THE DESIGN OF SPRINKLER IRRIGATION SYSTEM FOR NEW CHANCHAGA IRRIGATION SCHEME (NIGER STATE)

BY

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BEING A POST GRADUATE DIPLOMA PROJECT SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ENGINEERING, SCHOOL OF ENINEERING AND ENGINEERING TECHNOLOGY, FEDERAL UNIVERSITY OF TECHNOLOHY, MINNA, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF POST GRADUATE DIPLOMA IN AGRICULTURAL ENGINEERING.

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APPROVAL

This project work (report) entitled "the design of sprinkler irrigation for new Chanchaga irrigation scheme (Niger State)" by Iliya Auta meet the regulations governing the award of post graduate Diploma in Agricultural Engineering of Federal University of Technology Minna

ENGR (MRS) Z.D. OSUNDE ------------------------------
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DECLARATION

This project is my original work conducted under the supervision of ENGR. (MRS) Z. D. OSUNDE. To the best of my knowledge and belief the work has never been submitted to any University including Federal University of Technology Minna for the award of Post Graduate Diploma or any Degree

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DEDICATION

I wish to dedicate this work to my late father Rev. Auta Ijah Gwari and my mother Madam Anna Auta

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Niger State Ministry of Agriculture.

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ABSTRACT:

This project work presents the design of Sprinkler Irrigation System of Ten Hectare Land fork Vegetable Production at Chanchaga Village Minna Local Government of Niger State. The design criteria was based on the design information data obtained from Irrigation Charts, tables and calculations using experimental result. Water and soil analysis shows that they are suitable for sprinkler irrigation system. The design invalues main line, laterals, selection of sprinklers, nozzles and the power required to operate the system. The application efficiency was assumed to be 75%. Consumptive use (Cu) – 7mm/day. Depth of root zone – 0.6m. Water holding capacity 150mm/m. Moisture extraction level – 40% soil intake rate – 10mm/hr. These results show that the sprinkler system design is very suitable for the project area.

CONTENTS

CHAPTER ONE

.0 INTRODUCTION

1.1 INTRODUCTION - BACKGROUND

. New Chanchaga Irrigation Scheme is located between Latitude 9 34' – 9 37'N and Longitude 6 36' – 6 39' E and situated at Chanchaga village at the outskirts of Minna, the capital of Niger State. This village is about 10km from Minna Suleja Trunk A road. –Fig. 1.1

The idea of acquiring this land for Irrigation purpose by the Niger state Ministry of Agriculture in 1986, was because there was an increasing number of people wanting to participate in dry season farming and the existing scheme was too small to contain the great number of interested farmers. This coupled with the fact that civil servants were participating in the dry season gardening for vegetable production for their private use, made it necessary for the Ministry to look for more land in order to meet the high demand name. Hence the New Chanchaga Irrigation Scheme.

1.2 GENERAL DESCRIPTION OF PROJECT AREA

The proposed project area is a new site. However, 70% of the total area is cultivated annually out of which 30% is put under localised Irrigation in dry season. The Project area is about 30 Hectares and is moderately fertile. It is situated along River Chanchaga, (where it derived its name) having two main tributaries within the project area. It is mostly covered by economic trees.

1.3 CLIMATE AND VEGETATION

The project Area being in the tropics is characterized by distinct dry and wet seasons. The rainy season begins in April and ends in October. The rainfall is heaviest continous between the months of July and September; while harmattan sets in shortly after the rains, marking the beginning of the dry season. The mean annual rainfall is about 1218.7mm from meteorological data obtained from Minna airport.

The average annual temperature ranges from 21^0 C – 32^0 C. The Maximum evaporation period is April and the Minimum in the month of July.

The relative Humidity ranges from 70% - 95% in the year with the highest in the month of July/August. The wind blows South – West during rainy season and North – East during harmattan. The average wind speed is 6.5 km / hr with the highest of 13 km/hr. The sunshine hours have an annual average of 6.7hrs with the highest of 9.4 hours. The Climatic data obtained from Minna Airport is attached at appendix.

The vegetation of the project area is Guinea Savannah with high grasses.

1.4 SOURCE OF WATER SUPPLY

The source of water for Irrigation is River Chanchaga which bounds the project area on the South. This river is perennial and has dready been damed by the Niger State Water Board to supply water for Minna Municipality and environs. The River has sufficient water for the project area.

1.5 RELIEF AND DRAINAGE

The topographical map of this area shows that the land is fairly undulating with the natural drains as could be seen from the contour Map of the area. (see – Fig 1.2) the area has well drained soils. the land slopes towards the river.

1.6 SOIL STUDIES

The soil sampling carried out on the area shows that towards the River, soil is moist than the upper part where the soil is harder and drier. The dominant soil found in the area is silty clay loam and soils from the results obtained from soil studies carried out. by Niger State Ministry of Agriculture in congection with **SIGMA ENGINEERS NIGERIA LIMITED,** the soil of the project area can be classified as sandy clay loam. which is suitable for most agricultural crops. The soil is well drained with moderate infiltration rate. The soil has water holding capacity of about 145mm of water per meter depth of soil.

The soil pH is within the range of 6.0 –6.5, which indicate that it is slightly acidic. The soil has moderate permeability of (5.0 – 20.32) mm/hr and moderates percolation of 3-12min/mm. The soil porosity is moderate.

1.7 SPRINKLER IRRIGATION SYSTEM

Irrigation is the artificial application of water to soil for the purpose of supplying essential moisture for crop growth.

In many parts of the world, the amount and timing of rainfall are not adequate to meet the moisture requirements of crops and therefore Irrigation is very essential to raise crops necessary to meet the need of food and fibre.

In the sprinkler method of Irrigation, water is sprayed into the air and allowed to fall on the ground surface some what like natural rainfall. The spray is developed by the flow of water under pressure through small orifices or nozzles. The pressure is usually obtained by pumping. With careful selection of nozzle sizes, operating pressures and prinkler spacing, the amount of irrigation water is applied nearly uniformly at a rate suitable for the infiltration rate of the soil, there – by obtaining efficient Irrigation.

It is suitable for sandy soil or any other soil and topographic conditions where surface irrigation may be in-efficient or expensive, or where erosion could be particularly hazardous. Low rates and amounts of water may be applied such as are required for seed germination, frost protection, delay of fruit budding and cooling of crops in hot weather. Fertilizers and soil amendments may be dissolved in the water and applied through the Irrigation system.

1.8 PROJECT JUSTIFICATION

Every modern Irrigation method has both advantages and disadvantages which govern the decision of the choice of the system by the designer. It is therefore imperative to evaluate the project and chose the most appropriate method suitable to a given Local Condition.

Since the slope of the site in question, as revealed by topographical survey, is not gentle; this coupled with the fact that half of the farmers are civil servants who don't usually have time to keep to the irrigation schedule, consideration of other methods become unviable. Therefore, the viable economic option, as far as this site is concerned, is the use of the sprinkler system, apart from its advantages, is also adaptable to irrigation of most other crops and soils especially those silt clay loam type of soil of this area, justifies the selection of the site for the sprinkler system.

.9 PROJECT OBJECTIVES

The main objectives of this project include among others: -

(a) To design a sprinkler Irrigation System for the site in question. Presently there is no standard system adapted for the design.

(b) To make a model for the design.

(c) To enhance economic status of the participating dry season farmers in Chanchaga and environs.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 HISTORY

Irrigated is on ancient agricultural practice that was used about 8000 year ago in Mesopotamia, Egypt, China, Mexico and Peru.

Today, about 25% of the world densest populations are supported through Irrigation agriculture. In Egypt 100% of the cropland is irrigated. In Sudan also, well over half of the country's export income comes from cotton that is grown in Gezira through Irrigation (Michael, 1950)

2.2 IMPORTANCE OF IRRIGATION

Gulhati of India, (1958) stated well the importance of Irrigation in the world. Irrigation in many countries is an old art – as old as civilization – but for the whole world, it is a modern science – the science of survival.

The pressure to survive and the need for additional food supplies are necessitating a rapid expansion of Irrigation through out the world.. Even though Irrigation is of paramount importance in arid regions of the world or earth, it is becoming increasingly important in humid regions (Christians 1953)

Isrealsen and Hansen (1962) stated that Irrigation is an age – old art. Historically, civilization has followed the development of Irrigation. The antiquity of Irrigation is well documented throughout the written history of Mankind.

Genesis mentioned Amraphel , King of Shiner, a contemporary of Abraham, who is probably identical with Hammurable, Sixth King of the first dynasty of Babylon. He developed laws, bearing the name of Hammurabi indicated that the people had to depend on Irrigation for existence.

Further mention of Irrigation is found in II King 3:16-17 of the Holy Bible. "and he said: - Thus said the Lord, make this valley full of ditches. For thus the Lord, ye shall not see wind, neither shall ye shall not see rain; yet that valley shall be filled with water, that ye may drink, both ye and your cattle and your beasts."

An ancient Assyrian Queen supposed to have lived before 2000 B.C., is credited with directing her Government to divert the water of the Nile to irrigate the desert lands of Egypt. Irrigation canals supposed to have been built under this Queen of Assyria are still delivering water. Thus there are records and evidence of continuos Irrigation for thousands of years in the valleys of the Nile and for comparatively long periods likewise in Syria, Persia, India, Jova, and Italy.

Egypt claims to have the worlds' oldest dam, 355ft (107.92m) long and 40ft (12.16m) high built 6035 years ago to store water for drinking and Irrigation. Basin irrigation introduced on the Nile about 3300 B.C. still play an important part in Egyptian Agriculture.

In China, where reclamation was begun more than 4000 years ago, the success of every kings was measured by their wisdom and progress in water control activities. King Yu, of Asia Dynasty (220 B.C.) was elected king by the people as a reward for his outstanding work in water – control (Isrealsen and Hansen, 1962)

2.3 IRRIGATION IN NIGERIA

Irrigation by shaduf method was introduce into Nigeria between 1297 and 1596 from Egypt, (Usman, 1972), since then the importance of irrigation to increase food production had been taken seriously.

However, the rate of expansion of irrigated area has been very slow due to in-consistent agricultural policies by various Governments (Nwa, 1991)

Small independent farmers continued to use shaduf method of Irrigation and small pumps for irrigation along rivers, stream banks, near ponds, lakes and Fadama areas for the growth of their crops such as tomatoes, Vegetables, wheat rice etc.

In the present days, the involvement of the private sector in complex irrigation is very limited. Infact, installation and maintenance of complex Irrigation system has been left solely into the hands of both Federal and State Governments as a result of high initial cost in installation and maintenance. The Federal Government of Nigeria, has established a number of Large Irrigation Schemes such as Nigeria Sugar Company Bacita (NISUCO), River Basin and Rural Development Authorities (RB and RDA), the Savana sugar company Numan has produced sugar cane under large scale Irrigation.

The Irrigation Department of Niger State Ministry of Agriculture is currently Irrigating about 3, 000 Hecters of Land.

