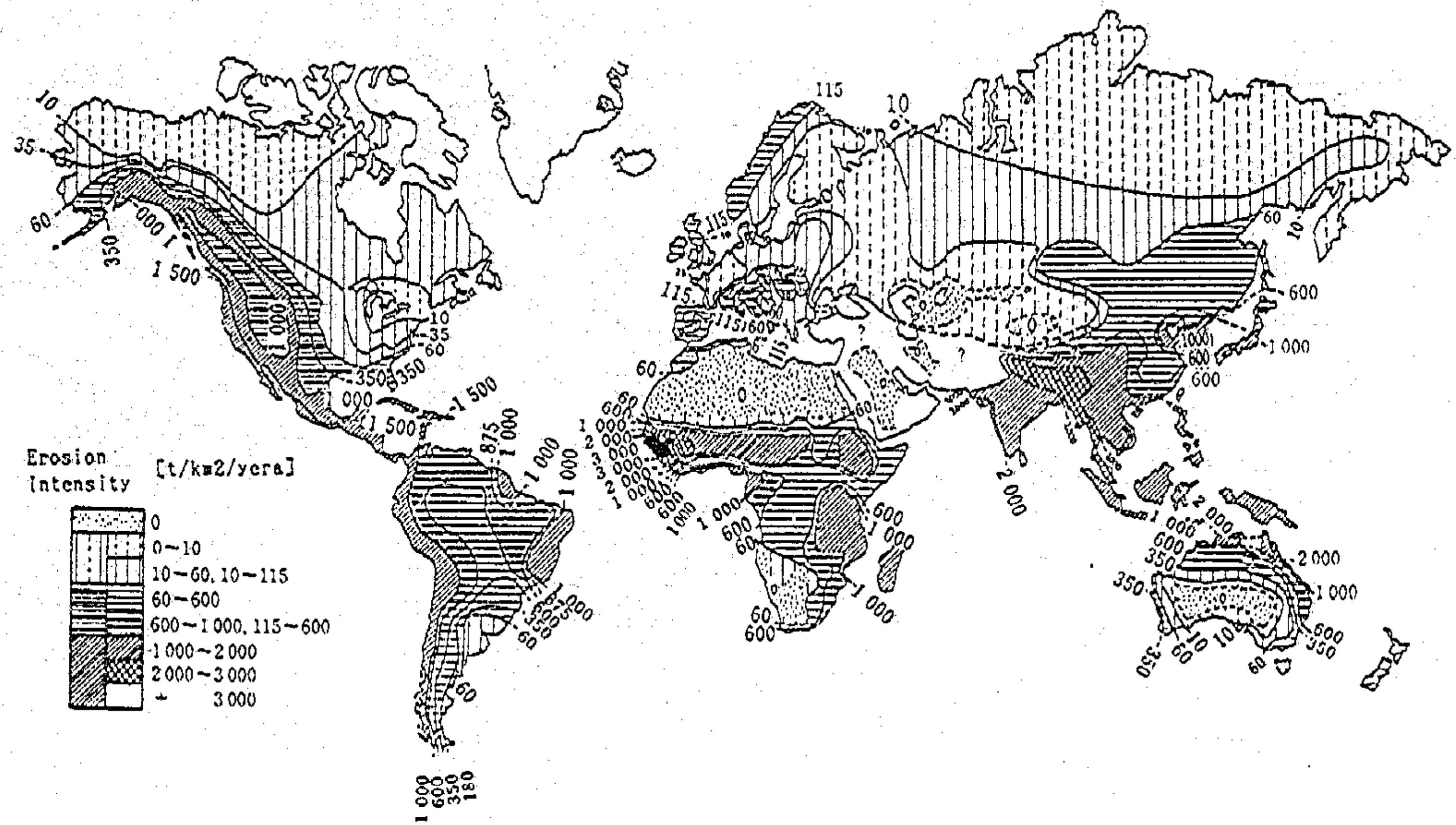


FIGURE-2 WATER EROSION INTENSITY IN THE WORLD

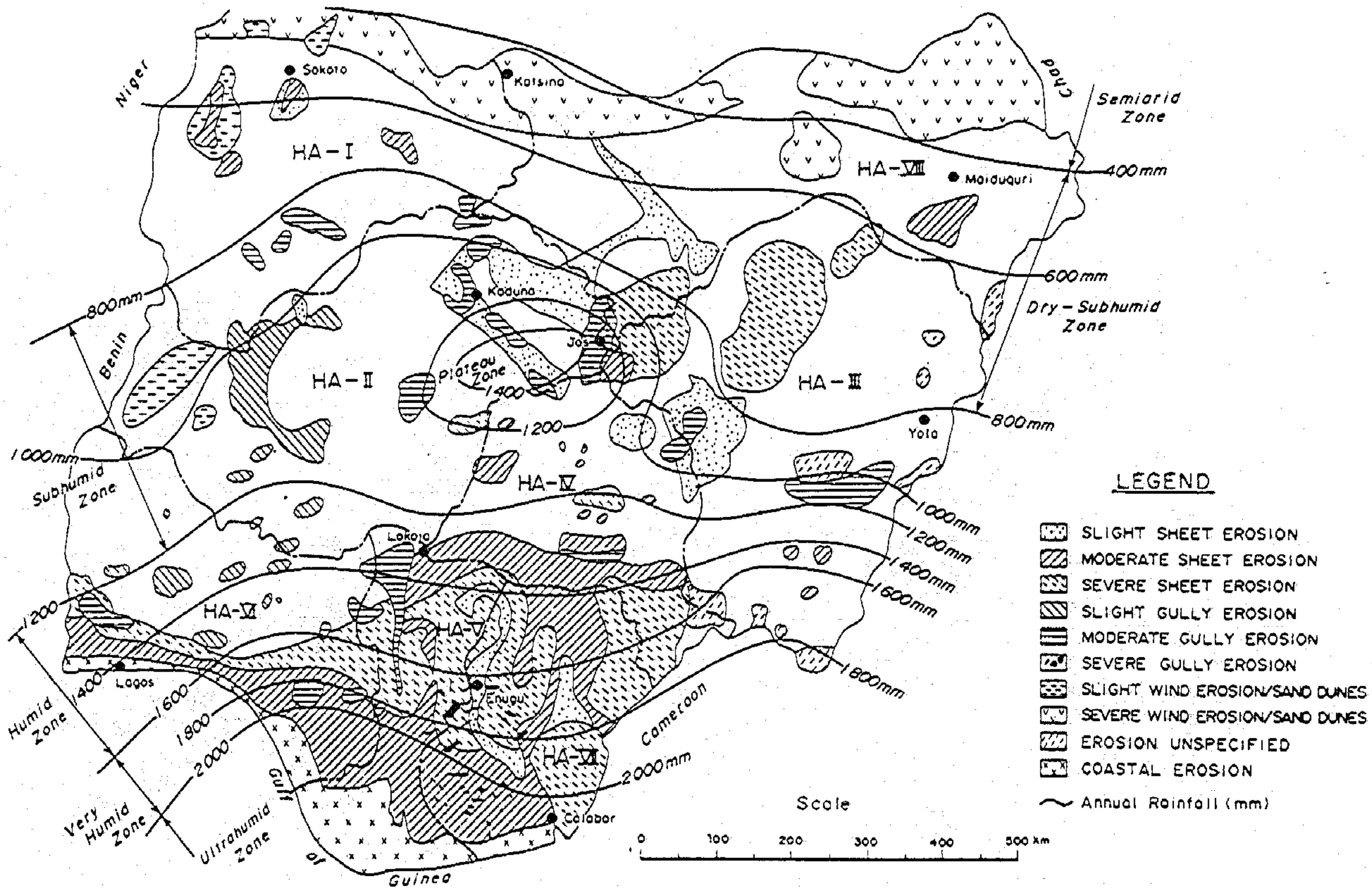


Fig. 3 Erosion Distributron and Climatic Zones

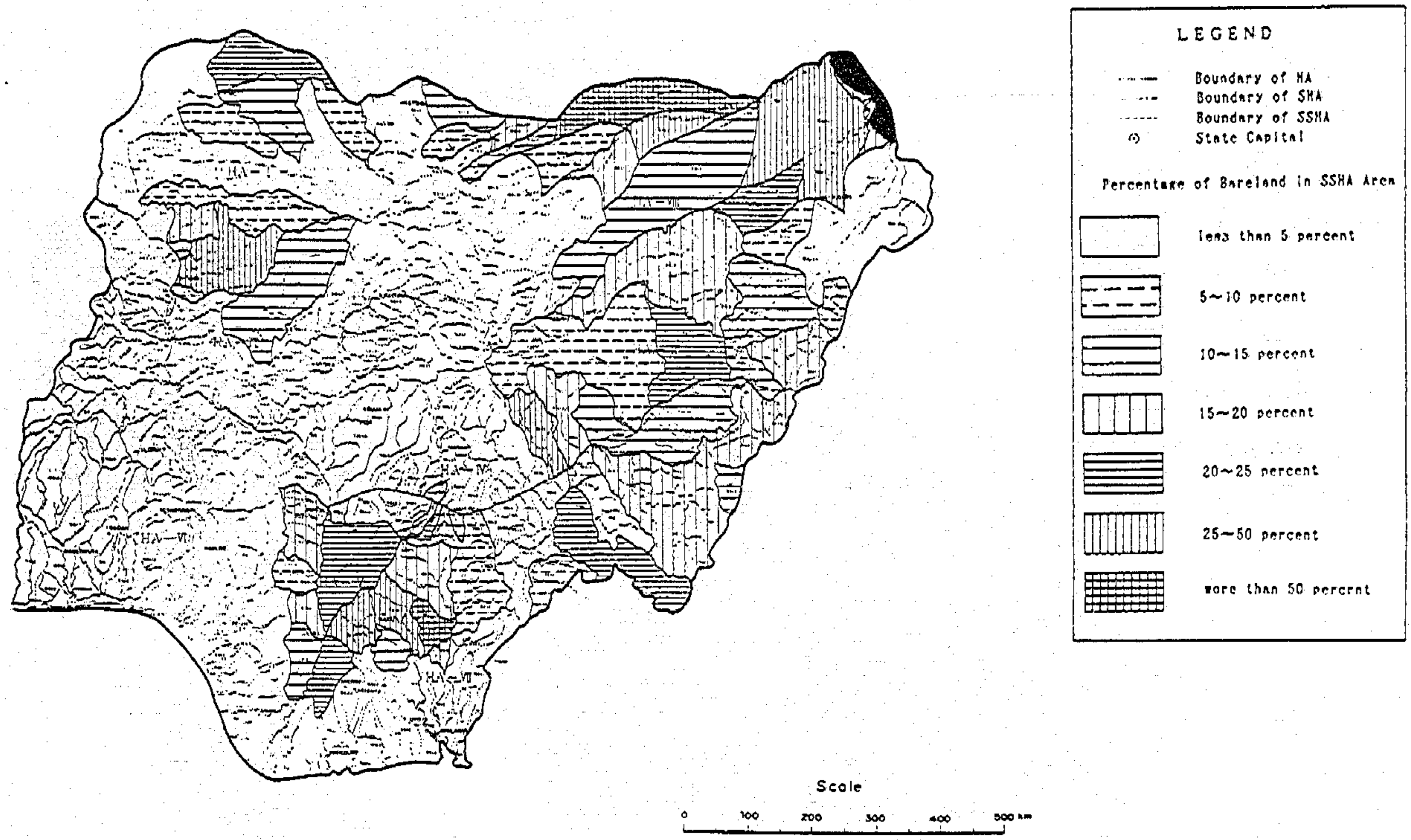


FIGURE - 4 BARELAND DISTRIBUTION

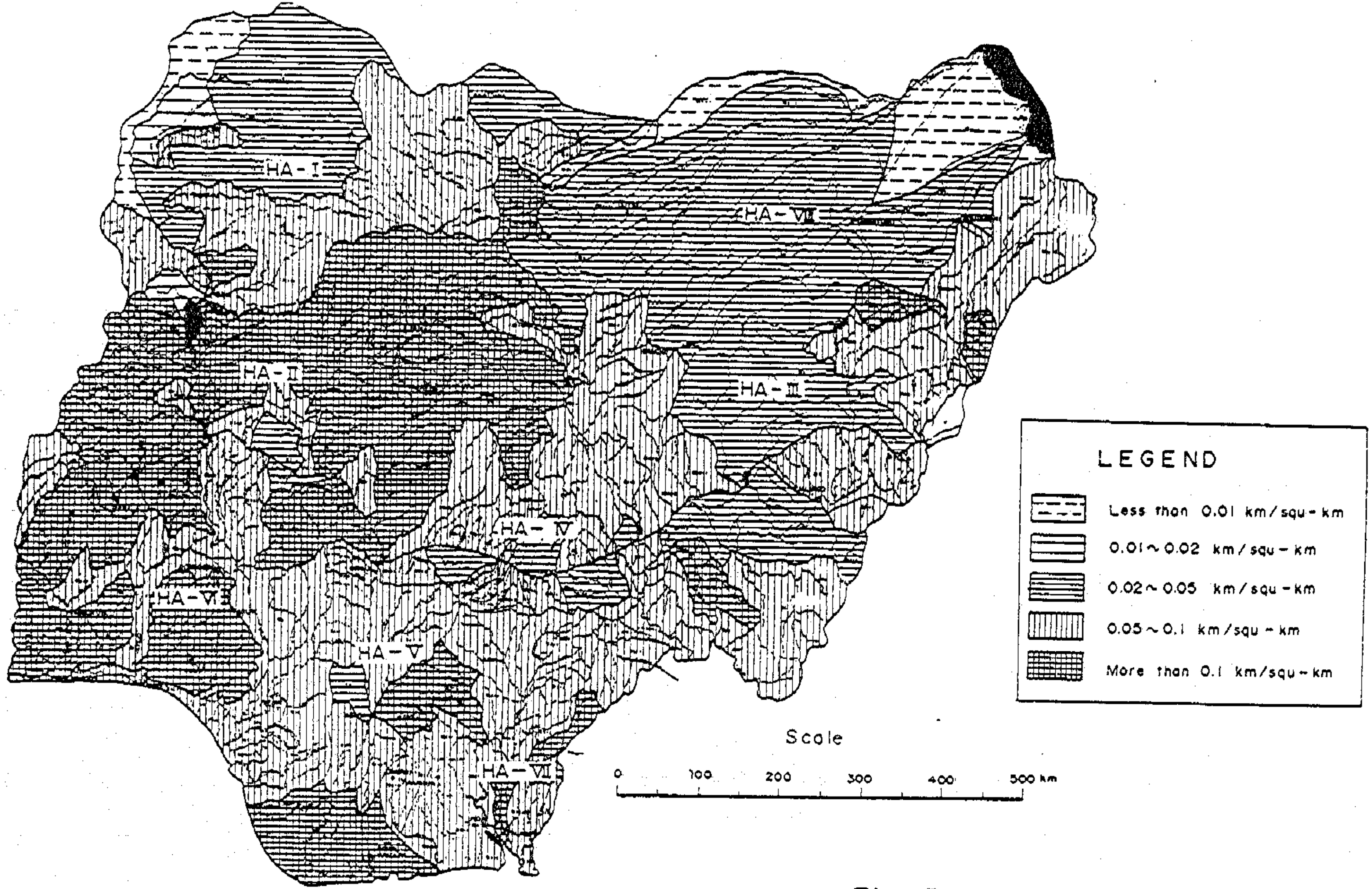


Fig. 5 River Density

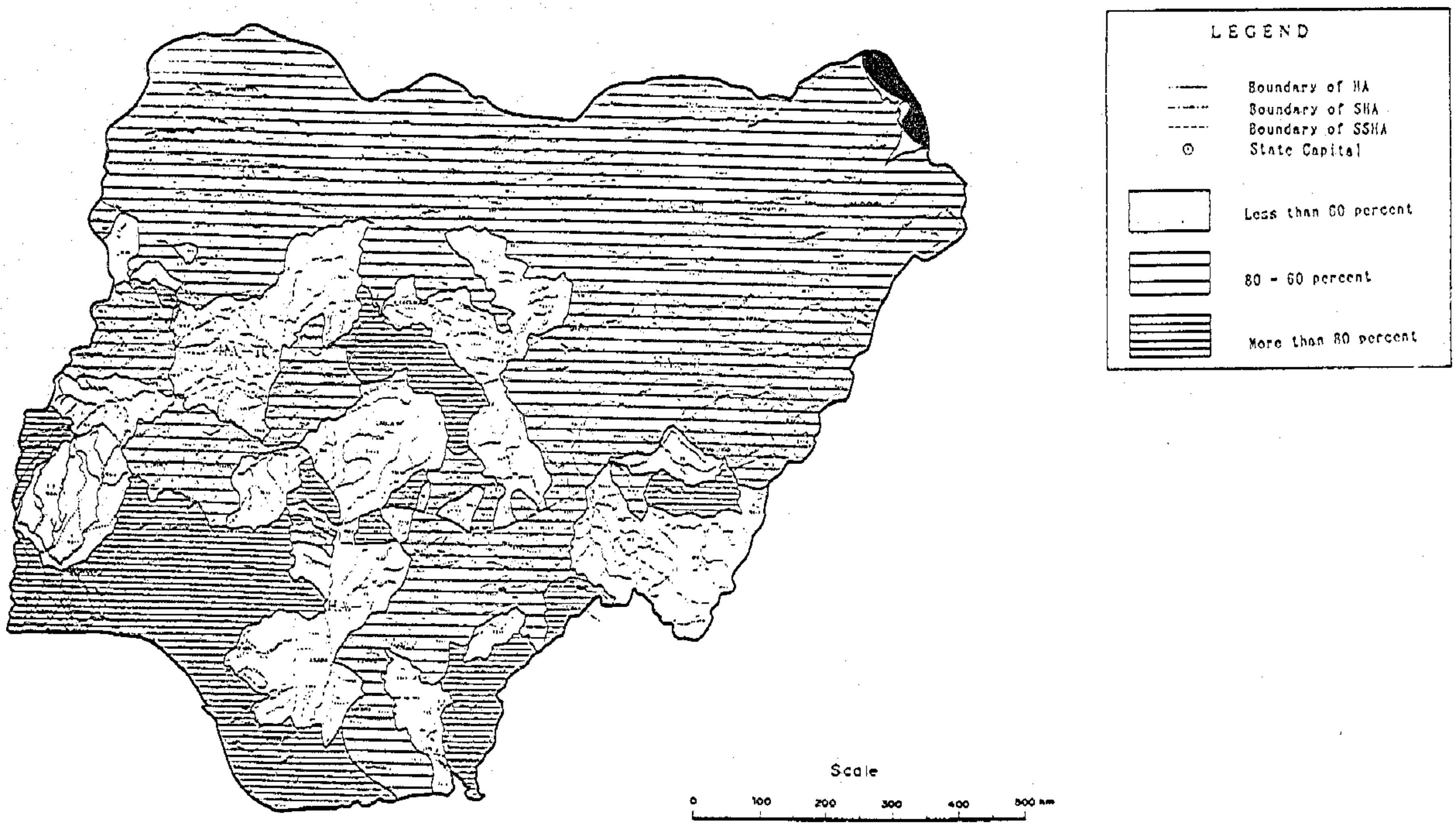


FIGURE-6 Vegetated Ground Ratio

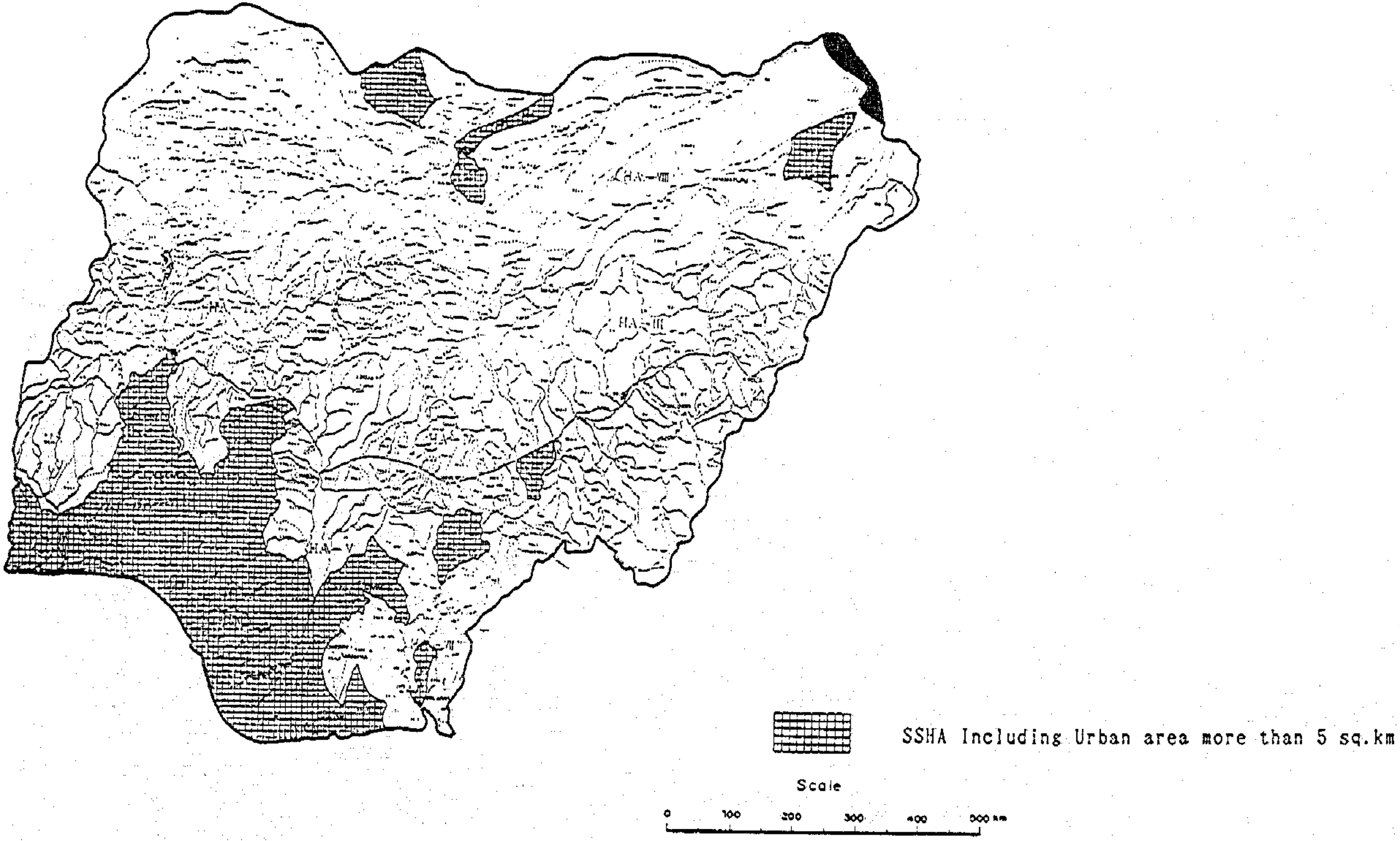


FIGURE - 7 URBAN AREA DISTRIBUTION

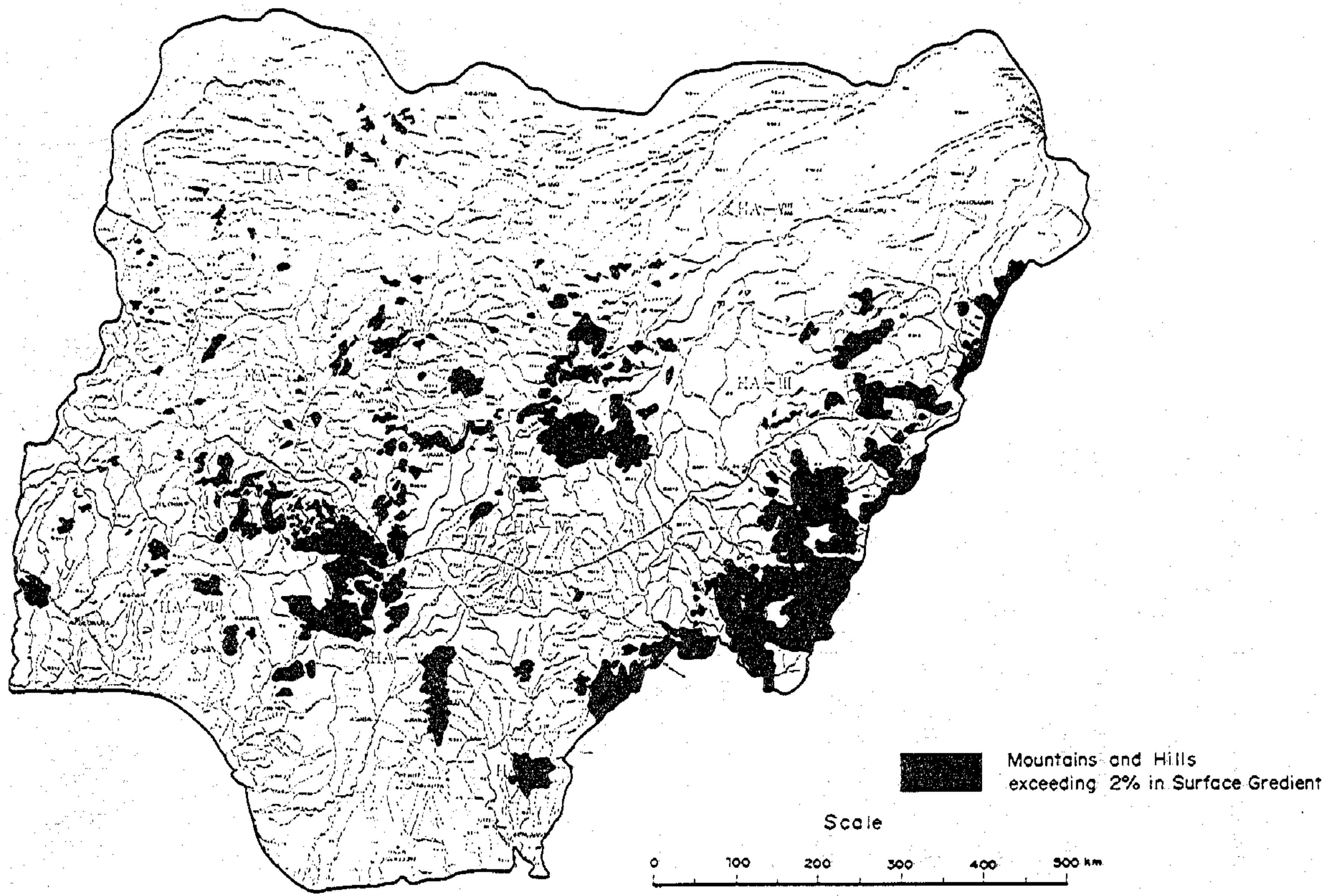


FIGURE- 8 DISTRIBUTION MAP OF MOUNTAINS AND HILLS

Appendix 7A-1 River Control Works

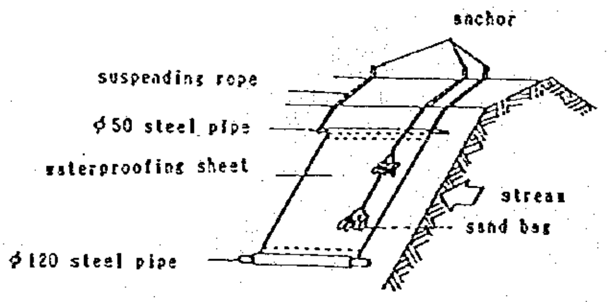
(1) Simple Bank Protection Work Method

