DESIGN OF SPRINKLER IRRIGATION SYSTEM FOR ZARA IRRIGATION SCHEME, NIGER STATE.

BY

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CERTIFICATION

This project work (report) entitled "THE DESIGN OF SPRINKLER IRRIGATION SYSTEM FOR ZARA IRRIGATION SCHEME (NIGER STATE)" was carried out BY ABDULKAREEM G. MAIRIGA in partial fulfillment for the award of Post-Graduate Diploma in Agricultural Engineering of FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

.... 15/6/2002 ....

ENGR. (MR.) P.A. IDAH *SIGN/DATE*

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DECLARATION

I conduct this Project under the supervision of ENGR. (MR) P.A. IDAH. 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 Postgraduate Diploma or any Degree.

ABDUKAREEM G. MAIRIGA

PGD/AGRIC. ENG./2000/2001/120

DEDICATION

I wish to dedicate this work to my late father, Mallam Alhassan Gambo and my late mother, Hajiya Hassana Gambo.

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In the name of the Almighty Allah, the beneficent and the merciful.

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ABSTRACT

This project work presents the design of Sprinkler Irrigation System of ten hectares for assorted vegetable production at Zara Village in Kagara Local Government of Niger State. The design criteria were based on the design information/data obtained from Irrigation charts, tables and calculations using experimental results. Water and soil analysis showed that they are suitable for sprinkler irrigation system. The design involved main-line, laterals, selection of sprinkler nozzles, spacing and the power required to operate the system, The application efficiency was assumed to be 75%, consumptive use (CU) 7mm/day. Root Zone depth is 0.6m. Water holding capacity 150mm/m. Moisture extraction level- 40%, soil intake rate- 10mm/hr. These results showed that the sprinkler system design is very suitable for the project area.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 DESCRIPTION OF THE PROJECT AREA.

Zara is a Village in Kusherki district in Kagara Local Government Area of Niger State. Zara is situated in the Northern part of Niger State along Lagos-Kaduna Trunk 'A' Road at about 160km away from Minna the Niger State capital. Zara Irrigation Scheme is located between latitude 10^0 30^0 N and 11^0 0^0 N and longitude 6^0 0^0E and 6^0 30^0 E -Fig 1.1. See Appendix I.

The 5km road that leads to the scheme branches at 0.5km from Zara Village on the left handside of Lagos-Kaduna Trunk 'A' road.

1.2 CLIMATE AND VEGETATION

Being in the tropics the scheme is charaterised by distinct dry and wet seasons. The rainy season usually begins in the middle of April and ends in October but the rain is heaviest and continuous between the month of July and September. As soon as the rainy season ends in October dry season immediately sets in. The harmattan which blows from November to February, makes evenings, nights and mornings cold.

Meteorological data of the area obtained from Kaduna State Water Board showed that rainfall ranges from 935mm – 1400mm annually.

Temperature ranges from 36.7^{0}C to 40^{0}C.

The daily evaporation rate ranges from 6.25mm to 12mm. The minimum evaporation rate is always in July while the maximum is in April.

The maximum relative Humidity ranges from 20% to 95% in the year. The wind speed ranges from 6.9 to 13km per hour. The maximum being in the month of July and minimum in the month of April. The sunshine hours have an annual average of 6.7 hrs with the highest of 9.4 hours.

The scheme area is a grassland area with scattered trees and extends over an area of about 500 hectares.

1.3 SOURCE OF WATER SUPPLY

The source of water for this project is River Bagoma which bounds the project area on the North-East and is perennial.

1.4 SOILS

The soil analysis carried out on the area showed the dominant soil found in the area is sandy-clay. (SIGMA ENGINEERS, 1998). The soils are well drained with moderate infiltration rate. The soil has water holding capacity of about 142mm of water per meter depth of soil. The soil pH ranges between 6.0 and 6.5 which indicate that it is slightly acidic. The soil has permeability of 7mm/hr.

1.5 SPRINKLER IRRIGATION SYSTEM

Irrigation is the artificial application of water to soil for the purpose of supply moisture essential 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 food and fibre need of the people.

In sprinkler method of irrigation water is sprayed into the air and allowed to fall on the ground surface just like 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 pressure and sprinkler spacings, the amount of irrigation water is applied nearly uniformly at a rate suitable for the infiltration rate of the soil, thereby obtaining efficient irrigation.

This system is suitable for sandy soils or any other soil and topographic condition 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 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.

1.6 PROBLEM DEFINITION

The flow of water in the field is not uniform due to faulty construction of canals and channels. As a result of the time consuming nature of the surface method currently being used in the project area, most participating farmers deserted the scheme. The maintenance cost of the surface method is high. The scheme does not serve only farmers from Zara Village but also farmers from neighbouring villages like Pandogari in Niger State and Birnin Gwari town in Kaduna State. It is thus desirable to replace the existing surface system with a more efficient system.

1.7 PROJECT OBJECTIVES

The main objectives of this project include among others:-

(a) To design a sprinkler Irrigation system for the project area in question.

(b) To make a model for the design.