2.4 SCOPE OF IRRIGATION

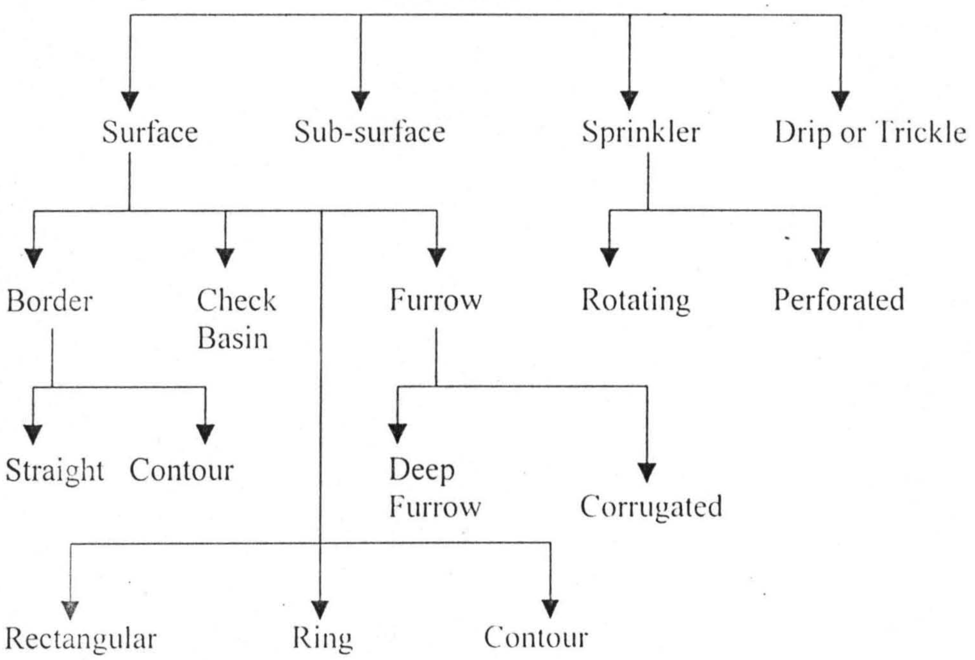
Irrigation science is not restricted to application of water to soil. It extends from the water shed to the farm and on to the drainage channel. The watershed yielding the irrigation water, the stream conveying the water, the management and distribution of the water, and the drainage problems arising from irrigation practices are all of concern to the

Irrigationist. Observing one portion of and irrigation system without considering its other components will lead to faulty design and inadequate preparation. (Isrealsen and Hansen. 1962)

2.5 IRIGATION METHODS

The methods of distributing Irrigation water can be classified as Surface. Sub-surface. Sprinkler or Overhead and Drip or Trickle. These are indicated schematically as follows: -

Table 2.5 IRRIGATION METHODS



2.5.1 SURFACE IRRIGATION

In this method of Irrigation, water is applied directly to the surface of the soil through a channel located at the upper reach of the field. Water may be distributed to the crop in Border strips, Check Basin, or Furrows as seen in Table 2.5. above.

.5.2 SUB-SURFACE IRRIGATION

In Sub-Surface Irrigation, water is applied below the ground surface by maintaining an artificial water table at some depth depending upon the soil texture and plant root depth.

2.5.3 DRIP OR TRICKLE IRRIGATION

Drip or Trickle method of Irrigation is one of the latest method of Irrigation which is becoming increasingly popular especially in areas with water scarcity. It is a method of watering plant root zone and a volume of water approaching the consumptive use of the plan thereby reducing each conventional losses as deep percolation, run off, and soil water evaporation. In this method, irrigation is accomplished by using small diameter plastic lateral line with devices called emitters or drippers to deliver water to soil surface near the base of the plant. The system applies water slowly to keep the soil moisture with in the desired range of plant growth.

2.5.4 SPRINKLER IRRIGATION

Sprinkler Irrigation is a versatile means of applying water to any crop, soil, and topographic conditions. It is particularly popular in humid regions because surface ditches and prior land preparation are not necessary and because pipe are easily transported and provide no obstruction to farm operations when Irrigation is not needed. Sprinkler is suitable for sandy soils or any other soil and topographic condition where surface Irrigation may be inefficient or expensive, or where erosion may be particularly hazardous. Low rates and amounts of water may be applied such as are required for seed germination, frost protection, delay of fruit budding and cooling of crops in hot weather.

Fertilizers and soil amendments may be dissolved in the water and applied through the Irrigation system. (Christiansen, 1948)

2.5.5 DESGN CRITERIA

The choice of various methods of Irrigation water application is influenced by a number of design criteria. Design requirements to be met vary according to climate, soil, crop, Hydrology, Topography and operational convenience and Economics as itemized below: -

(a) Climate: - This consists of rainfall, temperature, wind velocity and direction, Relative Humidity and sunshine.

(b) Hydrology: - The data should include water supply Quantity and Quality and distance from the source.

(c) Soil: - This should include the physical and chemical characteristics of the soil.

  (i) Physical:- These are depth, texture, permeability moisture holding capacity and infiltration rate

  (ii) Chemical:- They include the contents of Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca) Magnesium (Mg) and Aluminum (Al). The pH values of soils.

(d) Crop: - The data should include crop consumptive use, root zone depth and growing season.

(e) Topography: - This is the sloppiness or steepiness of the land.

(f) Operational Convenience: - This varies from place to place and the cultural practices of the people concerned.

2.6.0 SPRINKLER SYSTEMS

Sprinkler systems are of two major types, on the basis of the arrangement for spraying Irrigation water namely: -

(a) Rotating Head system

(b) Perforated Pipe system

Based on portability, sprinkler system are classified into the following types:-

(a) Portable System: - This has portable main lines and laterals and a portable pumping plant. It is designed to be moved from field to field or to different pumping sites in the same field. The system may be designed to be moved manually or by mechanical power. Comparatively the initial cost of this type of sprinkler is low, but high labour cost. The systems using mechanical power for moving laterals are usually the "wheel move system". This has a high capital investment and low labour cost.

(b) Semi-Portable: - This is similar to portable system except that the location of the water sources and the pumping plant are fixed.

(c) Semi-Permanent: -This system consist of a permanent mainlines and sub-mains, a stationary water source, fixed pumping plant, but portable lateral lines.

(d) Solid-Set System: - This system has enough laterals to eliminate movement.

(e) Permanent System: This consists of a permanently laid mains, sub-mains and laterals and a stationary water sources and pumping plant.
(Michael 1st Edition. 1950)

2.6.1 COMPONENT OF SPRINKLER SYSTEM

The parts of all the sprinkler system are similar in most respect. They consist of the pump to provide the needed pressure, the main pipe line and Laterals, risers and sprinkler heads. (Fig 2.6.1.)

(a) SOURCES OF WATER

The source of water is a place where water is obtained for Irrigation purposes, mostly, Rivers, Dams, Wells, etc.

(b) PUMPING SET

The pump usually lifts water from the source and pushes it through the distribution system and the sprinkler. It is important that the pump should be designed to lift the required amount of water from the source of supply to the highest point in the field and maintain adequate operating pressure.

System Capacity $$Q = \frac{25\ A\ Dg\ (L/S)}{9\ H\ Fi} \quad (1)$$

where Q = system capacity in L/S or m3/s

A = Area of the field to be Irrigated (M2)

Dg = Gross depth (mm)

H = Operational hours per day (hr)

Fi = Irrigation Frequency.

OR

$$Q = \frac{2780\ Ad}{FHE} \quad (2)$$

Where Q = discharge capacity of the pump (L/S)

A = Area to be irrigated in Hectare.

D = Net depth of water application (cm)

F = No of days allowed for the completion of Irrigation

H = No of actual operating hours per day.

E = water application Efficiency (%)

Michael. 1950

(c) MAIN LINE: -

This may be movable or permanent. permanent mains are used to best advantage on farms where field boundaries are fixed and where crops require full – season Irrigation. Movable mains are more economical when a sprinkler system is to be used on any of a number of fields. They generally have a lower initial cost and do not provide obstruction to field operations.

$$\frac{DH}{AL} = 15.270\, Q_n^{1.852} D^{-4.871} \quad \text{------- (3)}$$

Where

DH = Energy dropped by friction (m)

DL = Length of the pipe section (m)

Q_n = Total discharge in pipe (L/S)

D = Inside diameter of the pipe (cm)

(d) LATERALS:-
(e)

They are usually 6m or 9m lengths of aluminum or other light – weight metal pipe connected with couplers. In some cases the couplers are permanently attached to the pipes.

Equation (3) applies here also.

(e) RISER, HEAD AND NOZZLES

The riser directs water to the sprinkler heads which is finally sprayed out from the nozzles into the air and eventually drops down on plants or soil in form of rain.

There are rotating and non- rotating heads. For the rotating type. the heads used have two nozzles, one to apply water at a considerable distance from the sprinkler and the other to cover the area near the sprinkler centre.

Mostly agricultural sprinklers are of the slow rotating type.

They may range from small single nozzle sprinklers to grant multiple nozzle sprinklers that operate at high pressures.

2.6.2 TYPES OF SPRINKLERS

(a) Rotating sprinkler head

(b) Fixed Nozzle pipe

(c) Perforated pipe

(d) Big Bus/Traveller Irrigation Gun

(e) Centre Pivot Irrigation Head

(f) Hydrostatic power Roll wheel Irrigation Head

2.6.3 ADAPTABILITY OF SPRINKLER METHOD

Sprinkler Irrigation method could be used for almost all types of crops except Rice and Jute, which requires a lot of water which is achieved mostly through flooding. It is equally suitable for almost all types of soils except fine textured soils (heavy clay soil,) having infiltration rate of less than 4mm/hr.

Sprinkler Irrigation system does not require land-leveling operation which is one of the expensive aspect of irrigation practices, although it is not very good where there is drainage problem.

2.6.4 WATER REQUIREMENT

The estimation for water requirement (WR) is defined as the quantity of water required, regardless of the source, by a crop or diversed pattern of crops, in a given period of time, for its normal growth under field condition and it is given as: -

WR = ET + application losses + special needs - (4)

WR = Ir + Er + S - (5)

Where

Ir = Irrigation Requirement mm

Er = Effective Rainfall cm

S = Soil profile contribution

2.6.5. EVAPOTRANSPIRATION

Evapo – transpiration or consumption use is the sum of two terms:

(1) Evaporation: - which is water evaporating from adjacent soil. water surface or from the surface of leaves of the plant. Water deposited by dew, rainfall or sprinklers Irrigation and subsequently evaporating without entering the plant system is part of consumptive use.

(2) Transpiration: - which is water entering plant, roots and used to build tissue into the atmosphere.