Simple bank protection and grayne works are applied to temporarily prevent bank erosion and scouring at its early stage.

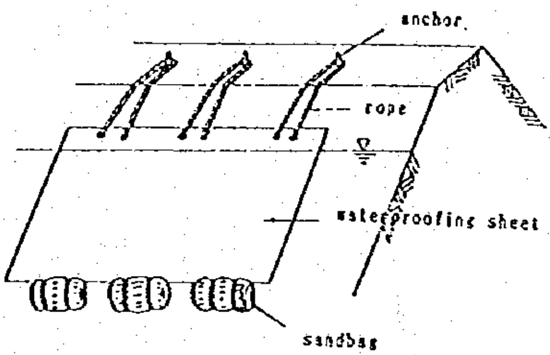
(a) Bank Protection Works

(i) Sheeting Work

The work is to directly cover banks using water-proof fiber reinforced sheets as shown in Figures below.



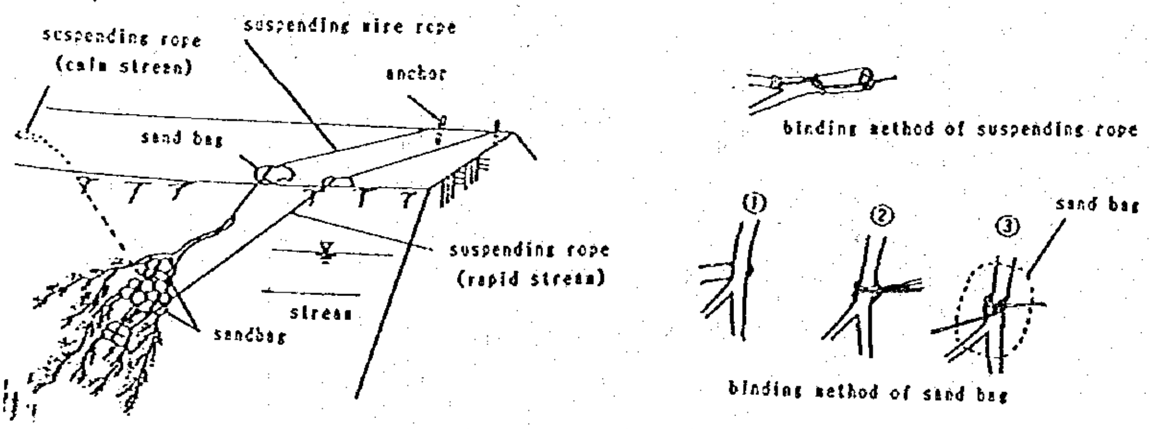
Sheeting Work 1



Sheeting Work 2

(ii) Bamboo Bundle or Foliage Flow Control Work

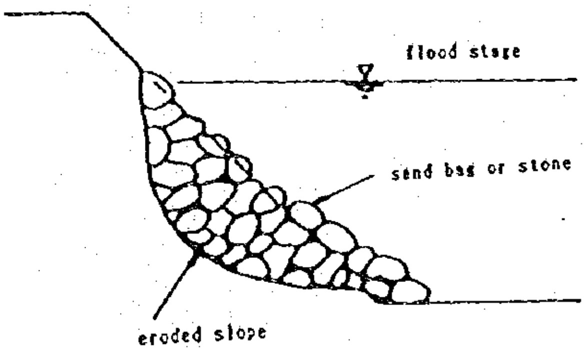
The work is to reduce current velocity of rapid streams hanging foliages with weights such as sand bags along the stream banks. When the steam current is extremely rapid, bundles of bamboo are used in steadied of trees.