1.8 PROJECT JUSTIFICAITON.

The slope of the project area is not gentle; this coupled with the fact that almost half of the farmers are from neighbouring villages and towns who do not usually have time to keep to the Irrigation schedule, hence conversion of the current surface method to sprinkler method, has become necessary. Sprinkler method is also adaptable to irrigation of most other crops and soils especially those sandy clay loam type of soil of this project area. A well designed sprinklers distribute water better than in other methods. Surface runoff of irrigation water can be eliminated. The amount of water can be controlled to meet crop needs, and light application can be made efficiently on seedlings and young plants, justifies the conversion to sprinkler system.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 HISTORY

Irrigation is an ancient agricultural practice that was used about 8,000 years ago in Mesopotamia, Egypt, China, Mexico and Peru.

Today, about 25% of the world densest population are supported through Irrigated Agriculture. In Egypt 100% of the crop land 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.

Irrigation is a modern science-the science of survival, though in many countries is an old art-as old as civilization.

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. It is becoming increasingly, important in humid regions as well (Christians 1953).

Isrealson 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 through out the written history of mankind.

An ancient Assyrian Queen supposed to have lived before 2000BC 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 continuous 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 world's oldest dam 107.92m (355ft) long and 12.16m (40ft) high built 6035 years ago to store water for drinking and Irrigation.

Basin Irrigation introduced on the Nile about 3300BC still plays an important part in Egyptian Agriculture.

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

2.3 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 water shed 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 system. Observing one position of an Irrigation system without considering its other components will lead to faulty design and inadequate preparation. (Isrealson and Hansen 1962).

2.4 IRRIGATION METHODS

There are four main methods of Irrigation namely surface, sub-surface, sprinkler or overhead and drip or Trickle.

2.4.1 SURFACE IRRIGATION METHOD

In this method, water is applied directly to the surface of the soil through a channel located at the upper most reach of the field. Water may be distributed to the crop in Border strips, check Basin or furrows. (Michael. 1950).

2.4.2 SUB-SURFACE IRRIGATION METHOD

In this method 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. (Michael, 1950)

2.4.3 SPRINKLER IRRIGATION METHOD

This method 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 (Christianson, 1953).

2.4.4. DRIP OR TRICKLE IRRIGATION METHOD

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 plant thereby reducing each conventional losses as deep percolation, runoff 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 within the desired range of plant growth (Michael, 1950).

2.4.5 DESIGN CRITERIA

The choice of various methods of Irrigation 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:-** This 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) Phosphorous (P) Potassium (K) Calcium (Ca), Magnesium (Mg) and Aluminium (Al). The PH values of soils.

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

(e) **Topography:-** This is the steepness of the land.

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

2.5.0 SPRINKLER SYSTEMS

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

(a) Rotating Head System

(b) Perforated Pipe System (Michael, 1950).

Based on portability, Sprinkler Systems are classified into the following types:-

a. **Portable System:-** This system has portable main lines and laterals and a portable pumping unit. 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 system 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 unit are fixed (Michael, 1950)

c. **Semi-Permanent:-** This system consists of permanent mainlines and sub-mains, a stationary water source, fixed pumping plant but portable lateral lines (Michael, 1950).

d. **Solid-Set System:-** This system has enough laterals to eliminate their movement. (Michael 1950).

e. **Permanent System:-** This system consists of permanently laid, mains, sub-mains and laterals and a stationary water source and pumping plant. (Michael, 1950).

2.5.1 COMPONENTS 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 pipeline and laterals, risers and sprinkler heads.

a. Pumping Set:-

The pump usually lifts water from the source and pushes it through the distribution system and the sprinklers. 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 maintained an adequate operating pressure.

System Capacity $$Q = \frac{2780Ad}{FHE} \quad \text{---------------------} (1)$$

Where Q = Discharge Capacity of the pump (L/S)

A = Area to be Irrigated in Hectares

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).

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

Where, Q = Discharge Capacity of the pump (gpm)

A = Area to be Irrigated (Acres) (Ha)

D = Gross depth of water application (inches) mm

F = No of days allowed for the completion of one Irrigation.

H = Number of actual operating hours perday.

b. MAIN LINE

This may be permanent or movable, permanent mains are used 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 field. They generally have a lower initial cost and do not provide obstruction to field operations.

:. LATERALS

This are usually 6m or 9m length of aluminum pipe connected with couplers. In some cases the couplers are permanently attached to the pipes.

d. RISER, SPRINKLER HEAD AND NOZZLES

The riser direct 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 sprinkler heads are of the slow rotating type.

They may range from small single nozzle sprinkler to giant multiple nozzle sprinklers that operate at high pressure. (Isrealson and Hansen, 1962).

2.5.2 ADAPTABILITY OF SPRINKLER METHOD

Sprinkler Irrigation method could be used for all types of crops except rice and jute, which require a lot of water which is achieved through flooding. It is equally suitable for almost all type of soils except fine textured soils (heavy clay soil) hawing Infiltration rate of less than 4mm/hr.

Sprinkler Irrigation system does not require land levelling operation which is one of the expensive aspect of Irrigation practices, although it is not very good where there is drainage problem (Isrealson and Hansen, 1962).

2.5.3 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.

2.5.4 EVAPOTRANSPIRATION

Evapo-transpiration or consumptive use is the sum of two terms:-

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

(ii) **Transpiration:-** Which is water entering plant roots and used to build tissue into the atmosphere.

2.5.5 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. (Michael, 1950).