2.6.6. NET DEPTH OF IRRIGATION WATER

The depth of water required from total available water point of view is given as the difference in the soils field capacity and the soil moisture content in the root zone

$$D_n = \frac{O_a \times MAD}{100} \text{ (mm)} \quad (7)$$

where

D_n = Net Irrigation required (mm)

MAD = Management Allowed Deficiency (%)

O_a = Available moisture in the soil (mm)

2.6.7 AVAILABLE MOISTURE CONTENT

$$O_a = \frac{C_n \times D_r}{100} \text{ (mm)} \qquad - \qquad (8)$$

where

O_a = available moisture content (mm)

C_n = Moisture holding capacity

D_r = Root zone depth

2.6.8 GROSS WATER APLLICATION DEPTH

This is the total amount of water applied through Irrigation and it needed for the determination of the application rate

$$D_g = \frac{100\ D_n}{E_a} \text{ (mm)} \qquad (9)$$

Where

D_g = Gross depth of water application (mm)

D_n = Net Irrigation Requirement

E_a = Water application Efficiency (%)

Consumptive use can apply to water requirements of crop on a field. farm. project or a valley. When the consumptive use of a crop is known, the water use of large units can be calculated Hence the term consumptive use and the following discussion generally refers to the crop.

Blaney – Criddle developed a simple field formula using temperature and day – time hours for the arid western portion of the united states. Their formula has been used extensively by the soil conservation service of the united states Department of

Agriculture where considerable data has been collected to determine the value of the co-efficient to be used for various crops.

(Isrealsen and Hansen, 1962)

By multiplying the mean monthly temperature (T) by the monthly percentage of day-time hours of the year (p) there is obtained a consumptive use factor expressed mathematically as follows:

$$ETo = P(0.46\,T + 8.13) \qquad (6)$$

Where

Eto = Reference crop Evapo-transpiration (mm/day)

P = % day-time hours

T = mean temperature in (0c)

2.6.9 IRRIGATION FREQUENCY

The number of days between irrigation's during periods without rainfall. This depends on:

(a) The consumptive use rate in the crop root zone and the amount of available moisture in the root zone.

(b)

(c) It is a function of crop, soil and water

$$F1 = \frac{Dg}{Cu} \quad \text{(days)} - (10)$$

Where

F1 = Irrigation Frequency

Dg = Gross depth of water application

Cu = Peak daily consumptive use (mm/day)

2.7 IRRIGAGTION PERIOD

This is defined as the number of days that can be allowed for applying one Irrigation to a given designed area during the peak consumptive period of the crop being irrigated.

The irrigation system is designed such that the irrigation period is always less or equal to the irrigation frequency.

$$I_p = \frac{In}{Ho} \quad \text{(day)} \quad (11)$$

Where

I_p = Net amount of moisture in soil between start of Irrigation and lower limit of moisture depletion.

Tn = Minimum Operating Time.

Ho = Number of actual operating hours per day.

2.7.1 COEFICIENT OF UNIFORMITY

This is the measurable index of the degree of uniformity obtainable for any size of sprinkler operating under given conditions.

The uniformity coefficient is affected by the pressure, nozzle size relation, sprinkler spacing and by wind condition.

$$Cu = 100\left(1.0 \frac{Ex}{Mn}\right) \quad \text{(Chritiansen. 1942)}$$

Where

Cu = Uniformity Coefficient

n = total number of observation points

M = Average value of all observations (mm)

(average application rate)

X = numerical deviation of individual observations from the average application rate (mm)

A uniformity coefficient of 100% (obtained with overlapping sprinklers) is indicative of absolutely uniform application, where as the water application is less uniform with a lower percentage.

A uniformity coefficient of 85% or more is considered to be satisfactory.

2.7.2 WATER QUALITY

In determining the quality of irrigation water, the soluble constituents that are of prime importance are calcium magnesium, sodium, sulphate, bicarbonates and boron. Poor water quality may result in various soil and cropping problems of which the most common ones are salinity, permeability and toxicity.

The quality of irrigation water is based on its total salt concentration, negative proportion of cations or sodium absorption ratio and the contents of bicarbonates and boron. The Irrigation water is expressed in terms of salinity, bicarbonate (HCO3) Magnesium (Mg) ratio and sodium adsorption ratio.

2.7.3 DESIGN OF SPRINKLER IRRIGATION SYSTEMS

A sprinkler irrigation system, to suit the condition of a particular site, is specially designed in order to achieve high efficiencies in its performance and economy. The step – by –steps procedure in the planning and design of sprinkler irrigation system is enumerated below.

1. INVETARY OF RESOURCES AND CONDITIONS

(a) Map of the Area: - It is essential that a map of the area concerned is prepared and drawn to scale with sufficient accuracy to show all dimensions so that lengths lof main and laterals can be scaled there from. It should be a contour map or, at least, should show all relevant elevations with respect to water supply pump location, and critical elevation in the fields to be irrigated. The elevation differences, together with friction losses in the mains and laterals and the pressure requirement of the sprinklers, determine the pressure that must be developed by the pump.

(b) Water supply – source, Availability and Dependability

It is important that an irrigation system of sufficient size is available to meet the maximum demand of crop. The quantity available should also meet the seasonal and annual requirements of the crops and the area to be irrigated. The water should be chemically suitable for irrigating the crops and soil of the area. It should not have any corrosive effect on the equipment. The water should be relatively clean and be free of suspended impurities so that the sprinkler lines and nozzles are not dogged.

(c) Climatic Conditions: - The consumptive use of a crop depends upon the climatic parameters such as temperature, radiation intensity, humidity and wind velocity. Sprinkler system is designed for the daily peak rate of consumptive use of crops irrigation by it. This has been discussed earlier. Equation (6) refers.

(d) Depth of Irrigation: - The depth of Irrigation is calculated on the basis of available moisture holding capacity of the soil in its different layers and the soil moisture extraction pattern of the crop in its root zone depth.

(d) Equation (7) Refers.

(e) Irrigation Interval: - From the point of view of sprinkler design, the irrigation interval is the length of time allowable between successive irritations during the peak consumptive use of the crop.

(f) Water Application Rate: - The rate of water application by sprinklers is limited by the infiltration capacity of the soil. Application at rates in excess of the infiltration capacity of the soil results in runoff, with accompanying poor distribution of water, loss of water and soil erosion. Table 2.2 presents water application rates for various soil conditions.

Table 2.7.3.1 suggested Maximum water Application Rates for Average soil, slope and cultural Conditions.

	Soil texture and Profile conditions	Maximum water application Rate for slope and cultural conditions (mm/h)			
		0% slope		10% slope	
		w/cover	bare	w/cover	bare
1.	Light sandy loams uniform in texture to 2m	43	25	25	15
2.	Light sandy loams over more compact sub soils	30	18	18	10
3.	Silt loams uniform in texture to 2m	25	13	15	8
4.	Silt loams over more compact sub soils	15	8	10	3
5.	Heavy texture clays or	5	3	3	2

clay loam.

Source: soil conservation service (1949)

(g) Sprinkler Spacing: - To achieve uniform sprinkling of water. it is necessary to overlap the area of influence of the sprinklers. The overlap increases with the increase in wind velocity Table 2.3 could be used as a guide in the design of sprinkler overlap under different wind conditions.

Table 2.7.3.2 Maximum spacing of sprinklers under

Windy conditions

S/No	Average wind speed	spacing
1.	No wind	65% of the diameter of the water spread area of a sprinkler.
2.	0-6.5 km/hr	60% "
3.	6.5-13 km/hr	50% "
4.	Above 13 km/hr	30% "

Adapted from Hurd (1969)

(h) Power Source: - The source of power to operate the pump is to be known in advance. Electric power is most convenient when the pump is stationary. Electric pumping sets are cheaper in initial cost and maintenance cost.

Portable diesel pumping sets are the most suitable and practical for fully portable sprinkler system.

2.7.4 FUTURE IRRIGAGTION GROWTH

As the population of the world increases, the demand for food and fibre for the people will also increase. With Irrigation water, many of there lands will become highly productive.

As long as the population is increased, material demand will also increase.

2.7.5 ECONOMICS OF IRRIGATION

Economics is very important in evaluating Irrigation practices, for Irrigation is largely for the purpose of profit maximization. Higher profits resulting from more efficient production will ultimatically result in lower price for the consumers and lower prices result in more consumption of food and fibres. The greater availability of food fibre result in higher standard of living for the people of the world.

Irrigation as well a as other Engineering and Agricultural works, are for the purpose of making the world a better place for living.

CHAPTER THREE

3.0 MATERIALS AND METHODS

In the design of any Irrigation system there are factors that must be considered in order to come up with the appropriate required design for the site in question.

In the case of New Chanchaga Irrigation scheme, the Topography, Climate, Water Resources, Soil characteristic and crop factors were considered for the sprinkler system Design.

3.1 TOPOGRAPHY

From the Land Survey carried out by the Irrigation Department of Niger state Ministry of Agriculture, the topographic Map of this area shows that the land is fairly undulating, as could be seen from the contour map Fig. 3.1, with the elevation varying from 91.79 to 103.16 meter above sea level. (A Temporary or Abitrary Bench Mark was survey).

3.2 CLIMATOLOGY

From the climatic data obtained from the Meteorological station at Minna Airport, the climate of the project area is essentially that of the Middle Belt with high temperature in summer (March – September). The wet season generally lasts from April – October while dry season which is marked by harmattan conditions prevailing for several weeks lasts from October – March.

3.3 WATER RESOURCES

The Water Resources is further divided into two categories as follows: -

(a) Water Quality: - River chanchaga kis the main sources of water. This river flows all the year round. There is an existing weir down stream of the project area. This was constructed by the Niger State Water Board in order to store water for domestic use. There also exist Tagwai Dam upstream which supplies water in case there is a short fall in the wier reservoir. So this is a clear indication that there will be enough water for the project area.

(b) Water Quality: - Although the water for Irrigation from the river is considered good enough, based on the fact that there is an existing Irrigation scheme down stream and villages, that use the water from the river for drinking and domestic work. It was still necessary o analyse the water, for this particular project. This was to ascertain that the water is free of elements that will have negative effects on the soil or crops to be grown. Water samples were collected in labeled sampling bottles to identify each sampling point. All samples collected were delivered to the Laboratory within 24 hour of collection for analysis.

The water samples collected in bottles were kept under a room temperature which did not exceed 25^0c on arrival from field, the idea was to reduce Microbial activities to the bearest Minimum.

3.3.1 LABORATORY ANALYSIS

Water quality measurement usually involves mainly Laboratory analysis. The measurement method were based on : -

(a) Total Number of analysis

(b) Frequency and scope of measurement

(c) Sensitivity and detection limits

(d) Constraints on accuracy and precision

Because of the recent advancement in technology, automated techniques for water pollution characterization was adopted.

A C – 100 series multiparameter Bench Spectrophotometer was used for the concentration in water of all the determinants.

3.3.2 PRINCIPLE OF OPERATION OF SPECTROPHOTOMETER

The colour of every object we see is determined by a process of absorption and emission of the electromagnetic radiation (light) of its molecules. Calorimetric analysis is based on the principle that specific compound react on the others to form a colour the intensity of which is proportional to the concentration of the substance to be measured. When a substance is exposed to a beam of light intensity I_o, a portion of the radiation is absorbed by the substance molecules and Radiation intensity I. lower than I_o is emitted. The quantity of radiation absorbed is given by the Lambert – Beer Law.

$$\text{Log } I_o / I = ET\ Cd$$

Where

$\text{Log } ^{Io}/I$ = Absorbance (A)

ET = Molar extinction Coefficient of substance at wave length T

c = Molar concentration of the substance

d = option distance light travel through samples.