Tree Flowing Method

(iii) Sand Bagging

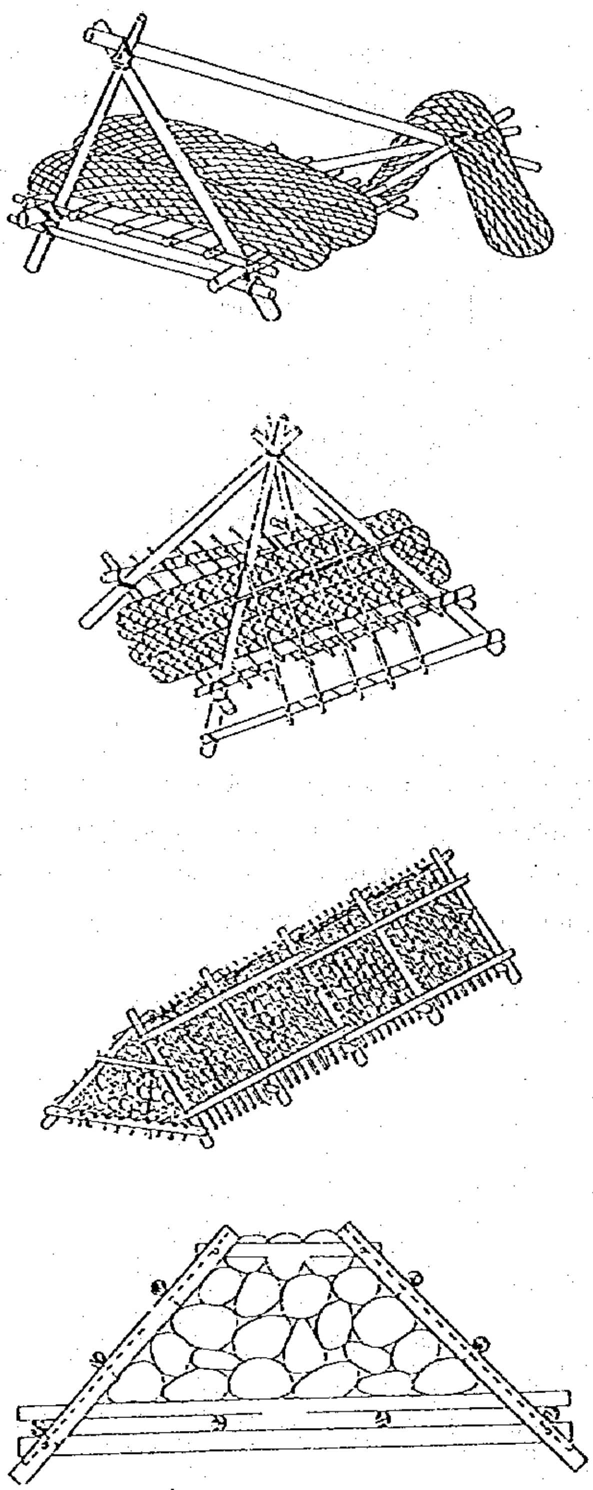
The work is to fill eroded banks with sand bags, boulders concrete blokes or other heavy materials for preventing the banks against further erosion.



Sand Bag Method

(b) Groyne Works

The work is to place crates or wooden frames as shown in the following Figures, on stream bottom for protecting streams against erosion due to riverbed evolution by reducing stream velocity or changing stream courses. Reinforced concrete is often substituted, particularly when a semipermanent groyne is required.



Examples of Wooden Frames

Appendix 7C-1 Countermeasures Against Gully Erosion

(1) Design of Drainage System

(a) Rainfall Intensity

It is not the total annual rainfall but the maximum rainfall intensity at a peak period that is more critical for design of a drainage system. Even if the peak period is short, the drainage system must have a sufficient capacity to discharge all the rainfall in the period. A probable rainfall intensity is used for design of a drainage system and is obtained by statistical processing of maximum rainfalls for durations of 5, 10, 20, 30, 40, 60, 80 and 120 minutes which have been collected through years of meteorological observation. Estimation of a probable rainfall intensity involves rather complicated statistical calculation and requires a large number of rainfall data. It is said that the meteorological station of each district in Nigeria has been collecting such rainfall data for a number of years and is now estimating probable rainfall intensities for future publication.

(b) Concentration Time

Concentration time (t) is the sum of inlet time (t_1) and flow time (t_2).

1. Inlet Time

Inlet time is time taken for rain water to flow from the farthest point of the relevant catchment area to drain. Standard inlet times for different conditions, modified from the standards of American Civil Engineering Society, are shown in the table below.

Area which has adequate drainage	5	minutes
Low density of inhabitation	10-15	minutes
Low density of inhabitation, bareland and farming land on gentle slopes	20-30	minutes
Grass land on gentle slopes	30-40	minutes
Forest area	30-60	minutes

However, Kerby Formula should be adopted to determine an inlet time in case that slope gradient exceeds 10%.

t_1 = $1.44 (\ell \times n / \sqrt{s})^{0.467}$ (Kerby Formula)

t_1; Inlet time (minute)

ℓ; Distance between drains and the farthest point of the relevant catchment area (m)

s; Slope gradient

n; Coefficient of retardation as shown in the Table below

Paved Surfaces	0.02
Bareland (compacted)	0.10
Bareland, Farming land	0.20
Grass land, Pasture	0.40
Forest	0.80

(c) Flow Time

Flow time is time taken for rain water to flow through drains to a planned site, and is estimated according to the following equation.

t_2 = ℓ / v

ℓ; Drain Length (m)

v; Mean Velocity (m/s)

Since a mean velocity is dependent on runoff rate, correction has to be made after run-off rate is calculated. In a usual procedure, the initial calculation is made assuming a mean velocity at 1.2 m/s.

(d) Runoff Rate

Run-off rate is calculated according to the rational formulas as follows;

Q = $Ci \times In \times A / 360$

In; Rainfall Intensity (mm/hr)

Ci; Run-off Coefficient

A; Catchment area (ha)

Q; Runoff (m^3/sec)

Run-off rate is defined as the maximum rate when the rainfall in the entire catchment area is collected at a planned site. Run-off reduction by infiltration, evaporation and stagnation is taken account of by run-off coefficient.

(e) Run-off Coefficient

Run-off coefficients for various land uses are shown in the Table below.

Inhabited area	0.70 - 0.95
Road Bareland (compacted)	0.50 - 0.90
Bareland, Farming land	0.40 - 0.80
Grassland, Pasture	0.30 - 0.50
Forest	0.10 - 0.20

When the catchment area comprise two or more land uses a weighted mean is estimated in proportion to an area of each land use.

(f) Mean Velocity

A mean velocity is calculated according to the Mannings Formula as follows:

$v = R^{2/3} \times i^{1/2} / n$

v; Mean velocity (m/sec)

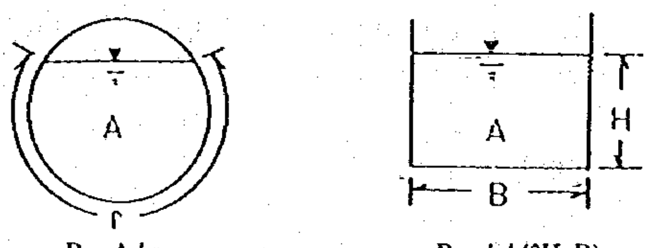
n; Roughness Coefficient ($sec/m^{1/3}$) as shown in the Table below.

R; Hydraulic Radius (m) as shown in the Figure below.

i; Surface Slope (Cannel gradient)

Roughness Coefficient

Steel pipe	0.010 - 0.017
Mortar	0.011 - 0.014
Concrete	0.010 - 0.020
Soil	0.016 - 0.033
Rock	0.025 - 0.050

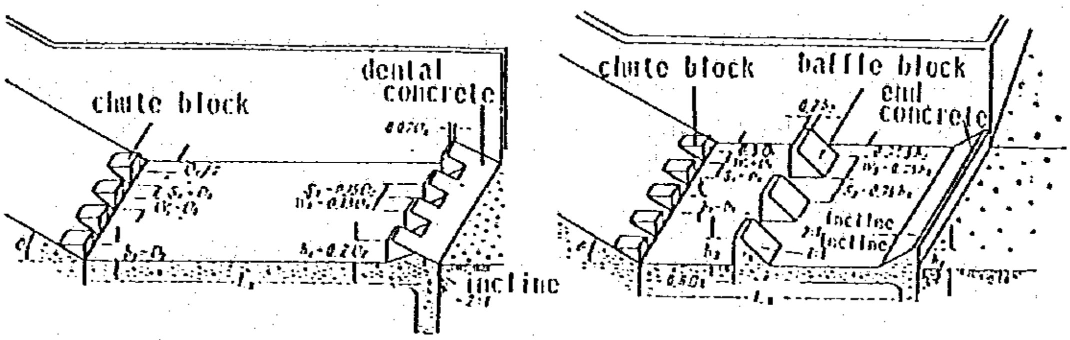


Hydraulic Radius

A desirable mean velocity (v) for a concrete drain ranges between 0.6 and 3 m/sec. Therefore, it is advisable to design a drain with a realistic hydraulic radius and length, so that the mean velocity calculated using the Manning Formula falls within this range. If the calculated mean velocity is significantly different from the assumed mean velocity (t_2) for the flow time estimation, re-estimation of the flow time, accordingly of the concentration time ($t_1 + t_2$), is made using the calculated mean velocity. Then, based on the estimated concentration time, a probable rainfall intensity (IN) and a runoff rate (Q) are re-calculated. If the recalculated run-off rate is within and close enough to the design capacity of the drain, the drain design is considered appropriate. Otherwise, it is necessary to redesign the drain and to repeat the above procedure until a satisfactory result is obtained.

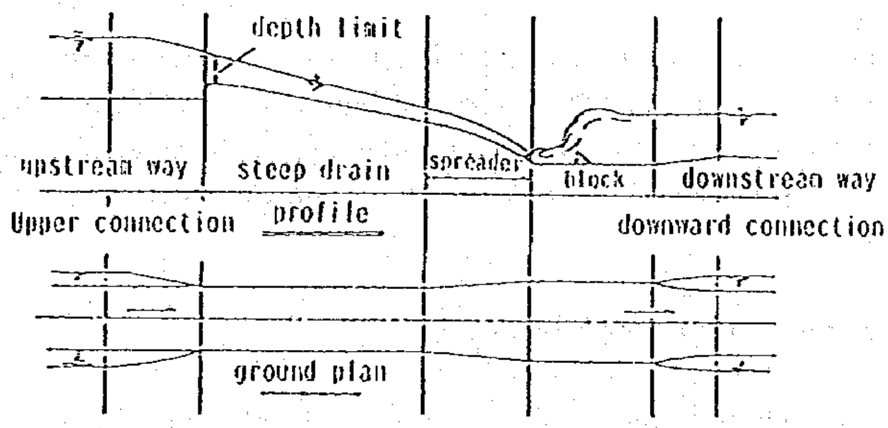
(g) Drop and Buffer Block

The current speed becomes higher with the inclination of a drain, resulting in a destruction of the water channel. If it is morphologically difficult to construct a drain with a gentle slope, install a drop between drainage canals to adjust an inclination of the drain. If the drainage works are big and the installation of a drop is difficult, reduce the current with a buffer block or rapid stream canal works. The following Figures show an example of a buffer block and rapid stream canal works, respectively.



Type I Type II

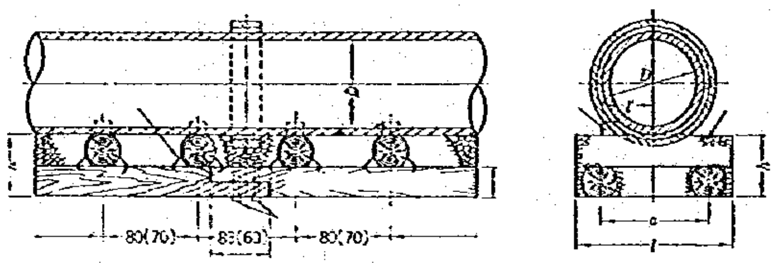
Buffer Block



Rapid Stream Canal

(h) Drain Foundation

When ready-made pipes or culverts are used for construction of drains, foundation work is required to prevent settlement, partial erosion, shifting and others undesirable effects which may damage drains. There are different types of foundation such as aggregate, sand, concrete, pillow and ladder foundations according to their materials or styles. Aggregate or sand foundation, made of tamped aggregates and/or sands, is suitable for drains founded directly on bed rocks. It is, however, not advisable to apply these foundation types to drains in Nigeria, in general, because of its high precipitation. Pillow foundation can be used when drains are constructed on stable ground. When ground comprises poor subsoil, ladder foundation is recommended. Ladder foundation is, as shown in the following figure, composed of a number of wooden sleepers fastened to a pair of wooden runner by bolts and nuts. The foundation is placed in trenches and backfilled upto the top of the sleepers by aggregates and sands. Pipes or culverts are secured onto the sleepers of the foundation by wedges.



Example of Ladder Foundation

Concrete foundation is required if pipes or culverts are oversized or reinforced. Concrete is applied on a base of tamped aggregates to a depth which gives an appropriate bearing surface. If necessary, the concrete foundation may be reinforced. Concrete foundation is also recommended for east-in place pipes and culverts.

(2) Example of Drainage System Design

An example of design of a drainage system is introduced below for a case of the Elu-Aokanu Section of the Obollo-Aforr/Iken Road which is located to one side of the main river running in the middle of a shallow basin.

(a) Rainfall Intensity

A probable rainfall intensity is obtained from the following Tables.

Kaduna

Return Period (years)	Duration (hrs)						
	0.50	1	2	4	8	16	24
2	60	38	24	15	9	5.5	4.2
5	80	50	30	18	11	7	5.2
10	90	58	35	22	13	8	6.2
25	110	65	40	27	16	10	7
50	130	79	50	30	18	14	9

Warri

Return Period (years)	Duration (hrs)						
	0.50	1	2	4	8	16	24
2	85	58	40	27	18	13	10
5	110	65	50	35	23	17	13
10	130	85	60	40	27	19	15
25	150	110	70	48	32	23	18
50	170	130	78	55	37	25	20

(J.W. E. Metibaiye, 1990)

The probable rainfall intensities of the 30 and 60 minutes durations for 5 year return period are read from the above Table for Warri as 110 (mm/h) and 65 (mm/h), respectively. Accordingly, the probability rainfall intensity for the concentration time (t) for 5 year return period is estimated as follows;

β $= 110 / 65 = 1.69$

b $= (60 - 1.69 \times 30) / (1.69 - 1) = 13.48$

a' $= 13.48 + 60 = 73.48$

I_5 $= 110 \times 73.48 / (t + 13.48)$

(b) Concentration Time

The basin, in which the road is located, has its total catchment area of 3252.5 ha, approximately one half (1630 ha) of which is considered to be responsible for the run off affecting the 10,000 meters section of the road within the basin. If all the runoff is discharged by one drain, the 10,000 meters long drain is required. However, it is unrealistic to construct such a long drain, because the cross section area of the drain becomes excessively large. Therefore it is advisable to design a drainage by splitting the entire section into the 1000 meters subsections with a culvert at each downstream end for discharging the runoff from each subcatchment area. To simplify the problem, the subcatchment area for each subsection is assumed to be one tenth of 1630 ha, that is 163 ha. It is also assumed for each subcatchment that the over-all slope gradient is 1% (1/100) and the distance between the drain and the furthest point of the subcatchment (ℓ) is 1,630 m. The terrain comprises mostly grassland, farmland and pastures with minimal development of residential areas. Therefore, the coefficient of retardation is assumed at 0.25 averaging those of bareland (0.10), farmland (0.20) and grassland (0.40). Using the parameters assumed as above, an inlet time (t_1) to each subsection of the drain is estimated at

$$t_1 = 1.44\,(1{,}630 \times 0.25 / \sqrt{1/100})^{0.467} = 69.9\ (\text{min}).$$

A flow time (t_2) for each the 1000 meters subsection is estimated with the assumed mean velocity of 1.8 m/sec at,

$$t_2 = 1000 / 1.8 = 555.6\ (\text{sec}) = 9.3\ (\text{min.}).$$

Therefore, the concentration time ($t_1 + t_2$) is approximately 79.2 minutes.

