CROP WATER REQUIREMENT AND CROPPING SYSTEM IN PROJECT PLANNING WITH REFERENCE TO KOLAR PROJECT

A DISSERTATION

Submitted in partial fulfilment of the requirements for the award of the degree

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in

IRRIGATION WATER MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the dissertation titled "**CROP WATER REQUIREMENT AND CROPPING SYSTEM IN PROJECT PLANNING WITH REFERENCE TO KOLAR PROJECT**" which is being submitted in partial fulfilment of the requirements for the award of Master's degree of Engineering in **Irrigation Water Management** at Water Resources Development Training Centre (WRDTC), University of Roorkee, Roorkee, is an authentic record of my own work carried out during the period of 16th July to 31st December, 2000, under the supervision and guidance of **Dr. S. K. Tripathi**, Professor, WRDTC, University of Roorkee.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

Roorkee **(MAKARAND GOLWALKAR)**

Dated : 31.12.2000

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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SYNOPSIS

The basic objective of this study is to observe the variations that have occurred in the crop water requirements of a suggested cropping system due to changes in the micro climatic conditions in the command area of the Kolar project. The initial planning of any irrigation project begins with the computations of crop water requirements of a proposed cropping pattern for the command area of that project. Usually climatological approaches are used to determine the crop water requirements using historical climatologic data available at the nearest site.

On the basis of these crop water requirements, the net irrigation requirement and gross irrigation requirement considering certain project efficiency are calculated. Thus the computed gross water requirements are useful to fix the discharging capacities of the canal systems and the storage capacities of dams/reservoirs in the cases of storage irrigation project.

As the crop water requirements are closely related with the climatic conditions, so any variation that will take place in the climate will directly affect the crop water use and ultimately the discharging capacity of the canal system and the area to be irrigated. Considering this concept, an attempt is made to collect the climatological data from 1984 to 1999 of the Hoshangabad station, which is the nearest I.M.D. station of the command area of the Kolar project, and this data is processed to compute the crop water requirement.

The results of this study show that the crop water requirements has increased by about 10.21% with reference to that adopted at the initial planning stage. Resulting to which crop yields will decrease as available water is limited. The canal system has adequate capacities to meet out the increased water requirements.

As the Kolar project is a reservoir project so quantum of water available for the irrigation is limited. In such a situation to fulfil the need of increased crop water requirements the only way remaining is to improve the irrigation efficiency and control the cropping pattern.

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INTRODUCTION

1.1 GENERAL

Irrigation for agricultural development has a high priority in India where the production of food grain has to keep pace with the requirements of rapidly increasing population. The availability of land and water resources per capita are fast depleting. In such situations, well planned and efficiently utilized irrigation system will definitely lead us to overcome the growing problem of food shortage to feed the ever increasing population of India.

In order to achieve the optimum utilisation of irrigation system, the fertility of the soil to be maintained, a suitable cropping system to be adopted. In addition, the irrigation water supplies are to be ensured in order to obtain the economic and optimum utilisation of available irrigation water supplies.

The crop water requirement is a subject of vital importance to the irrigation engineers for making the most economic use of irrigation water and designing the main and distribution system so as to provide water to the cultivators as required. The main purpose of irrigation is to supply the needed moisture to the soil around the root zone of the plant. If the root zone is not uniformly moistened or if either too much or too little water is added, the result is the diminished harvest.

Crops require water in appropriate quantities at specific intervals for their normal growth and for giving maximum yields. It is therefore essential to have knowledge about the quantum of this requirement and their timings so that the irrigation system could be operated accordingly. The needs of the crop generally depend upon their types, rainfall incidence, climatological conditions, land grading and levelling, drainage conditions, soil characteristics etc. However, out of the aforesaid factors, the climatological conditions play an important role to affect the crop water requirements.

1.2 OBJECTIVE OF STUDY

The basic objectives of this study are :

(1) To observe the variation, if any, that have occurred in the crop water requirements of a suggested cropping system due to changes in the micro climatic conditions in the command area of the Kolar irrigation project,

(2) To check the adequacy of the existing canal system to meet out the increased crop water requirements if observed due to changes in the micro climatic conditions in the command area of the Kolar project.

The initial planning of any irrigation project begins with the computations of crop water requirement of a proposed suitable cropping pattern for the command area of that project. Usually climatological approaches are used to determine the crop water requirements using historical climatological data available at the nearest site.