Therefore, the concentration 'C' can be calculated from the colour intensity of the substance determined by the emitted radiation. I. as the other factors are known.

able 44 Operating Figures for Some Sprinklers (Square Pattern)

Nozzle mm	Pressure kg/cm^2	Wetted Diameter m	Discharge m^3/hr	Spacing m	Area Irrigated m^2	Precipitation mm/hr
4.5	2.0	13.5	1.1	12 x 18	215	5.0
	2.5	14.0	1.2	12 x 18	215	5.5
	3.0	14.5	1.3	18 x 18	325	4.1
5.0	2.0	13.5	1.3	12 x 18	215	6.2
	2.5	14.5	1.5	18 x 18	325	4.6
	3.0	15.0	1.6	18 x 18	325	5.0
6.0	2.0	14.5	1.9	18 x 18	325	6.0
	2.5	16.3	2.2	18 x 24	430	5.0
	3.0	16.5	2.8	18 x 24	430	5.5
4.5/4.8	2.0	14.0	2.3	12 x 18	215	10.8
	2.5	14.8	2.6	18 x 18	325	8.0
	3.0	15.5	2.8	18 x 18	325	8.8
5.0/5.5	2.5	16.0	3.3	18 x 18	325	10.2*
	3.0	16.3	3.6	18 x 24	430	8.4
	3.5	16.6	3.9	18 x 24	430	9.1
5.0/7.5	3.0	19.0	5.3	24 x 24	575	9.3
	3.5	19.3	5.8	24 x 24	575	10.7
	4.0	20.0	6.2	24 x 24	575	10.7
6.0/7.5	3.0	17.7	6.1	18 x 24	430	14.0
	3.5	18.5	6.6	24 x 24	575	11.3
	4.0	19.0	7.0	24 x 24	575	12.2

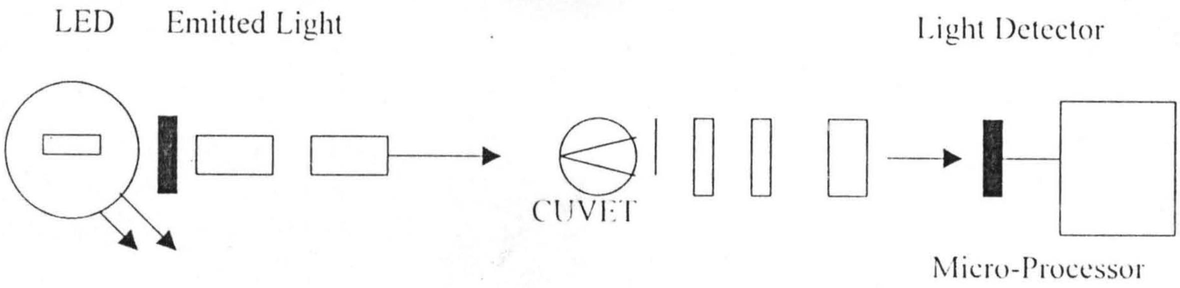


Fig. 3.2 BLOCK DIAGRAM OF SPECTROPHOTOMETER

A Macromatic LED (Light Emitted Diode) emitts radiation at a single wave length. supplying the system with the intensity, I. Since the substance absorbed the colour complimentary to the on it emits. Hauna Spesctrophotometer uses LED that emits appropriate wave length to measure the sample. The photoelectric cells collects the radiation, I, that is not absorbed by the sample and converts it into on electric current, producing a potential in the MV range.

The Micro – Processor uses this potential to convert the in-coming value into the desired measuring unit and display it on the LED.

3.3.3 P.H MEASUREMENT

Specifications

Range : - 4.9 – 8.5 PH

Accuracy : - + 0.1 PH

Light Source : - Light Emitting Diode at 555mm

Method : - Adaptation of the Phenal Red Method.

The reaction with the re-agent causes a red tint in the sample.

3.3.4 PHOSPHATE

Specifications

Range: - 0.0 – 30.0 mg/l

Accuracy : - + Img/l + 4% of reading

Light Source: - Light Emitting Diode at 470mm

Method : - Adaptation of the standard Method for the Examination of water and waste water (WHO, 1996, 18th Edition) Amino acid method. The reaction between phosphate and the reagent causes a blue tint in the sample.

3.3.5 NITRATE

Specifications

Range : - 0.0 – 85 mg / l

Accuracy : - + 0.5 mg/l + 10% of reading

Light Sources : - Light Emitting Diode at 555 mm

Method : - Adaptation of the Calcium Reduction Method. The reaction between the nitrate and the reagent causes an amber tint in the sample.

3.3.6 DISSOLVED OXYGEN

Specifications

Range : - 0.0 – 10.0 mg/l

Accuracy : - + 0.4 mg/l + 3% reading

Method : - Adaptation of standard method for the examination of water and waste water (WHO 18th Edition) Oxide modified winkler method. The reaction between dissolved oxygen and the reagent cause a yellow tint in the sample.

3.3.7 POTTASSIUM

Specifications

Range : - 0.0 – 20.0 mg/l

Accuracy : - + 0.1 mg /l + 2% reading

Light source : - Light Emitting Diode at 768mm

Method : - Adaptation of stander method for the examination of water and waste water (18th Edition). Flame emission spectrophometry I Method

3.3.8 ELECTICAL CONDUCTIVITY (Micro Ohms /CM)

The salt concentration in any Irrigation water is easily measured by determination of Ec, it measures the ability of any water to conduct electricity and is expressed as Micro Ohms/cm = 0.1 Micro ohms /cm (0.0 – 1 Ohms/cm). From the result of water analysis carried out, the EC values for all samples range from 0.05 to about 0.10 Ohms/cm meaning that they could safely be used to Irrigate most crops on most soils in the field with little or no likelihood that soil salinity will develop.

3.4 SOIL ANALYSIS

The objectives this was to collect for analysis composite surface (0.15cm) soil samples to evaluate the fertility status to the soil with respect to elements related to the determinants being considered and to determine whether or not the soil of the study area requires additional Macro – Elements (Fertilizers)

3.4.1 SAMPLING

The sampling was guided by pre-determined irrigation lay out at a depth of 0 – 15cm at each sampling point. Samples were collected at random points within the project area. Four samples were collected by means of soil augers at the project area.

3.4.2 PRE-TREATMENT

As soon as samples were obtained in the field. they were taken for pretreatment. This involves air drying for 2 – 3 days. after which they were grinded with a porcelain Motar and pestle.

3.4.3 SOIL PH

The pH of the soil was determined in a 1:21/2 ratios of soil to solution. Suspension ratio's of water and 1 mole of KCL respectively. The PH was read using the glass electrode PH meter.

3.4.4 AVAILABLE PHOSPHOROUS

This was determined using Bray – 1 method which employs a mixture of 1 mole of NH4F (Ammonium Floride) and 0.5 mole HCL (Hydrochloric acid) the colour absorbance was read colorimetrically on the spectrophotometer.

3.4.5 TOTAL NITROGEN

This was analysed using Micro-Kjeldahe Method of Bremmer black (1965)

3.4.6 EXCHANGEABLE POTTOSSIUM CATION

A mole NH OAC (ammonium acezte) at PH7 mixture was used to determine the concentration of potassium with the aid of a Flame photometer.

3.4.7 SOIL PARTICLE-SIZE DISTRIBUTION

The particle size analysis was carried out on previous air-dried soil samples that had been sieved through a 2mm mechanical sieve. Hydrometer method as described by Boryouccus (1954) was used and Neutral sodium Hexameta phosphate (calgon) used as dispersing agent.

3.4.8 SOIL ORGANIC MATTER CONTENT ANALYSIS

Organic matter in formed from the residues of plants and animals. Its main function is to provide nutrients and mico- organism for plant life, as well as improve and stabilize the soil texture. Addition of organic matter provides water storing capacity of sand and drainage characteristics clays and silts.

The apparatus used n the determination of soil organic matter are 500ml flask and 200°c thermometer. The soil is grounded to pass a 0.5mm screen contact with iron and steel. A weighed sample not exceeding 10gm and containing 10 to 25 mg of organic carbon, is transferred into a 500mc flask and 10mc of potassium is added followed by 20ml of concentrated H2SO4. The thermometer is inserted into the mixture and heated gently so as attain a temperature of 150oc in a heating time of about 1 minute. The contents of the flask are then allowed to cool, a few drops of water and an indicator is added. The mixture is filtrated with ferrous sulphate solution until colour changes from green to red.

3.4.9 SOIL INFILTRATION TEST

The main objective of this test was to determine the sample size necessary to estimate the means and standard deviation of infiltration parameters at desired levels of confidence. Four field tests were conducted on the project area using cylindrical infiltration meters method.

3.4.10 TEST METHOD

Two cylindrical infiltrimeters with different diameters were used. The inner cylinders from which the infiltration measurements were taken was 30cm in diameter and outer cylinder which was used to form the buffer pond was 60cm in diameter. The cylinders were installed at about 12cm deep in the soil. This was accomplished by marking the outside of the cylinders at the 12cm level and driving the cylinders up to the mark. This was done by a falling weight type hammer striking on a wooden plank placed on top of the cylinder to prevent damage to the edges of the metal cylinder. The water level was read with the field type point gauge. The point rod was set at the desired level to which water is to be added. A stop watch was used to note the instant the addition of water begins and the time the water reaches the desired level. The total quantity of water added to the inner cylinder was determined by counting the Number of full containers of water and the fractional volume in the Jar which is added last. The difference between the quantity of water added and the volume of water in the cylinder at the instant. It reaches the desired point was taken as the quantity of water that infiltrates during the time interval between the start of filling and the first measurement. After the initial reading point, gauge measurements were made at equal intervals to determine the amount of water that has infiltrated during the time interval. The average depth of water maintained was 5 – 11cm.

3.4.11 CLASSES AND AVAILABLE SOIL WATER

Soil water has been classified as hygroscopic, capillary and Gravitational water.

Hygroscopic water is found on the surface of soil grains and not capable of movement by action of gravity or capillary forces.

Capillary water is that part in excess of hygroscopic water which exist in the pore space of the soil and is restrained against the forces of gravity in a soil that permit unobstructed drainage.

Gravitational water is that part of excess of hygroscopic and capillary water which move out of the soil if favourable drainage is provided.

3.4.12 BULK DENSITY OF SOIL

The bulk density of the soil is ratio of mass of the soil and the specific value. Soil sample was weighed and pound into a measuring cylinder whose initial water has been determined.