(c) Runoff Rate

The probable rainfall intensity (I_N) for the concentration time 79.2 minutes for a 5 year return period is estimated at,

$$I^{79.2}_{5} = 110 \times \frac{73.48}{79.2 + 13.48} = 87.2\ (\text{min/h})$$

Assuming a runoff coefficient at 0.40 (mean of grass land, pasture), the runoff rate (Q) is estimated at,

$$Q = (1/360) \times 0.40 \times 87.2 \times 163 = 15.8\ (\text{m}^3/\text{sec}).$$

(d) Mean Velocity (Manning Formula)

Supposing that a drain with an effective dimension of 2 meters in high and 3 meters in width is installed for a 1000 meters-subsection with a surface slope of 1/1000, the hydraulic radius (R) is estimated at,

$$R = (4 \times 2) / (4 + 2 \times 2) = 1.000\ (\text{m})$$

Taking a roughness coefficient of 0.015 for a concrete drain, a mean velocity (V) is estimated at,

$$V = 1 / 0.015 \times (1.000)^{2/3} \times (1 / 1000)^{1/2} = 2.1\ (\text{m/sec})$$

Therefore, the volume discharged by the drain is approximately 16.8 m^3/sec., which is larger than the estimated runoff rate of 15.8 m^3/sec. However, the estimated mean velocity as above is much faster than the initially assumed mean velocity of 1.8 m/sec. Then, using the estimated mean velocity of 2.1 m/sec, a flow time and a runoff rate are re-estimated as follows;

$t_2 = 1000 / 2.1 = 476.2\,(sec) = 7.9\,(min)$
$t_1 + t_2 = 69.9 + 7.9 = 77.8$
$I_5 = 110 \times 73.48 / (77.8 + 13.48) = 88.5\,(mm/sec)$
$Q = (1/360) \times 0.40 \times 88.5 \times 163 = 16.0\,(m^3/sec)$

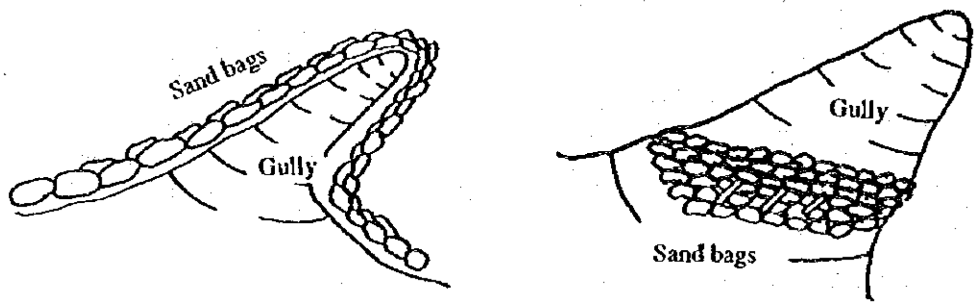
The estimated runoff rate (16.0) is smaller than the capacity of the drain (16.8). Therefore, a drain with this dimension (2 m high and 4 m wide) should be capable of discharging the runoff of the probable rainfall intensity for 5 year return period.

Appendix 7C-2 Gully Erosion Control Works

(1) Techniques of Gully Erosion Control Work

(a) Use of Sand Bags and Wood

In order to prevent gully erosion, it is most effective and inexpensive to remove excessive surface water from gully erosion sites. Improvement of water courses is a desirable control work to remove excessive surface water. It is, however, economically impractical to improve water courses at all the erosion sites, taking account of the considerable amount of work. Besides, unexpectedly heavy rain exceeding the capacity the improve water courses may occur or the water courses themselves may become ineffective due to damages. At any rate, therefore, flood control activities during the rainy season are necessary to prevent damages due to excessive surface water flows on an occasion of heavy rainfall. As recommended, flood control teams, comprising local residents, are effective to control excessive surface water flowing into gullies or to prevent debris flowing out of gullies, using sand bags, as show in the figure below.



To prevent surface water flowing into gully

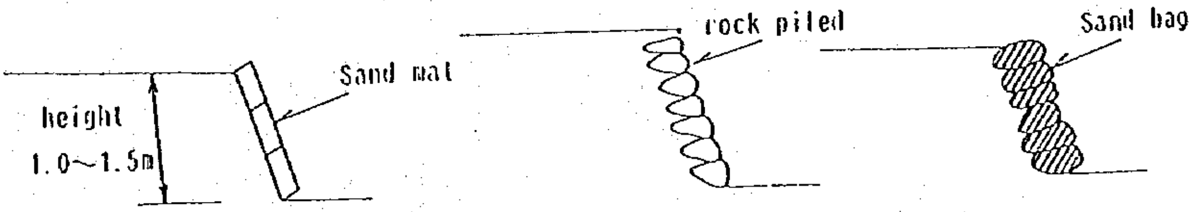
To prevent debris flowing out of gully

Sand Bag Piling Work

Use of sand bags and wood is very effective to protect small gullies at early stage by constructing their dams using sand bags and wood.

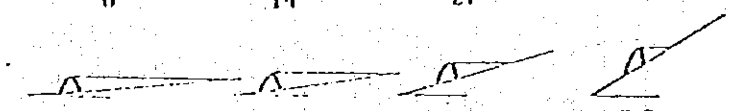
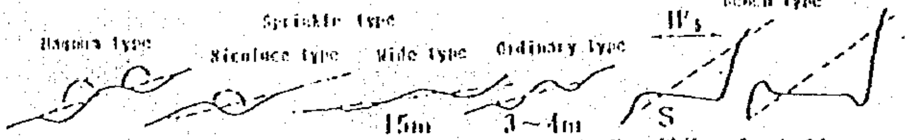
(b) Terracing

Mass-movement of surface soils, including landslide, occurs on relatively steep slopes due to excessive gravitational loads of soil masses. Terracing is often used to stabilize soil masses on slopes. In the countries of southern and eastern Asia where landslide frequently occurs, cropping on terraced surface has been found effective to prevent not only landslide but also debris flows. The figure below shows examples of terracing which is being actually practiced to prevent landslide in the Chinese Yellow Region.



Typical Slope Protection Works in the Yellow Soil Zone in Chaina

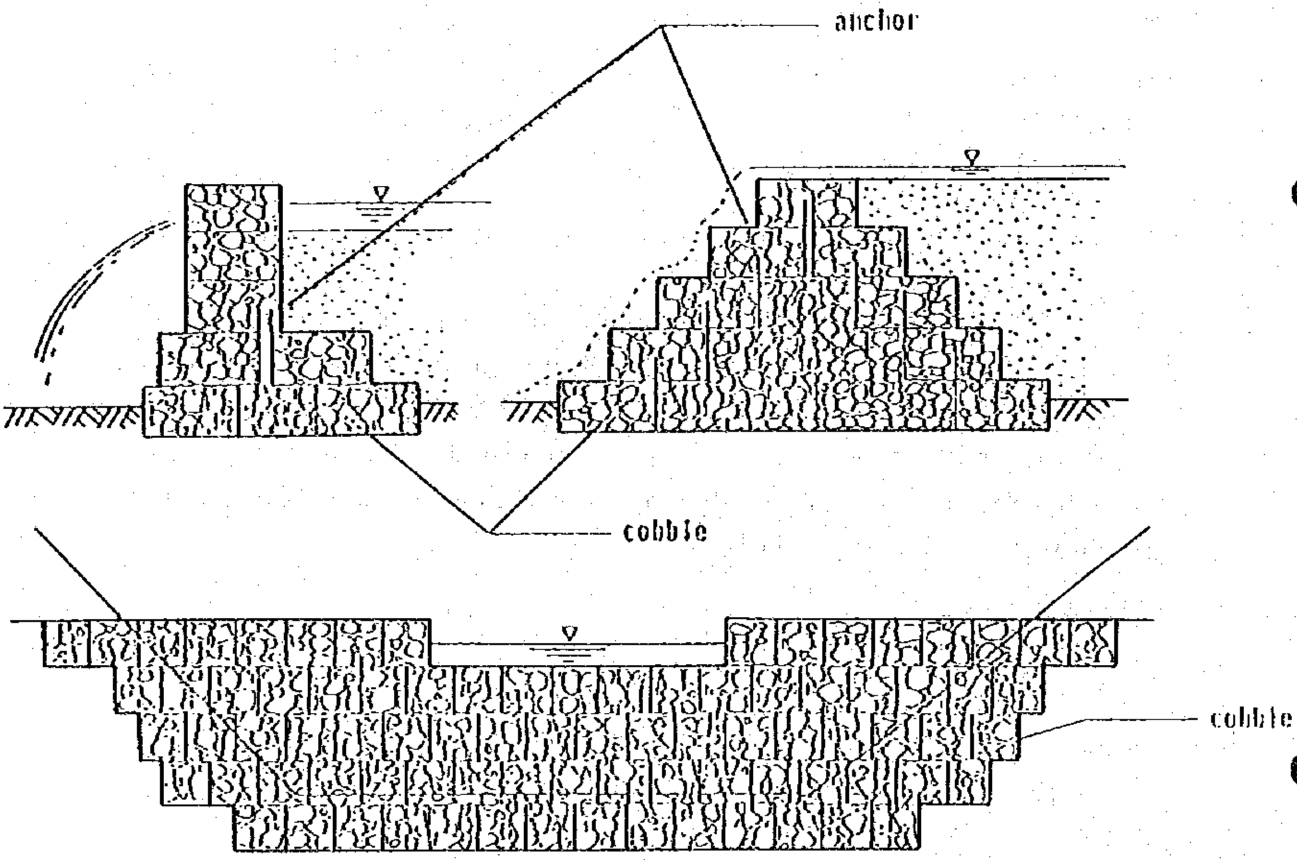
Use of sand bags filled with crushed concrete or aggregates is considered to be simple and effective for terracing work in Nigeria. The sand bags are applied to slope faces of terraces with plastering cement and piling poles for support. Highs and widths of terraces are determined according to engineering characteristics of soils. The following figure shows standards of terrace design used in Kenya, America and China.

Method		Summary			
Terracing	Contour band	Protection by terrace filling [2]			
		6°	14°	27°	33°
	incline form				
	height [m]	0.2	0.2	0.2	0.2
	width [m]	1.9	0.7	0.4	0.3
	capacity [m^2/m]	0.19	0.07	0.04	0.03
	interval [m]	20	15	10	8
	Terrace forming	Protection by terrace forming on the contour [3] 			
	interval	V_s = aS + b Vertical interval V_s [ft], incline S [%] a 0.3-0.6, b 1 or 2 (a and b are decided from resistance of soil against erosion)		V_s = Wb/(cot S - cot β) Vertical interval = V_s [m], incline = S [degree] Width of terrace = W_s [m] incline of cutting slope β (70-75)	

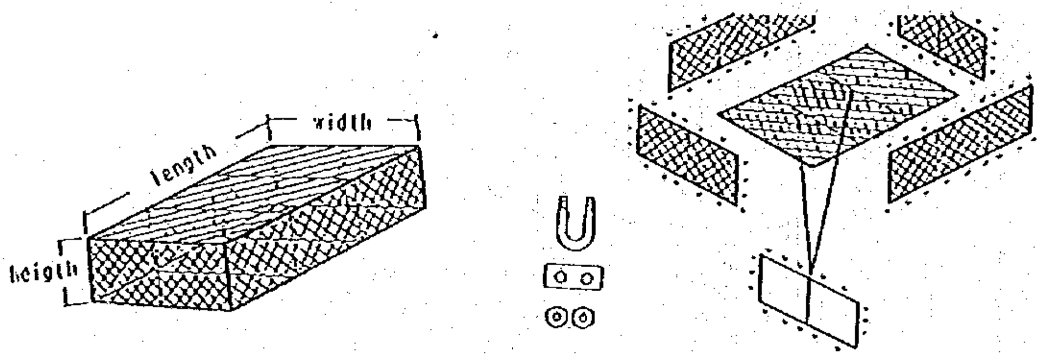
Protection Method by Terracing

(c) 'Sabo' Dam

Recent 'Sabo' dams have different design and are move expensive in their construction costs than conventional dams. Therefore, it is not advisable to adopt of recent styles at all erosion sites from an economical point of view. A gabion dam, as shown in the Figures below, is reasonable in its construction cost and is recently revalued for its merits from economical and landscape points of view. This style of dams, having been already adopted in the Haipang project, will become more popular.

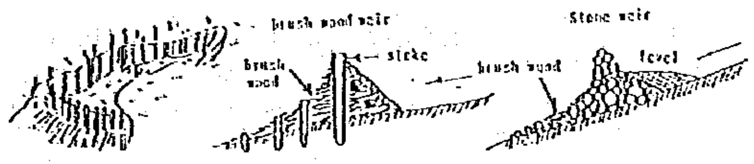


Example of Gabion Dam

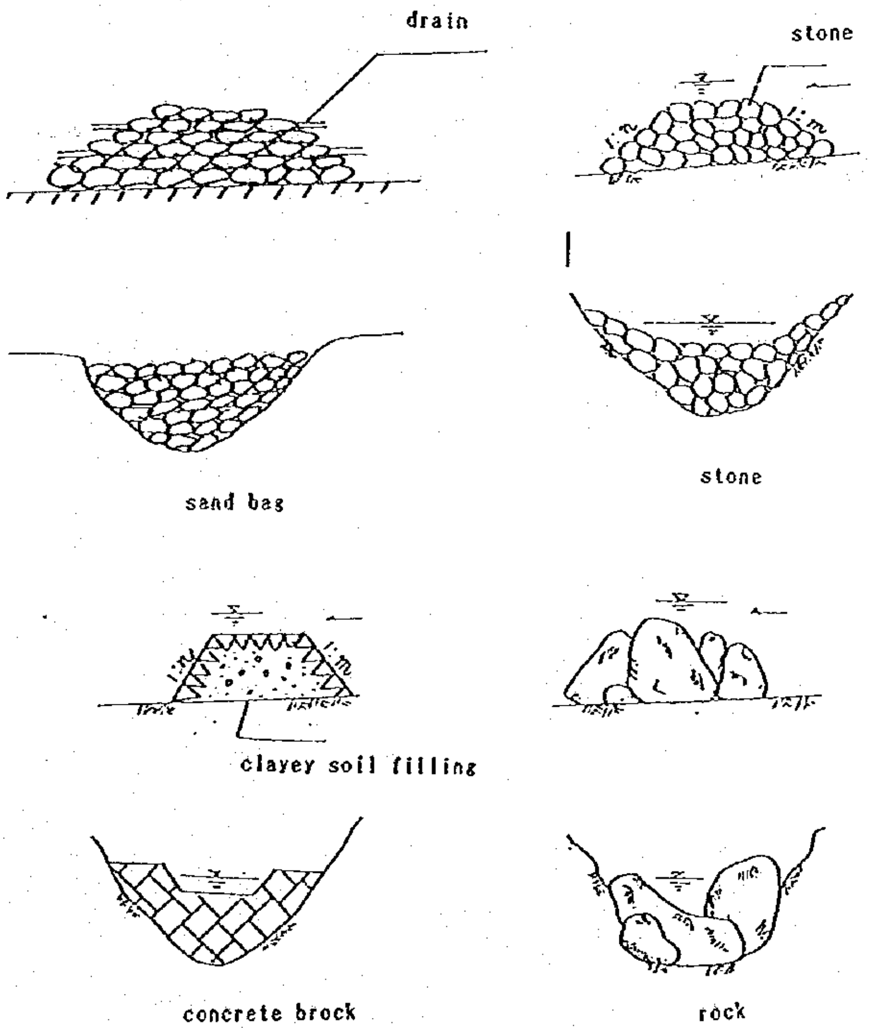


Structure of Gabion

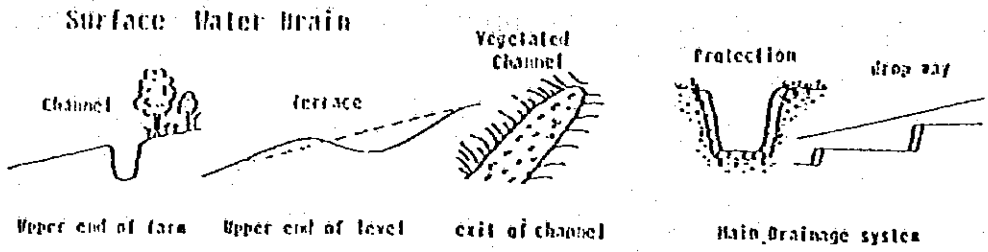
If gullies are shallow in their early erosion stages simple protection work, as shown below, is effective for preventing them against further progress of erosion.