2.5.6 GROSS WATER APPLICATION DEPTH

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

$$Dg = \frac{100Dn}{Eq} \text{ (mm)}$$

(Isrealson and Hansen, 1962)

Where

Dg = Gross depth of water application (mm)

Dn = Net Irrigation Requirement

Eq = Water Application Efficiency (%)

Consumptive use also means water requirements of crop on a field, farm, project or a valley.

Blaney- Criddle developed an simple field formula using temperature and day time hours for the arid western portion of the United States. This formula has been used extensively by the soil conservation services of the United State Department of Agriculture. Where considerable data has been collected to determine the value of coefficient to be used for various crops.

(Isrealson 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:-

$$ET_0 = P\ (0.46T + 8.13)$$

Where

ET_0 = Reference Crop Evapo-transpiration (mm/day)

P = % day time hours

T = Mean temperature in (^0C)

2.5.7 IRRIGATION FREQUENCY

This is defined as number of days between irrigation during periods without rainfall. This depends on the consumptive use rate in the crop root zone and the amount of available moisture in the root zone. (Isrealson and Hansen, 1962)

2.5.8 IRRIGATION 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. (Michael, 1950).

2.5.9 CO EFFICIENT 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.

$$Cu = \frac{100\,(1.0EX)}{Mn}$$ (Chritiansen, 1953)

Where

Cu = Uniformity Coefficient

n = total number of observation points

M = Average value of all observation points (mm) (average application rate)

X = Numerical deviation of Individual observations from the average application rate. (mm)

A uniformity co efficient of 100% (obtained with overlapping sprinkler) 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.

2.6.0 DESIGN OF SPRINKLER IRRIGATION SYSTEM.

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 given below:-

1. INVENTORY OF RESOURCES AND CONDITIONS

i. **Map of the area:-** It is essential that a map of area concerned is prepared and drawn to scale, with sufficient accuracy to show all dimensions so that length of main and laterals can be scaled out from there. It should be a contour map or at least should show all relevant elevations location and critical elevation in the fields to be Irrigated. The elevation differences, together with frictional losses in the mains and laterals and the pressure requirements of the sprinklers determine the pressure that must be developed by the pump. (Michael, 1950)

ii. **Water Supply- Source, Availability and Dependability.**

It is important that sufficient irrigation water is available to meet the maximum demand of crop. The quantity of Irrigation water 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 clogged.

iii. **Climate 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 consumptive use of crops Irrigated by it. (Michael, 1950)

iv. **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. (Michael, 1950)

v. Irrigation Interval: From the point of view of sprinkler design the Irrigation interval is the length of time allowable between successive irrigation during the peak consumptive(Michael,1950)

vi. **WATER APPLICATION RATE**

The rate of water application by sprinklers depends on the rate of the infiltration capacity of the soil. Application 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 below presents water application rates for various soil conditions. (Michael, 1950)

Table 2.6.0 suggested maximum water application rates for average soil, slope and cultural conditions.

Soil texture and profile conditions	**Maximum water application rate for slope and culture condition (mmlh)**			
	0% slope		**10% slope**	
	W/cover	**Bare**	**W/cover**	**bare**
1. Light sandy loam uniform in texture to 2m	43	25	25	15
2. Light sandy loams over more compact sub soil.	30	18	18	10
3. Silt loams uniform in texture to 2m	25	13	15	8
4. Silt loams over more compact sub soil	15	8	10	3
5. Heavy texture clays or clay loam	5	3	3	2

Source: Michael (1950)

vii. **Sprinkler Spacing**:- To achieve uniform sprinkling of water, it is necessary to over lap the area of influence of the sprinklers. The overlap increases with the increase in wind velocity. Table 2.6.1-could be used as a guide in the design of sprinkler overlap under different wind conditions.

Table 2.6.1 maximum spacing of sprinkler 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.	0-6.5km/hr	60%
3.	6.5-13km/hr	50%
4.	Above 13km/hr	30%

Source: Adapted from Michael (1950)

viii **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 and maintenance costs. (Michael, 1950).

Portable diesel pumping sets are the most suitable and practical for fully portable sprinkler system (Michael, 1950).

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.

For Zara 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 Ministry of Agriculture and Natural Resources Irrigation Department, the topographic map of area shows that the Land is fairly undulating.(Fig. 3.1) See appendix II.

3.2 CLIMATE

From the meteorological data got from Kaduna State Water Board, the climate of the project area is essentially that of the middle Belt with high temperature in summer (March-September). The wet season generally last 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 Quantity:-** River Bagoma is the source of water. The river flows all the year round. The flow is more than required for the project area.

i. **Water Quality:-** The water for Irrigation from the river is considered good enough based on the results of the laboratory analysis, when compared with the values in class 1 of the "STANDARD FOR IRRIGATION WATER:

3.4 SOIL CHARATERISTICS

Two major analysis were done namely mechanical and chemical analysis.

3.5.0 DESIGN PROCEDURE OF SPRINKLER SYSTEM

In the design of sprinkler system the following were considered:-

i. Application depth

ii. Irrigation interval

iii. Irrigation period

iv. Volume of water required

v. Capacity required

vi. Area to be Irrigated per day

vii. Sprinkler discharge

viii. Lateral discharge

ix. Main line design

x. Pressure requirement.