The difference between the final and initial water will give the value of the sample.

$$Dn = \frac{Ms}{Vs} \text{ ----------------- (i) (Brady 1984)}$$

Where Db = Bulk density in (g/cm3)

Ms = Mass of dry soil in (g)

Vs = Volume of soil in (cm3)

The bulk density of the soil is = 2.48g/cm3

3.4.13 SOIL MOISTURE CONTENT

Soil sample was obtained at a depth of about 30cm using soil auger. The soil moisture content was determined and expressed in depth. The moisture content is 10.5% and expressed in depth of 7.812 cm.

$$Mc = \frac{Ww - Wd}{Wd} \times 100 \text{ ------ (ii)}$$

Where Mc = Moisture content in %

Ww = Weight of wet soil in (g)

Wd = Weight of dry soil in (g)

The expression of moisture content in depth is

$$d = \frac{Pw \times As \times D}{100} \text{ -------------(iii) (Isrealsen 1962)}$$

where Pw = Weight of soil moisture content in (%)

As = Apparent specific

D = Depth of root zone in (cm)

3.5.0 DESIGN PROCEDURE OF SPRINKLER SYSTEM

In Design of sprinkler system the following are considered:

(i) Application Depth

(ii) Irrigation Interval

(iii) Irrigation Period

(iv) Volume of Water required

(v) Capacity Requirement

(vi) Area to be Irrigated per day

(vii) Sprinkler Discharge

(viii) Lateral Discharge

(ix) Main Line Design

(x) Pressure Requirement

3.5.1 GROSS APPLICATION DEPTH

This kiss calculated by using the equation:-

$$d = \frac{(Psa)\,D}{Ea}$$

Where

d = gross depth of application (mm)

P = Fraction moisture extraction level

Sa = Moisture holding capacity of soil (mm/m)

D = depth of root Zone (mm)

Ea = application Efficiency 0.75 (fraction)

3.5.2 IRRIGATION INTERRURAL

This is the number of days allowed between one irrigation and another. It is the ratio of gross depth of application to the peak consumptive use: - i.e.

$$Fi = \frac{d}{Cu.}$$

Where

Fi = Irrigation Interval (days)

d = gross application depth mm

Cu = peak consumptive use of the crop mm/day.

3.5.3 IRRIGATION PERIOD

This is the required to complete one irrigation in hours.

It is calculated by using the equation

$$\text{Irrigation period} = \frac{\text{depth of irrigation (mm)}}{\text{Soil intake rate (mm/hr)}}$$

3.5.4 VOLUME OF WATER REQUIRED FOR 10 hr

This is given by equation

$$V = \frac{Ad}{Ea}$$

Where

V = Volume of water required (m3)

A = Area to be irrigated (m2)

d = depth of application (m) (seasonal requirement)

Fa = application Efficiency (traction)

3.5.5 CAPACITY REQUIREMENT

One of the parameters of the sprinkler system which needs to be evaluated is its capacity requirement. The required capacity of a sprinkler system depend on the size of the area to be irrigated, the gross depth of application at each irrigation and the net operating time allowed to apply the depth.

It is determined by the use of the equation

$$Q = \frac{453AD}{FH} \quad \text{(FAO 1984)}$$

Where

Q = Discharge Capacity (gpm)

A = Area to be Irrigated (Acre / (ha)

D = gross depth of application (inches / (mm)

F = Number of days allowed for completion of one irrigation

H = Number of actual operating hours / day

3.5.6 AREA TO BE IRRIGATED PER DAY

This can be determined by the use of Equation.

$$qt = ad$$

where

q = discharge (cubic ft/sec)

t = time required to complete on Irrigation (hour)

a = area that can be irrigated with a given discharge (q) (acres)

d = depth of application (inches)

3.5.7 SPRINKLER DISCHARGE

This can be determined by the equation

$$q = \frac{Si \times Sm \times I}{96.3} \quad \text{(FAO 1984)}$$

where

q = sprinkler discharge (gpm)

Si = sprinkler spacing (ft)

Sm = Lateral spacing (ft)

I = optimum application rate (mm/hr) inches / hr

3.5.8 LATERAL DISCHARGE

The design is based on lateral on level ground. Allowed pressure loss due to friction in the lateral line is 20%.

Discharge per ,lateral = discharges / sprinkler (q) X

Number of sprinkler lateral.

i.e. Allowable loss per 100 ft

$$= \frac{0.20pa \times 2.31}{{}^{L}/100 \times F}$$

Where

Pa = pressure

F = Correction factor for frictional losses in pipes

L = length of lateral.

3.5.9 MAIN LINE DESIGN

The allowed loss in the main line is given by the equation

$$Pm = Pa + \frac{3}{4}(Pf + Pr)$$

Where

Pm = pressure required to lift water in the risers per sprinkler

Pa = Operating pressure (Psi)

Pf = Actual pressure loss due to friction (Psi)

Pr = Pressure loss due to riser pip (Psi)

$\frac{3}{4}$ = factor used to provide for the average operating pressure (Pa) at the centre of the line.

3.5.10 PRESSURE REQUIREMNT

To elect a pump and power unit that would operate the system efficiently it is necessary to determine the total pressure losses in the system or the total dynamic head against which water must be pumped.

(a) Static Head:-

This is the difference in elevation between the water source and the point of discharge or the vertical distance the water must be raised or lowered.

(b) Total Dynamic Head:- (TDH)

$$TDH = Hl + Hf + hf + Hs$$

Where

Hl = pressure head required to operate the lateral line.

Hf = friction loss in the main / submain line

hf = friction losses in fittings and values.

Hs = toatal static head including suction lift.

(c) Selection of Pump and Power Unit.: -

Having determined the total dynamic head, pump size can be computed by the use of equation

$$\text{Pum size} = \frac{QH}{100E} \quad (KN)$$

where

Q = Max – discharge (litre / sec)

H = Total Dynamic Head (m)

E = Pump Efficiency (0.75)

100 = constant

- Water Harse Power (WHP)

$$= \frac{QH}{3960}$$

where

Q = discharge (gpm)

H = TDH (ft)

- Break Horse Power = $\frac{\text{Water Horse Power}}{\text{Efficiency}}$

$$BHP = \frac{WHP}{EFF}$$

3.6.0 CROP DATA

Crop to be grown – Assorted vegetables

Depth of root zone – 0.6m

Average daily water requirement – 6mm/day

3.7.0 DESIGN DETAILS

- Major Crop (Proposed) – Assorted Vegetables
- Area – 10 ha
- Peak Consumptive use (cu) – 7mm / day (FAO 241984)
- Soil type – Sandy Clay Loam
- Moisture Extraction Level – 40%
- Application Efficiency Ea – 75% (sprinkler system)
- Soil intake rate (Si) 10mm/hr (Infiltrometer Test).

CHAPTER FOUR

4.0 DESIGN CALCULATION OF SPRINKLER IRRIGATION SYSTEM

4.1 CHOICE OF SYSTEM

Every modern Irrigation method has both advantages and disadvantage which govern the decision of the choice of the system by the designer. It is therefore imperative to evaluate the project and choose the most appropriate method suitable to a given local condition.

Since the slope of the site in question as revealed by the topographical survey .is not gentle, considerations of the other methods becomes unviable.

Therefore the viable economic option as far as this site is concerned is the use of sprinkler system. The system apart from its advantages is also adaptable to irrigation. of most other crops. especially those sandy clay loam type .of soil.

4.2 DESIGN PROCEDUR

The following parameters are to be determined.

(i) Capacity Requirement (Gross Water Requirement)

(ii) Depth of Application, Irrigation Period and Irrigation Interval.

(iii) Sprinkler Discharge. size spacing and the operating pressure.

(iv) Lateral Design -- discharge. size and head loss

(v) Main line Design – discharge. size and total pressure required.

(vi) Total Dynamic Head.

(vii) Pump Capacity and Power Unit.

4.3 DESIGN DETAILS

The project area is 10ha located very closed to River Chanchaga. A semi permanent sprinkler Irrigation System is adopted for the design of the project. the mainline is semi – permanent while the laterals and the sprinklers are portable. Hydrants are installed at specific locations as shown on the schematic map fig. 4.1

Good quality source of water is available from the adjacent River Chanchaga and can be extracted through the season. The consumptive use is 7mm/day – (FAO 241984)

Considering the type of soil on site the following parameters are determined

Field Capacity (FC) = 31%

Wilting Point (WP) = 14%

Infiltration Rate = 10mm/hr

Depth of Root Zone = 0.6m

4.4 CALCULATIONS

Using the equation: -

(a) RAM = Pa (FC – WP) he x 10mm

Where : -

RAM = Readily Available Moisture

Pa = Lower allowable Limit

(in in the design it is fixed at 50%)

FC = Field Capacity of the Soil type by Volume

WP = Wilting Point by Volume.

he = Rooting depth

The figure (10) appears for conversion of volume to linear dimension.

$$RAM = 0.5\,(31 - 14)\,0.6X10$$

$$= 51mm$$

=======

(b) Irrigation Interval

This is the number of days allowed between one irrigation and another. It is the ratio of the gross depth of application to the peak consumptive use i.e.

$$\text{Irrigation Interval} = \frac{\text{Net depth of Application}}{\text{Consumptive use}}$$

$$= \frac{51}{4} = 7days$$

======

(c) Irrigation Period

This is the time required to complete one irrigation in hours. It is calculated by the use of the equation: -

$$\text{Irrigation period (T)} = \frac{\text{depth of Irrigation (d)}}{\text{Soil intake rate (Si)}}$$

$$= \frac{51}{10} = 5.1 \text{ hours}$$

=======

i.e. Each setting will irrigate for 5 hours before next shift

(d) Design Capacity

One of the parameters of the sprinkler system which needs to be evaluated is its capacity requirement. The required capacity of a sprinkler system depend on the size of the area to be irrigated, the gross depth of application at each irrigation and the net operating time allowed to apply the depth. It is determined by the use of the equation: -

$$Q = \frac{453\ AD}{FH} \qquad \text{(FAO 1984)}$$

Where : -

Q = Discharge capacity in gallons per minute (gpm)

A = Area to Irrigated (Acres) (ha)

D = gross depth of application (inches) mm

F = Irrigation Interval (days)

H = Number of actual Operating hours per day.

In this design : -

A = 10 ha = 25 Areas

D = 51mm = 2 inches

F = 7 days

H = 8 hours

$$\therefore \quad Q = \frac{453 \times 25 \times 2}{7 \times 8}$$

= 405 gpm = 31 Litres/sec

4.5 SELECTION OF SPRINKLER SIZE, SPACING AND OPERATING PRESSURE

To determine the area that can be irrigated in a day, this equation is used : -

$$Qt = ad$$

Where

q = discharge (Cubic ft/sec)

t = time required to complete one Irrigation (hrs)

a = area that can be irrigated with a given discharge (acres)

d = depth of application (inches)

In this design : -

q = 405gpm = 1.1 cusecs

t = 8 hours

d = 51mm (2 inches)

$$\therefore a = \frac{qt}{d} = \frac{1.1 \times 8}{2} = 4.4 \text{ Acres}$$

$$= 1.78 \text{ i.e. } 2\text{ha}$$

i.e. Area that can be Irrigated in a day of 8 hour of working 2ha

The farm id divided into 5 plots of 2ha each (see schematic map) one plot is to be irrigated in a day.

Two (2) shifts of 4 hrs per setting would be required per day.

- Size of each plot is 100m x 200m

- In one setting, area to be irrigated = 100m x 100m = 1ha

For economic reason portable laterals and sprinklers are adopted; provision is made only for laterals and sprinkler that would be required per setting.