Simple Dams Using Wooden Stone Fences (Brush Wood Weir)



Examples of Simple Dam Using Sandbags, Rocks, Stones and Concrete Blocks

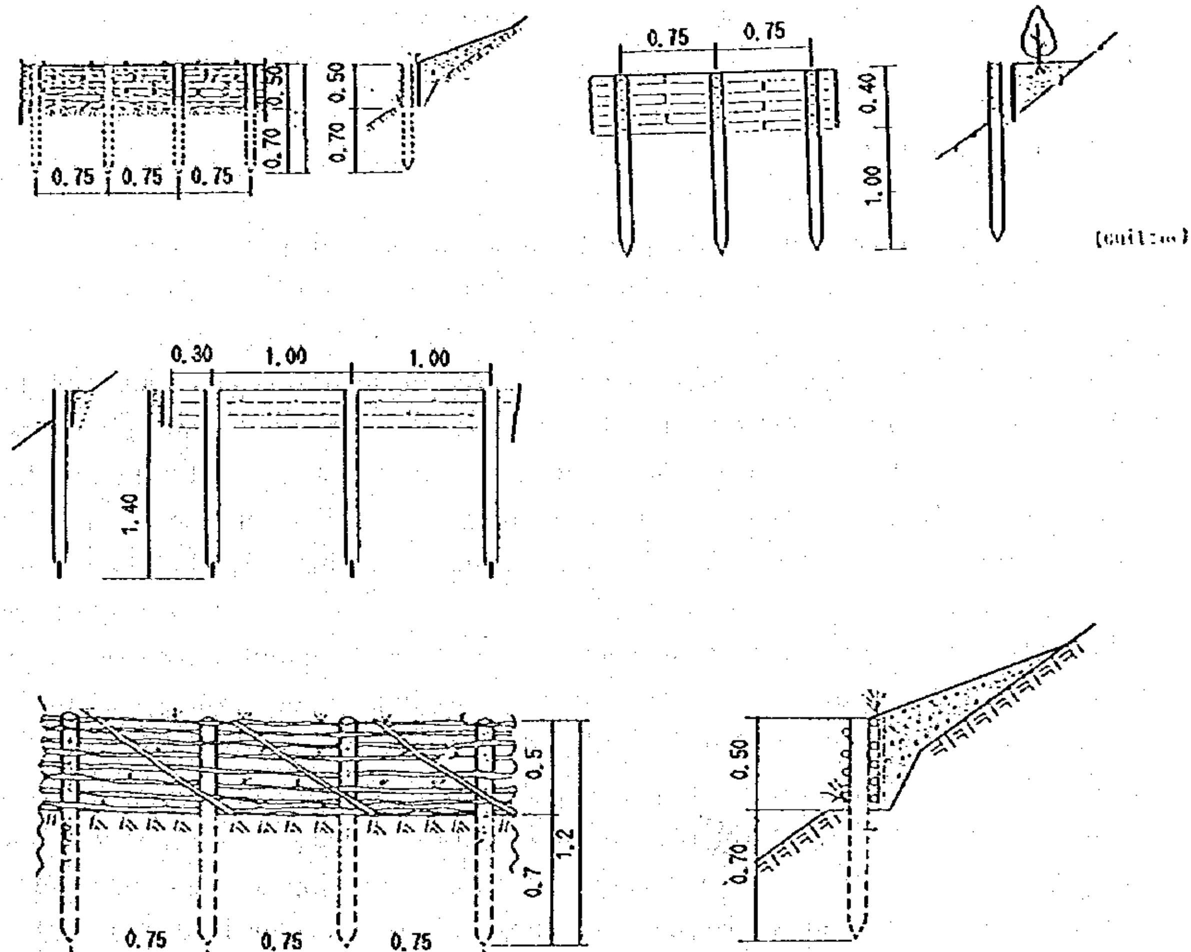


Examples of Water Drains for Erosion Protection of Shallow Gullies

(d) Hillside Work

Hillside work is to protect steep slopes or cliffs against destruction. Wooden fences are most commonly used as shown in the following Figure.

Soils are filled behind fences with vegetation. Penetration depths of fences are determined according to slope inclination. Concrete support may be applied at the foot of fences for particularly unstable slopes.



Hillside Work Using Wooden Fences

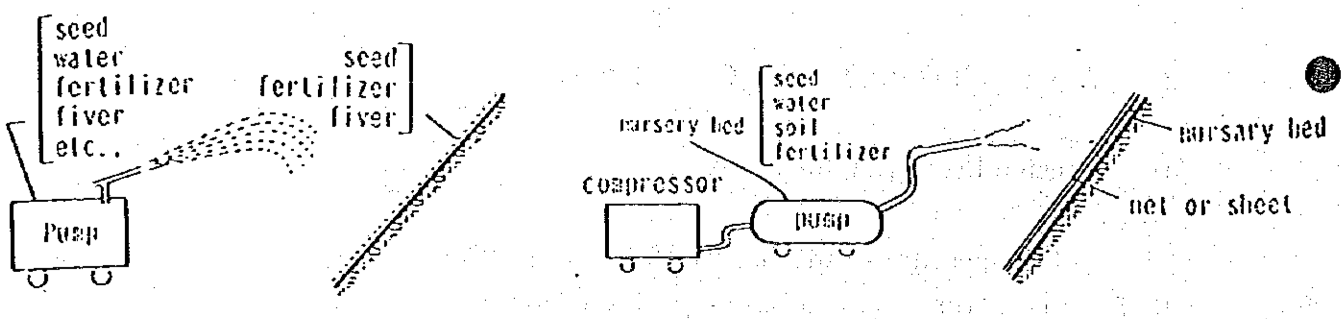
(2) Agronomic Gully Erosion Control Work

(a) Erosion Protection Measures

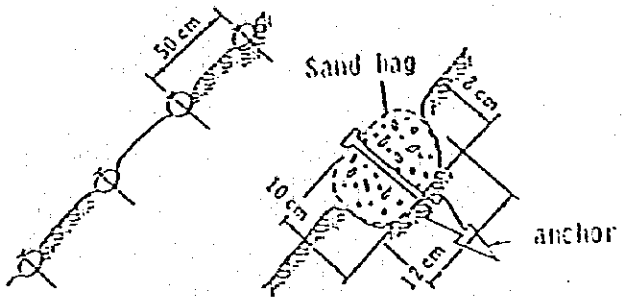
Taking account of intense rainfall and ground conditions in Nigeria, it is difficult to control gully erosion only by agronomic techniques except for limited areas susceptible to minor gully erosion. However, agronomic techniques are often effective when used with other erosion control works. It is fundamentally important to manage farming in an orderly manner. The Table 1 is a list of agronomic erosion protection techniques (Morgan, 1986). Slash-and-burn farming is presented in the list as an erosion control method by is regard appropriate only when a sufficient fallow period, mulching or other protective farming techniques can be applied. Some of the listed agronomic methods may be applied at the sites where other erosion control works have been completed by FEPA.

(b) Revegetation

Turfing only is not sufficient to keep slopes stable but is effective to suppress erosion of surface soils. The table 2 is a list of methods of revegetation. Soils used at revegetation sites in Nigeria are usually laterites or friable sandstones. These types of soils are poor in organic substances as neutrition for plants to take roots. Therefore, it is difficult to revegetate sites comprising these types of soils only by simple sowing. The spray nursery bed, the turfing and the sand bag methods are considered to be suitable for application to the Nigerian soils in general. In the spray nursery bed method, nylon nets are placed on slopes and are sprayed with a mixture of soils, seeds, fertilizers and moisture retainers. The method is applicable even for protection of outcrops comprising Cretaceous sandstones. The Figure below shows a conceptual diagram of this method. In the turfing method, stretches of turf are placed on slopes and are fixed with wooden nails. This method is suitable for protection of a narrow land comprising lateritic soils. In the sand bag method, sand bags contains seeds, soils, fertilizers and moisture retainer are fixed by anchors on protecting slopes. This method is effective for protection of slopes comprising sandstones or laterites and is applicable even to slopes steeper than 35 degree. The Figure in the page 25 shows an example of the sand bag method practiced in an arid region of West Africa.

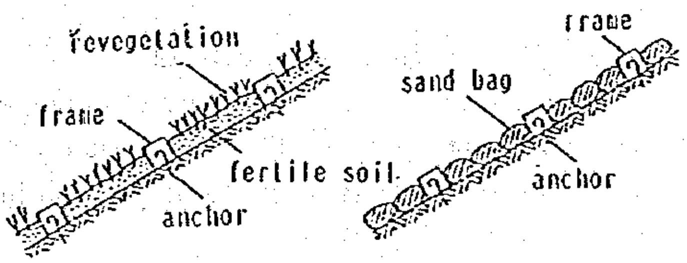


Spray Nursery Bed Work



Sand Bag Work

In case that application of any hillside works is difficult due to extreme steepness of protecting slopes and satisfactory results cannot be expected even with use of the spray nursery bed method, for extensive slope faces, the frame revegetation method is an alternative. In this method, concrete frames are constructed on the slopes and nursery beds or sand bags are placed within the frame as shown in the Figure below.



Frame Revegetation

Table 3 shows some plants used for revegetation in various parts of the world. One of the conditions to succeed in revegetation in Nigeria is to select suitable kinds of plants which are resistant to hot and dry climate and capable to grow in innutritious conditions. Plants which satisfy these conditions are crimping red fescues, orchard grass and miscanthus. Miscanthus is excellent under the hot and dry climatic conditions in Nigeria. Nigerian panpus grass grows wild in Nigeria and takes root even in laterite. It is a plant suitable for the Nigerian climate. Since the Nigerian panpus grass does not take root deep enough into the soil, it has a weak point of being easily washed away by strong surface water flows. However, it is considered that this plant can be used for vegetation on a flat surface such as a terrace, at a low cost if attention is paid to drainage. Bamboo's growing wild in various southern states such as Anambra and Imo, take roots deep into the sandstone layers and also resist erosion. At many erosion sites, parts where bamboos grow wild are free from erosion. Planting bamboos is considered to be effective for protection of a gentle slope. Furthermore, short bamboo grass seems to be suitable for protection of steep slopes, but they do not grow wild in Nigeria. The state of Anambra had a plan to introduce bamboo grass from China. The plan not been realized. An introduction of bamboo grass should also be studied in the future.

There are two types of moisture retainers. One is made of macro molecular compounds and the other is made of natural porous materials. As macromolecular compounds, EBa, DH-2, PVM/MA and other compounds are generally used. As natural materials, vermiculite, perlite, zeolite and others are available. Since EBa and DH-2 are used for the desert afforestation works in various countries of Africa, their introduction into Nigeria is considered to be relatively easy. As for natural materials, zeolite is produced in Cameroon and is introduced into Nigeria as water filtering material. If zeolite is supplied stably, it can be used effectively as a water retainer because of its low cost.

Biotechnological research on improvement of soil bacteria is now being done actively. Bacteria capable of decomposing agglutinated laterite layers and providing plants with nutrition. Nourished by plantation have been developed but have not been used in practice. It seems to be possible to perform a wide-range plantation at a low cost in the future.

(3) Proposed Erosion Control Project

(a) Isiamigbo Village Erosion Site

Isiamigbo Village is located east of Awka, the capital of Anambra State. This gully constitute a part of Aguru/Nanka Gully Erosion Complexes and is 5 km long, 70 meters or more deep, and 300 to 500 meters wide. The gully is branched into five sections. The widest part of the gully where five branches gather together is about 1,000 meters wide The JICA Team made an on-site survey twice in 1992 and 1993. The 1992 survey showed that this erosion site was not formed by only gully erosion but the left bank was dissected by a landslide and the right bank was dissected by gully erosion. Figure APP.1-1 shows the situation in the 1993 survey. The following findings are confirmed by the 1992 and 1993 surveys.

1. A new cave-in has not been recognized in a landslide area of the left bank since the 1992 investigation. Although a new gully face is observed in a gully erosion section on the sandstone layers of the right bank, significant expansion of the gully was not recognized.

2. Collapsed soils and sands accumulated at the bottom of the gully. Sedimentation of soils and sands in recognized down to nearly the original ground surface on the left bank and down to 20 to 30 meters from the original ground on the right bank. Furthermore, the depositional surface of earth and sand generally forms a very gentle slope.

3. The gully slope of the sandstone layers rises steeply almost perpendicularly. The exposed surfaces of sandstone lays look smooth.

4. It is assumed that even the thinnest part of sedimentary earth and sand at the bottom of the gully is as thick as 20 meters or more and stable clods are generally formed.

5. Sedimentary soils and sands contain about 30% of clay and silt and have high water retention, montmorillonite, shows a high water content.

6. Slight recovery of vegetation is observed over its sedimentary soils and sands on the left bank.

7. Sedimentation of soils and sands extends to River Odo, a branch of the Upper Anambra River connected to the gully. The soils and sands on the river beds seem to be 10 meters thick or more.

8. There is spring water at several places of the gully slope. The amount of spring water is about 30 liters/min at each place. The ground water level is assumed to be in a sandstone layer of approximately 50 meters deep from the original ground surface, judging from the elevation of the spring water.

9. The ground surface near the gully is covered relatively densely with grass, shrubs, bamboos, etc. On the periphery or in an area 30 meters away from the gully yam and vegetable are produced by dray field farming. Mulching is performed in a good condition on a fallow ground.

10. The intercept drain laid on the periphery of the gully is not damaged and is in good condition. Judging from the condition of the surface soil on the periphery of the gully, the intercept drain seems to function effectively to drain surface water.

The differences between the information obtained from this survey and the existing report are as follows;

1. The existing report has explained that the gully is expanding year after year and its speed was 3 to 6 m/year, but the gully expansion appears to have come to an end or slowing down according to the observation.

2. It has been considered that most of soils and sands generated by erosion are composed of fine sands and are washed away from the erosion site, but deposited sediments consist of sandy fragments of mudstone and chalk mixed, with clay and silt, forming stable sedimentary layers.

In spite of the JICA-Team's observation as above, the gully erosion will continue as sediments deposited in the main gully are eroded away. In order to hold this gigantic gully as it stands, a tremendous amount of money will be required for large scale civil engineering works such as hillside works for steep gully walls, installation of a complete drain network system within the main and branch gullies, construction of a number check dams, landslide protection works for the right bank of the main gully and so forth. A thorough site investigation is necessary for planning and design of these civil engineering works.

It may be practical and advisable to construct a large check dam, with a length of some 1.5 km and a height of approximately 10 m, near the mouth of the main gully in order to prevent wash-out of sediments from the gully (Fig. App.1-3). Once the first dam is filled by sediments, the second dam, with a shorter length and a similar height, is constructed, stepping up from the first. Thus, construction of check dams is continued until the peripheral walls of the gully are stabilized with a sufficiently gentle slope resistant to erosion. This slope angle is approximately 35° for top soils comprising mainly sands and gravels. Two or three steps of dams are considered sufficient to ultimately make the gully walls stable. Concrete dams are preferred in terms of strength. However, gabion dams, using steel frames for individual gabions containing cobbles, can be substituted as shown in the figure on page 7C.2-3. Since the gully front advances until the gully walls are stabilized, it is necessary to monitor the gully by periodical surveying or more conveniently by satellite image analysis immediately after each wet season. If nearby residences or other surface structures are in immediate danger, they must be evacuated or relocated.

After the gully has been stabilized, a central drainage system should be installed to drain rainfall runoff of the catchment including the gully. Revegetation and farming will become also possible on the stabilized slopes.

The existing intercept drain, located near the periphery of the catchment, appears ineffective to drain rainfall runoff for preventing the advance of the gully. It must be noted that the drain be maintained in good standing to prevent triggering new gullies.