3.5.1 DESIGN DETAILS

- Major crop (proposed)-Assorted vegetables
- Area - 10ha
- Peak consumptive use (Cu) – 7mm/day (FAO, 1984)
- Depth of root zone – 0.6 (ditto)
- Water holding capacity – 150mm/m (ditto)
- Soil type – sandy clay loam
- Moisture extraction level – 40%
- Application efficiency Ea – 75% (sprinkler system)
- Soil intake rate (sl) 10mm/hr (FAO, 1984)

3.5.2 DEPTH OF APPLICATION

This is the gross depth of water required per Irrigation and are calculated using the equation.

$$d = \frac{(psa)D}{Ea}$$

Where

d = gross depth application (mm)

P = fraction- moisture extraction level

Sa = moisture holding capacity of the soil mm/m

D = depth of root zone (m)

Ea = application efficiency – 0.75 (fraction)

For this design

$$d = \frac{0.4 \times 150 \times 0.6}{0.75} = \underline{48mm}$$

3.5.3 IRRIGATION INTERVAL

This is the number of days 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

For this design

$$Fi = \frac{d}{Cu} = \frac{48}{7} = 6.86 \text{ days}$$

$$= \underline{7 \text{ days.}}$$

3.5.4 IRRIGATION PERIOD

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

$$T = \frac{d}{Si}$$

Where

T = Irrigation period (hrs)

d = gross depth of application (mm)

Si = soil intake rate (mm/hr)

$$T = \frac{48}{10} = 4.8 \text{ hrs}$$

i.e. Each setting will Irrigate for 4.8 hours before next shift.

3.5.5 CAPACITY REQUIRED

One of the parameters of the sprinkler system which was evaluated is its capacity requirement. The required capacity of a sprinkler system depends on the size of the area to be irrigated, the gross depth of application at each irrigation and the net operating time to apply the depth. It is determined by using of the equation. $Q = \frac{453AD}{FH}$ (FAO 1984)

Q = Discharge Capacity (gpm)

A = Area to be irrigated (Acres)

D = gross depth of application (inches)

F = Number of days allowed for completion of one Irrigation.

H = number of actual operating hours per day.

For this design

A = 10ha = 25 Acres

D = 48mm = 1.9 inches.

F = 7 days

H = 10 hours

453 = constant

$Q = \frac{453 \times 25 \times 1.9}{7 \times 10}$ (gpm)

= 307gpm = 23 litres/sec.

3.5.6 SELECTION OF SPRINKLER SIZE, SPACING AND OPERATING PRESSURE

To determine the area to be irrigated in a day, the 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 (Hac)

d = depth of application (mm)

in this design

q = 23litres/sec (0.81 cusecs)

t = 10 hours

$d = 48mm$ (1.9inches)

$\therefore a = \frac{qt}{d} = \frac{0.81 \times 10}{1.9} = 4.27$ Acres

$= 1.729$ ha

i.e. Area that can be irrigated in a day of 10 hours of working is 1.729ha. the farm is divided into 6 plots of which each one plot is to be irrigated in a day.

Two shifts of 5 hours per setting would be required per day.

- Size of each plot is 240m X 72m
- In one setting area to be irrigated is 240m X 36m = 0.864ha.

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

In this design, the following selections were made (from Nomograph) See Appendix III with an application rate of 8mm/hr and a sprinkler spacing of 18m X 18m, the corresponding sprinkler size = 5.5mm X 3mm, and operating pressure of $3.5kg/cm^2$. This selection is to with-stand an average wind speed of 15km/hr and a sprinkler discharge of $2.6m^3/hr$. The above selection was checked by using the equation.

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

Where

q = sprinkler discharge (gpm)

Si = sprinkler spacing (ft)

sm = lateral spacing (ft)

I = optimum application rate (inches/hr)

In this design

S_I = 18m (60 ft)

Sm = 18m (60 ft)

I = 8mm/hr (0.315 in/hr)

$$\text{Therefore } q = \frac{60 \times 60 \times 0.315}{96.3} = 11.8 \text{ gpm} = 0.89 \text{ litres/sec.}$$

$= 2.68m^3/hr$

Therefore the selection of $2.6m^3/hr$ as the q is adequate.

3.5.7 LATERAL DESIGN

This design was based on lateral of level ground. In this case, the allowable pressure loss due to friction in the lateral line = 20% of the operating pressure (pa) for sprinkler

Source:- soil conservation service National Eng. Hand book section 15.

According to the rule, allowable, loss per 100ft $= \dfrac{0.20 \text{ pa} \times 2.31}{\frac{L}{100} \times F}$

Where

Pa = pressure

F = correction factor for friction loss in pipes (from table 3.5.7) See appendix IV

L = length of lateral

In this design

L = 240m (787.39 ft)

Pa = 3.5kg/cm^2 (50 psi)

F = 0.384 (from table)

2.31 = constant

:. Allowable $= \dfrac{0.2 \times 50 \times 2.31}{\frac{787.39}{100} \times 0.384} = 7.64$ ft

= **2.33m**

Discharge per lateral = discharge per sprinkler x number of sprinklers per lateral

=2.68 x 13

= 34.84m3/hr (153.4gpm)

From the table (3.5.7 (B) See appendix V.

With the head loss 2.33m (7.64ft) and discharge of 34.84m3/hr (153.4 gpm), the corresponding size of lateral pipe is 75mm (3 inches).