- In this design, average wind velocity of 15 km/hr, an application rate of 10mm/hr and spacing of 18m x 18m were adopted sprinkler discharge is given by the equation: -

$$q = \frac{Si \times Sm \times I}{96.3} \quad \text{(gpm)}$$

where:

q = sprinkler discharge (gpm)

Si = Lateral spacing along the lateral (ft)

Sm = Lateral spacing along the main (ft)

I = Optimum application rate (inch/hr)

In this designed: -

Si = 18m (60 ft)

Sm = 18m (60 ft)

I = 10mm/hr (0.4/hr)

$$\therefore \quad q = \frac{60 \times 60 \times 0.4}{96.3} = 15\text{gpm} = (1.1 \text{ litres/sec})$$

i.e. discharge per sprinkler = 15gpm or 1.1 Litre/sec.

.: The selection of q = 2.6m3 /hr is ok

From Nomograph: -

Size of nozzles = 5.5mm x 3mmm

Operating pressure = 3.5 kg/cm2 (50 psi)

With a spacing of 18m x 18m

3 Laterals and sprinklers would be required per setting for 1ha.

4.6 LATERAL DESIGN

The designed is based on lateral on level ground. In this case, the allowable pressure loss due to friction in the lateral line would be equal to 20% of the average operating pressure for sprinklers "Pa"

To determine the size of pipe required. first divide 20% of "Pa" (in feet) by the product of the length of the lateral line in 100 feet sections and the appropriate factor "F" taken from table 4.6. This calculation would result in allowable loss in feet per 100ft.

If the total lateral discharge were carried through the entire line.

i.e. Allowable per 100ft = $\frac{0.20 \text{ Pa} \times 2.31}{2/100 \times F}$

Where 2.31 is a factor for converting PSI to feet (pressure head)

In this design

L = 135 = 405ft

Pa = 3.5 Kg/cm2 = 50 psi

F = 0.415 (from Table 4.6)

Therefore:

$$\text{Allowable loss} = \frac{0.2 \times 50 \times 2.31}{\frac{405 \times 0.415}{100}}$$

= 13.90ft (4.6m)

Discharge per lateral = discharge / sprinkler x No of sprinklers p x lateral.

= 11.8 x 8 = 94.4 gpm (22.7m3/hr)

From the table: -

With the head loss of 13.90ft and discharge of 94.49pm, the corresponding size of lateral pipe is = <u>3" (75mm)</u>

4.7 MAIN LINE DESIGN

The allowable loss in the main line is given by the equation :-

$Pm = Pa + ¾ (Pt + Pr)$

Where : -

Pm = pressure required to lift water in the risers / sprinklers

Pa = Operating pressure (Psi)

Pf = Actual Pressure loss due to friction

Pr = pressure loss due to riser pipe

¾ = factor used to provide for the average operating pressure of the centre line

in this Design: -

Pa = 50 Psi

Pf = from Table 4ft = 1.4m (2 Psi)

Pr = 1.45 Psi (1m high)

.; Pm = 50 + 3/4 (2 + 1.45)

= 52.6 Psi (105 ft) = 35m

To determine the friction loss along the main line assume a diameter (pipe size) of 6" with a Q (Max. discharge) of 384 gpm with a corresponding head loss on the table per 100ft is 1.67ft

The length of the main line = 300m = 900ft

.: The allowable loss in 900ft main line

$$= \frac{900 \times 1.67}{100}$$

= 15ft

and this is less than 31.5ft

Hence th e selected size of the main line of 6" is o.k. (i.e. 150mm)

4.8 PRESSURE REQUIREMENTS

To select a pump and power unit that will operate the system efficiently, it is necessary to determine the total pressure losses in the system of the Total Dynamic Head (TDH) against which water must be pumped.

(a) Static Head: -

This is the difference in elevation between the water source and the point of discharge or the vertical distance the water must be raised or lowered.

In this design the static head

= 99 – 96 = 3m (9ft)

TDH is the sum total of: -

(i) pressure head required to operate the lateral line – HL.

(ii) Friction loss in main line / submain - HF

(iii) Friction loss in fittings and Values – hf

(iv) Total static head including suction lift – Hs

.: TDH = HL + HF + hf + Hs

hf is negligible

.: TDH = HL + HF +Hs

In this design

HL = 105 ft (35m)

HF = 15 ft (5m)

Hs 9ft (3m)

.: TDH = 105 + 15 + 9 = 129ft (43m)

(b) Selection of Pump and Power Unit: -

Having determined the total dynamic head, pump size can be computed by use of the equation.

$$\text{Pump size} = \frac{QH}{100}$$

where

Q = Max. discharge (lit/sec)

H = total dynamic head (m)

E = Pump Efficiency (usually 0.75)

In this design

Q = 31 Litres / sec.

H = 129ft (43m)

E = 0.75

$$\text{.: Pump Size} = \frac{31 \times 43}{100 \times .75} = 17.7 \text{ KN}$$

$$= 18KN$$

- Water Horse Power (WHP)

This is the theoretical horse power required for pumping.

It is the head and capacity of the pump expressed in terms of horse power. It can be computed by the use of the equation.

$$WHP = \frac{QH}{3960}$$

Q = discharge (gpm)

H = total dynamic head (ft)

$$.: = \frac{405 \times 129}{3960} = \underline{13.2}$$

- Break Horse Power = $\frac{WHP}{Efficiency}$

Assume efficiency = 0.75

$$.: \quad BHP = \frac{13.2}{0.75} = 17.6$$

$$.: \quad BHP = 18$$

Hence a pump of 18KN (18HP) with discharge capacity of 31 litres / sec. Required.

In view of the high cost of sprinkler equipment, it has been recommended to procure only one set of equipment that can irrigate 2 ha in a day and 10 ha in 5 days with 2 shift per day. The items required per setting are at the bill of quantities.

BILL OF QUANTITIES

S/NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT (#)
1.	6" Alluminium Pipes Main	No	85	3,500	237,500
2.	3" Alluminium Pipes Late	No	120	3,000	360,000
3.	sprinklers with 1m risers & stabilizing battern Hydrants	No	40	1,500	60,000
4.	Elbows	No	13	1,000	13,200
5.	End Cup 6"	No	6	500	3,000
6.	End Cup 3"	No	6	500	3,800
7.	6" Couplers	No	6	400	2,400
8.	6" Couplers	No	85	550	46,750
9.	3" Couplers	No	120	450	54,000
10.	High Pressure Pump capacit 25.6 Litres sec. At 43m the and 20 HP (15.4KN)	Set.	1	-	1,975,000
11.	6" Central Value	No	2	25,000	50,000
	Add 10% for contingencies				**#2,793,650 279365**
	Total				**#3,073,015**

CHAPTER FIVE

5.0 RESULTS AND DISCUSSION

Based on the factors considered for the design of Sprinkler Irrigation System, the following results were obtained for the design of New Chanchaga Irrigation Scheme.

(i) Discharge Capacity of the System.

The required capacity of the system depends on the size of the area to be Irrigated (design area), the gross depth of water applied at each irrigation, and the net operating time allowed to apply water to this depth.

Based on the above factors, the system capacity was calculated and the I got it to be 31 Litres per Sec.

(ii) Application Depth

This is the gross depth of water required per irrigation. This is a function of root zone depth, application efficiency, moisture holding capacity of the soil, and the fraction moisture extraction level. This was calculated to give 51mm

(iii) Irrigation Interval

This is the number of days allowed between one irrigation and another. It is the ratio of the gross depth of application to the peak consumptive use. This was calculated to give 7 days.

(iv) Irrigation Period

This is the time required to complete one irrigation in hours. It is a ratio of gross depth to the soil intake rate.

This was calculated to give 4.8 hours so I take it to be 5 hours.

(v) Area to be Irrigated per Day

From the irrigation period and area to be irrigated per setting. kit will take 2 Hect / day

(vi) Sprinkler Discharge

This is the required discharge of an individual sprinkler and is a function of thee water application rate and the two-way spacing of the sprinklers. It was determined to give 1.1 Litres per sec.

(vii) Lateral Discharge

This was calculated by getting the product of discharge per sprinkler and the No of sprinklers per lateral. This was found to be 13.2 Litres / sec

(viii) Main Line Discharge

The main line discharge is the system discharge capacity minus the frictional loss in the main. This gave me 29 Litres / sec.

(ix) Pump Capacity

Based on the total pressure losses in the system and the Total Dynamic Head against which water must be pumped.

5.1 DISCUSSION

From the above results. it is very clear that the ten hectares can be irrigated in 5 days with allowance of 2 days for the equipment maintenance. This will also serve as a resting period for the staff.

Hence. Sprinkler Irrigation is the most suitable system of Irrigation that can be adopted for the project area.

However. it should be note that all sprinkler manufactures should provide performance data for their equipment. The performance data should include the effective diameter under no wind conditions, discharge for various nozzles and pressures and minimum recommended operating pressure for the various nozzle sizes. Up to a point, as pressure is increased, the effective diameter is also increased and more uniform application may result. For a good breakup, the pressure should be increased as the nozzle size increases.

For this project area, the following are required for effective coverage and uniformity:

(1) 53 No, of pipes for main line of 6" diameter.

(2) 13 Hydrant points or out-lets on the main line.

(3) For economy reason, we require 3 laterals of 4" diameter pipe to Irrigate 2 ha / day with one shift.

(4) 105 No. of lateral pipes of 4" diameter.

(5) 36 No. of sprinkler per setting with the above, 2 ha. One expected to be irrigated daily with 2 settings which 10 hours per day.

Water application could be started by 8:00 am to 1pm for the first setting and I hour will be used for moving the equipment or pipes for second setting this will start from 2pm to 6pm.

It should also be noted the design is not for the irrigation of the exact 2 ha per day, an allowance of 0.3 ha is given to take care of unforeseen stoppages that might occur during the operation.

In this design, it is also expected that the main line and position of the pump is permanent, while the laterals are moved per end of each setting i.e. a semi permanent system is adopted here.

6.2 RECOMMENDATION

In view of results obtained, I wish to recommend the following: -

(i) that the water for irrigation should be free of depris to avoid elagging of the sprinkler nozzles.

(ii) that the pipes should not be roughly handle when shifting to another position. this is to avoid breakage and blockage of nozzles by soil.

(iii) that the manufacture service recommendation for the equipment should be strictly adhered to.

(iv) that the equipment should be kept in a shed and protected from rains after the irrigation season.

(v) that general maintenance work should be done to the equipment before and after irrigation season.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The design of this sprinkler irrigation system is for 10 hectres of land at Chanchaga village. This is the most suitable for the project area because of the following factors considered in the design: -

(i) Uniform water distribution

(ii) Undulating nature of the land

(iii) The type of crop to be grown i.e. assorted vegetables

(iv) Sandy clay loamy type of soil in the area.

(v) The land needs to be brought to production quickly

(vi) The labour which is not experienced

This design is composed of a 495m long main line and 3 laterals of 210m long each. These laterals have 36 sprinklers which will irrigate 2 hectares / day.