(b) Erosion Control Works in Aguru Lake Erosion Site

The Aguru Lake Erosion Site is located at the wet end of the Aguru/Nanka Gully Erosion Complex. A typical accelerated erosion due to lack of proper construction of roads and associated side drains is observed. Washout of surface soil is found extensively, and a medium-scale gully and a number of rills are developed. JICA made an on-site survey twice in 1992 and 1993. The situation in 1993 was shown in Figure APP.2-1. The results of the on-site surveys are summarized below.

1. The washout area of surface soils has expanded by about 2,000 m^2 compared to that at the time of the 1992 survey.

2. The main gully in the center has increased in both width and depth. The number of rills has also increased.

3. The top soil is characterized by the secondary lateritic sediments comprising fine-grained sands with minor clay or silt. The average thickness of the top soil is estimated at about 5 m. A gravel bed,

containing pebbles of 5 to 10 mm in diameter, is developed on the lower slopes.

4. An agglutinated laterite crust is formed on the upper part of the top soil and is very rigid.

5. The gully slope rises almost perpendicularly and there are numerous traces of piping of 10 to 20 cm in diameter. Traces of water passage of 5 to 10 cm is found at the slope toe.

6. The gully ends in bush and a water passage is formed running toward Aguru Lake.

7. Bamboos grow gregariously in a part of the bareland, and no washout of surface soil is found where the bamboos take roots.

8. Soils and sands generated by erosion are washed out and their accumulation is thin at the gully bottom. However, there is a thick accumulation of soils and sands on a gentle slope between the gully end and the bush, where vegetation is buried under soils and sands.

9. The road facing the erosion site has a gradient of 10%. Side drains with a width of 1 m and a depth of 0.8 m, have been installed on both sides of the road, and the catchment distance is 3 km or more.

10. There are a palm tree plantation, a natural forest, grasslands, and cassava cultivation around the area affected by gullies and rills. The cassava field in the lower part of the erosion site is protected by gutters and furrows.

11. The road slopes downward about 1 meters from the erosion site and a violent washout of surface soil also occurred around the bottom of the hill.

It is obvious that the gully erosion has been caused by the poorly constructed road with the side drains having insufficient capacity (cross-section area: 0.8 m^2) to discharge rainfall runoff in the relevant catchment. Therefore, it is necessary to reconstruct the road and the side drains, together with gully restoration and erosion control works. A conceptual plan of the gully restoration, erosion control and road reconstruction works is proposed as follows (Fig. APP.2-2);

1. Gully Restoration and Erosion Control Works

1-1. Main Drain

Cross-section Area	:	7.5 m^2, (3.0 m wide, 2.5 m deep)
Total Length	:	400 m
Drop	:	At 3 locations (to keep the drain gradient at 1/400)
Make	:	Concrete

1-2. Check Dam with Apron

Number	:	1
Type	:	Gabion
Dimension	:	5 m high, 15 m long, 15 m wide at the bottom
Location	:	At the lower end of the main gully.

1-3. Excavation and Levelling

Both sides of the main gully where affected by minor gullies and rills.

1-4. Sandbag Piling

To stop the sideway water flow from the gully erosion site.

1-5. Revegetation after Excavation and Levelling

Method : Block turtling or nursery bed spray.

2. Road Reconstruction

2-1. Road

Width	:	7 m
Length	:	3 km
Surface	:	Paved

2-2. Side Drain (both side of the road

Average Cross-section Area: 3.25 m^2 (1.75 m wide, 1.25 m deep)

Length : 3 km

Make : Concrete

2-3. Culvert

Interval : At an appropriate interval

Dimension : 7 m long, 1.75 m wide, 1.25 m deep

Make : Concrete

2-4. Drop

Interval : So that the drain gradient is kept at 1/400.

Cross-section Area : The same as drain

Make : Concrete

Note 1. The cross-section area of the drains has been determined using the following parameters

Catchment Area : 100 ha

Rainfall Intensity :

Using the record at Warri (Appendix 7C-1 (2))

5 year return period (I_5)

110 mm/h for 30 minute-duration

65 mm/h for 60 minute-duration

$I_5^t = 110 \times 73.48 / (t + 13.48)$, (t; concentration time)

Co-efficient of Retardation:

0.20, considering that the catchment area consists mainly of bareland, farmland, grassland and residential area.

Average Slope Gradient of the Catchment Area: 1/50

Runoff Co-efficient : 0.45

Roughness Co-efficient : 0.015 (for concrete)

Note 2. The cross-section area for the side drains much be determined with detailed parameters specific for each subsection between culverts.

TABLE APP-1 AGRONOMIC PROTECTION WORK FOR EROSION

Method		summary
Method of Planting	Slash-and burn	Traditional planting of tropical and subtropical zone. Farming after burning small area in the forest. Roots of trees and embers loft as they are. Commonly planting is carried out without plowing. Productivity falls in 4-5 years. Weeds and shrubs enter and vegetation is regained. It nees 7-20 years for the forest to be regained. If the follow years are too short. There is possiblility for erosion to start.
	ordinary cropping	The term when ground is covered is short. After harvesting, ground is eroded easily. The eroded out material is estimated as 1-12 kg/year/m² by USDA. At planting time, protect surface soil by dense cropping and at other times, protect ground by mulching or planting cover.
	grass land	Coverage is very high except the first year after sowing. Grass land is effective for soil conservation. Protection from water flooding is inferior to forest.
	pasture	Effect for soil conservation is high (same as grass land). But livestock trample and surface is compacted so that water retaining capacity is decreased. Ineffective against gully formation.
	covering field	Planting during fallow time. Typical covering grass as are rye, oat, clover, horse bean, etc., Sometimes planted with crops or after harvesting.
	terraced field	Cultivation in a belt along the contour. Commonly planting crops and covering grass alternately. The belt width of planting crop is decided by incline of hillside and soil density. Standard incline: belt width as follows. 2-5%:30m 6-9%:25m 10-14%:20m 15-20%:15m Combined with terrace formation for slope protection.
	mixed cropping	Traditional planting in tropical zone for soil concervation. Many kind of crops planted at same time and coverage confines for a time through out the year.
	dense planting	Covering surface by dense crop and protect soil. For exampe, if density of maize cropping is increased 5 times, surface runoff is reduced to 20%.
mulching		Dead vegetation remaining after harvest is left to cover the surface. Protects the surface from raindrop impact and it is also effective to prevent surface runoff.
revege-tation	gully protection	Masking the bottom and slope of gullies stable by revegetation with grass. If construct erosion control facilities at same time, it should be possible to effectively stop expansion of erosion. For example, the yellow soil zone in China, cut the water runoff 65-80% by revegetation and cut surface runoff 50-60%.
	landslide protection	Stabilizing dangerous slopes and landslide deposits by planting grass or trees. Revegetation has the possibility of accelerating lands lide because of increased subterranean water and loading, but generally effective protection and intertwining of roots exceeds risk of landslide.
	afforestation	Effective for arid areas. Adopted for upper end of the start point of gully erosion and protection around water reservoirs.
	grass planting	Adopted for protection and prevention of re-erosion of arid area and moving dunes.
windbreak forest		Maintaining existing forest or growing forest by revegetation. Multi-purpose of protection against water erosion, wind erosion, gale, fog, and conservation of landscape. Semipermanent and very effective but nees much maintenance and high cost of plants. Sometimes use net or fence at same time.
agro-forestry		Mixed farming with useful trees (fruit, cacao, coffee, rubber trees). Forest is used as protection of farm land, windbreak around contour band, and inhabited areas.
main-tenance of soil	maintain organic substance	Increasing organic matter in the soil. Soil particles connected to each other by organic matter improves protection ability against erosion.
	cultivation	Plowing to replace surface soil with subsoil so that surface particles become to rough and protection ability improves. Include coarse pudding and stilling. But too much planting sometimes causes gullies. Ridgeing on contour is effective to protect for erosion provided that maintenance is satisfactory, but ridge often causes gully formation.
	protection cultivating	1) Plowing on belt or spot. Other part is left as it is. 2) Plowing but leave stumps and roots of trees. 3) Plowing only necessary part of nursery bed or not plowing and drill sowing.
	soil improvement	Make the soil particles stable with natural and chemical soil improvement matter. Improvement of antierosion ability by increasing water retention capacity.

TABLE APP-2 METHODS OF REVEGETATION

Work	Method	Material	Sub-material	Plant	Resistant to erosion directly after completion	Suitable condition	Note
Spray Sowing	Spray seeds mix to a thickness of 1cm to the slope with a pump.	seed, fertilizer, water, woody fibre, additives etc.,	net, wire, straw mat, fence	grass	very little	Suitable for silt hardness under 23mm and sand, hardness under 27mm.	with asphal: resistance to erosion increases. On slope of cutting, additional fertilizer is necessary.
Spray Fertile Soil	Spray fertile soil and seed with mortal gun.	soil, seed, fertilizer, water, etc.,	net, straw mat	ditto	ditto	Suitable for cutting slope and soil with much cobble.	suitable for environmental reconstruction additional fertilizer is necessary.
Spray Nursery Bed	Spray nursery bed and seed 3~10cm thick to the slope	Soil, cement, seed, water, fertilizer, etc.,	net	ditto	ditto	ditto, and, cracked rock slope.	ditto, and suitable for slopes over 45° .
		artificial nursery material synthetic resin, seed, water, fertilizer, etc.,	ditto	ditto	effective	ditto, and very steep slope.	ditto, but, additional fertilizer is not necessary.
		artificial nursery material cement, seed, water, fertilizer, etc.,	ditto	ditto	very effective	ditto, and very hard rock, acid soil.	ditto
Turfing	hand work	lawn (carpet)	wood skewer, nursery soil	lawn	effective	suitable for sand with much cobble.	suitable for small areas of scenic value.
		lawn (roll)	ditto	ditto	ditto	ditto	ditto
Plant mat	ditto	straw mat sowing seed with fertilizer.	ditto	grass shrub	very effective	ditto, and dry area.	Recently chemical fibre net substituted for straw net.
Line Turfing	ditto	lawn (line)		lawn	No	suitable for soil containing silt.	suitable for small areas.
Line Planting	ditto	straw mat sowing seed with fertilizer.		grass	ditto	ditto	ditto
Sand Bag	Pile sand bags	bag, soil, seed, fertilizer.	anchor, frame	grass shrub	very effective	suitable for soil hardness more than 23mm.	suitable for slope less than 45° .
Pot Planting	Spray Sowing or Spray Fertile Soil after fertilized to drilling hole	solid fertilizer, seed fertilizer, woody fibre, additives, etc.,	net	ditto	very little	ditto	same as Spray Sowing and Spray Fertile Soil.
Planting tree	hand work	nursery stock, adult tree	post	shrub tree		suitable for gentle slope.	Take that the slope doesn't collapse from tree pots before root growth.
Frame Revegetation	reinforced concrete and planting grass	reinforced concrete soil, seed, fertilizer	anchor, sand bag	grass	very effective	suitable for steep slope.	Suitable for slope more than 60° .

TABLE APP-3 REVEGETATION PLANTS

Grass	Height (m)	Sowing season (month)	life	shace	germination percentage (%)	purity (%)	number of seeds per 1g	sterility tolerance	drought resistance	wet endurance	heat tolerance	cold resistance	acid rolerance	properties
Weeping Love Grass W. L. G.	0.7 ~ 0.9	4 ~ 5	perennial	growth habit	87	85	3.000	○	○	×	○	△	○	Suitable for every soil. Resistant to heat and drought. Unsuitable for shade.
Kentucky 31 Fescue K. 31F.	0.8 ~ 1.2	3 ~ 5 9 ~ 10	〃	〃	90	85	400	×	×	○	○	○	△	Suitable for every soil. Resistant to cold. Suitable for mixed sowing.
Crimping Red Fescue C. R. F.	0.3 ~ 0.5	3 ~ 4 9 ~ 10	〃	subterranean stem	80	80	970	○	○	△	○	○	○	Suitable for sand. Resistant to drought. Little poor resistant to heat.
Timothy T i m.	0.3 ~ 1.0	3 ~ 4 9 ~ 11	〃	growth habit	90	85	2.500	○	△	○	△	○	△	Suitable for cold and damp areas. Unsuitable for shade.
Orchard Grass G. G.	0.8 ~ 1.0	4 ~ 5 9 ~ 10	〃	〃	85	80	1.100	○	○	○	○	○	○	Very suitable for every soil. Little poor resistant to drought. Resistant to cold.
Kentucky Blue Grass K. B. G.	0.3 ~ 0.4	3 ~ 5 9 ~ 10	〃	subterranean stem	80	85	4.300	○	×	○	×	○	×	Resistant to cold and shade. Germination takes a long time.
Perennial Rye Grass P. R. G.	0.5 ~ 0.7	3 ~ 4 9 ~ 10	〃	growth habit	90	90	450	×	△	○	△	○	△	Requires richness of soil. Unresistant to drought. Requires miced sowing.
Italian Rye Grass I. R. G.	0.6 ~ 1.0	2 ~ 4 9 ~ 11	annual	〃	90	97	400	×	△	○	△	○	×	Requires much sunshine. Resistant to drought. Useful for emargency work.
Bermuda Grass B. G.	0.1 ~ 0.2	4 ~ 6	perennial	subterranean stem	85	80	3.400	○	○	×	○	×	○	Suitable for heat and drought. Unsuitable for sunshine.
Babbi Ha Grass B. H. G.	0.3 ~ 0.5	4 ~ 6	〃	prostrate type	40	90	300	○	○	×	○	×	△	Suitable for sand. Resistant to heat and drought. Germination rate is poor.
White Clover W. C.	0.2 ~ 0.3	3 ~ 5 9 ~ 10	〃	terrestrial stem	90	30	1.400	○	△	○	△	○	△	Suitable for every soil. Unresistant to drought. Requires mixed sowing.
Red Top R. T.	0.4 ~ 0.6	3 ~ 4 9 ~ 10	〃	terrestrial subterranean stem	90	85	12.000	△	△	○	△	○	○	Suitable for every soil. Resistant to cold. Requires mixed sowing.
Artemisia	0.5 ~ 1.0	3 ~ 5	〃	growth habit	50 ~ 80	85	3.500 ~ 4.000	○	○	○	△	○	△	Suitable for every soil. Unsuitable for erosion site.
Polygonum	0.5 ~ 1.5	3 ~ 6	〃	〃	20 ~ 60	85	500 ~ 600	○	○	○	×	○	○	Suitable for every soil. Resistant to drought and cold.
Miscanthus	1.0 ~ 2.0	3 ~ 6 10 ~ 11	〃	〃	20 ~ 60	90	1.000 ~ 1.500	○	○	△	○	○	△	Suitable for every soil. Germination rate is uneven.
Lespedeza Cuneata	0.3 ~ 0.5	3 ~ 6	〃	prostrate type	60 ~ 70	98	720	○	○	△	△	○	△	Suitable for sterite soil and hard soil. Resistant to drought. Using as fodder.
Lespedeza Pilosa	1.0 ~ 2.0	3 ~ 6	〃	deciduous shrub	60 ~ 80	90	40	○	○	×	○	○	△	Germination is good. Extensive root growth wildly. Resistant to shade.
Tribulus Terrestris	1.0 ~ 2.0	3 ~ 5	〃	〃	50 ~ 80	90	160	○	○	×	○	○	△	Growth is very slow. Extensive root growth wildly. Resistant to shade.
Alnus Serrulatoides	10.0 ~ 20.0	3 ~ 6	〃	deciduous arboreal	30 ~ 60	90	1.250	○	○	○	△	○	△	Resistant to sterile soil and cold. Growth is very slow.
Alnus Firma	4.0 ~ 7.0	3 ~ 6	〃	〃	30 ~ 60	85	750	○	○	×	○	△	○	Resistant to sterile soil and heat. Gemination rate reduces in cold.
Nigerian Punpas Grass	0.7 ~ 1.5	3 ~ 6	〃	growth habit				○	○	○	○	○	○	Resistant to drought and heat. Unsuitable for shade.
Japanese short bamboo Grass	0.5 ~ 1.0		〃	sabterranean stem				○	○	○	○	○	○	Resistant to drought and heat. Unsuitable to shade.

Sowing season is according to Tokyo Japan.