3.5.8 MAIN LINE DESIGN

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

Pm = pa + ¾ (pf + pr)

Where

Pm = pressure required to lift water in the users/ sprinkler

Pa = operating pressure (PSi)

Pf = actual pressure loss due to friction (PSi)

Pr = pressure loss due to riser pipe PSi)

¾ = factor used to provide for the average operating pressure (pa) at the centre of the line.

In this design

Pa = 50 PSi

Pf = 2.33m (3.38PSi)

Pr = 1m (1.45 PSi)

Pm = 50 + ¾ (3.38 + 1.45)

= 53.6 PSi = 37m (121.28ft)

To determine the friction loss along the main line assume a diameter (pipe size) of 100mm (4") with a max. discharge (Q) OF 23 liters/see (307 gpm) with a corresponding head loss on the table per (100ft is 8.142ft) 30m is 2.64m See appendix VI.

The length of the main line = 488m = (1600ft)

The allowable loss in the 1600ft main line

$= \frac{1600}{100} \times 8.142 = 130.27$ ft

This is greater than 30% of pm. A bigger diameter of 150mm (6") is tried.

The corresponding loss per 100ft is 1.094 for 6" diameter pipes.

Allowable loss in the main line

$= \frac{1600}{100} \times 1.094 = 17.5$ft

= 5.33m

and this is less than 36.38ft which is 30% of pm. Hence the selected size of the main line of 150mm (6") is adequate.

3.5.9 PRESSURE REQUIREMENTS

To select a pump and power unit that will operate the system efficiently, it is necessary to determine the total pressure loss in the system or 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

= 202.86 - 183.79 = 19.07ft = 5.81m.

b. Total dynamic head (TDH) is the sum total of :-

i. Pressure head required to operate the lateral line – HL.

ii. Friction loss in the main line/ sub main –HF.

iii. Friction loss in fittings and values- HF .

iv. Total static head including suction lift – HS.

$$TDH = H_L + HF + Hf + HS$$

But Hf is negligible.

$$TDH = HL + HF + HS$$

In this design

HL = (121.28ft) 37m

HF = (17.5 ft) 5.33m

HS = (19.07ft) 5.81m

TDH = 37 + 5.33 + 5.81 = 48.14m (157.94ft)

c. Selection of pump and power unit – having determined the total dynamic head, pump size was computed using the equation.

Pump size = $\frac{QH}{100E}$ (KN) (soil conservation services National ENG. Hand Book section 15)

Where

Q = max-discharge (liters/sec)

H = total dynamic head (m)

E = pump efficiency (0.60)

100 = Constant

In this design

$Q = 307gpm = 23$ liters/sec

$H = 48.14m$ (157.94ft)

$$\text{Pump size} = \frac{23 \times 48.14}{100 \times 0.60} = 18.5 \text{ KN}$$

$= \underline{\mathbf{18.5\ KN}}$

WATER HORSE POWER (WHP)

This is the theoretical horsepower required in terms of power. It was computed by the using the equation.

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

Where

Q = discharge (gpm)

H = total dynamic head (ft)

$$WHP = \frac{307 \times 157.94}{3960}$$

$= \underline{\mathbf{12.24\ HP}}$

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

i.e. $BHP = \frac{WHP}{EFF}$ (Soil conservation service National Eng. Hand Book Section 15).

Assume Efficiency = 0.60

$$\therefore BHP = \frac{12.24}{0.60} = 20.4$$

<u>21HP</u> was adopted

In view of the high cost of sprinkler equipment. It has been recommended to procure only one set of equipment that can Irrigate 1.729ha in a day and 10ha in 6days with 2 shifts per day for the experimental purposes.

The items required per setting are at the bill of quantities given below.

3.6.0 BILL OF QUANTITIES

S/NO	DESCRIPTION	UNITY	QTY	RATE	AMOUNT
1.	Alluminium pipes main 150mm	No	60	3625	217,500.00
2.	Alluminium pipes laterals 75mm	No	120	3100	372,000.00
3.	Sprinklers with 1m riser and stablizing battern.	No	30	1500	45,000.00
4.	Hydrants	No	8	1120	8960.00
5.	Elbows	No	3	750	2250.00
6.	End cup 150mm	No	4	625	2500.00
7.	End cup 75mm	No	4	600	2400.00
8.	Couplers 150mm	No	60	565	33900.00
9.	Couplers 75mm	No	120	515	61800.00
10.	High pressure pump	Set	1		1,975,000.00
11.	Central valve 150mm	No	2	25250	50,500.00
					2771810.00

Add 10% for contingencies 277181.00

GRAND TOTAL N3,048,991.00

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

Based on the factors considered for the design of sprinkler Irrigation system, the following results were obtained for the design of Zara Irrigation Scheme.

(i) WATER QUALITY

The following results were obtained:-

ii. Electrical conductivity of the water is 980 micromhs/cm at 25^0C.

iii. Sodium-Adsorption Ratio (SAR) is 8meq/litre

iv. Bicarbonate in water is 1.2meq/litre.

v. Boron in water has been determined to be 0.025ppm.

vi. Sodium percentage ($Na^0\%$) is 52%.

Salt content is 600ppm.

(ii) SOIL CHARACTERISTICS:- The following results were obtained from the two analysis done.