The system is to irrigate the whole area within 5 days, giving a break of 2 days in a week.

This is ok for the area.

A high pressure pump of capacity 20 Hp with discharge capacity of 35 Litres / sec is required to pump water for irrigation of the area.

REFERENCES:

1. Hansen (1960) in Schawab G.O. Frevent r. K., Edmister T.W., Soil and Water Conservation Engineering (3rd edition)

2. A. M. Micheal (1985) Irrigation Theory and Practice

3. O. W. Isrealsen and V.E. Hansen (3rd Edition) (1962) Irrigation Principles and Practices.

4. M.E. Jensen, Design and operation at Farm Irrigation Systems.

5. G. Larry (1988) Principles of Farm Irrigation System Design John Willey and Sons Inc. new York U.S.A.

6. F.A.O. Irrigation and Drainage Paper 21 (April 2000):- PP 1-4.

7. F.A.O. Irrigation and Drainage Paper 12 (1972):- Water use Seminar, Damascus Paper 121.

8. Stanley's Butter, Practice Hall Inc. Englewood diff N.J. (1957)) Engineering Hydrology.

9. Bakai K., Upadhyaya S.K., Sime M., (members) American Society of Agricultural Engineers (1992): Variability of a double Ring infiltration test

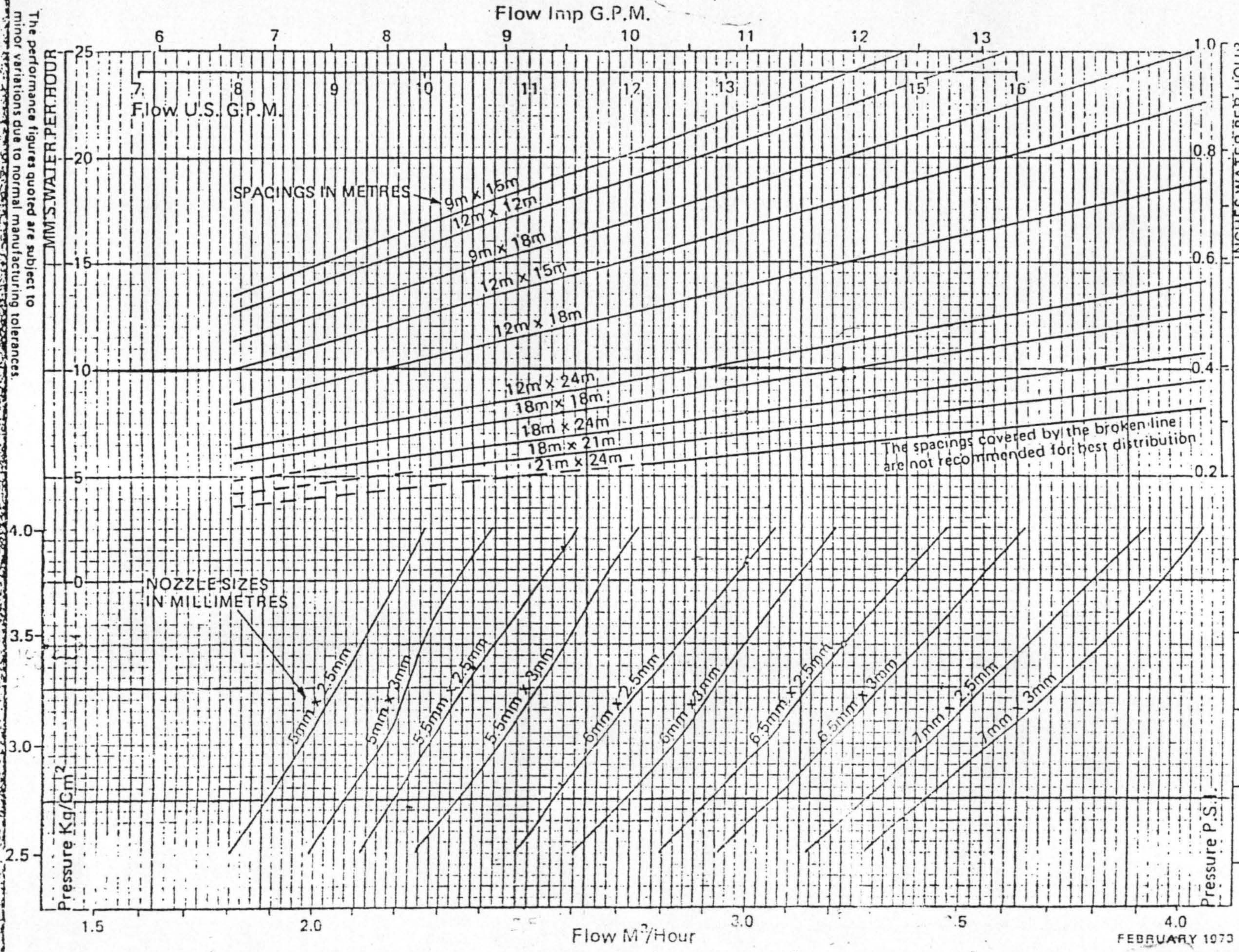
10. Christiansen J.E. "Irrigation by Sprinkling" California Agr. Ept. Sta. Bull 670

11. F.C. Scobey "The Flow of Water in Riveted Pipes" U.S. Agr. Tech. Bull 150.

12. Mohammed B., Dept. of Agric. Engineering F.U.T. Minna: Comparative analysis of reference evapotraspiration models in Minna paper presented at International/milleniun conference of the Nigerian Institution of Agricultural Engineers Ibadan 11th – 15th September 2000.

800 series sprinklers

Type no. 30-72
Full circle
Twin nozzle



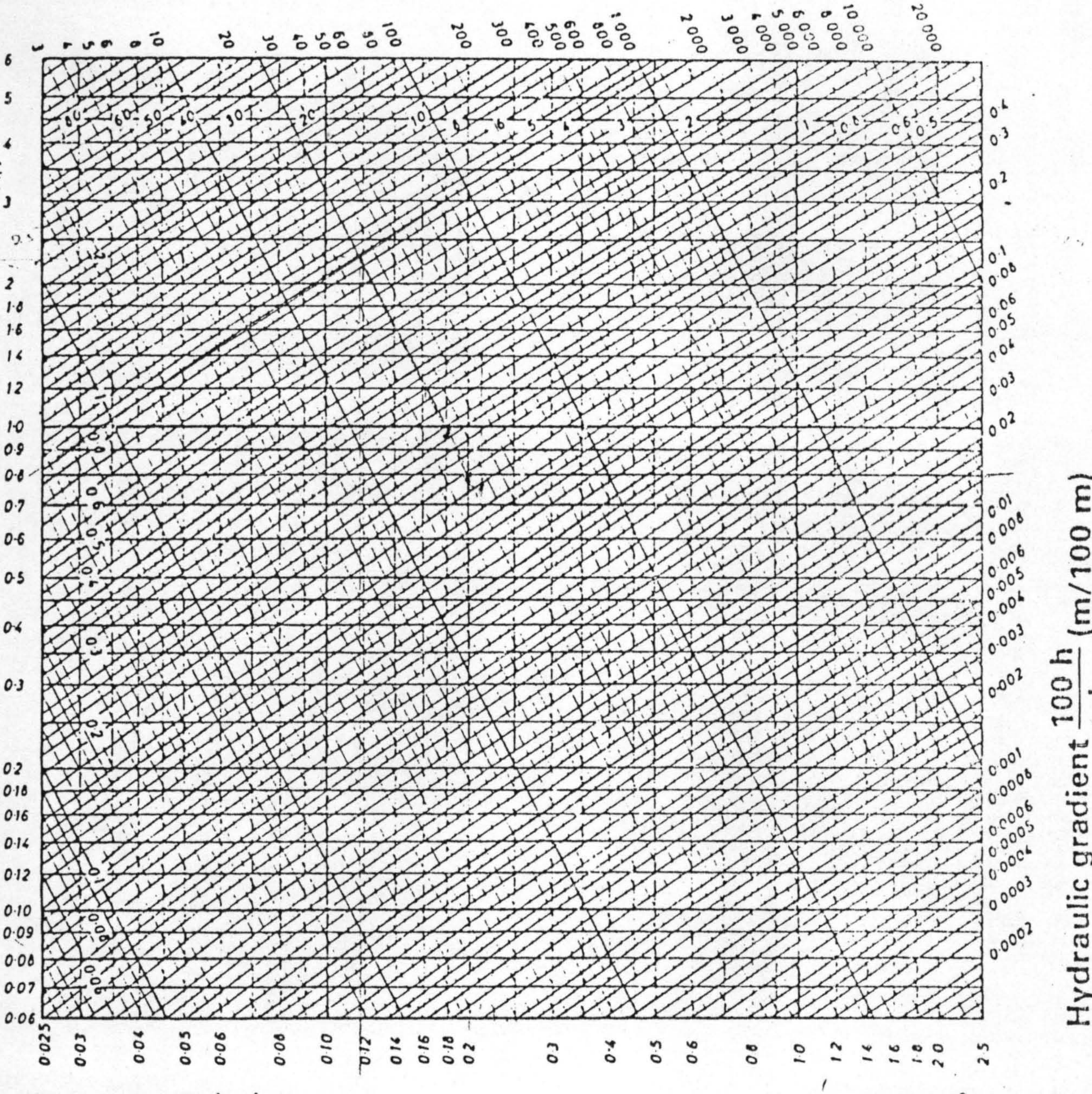
The performance figures quoted are subject to minor variations due to normal manufacturing tolerances.

FEBRUARY 1973

List of surfaces with roughness k_s = 0·03 mm

Good examples of	Wrought iron Coated steel Clayware (glazed or unglazed) with sleeve joints and 'O' ring seals
Normal examples of	Asbestos cement Spun bitumen lined metal pipes Spun concrete lined metal pipes Uncoated steel Clayware (glazed or unglazed) with spigot and socket joints and 'O' ring seals – dia <150 mm Pitch fibre (lower values refer to full bore flow) U PVC with chemically cemented joints
Poor examples of	

Discharge Q (l/s) *for pipes flowing full*



Diameter D (m)

Water at 15°C

Fig 4 $k_s = 0{\cdot}03$ mm

TABLE [illegible]I - Friction loss in feet per 100 feet in lateral lines of Portable aluminium pipe with coupling (Based on scobey's formular and 30 feet-pipe lengths).