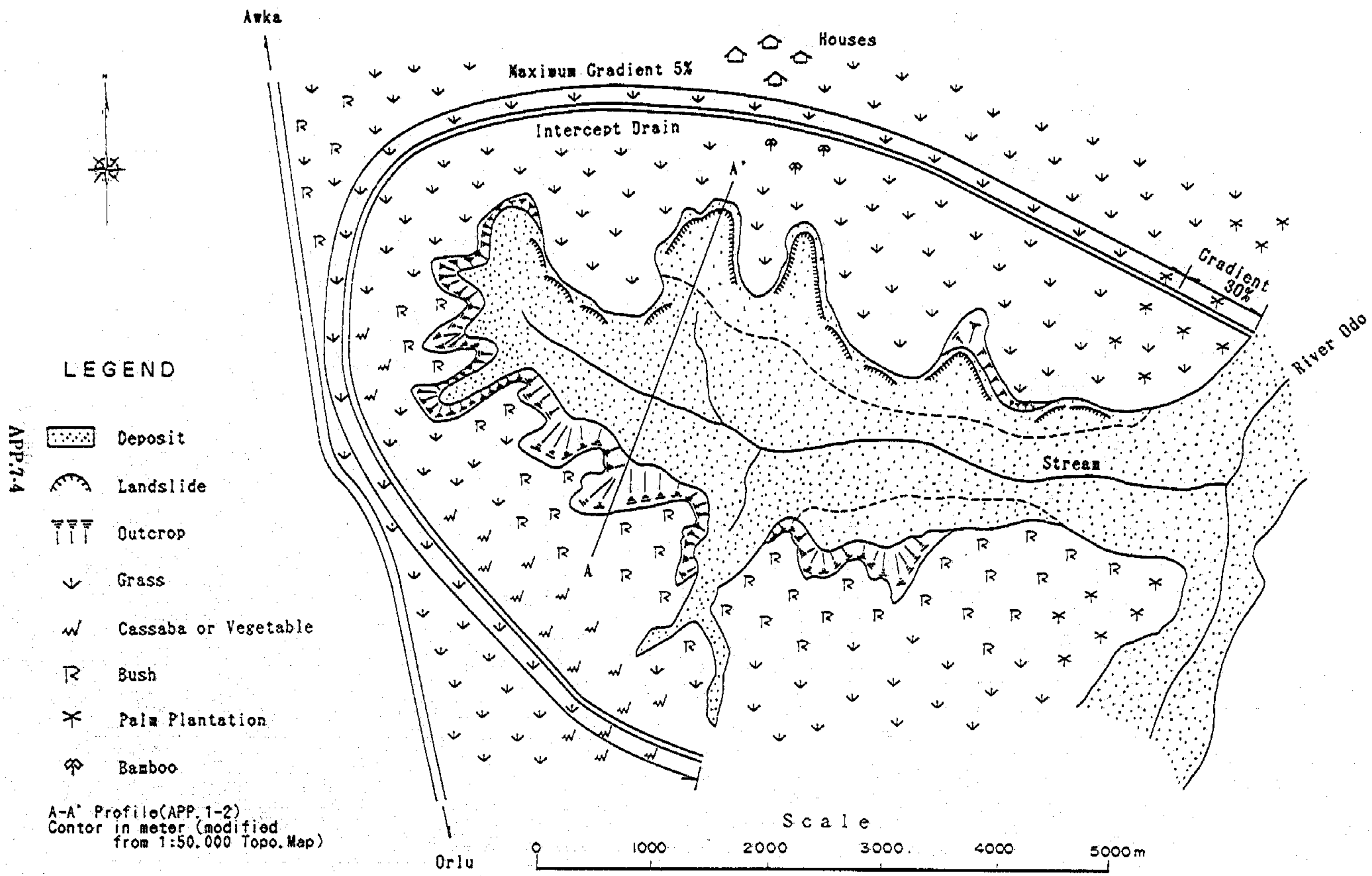


FIGURE APP.1-1 SKETCH PLAN OF THE ISIAMIGBO EROSION SITE

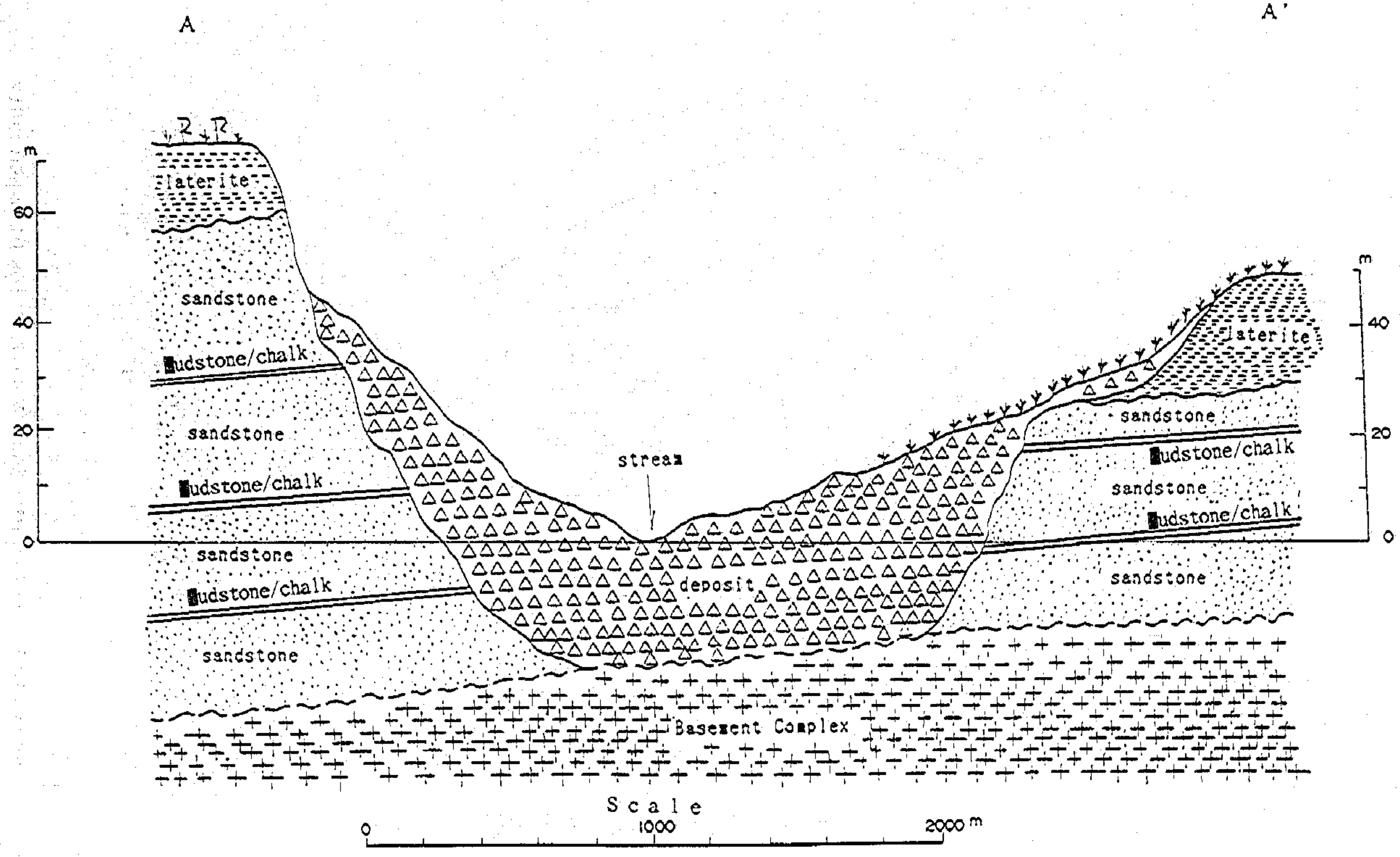


FIGURE APP. 1-2 SKETCH PROFILE

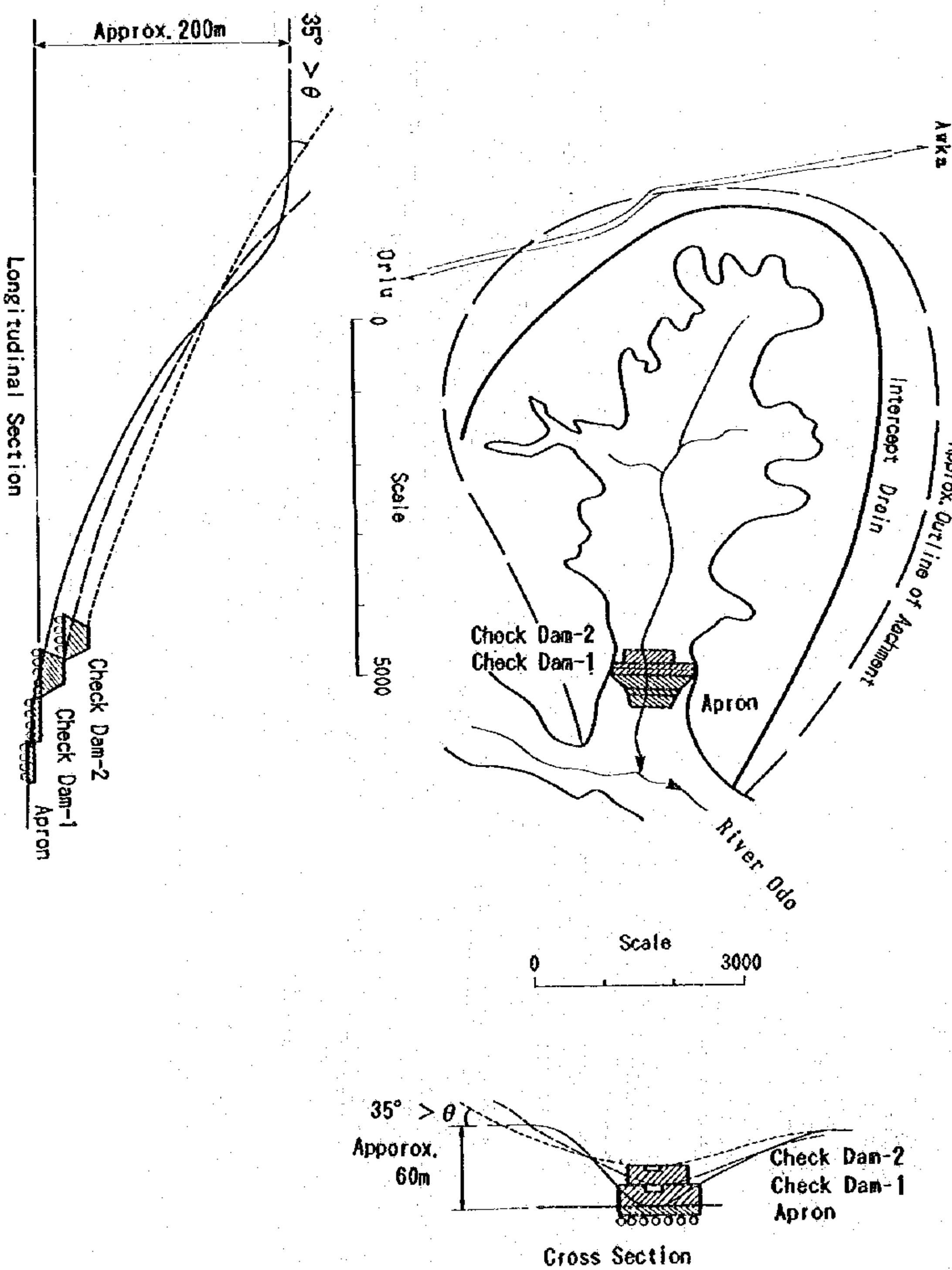


FIGURE APP. 1-3 CONCEPTUAL SABO WORK PLAN FOR ISIAMIGBO GULLY

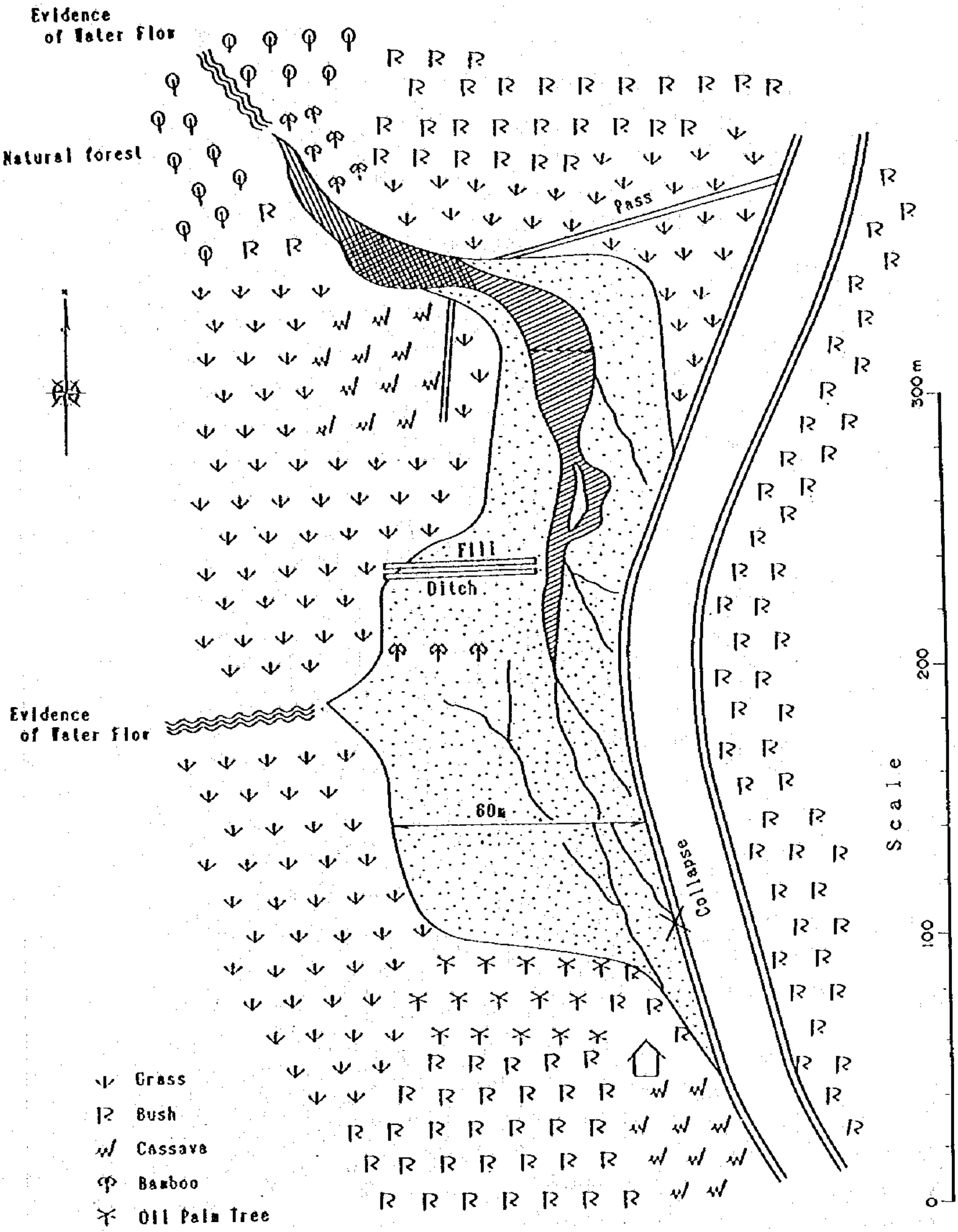


FIGURE APP. 2-1 SKETCH PLAN OF THE AGURU LAKE EROSION SITE

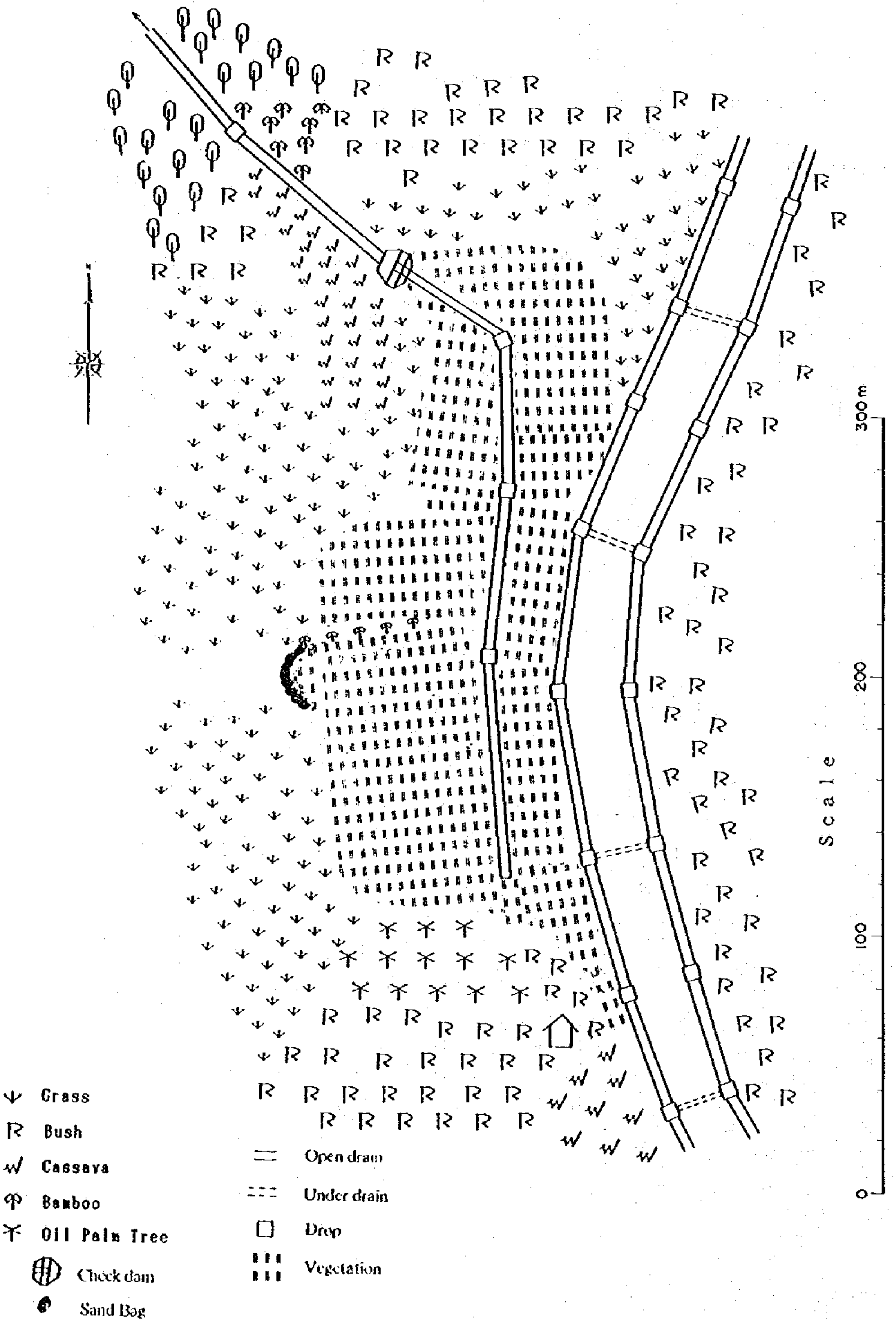


FIGURE APP. 2-2 PROPOSED EROSION CONTROL WORKS

CHAPTER 8. HYDROPOWER GENERATION

CHAPTER 8: HYDROPOWER GENERATION

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CHAPTER 8. HYDROPOWER GENERATION

8.1 GENERAL BACKGROUND

8.1.1 Historical Perspectives

As of 1960, the bulk of power production in Nigeria was from the coal hauled from the Enugu mines with major power plants then at the Oji River (30 MW) at Enugu, the Challawa at Kano and the Ijora (95 MW) at Lagos. The Oji River was used to distribute the power to Enugu, Nsukka, Onisha and other towns around. The Ijora at Lagos was used to feed Lagos and environs and also was transmitted to Ibadan and most of other towns in the then Western Nigeria. The gas-fired plant at Afam fed Aba, Port Harcourt, Umuahia, Ikot Ekpene, Uyo and Calabar. In the north, the coal-fired Challawa and other diesel power sets at Kaduna, Zaria, Maidnguri, Yola, Sokoto and Gusau produced the power for distribution to all the major towns.

As Nigeria progressed into the independence in 1960, the need to provide cheaper power source for the country had become more glaring. In this process, two alternatives were conceived, viz. (1) building a huge dam at Kainji of the Niger River, and (2) use of the associated gas being flared in the Niger delta from the oil exploration. Eventually, the first alternative was embraced. Then, the Niger Dams Authority was organized under Act No.13 of 1962 and charged with the primary responsibility of constructing a Kainji Dam for power generation and secondarily for the improvement of navigation by flood control and the provision of irrigation and fisheries.

For the Kainji hydro project, a consortium of NEDECO and Balfour Beatty was pooled to provide a feasibility study which was accepted by the FGN for Nigeria's first major hydro dam to emerge. The dam constructed by the Italian firm of Impregillo and the British consultant of Merz & M'clellan was the culminating ambition of a 15-year dream that started with the preliminary survey by NEDECO as far back as 1953. Although the Kainji Dam was designed for an output of 960 MW (12 × 80 MW Kaplan), only nine units with an aggregate of 760 MW was possible due to the error in over-estimating the Niger inflow which was subject to the climatic vagary and Sahelian drought in the upper Niger basin. In February of 1969, the first four units of generators was commissioned four years after the dam completion; however, a full output of these could not be utilized because the national grid was incomplete. As an interim measure, thus, a 330/132 KV transformer placed at Oshogbo was mobilized to feed the Kainji power into the Oshogbo - Benin - Ughelli leg and the Oshogbo - Ibadan - Lagos leg of the already completed 330 KV lines operated at 132 KV at that time, and Oshogbo was chosen as a National Control Centre of the grid network.

At the end of the Civil War in 1970, the Federal Minister of Mines and Power advised the FGN on the need for more power plants and transmission lines to be built for a well-coordinated grid system. In 1978, a 1,020 MW steam power plant at Ogorode near Sapele was commissioned. The Sapele power was transmitted over the newly erected Sapele - Benin 330 KV double circuit line to the grid substation at Benin from where it was then re-transmitted to Ikeja-West at Lagos over the newly constructed Benin-Ikeja West 330 KV inter - tie line designed to improve the inter-area transmission reliability.

With the sporadic growth in power demand, it was imperative that more power plants utilizing the hydro resources of the Niger and the Kaduna and the natural gas deposits of oil producing areas should be built. In line with the recommendation made by the consortium of NEDECO and Balfour Beatty, the 540 MW Jebba hydro (97 km downstream of the Kainji) was commissioned in 1984, and also the 600 MW Shiroro hydro on the Kaduna River was brought into stream in 1989.

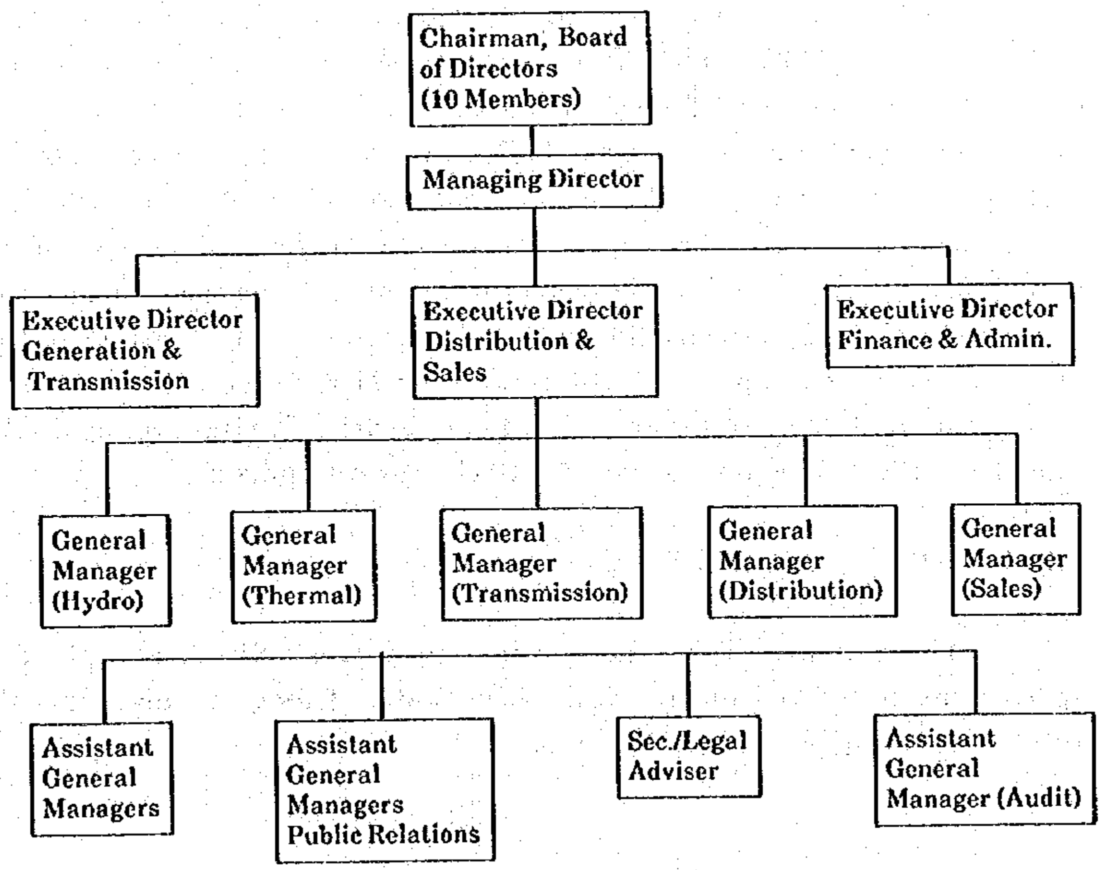
At present, a total aggregate of the capacity installed at power plants under the National Electric Power Authority (NEPA) is 6,000 MW, of which the hydro is 1,900 MW and the thermal is 4,100 MW.

8.1.2 Organizations

The electricity supply industry is currently being undertaken at four levels:

(1) National Electric Power Authority (NEPA)

The NEPA came into existence in 1972 when the defunct Electricity Corporation of Nigeria was merged with the former Niger Dams Authority by a Decree, No. 24 of 1972. Its mandate is to maintain an efficient and well-coordinated system to provide the power including generation, transmission and distribution for all parts of Nigeria. The NEPA has the status of a quasi-commercial, autonomous corporation which has been partially commercialized under the Technical Committee on Privatisation and Commercialization (TCPC). Its operations falls under the general surveillance of the Federal Minister of Mines and Power who is responsible for approving import policies and decisions about power supply. The NEPA is controlled by a board of directors whose organizational structure is shown below:



(2) Nigerian Electricity Supply Corporation (NESCO)

The NESCO at Bukuru near Jos, Plateau State commenced the operations as an electric utility company in 1929 with the construction of a hydro electric power plant at Kurra Falls. The company concession allows it to supply the Plateau mining fields with the power; in addition it provides a bulk supply to the NEPA for distribution in various areas of Plateau State such as Barakin Ladi, Miango, Shedam, Langtan, Keffi, Garaku, etc. Currently, the company operates 7 hydro electric plants and a large diesel plant with an installed capacity of 33 MW and an energy output of 170 GWH per annum. The NESCO is owned by its parent company in England NICON, the Nigerian Mining Corporation and the Plateau State Government. Since its inception, it has been operating under a special licence granted by the Federal Ministry of Power and Steel in accordance with the Electricity Laws of Nigeria. For its operation, the NESCO maintains a system of transmission at 66 KV and distribute power at 33 KV and 11 KV to many towns and villages in the Plateau State.

The company's investment in its power generating business is valued at N250 million (1993) which includes the construction of dams, reservoirs, canals, transmission and distribution systems. Presently, the NESCO is contemplating on developing the Sha Falls hydro potential located some 80 km south-east of Jos and 120 km from the Federal Capital of Abuja, which is capable of having an installed capacity of 200/300 MW for peak load when run in conjunction with the NEPA national grid as a pumped storage scheme with a lower reservoir to be directly linked to the upper one. As a base load, this scheme is currently capable of sustaining a 60 MW power with an annual energy output of 220 GWH to be linked to the Federal Capital over a 132 KV line. The NESCO Inventory of dams is attached as Appendix 8-1.

(3) State Rural Electricity Boards

These Boards take the power supply from NEPA at bulk and redistribute to the consumers within each State. This group also runs the power generating plants in remote areas.

(4) Private Companies and Individuals

The aggregate of power plants by these private bodies was recently assessed by a team from London Economics at about 2,500 MW that is equivalent to 42 percent of the NEPA's total installed capacity of 6,000 MW.

8.1.3 JICA-NWRIS and Database

The hydropower generation sector was included in the Nationwide Socio-Economic Inventory Survey as is explained in Chapter 1 of this Report which was conducted by Skoup & Co., Ltd., Enugu. The output of the Skoup survey is compiled in the Final Report dated January 29, 1993 and the Addendum to Final Report dated February 25, 1993 with the Base Maps, several copies of which were submitted by the JICA Team to the FMWRRD for future reference.

Major outputs of the Report are summarized below:

Form N-4.1: Current situation of the power demand-supply relations on the national and regional basis.

- Historical data on the nationwide power demand and supply are available, and Form N-4.1 (1a) and N-4.1 (1b) have been completed nationwide from sometimes in 1970 up to the year 1992. Historical data on the regions demand are available for 1988 - 1991 [Form N-4.1 (1c)].
- Form N-4.1 (2) series on the historical data on existing hydropower projects have been completed in sets, for Shiroro N-4.1 (2)(1a) - N-4.1(2)(1e), Jebba N-4.1(2)(2a)-N-4.1(2)(2e) and Kainji N-4.1(2)(3a) - N4.1(2)(3e).
- Historical data for six NESCO mini-hydropower plants are given in Forms N-4.1(3)(a)-N-4.1(3)(f), in respect of the monthly power output for the years 1976 - 1990.

Form N-4.2: Power demand projection for the years of 2000 and 2020.

- Forms N-4.2(1) and N-4.2(2) in respect of the demand/supply projections for the years of 2000 and 2010 and the capital cost, respectively, have been completed as much as the data are available. Data for the demand/supply projections were sourced from the NEPA Headquarters, Lagos and from the Long-Term Perspective Plan Study by Unifecs Consultancy Services for the National Planning Commission. There are some doubt as to the accuracy of the data supplied by NEPA.

- Form N-4.2(1a) is completed for the power demand/supply projections for the years of 2000 and 2020 for the only private mini-hydropower project in Nigeria - NESCO.

Form N-4.3: Hydropower projects proposed by the NEPA

- Form N-4.3(1) at Zungeru, Mambilla, Katsina-Ala, Makurdi, and Lokoja has been completed in respect of the proposed projects. It is understood that the proposed Ikom project is no longer being promoted.
- Historical hydrological data on the proposed projects are available and the sets of Form N-4.3(2) have been completed.
- Form N-4.3(3) on the environmental conditions at proposed projects has been completed.

Form N-4.4: Idea of the mini-hydro schemes

- Form N-4.4 has been extended to include some projects under the RBDAs, in compliance with the JICA comments on the First Progress Report. These are

  - Dadin Kowa Dam
  - Ikere Gorge Dam
  - Challawa Gorge Dam
  - Oyan Dam

Although the dams have been constructed, the NEPA has yet to take them over for power generation. The NESCO hydropower project in Jos has just one proposed mini-project at Sha on the Sha River. It is still in a conceptual stage.

It may be noted that the Skoup outputs as mentioned above have been cross-checked by the JICA Team, and the inventory of hydro dams and relevant