(iia) MECHANICAL ANALYSIS

The following results were obtained

i. Top soil texture 0.3mm in diameter

ii. Permeability 7mm/hr

iii. Soil depth 1 meter

iv. Soil type:- Sandy clay loam.

v. Water holding capacity is 142mm/m.

(iib) CHEMICAL ANALYSIS

The chemical analysis of the soil samples are shown at follows:-

Soil sample	Organic carbon %	CA IN MEQ	Mg IN MEQ	I IN MEQ	NA %	PH
1.	1.34	2.70	1.14	0.67	0.10	4.0
2.	0.86	2.06	0.82	0.44	0.05	3.9
3.	0.27	1.67	0.76	0.26	0.04	4.0
4.	0.50	1.91	0.84	0.27	0.03	4.2
5.	0.80	1.54	0.92	0.28	0.02	3.9
6.	0.60	2.34	0.78	0.28	0.12	4.0
7.	0.54	2.05	1.07	0.32	0.07	3.9
8.	0.48	2.54	1.14	0.25	0.02	4.1
9.	0.159	2.54	0.80	0.24	0.04	4.0

iii. **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 the depth.

Based on the above factors, the system capacity was calculated and gotten it to be 23 litres per sec.

iv **Application Depth:** This is the gross depth of water 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 be 48mm.

v **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 user. This was calculated to be 7 days.

vi **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 4.8hrs so I approximate it to be 5 hours.

vii. **Area to be Irrigated per day:-**

From the Irrigation period and area to be irrigated per setting, it will take 1.729ha/day.

viii **Sprinkler Discharge**

This is the required discharge of an individual sprinkler and is a function of the water application rate and the two way spacing of the sprinklers. It was determined to be 0.89 litres per second.

ix. **Lateral Discharge**

This was calculated by getting the product of discharge per sprinkler and the No of sprinkler per lateral. This was found t be 11.6 litres/sec.

x. **Main Line Discharge**

The main line discharge is the system discharge capacity minus the frictional loss in the main. This gave 23 litres/sec.

xi. **Pump Capacity**

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

4.1 DISCUSSION

From the above results, it is clear that the ten hectares can be irrigated in 6 days with allowance of 1 day 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 noted that all sprinkler manufactures usually provide performance data for their equipment. The performance data usually include the effective diameter under no wind conditions, discharge for various nozzles and pressures and minimum recommended operating pressure for the various nozzles sizes. Up to a point, as pressure is increased the effective diameter is also increased and more uniform application may result. For a good break up, pressure should be increased as the nozzle size increases.

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

1. 60 No of pipes for main line of 150mm (6") diameter.
2. 23 Hydrant points or out-lets in the main line.
3. For economy reason, 2 laterals of 75mm (3") diameter pipe to Irrigate 1.729ha/day with one shift is required.
4. 120 no of lateral pipes of 75mm (4") diameter
5. 30 no of sprinklers per setting with the above 1.729ha one expected to be Irrigated daily with 2 settings of 10 hours per day.

   Water application could be started by 7.30 a.m. to 12.30pm for the first setting and 1 hours to be used for moving the equipment or lateral pipes for second setting this will start from 1.30 p.m. to 6.30p.m.

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

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The design of this sprinkler irrigation system is for 10 hectres of land at Zara 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 loam type of soil in the area.

v. The labour which is not experienced.

This design is composed of a 488m long main line and 2 laterals of 240m long each. These laterals have 26 sprinklers which will irrigate 1.729 ha/day.

The system is to Irrigate the whole area within 6 days, given a break of 1 day in a week.

This is adequate for the area. A high-pressure pump of capacity of 21 HP with discharge capacity of 25 litres/sec. is required to pump water for irrigation of the area.

5.2 RECOMMENDATIONS

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

i. That the water for Irrigation should be free of debris to avoid clogging of the sprinkler nozzles.

ii. The pipes should not be rough handled when shifting to another position, this is to avoid breakage and blockage of nozzles by soil.

iii. The manufacturer service recommendations for the equipment should be strictly adhered to.

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

v. General maintenance work should be done to the equipment before and after Irrigation season.