FLOW gp.m	2-inch² ks=0.34	3 inch² ks=0.33	4-inch² ks=0.32	5-inch2 ks=0.32	6 - inch² ks=0.32
40	4.49	0.565	0.130		
50	6.85	0.858	0.193		
60	9.67	1.21	0.280		
70	12.9	1.63	0.376	0.122	
80	16.7	2.10	0.484	0.157	
90	20.8	2.63	0.605	0.196	
100	25.4	3.20	0.738	0.240	0.099
120		4.54	1.04	0.339	0.140
140		6.09	1.40	0.454	0.188
160		7.85	1.80	0.590	0.242
200		12.0	2.76	0.896	0.370
220		14.4	3.30	1.07	0.443
240		16.9	3.90	1.26	0.522
260		19.7	4.54	1.47	0.608
280		22.8	5.22	1.70	0.700
300		25.9	5.96	1.93	0.798
320		29.3	6.74	2.18	0.904
340		32.8	7.56	2.45	1.02
360		36.6	8.40	2.74	1.13
400		44.7	10.3	3.34	1.38
420			11.3	3.66	1.51
440			12.3	4.00	1.66
460			13.4	4.35	1.80
480			14.6	4.72	1.95
500			15.8	5.10	2.12
550			18.9	6.72	2.52
600			22.2	7.22	2.98
650			25.9	8.40	3.46
700			29.8	9.68	3.99
750			33.8	11.0	4.54

300					12.5	5.15
350					14.0	5.78
900					15.6	6.44
950					17.3	7.14
000					19.0	7.86

1. For 20 ft pipe lengths, increase values in the table by 7%
   For 40 ft lengths, decrease values by 3%

2. Outside diameter.

TABLE 2 - Factor (F) for computing friction loss in a line with multiple outlets:

OUTLETS No.	VALUES OF F	OUTLETS No.	VALUES OF F
1	1.000	16	0.377
2	0.634	17	0.375
3	0.528	18	0.373
4	0.480	19	0.372
5	0.451	20	0.370
6.	0.433	21	0.369
7	0.419	22	0.368
8.	0.410	23	0.367
9	0.402	24	0.366
10	0.396	25	0.365
11	0.392	26	0.364
12	0.388	27	0.363
13	0.384	28	0.363
14	0.381	29	0.363
15	0.379	30	0.362

Table 44 Operating Figures for Some Sprinklers (Square Pattern)

Nozzle mm	Pressure kg/cm^2	Wetted Diameter m	Discharge m^3/hr	Spacing m	Area Irrigated m^2	Precipitation mm/hr
4.5	2.0	13.5	1.1	12 x 18	215	5.0
	2.5	14.0	1.2	12 x 18	215	5.5
	3.0	14.5	1.3	18 x 18	325	4.1
5.0	2.0	13.5	1.3	12 x 18	215	6.2
	2.5	14.5	1.5	18 x 18	325	4.6
	3.0	15.0	1.6	18 x 18	325	5.0
6.0	2.0	14.5	1.9	18 x 18	325	6.0
	2.5	16.3	2.2	18 x 24	430	5.0
	3.0	16.5	2.8	18 x 24	430	5.5
4.5/4.8	2.0	14.0	2.3	12 x 18	215	10.8
	2.5	14.8	2.6	18 x 18	325	8.0
	3.0	15.5	2.8	18 x 18	325	8.8
5.0/5.5	2.5	16.0	3.3	18 x 18	325	10.2*
	3.0	16.3	3.6	18 x 24	430	8.4
	3.5	16.6	3.9	18 x 24	430	9.1
5.0/7.5	3.0	19.0	5.3	24 x 24	575	9.3
	3.5	19.3	5.8	24 x 24	575	10.7
	4.0	20.0	6.2	24 x 24	575	10.7
6.0/7.5	3.0	17.7	6.1	18 x 24	430	14.0
	3.5	18.5	6.6	24 x 24	575	11.3
	4.0	19.0	7.0	24 x 24	575	12.2

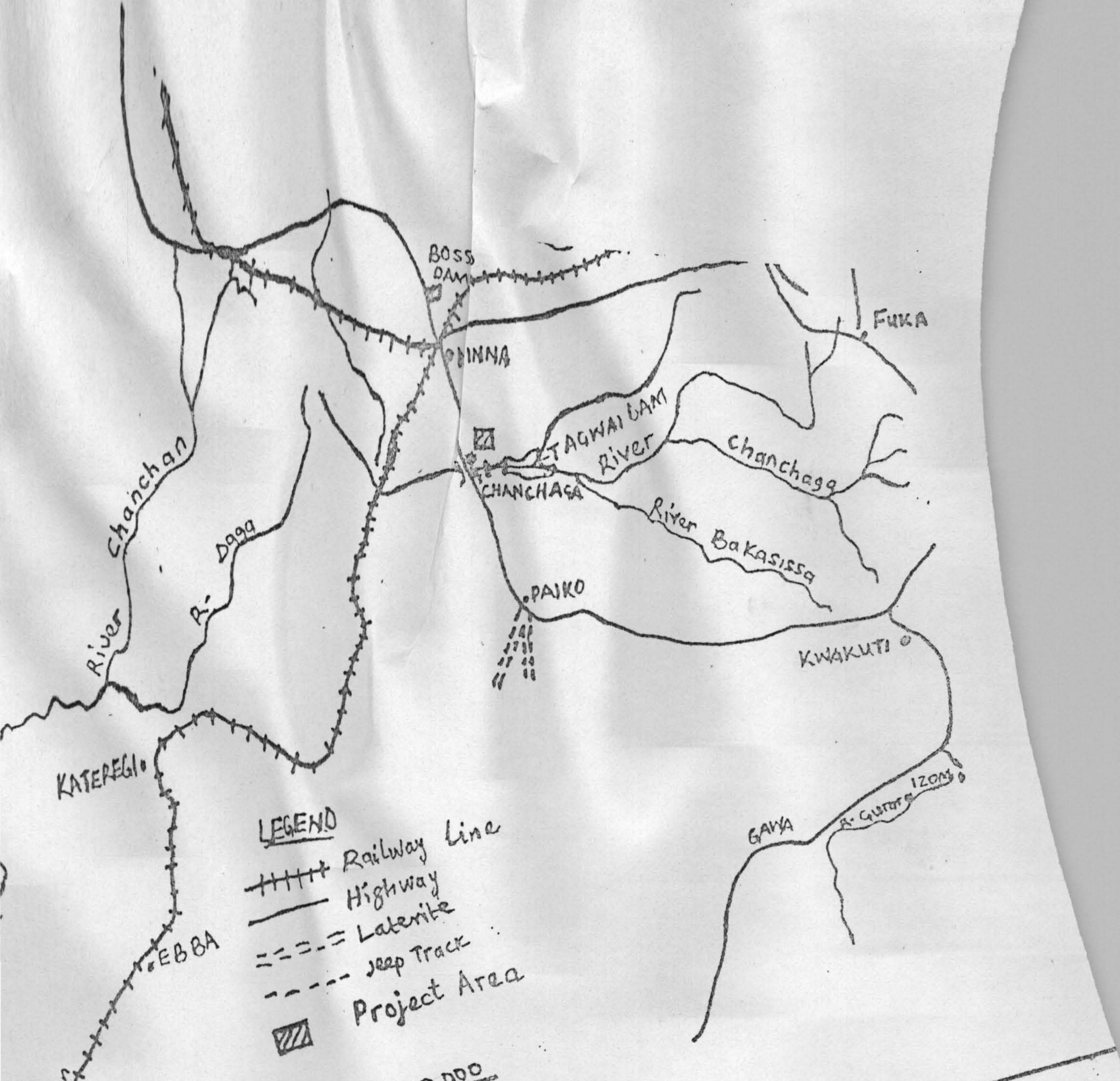


Fig 1.1 A MAP SHOWING PROJECT AREA

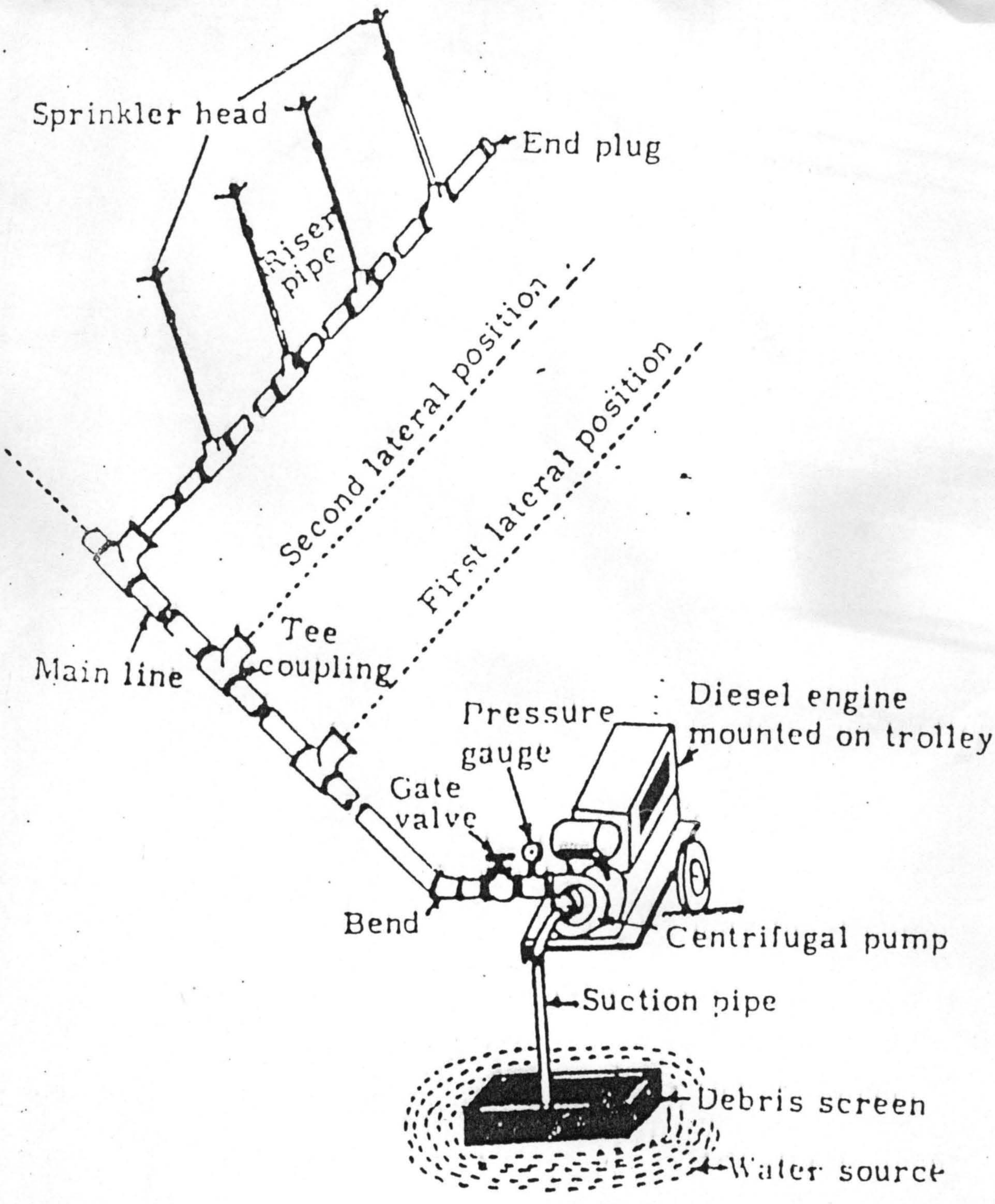


Fig 2.6.1 COMPONENTS OF SPRINKLER IRRIGATION SYSTEM