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LOCATION MAP Appendix I

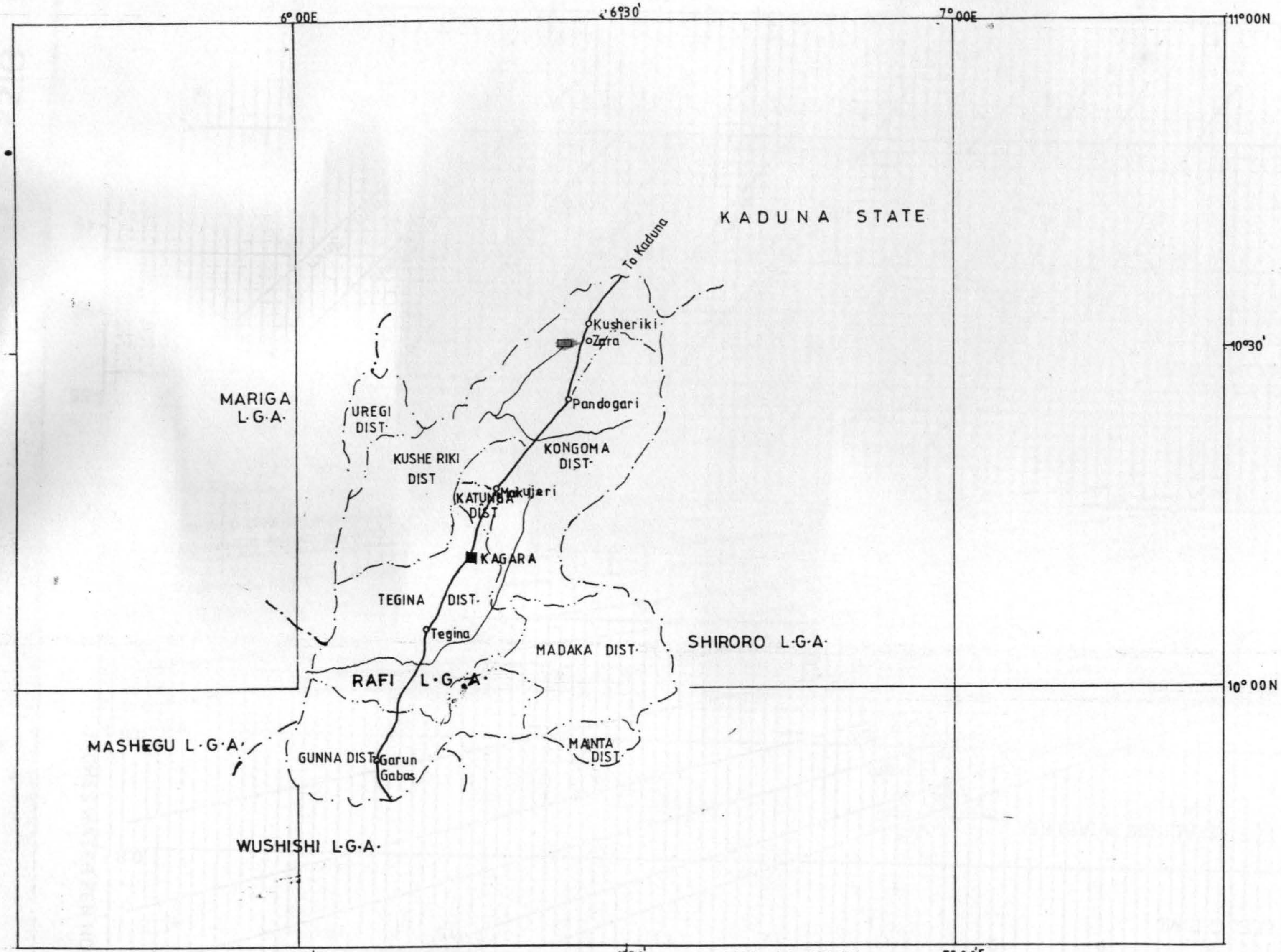


Fig 1.1

SCALE 1 625,000

LEGEND

- Local Govt Boundary
- District
- Local Govt HQ
- Road
- Project Area

APPENDIX IV

TABLE 8.5.7(A) 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

APPENDIX IV

TABLE 3.5.7(B) - Friction loss in feet per 100 feet in lateral lines of Portable aluminium pipe with couplins (Based on scobey's formular and 30 feet-pipe lengths).

FLOW gp.m	2-inch[2] ks=0.34	3 inch[2] ks=0.33	4-inch[2] ks=0.32	5-inch2 ks=0.32	6 - inch[2] 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

........../2

800				12.5	5.15
850				14.0	5.78
900				15.6	6.44
950				17.3	7.14
1000				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 3.5.8 -- Friction loss in feet per 100 feet in main lines of portable aluminum pipe with couplings
(Based on Scobey's formula (K_s = .40) and 30-foot pipe lenghs)[1]

Flow (gallons per minute)	3-inch[2] (2.914)	4-inch[2] (3.906	5-inch[2] (4.896)	6-inch[2] (5.884)	7-inch[2] (6.872)	8-inch[2] (7.856)	10-inch[2] (9.818)
40	0.658	0.157					
50	1.006	.239					
60	1.423	.339					
70	1.906	.449	0.150				
80	2.457	.584	.193				
90	3.073	.731	.242				
100	3.754	.893	.295	0.120			
120	5.307	1.263	.417	.170			
140	7.113	1.693	.560	.227			
160	9.169	2.182	.721	.293			
180	11.47	2.729	.967	.366			
200	14.01	3.333	1.102	.448	0.209		
220	16.79	3.996	1.321	.537	.251		
240	19.81	4.713	1.558	.633	.296		
260	23.06	5.488	1.814	.737	.344		
280	26.55	6.316	2.089	.849	.397		
300	30.27	7.203	2.381	.967	.452	0.235	
320	34.22	8.142	2.692	1.094	.511	.265	
340	38.39	9.137	3.020	1.227	.573	.298	
360	42.80	10.18	3.366	1.368	.639	.332	
380	47.43	11.29	3.731	1.516	.708	.368	
400	52.28	12.44	4.113	1.671	.781	.399	0.136
420		13.65	4.513	1.833	.857	.445	.149
440		14.57	4.930	1.988	.936	.486	.163
460		16.23	5.364	2.179	1.019	.529	.177
480		17.59	5.815	2.363	1.104	.573	.192
500		19.01	6.284	2.554	1.193	.620	.208
550		22.79	7.532	3.060	1.430	.742	.249
600		26.88	8.886	3.611	1.687	.876	.294
650		31.30	10.35	4.204	1.965	1.020	.342
700		36.03	11.91	4.839	2.262	1.174	.394
750		41.08	13.58	5.517	2.520	1.339	.449
800			15.35	6.237	2.915	1.513	.507
850			17.22	6.999	3.271	1.698	.569
900			19.20	7.801	3.646	1.893	.635
950			21.28	8.645	4.041	2.097	.703
1000			23.45	9.530	4.454	2.312	.775
1100			28.11	11.42	5.338	2.771	.929
1200			31.75	13.58	6.298	3.269	1.096
1300				15.69	7.333	3.806	1.277
1400				18.06	8.441	4.382	1.470
1500				20.59	9.624	4.996	1.675
1600				23.28	10.88	5.648	1.894
1700				26.12	12.21	6.337	2.125
1800					13.61	7.064	2.369
1900					15.08	7.829	2.625
2000					16.62	8.630	2.894

1 Where 20-ft. Sections of pipe are used, increase values show in the table by 7.0 percent.
Where 40-ft. sections of pipe are used, decrease values whown in the table by 3.0 percent.

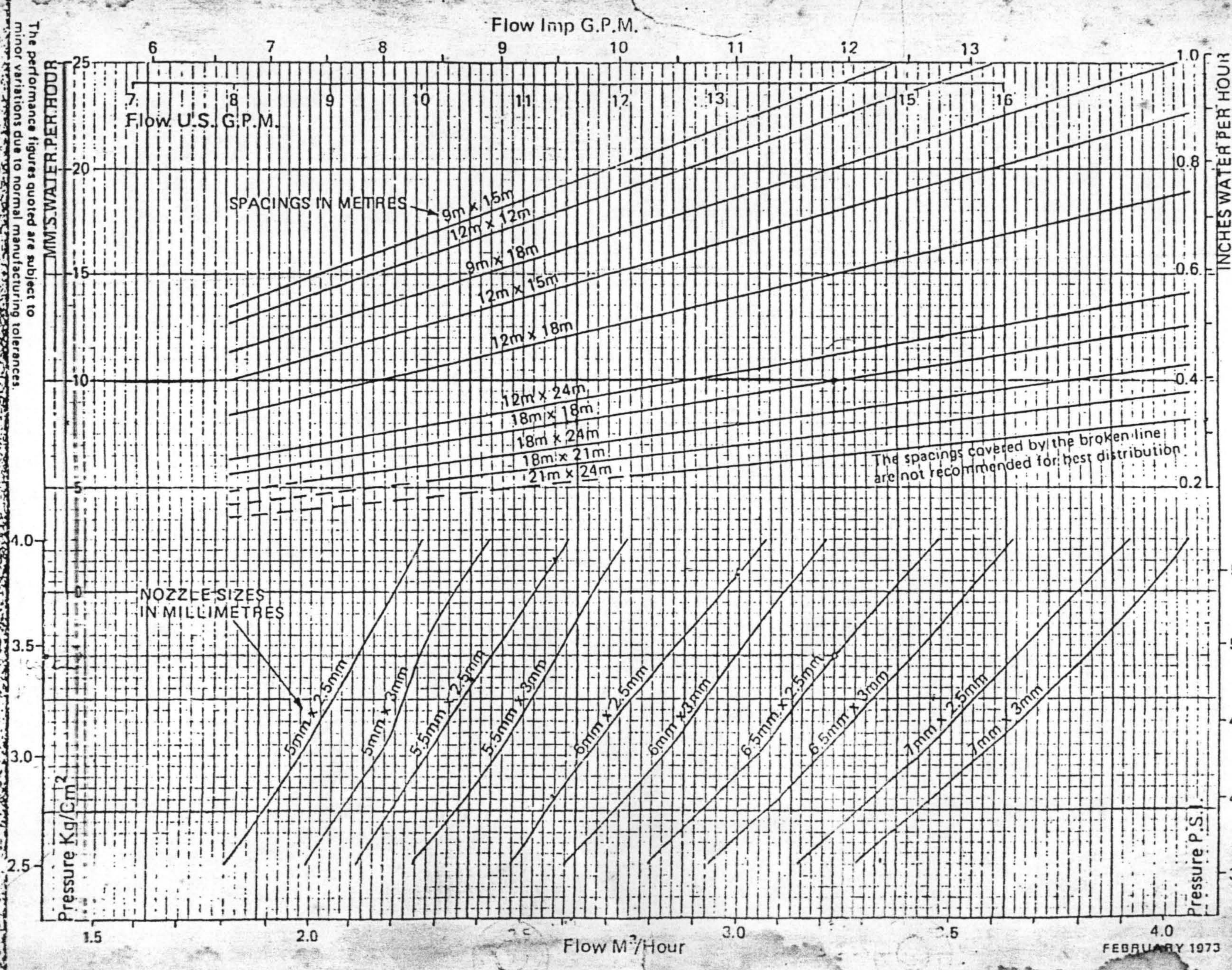
2 Outside diameter, inside diameter in parentheses.

APPENDIX III

300 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

APPENDIX IV

TABLE 8.5.7(A) 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