On the basis of these crop water requirements, the net irrigation requirements and gross irrigation requirements considering certain project efficiency are calculated. Thus the computed gross requirements are useful to fix the discharging capacity of the canal systems and the storage capacities of the dams/reservoirs in the cases of storage irrigation project.

As the crop water requirements are closely related with the climatic conditions so any variation that will take place in the climate will directly affect the crop water use and ultimately the discharging capacity of the canal system and the area to be irrigated.

Considering this concept, an attempt is made to collect the climatological data from 1984 to 1999 of the Hoshangabad Station, which is the nearest Indian Meteorological Station of the Kolar project, and the crop water requirements are carried out and ultimately the adequacy of canal system is checked in this study. Modified Panman method is used to assess the crop water requirements and the cropping system for the Kolar project is suggested by Agriculture Department of Madhya Pradesh.

The entire procedure for assessment of crop water requirement may also be helpful in the planning of any new irrigation project.

Chapter 2

REVIEW OF LITERATURE

2.1 CROP WATER REQUIREMENTS

The availability of water in the right quantity and at right time is essential for healthy plant growth and yield. The estimation of crop water requirements is one of the basic needs for planning of any irrigation project. The crop water requirements are defined as "The depth of water needed to meet the water loss through evapotranspiration (ET_{crop}) of a disease free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment."

Or in simple words we can say that amount of water required at the root zone of a plant (crop), right from germination (sowing) of the seed upto the time of harvest for healthy growth and optimum yield is termed as the Crop Water Requirement (CWR). It includes the amount of water required for (a) consumptive use (CU or ET_C or ET_{crop}), (b) special needs like land preparation, palewa, nursery, transplantation and (c) percolation and application losses depending upon the type of crop grown and the soil water characteristics.

Evaporation, transpiration and consumptive use are the important factors in estimating crop water requirements and thereafter the irrigation requirement for the planning of any irrigation system.

Evaporation

It is the process during which a liquid changes into a vapour or gas. The process of evaporation of water in nature is one of the fundamental components of the hydrological cycle by which water changes to vapour through the absorption of heat energy. This is the only form of moisture transfer from land and oceans into the atmosphere.

Transpiration

It is the process by which water vapour leaves the living plant body and enters the atmosphere.

Evapotranspiration (ET_{crop})

It denotes the quantity of water transpired by the plants during their growth plus the moisture evaporated from the surface of soil and vegetation.

Consumptive Use (CU)

Water is mainly needed to meet the demands of evapotranspiration (ET_{crop}) and the metabolic activities of the plant. Both of these together is known as Consumptive Use (CU).

Since the water required in the metabolic activities of the plant is very less (1% or below 1%) hence it is negligible. Therefore, ET_{crop} is practically considered as Consumptive Use (CU).

As it is already mentioned above that water requirement includes the consumptive use (CU or ET_{crop}), losses during the application of irrigation water (unavoidable losses) and the quantity of water required for special needs such as land preparation, nursary, transplantation etc., so it may be formulated as follows :

$$CWR = ET_{crop} \text{ or CU + application losses + special needs.}$$

Thus crop water requirement is therefore a 'demand' and the supply that consist of contribution from any of the sources of water. The sources may be irrigation water (IRRG), effective rainfall (ER) and soil profile contribution (ΔS) including that from shallow water table. Numerically therefore crop water requirement is given as

$$CWR = IRRG + ER + \Delta S$$

or $$IRRG = CWR - (ER + \Delta S)$$

Thus, by knowing CWR, ER and ΔS, one can find out the amount of irrigation water which is to be supplied. The computation of CWR involves ET_{crop}, application losses and special needs, out of which application losses depends upon the system efficiency and special needs depends upon type of crop and soil type. So these may be found out for a particular irrigation system having its command area with certain cropping pattern.

The remaining term, i.e., ET_{crop} is to be determined. There are various methods for the determination of ET_{crop}, i.e. evapotranspiration. These methods can broadly be classified into three groups namely :

(1) Methods based on direct measurements

(2) Methods based on evaporation data

(3) Methods based on climatological data.

2.2 DETERMINATION OF EVAPOTRANSPIRATION (ET_{crop})

2.2.1 Methods Based on Direct Measurements

The principal methods for direct measurements of evapotranspiration are

(1) Lysimeter Experiments

Lysimeter studies involve the growing of crops in large containers (lysimeters) and measuring their water loss and gains. A lysimeter can be defined as a device in which a volume of soil planted with vegetation is located in a container to isolate it hydrologically from the surrounding soil. Mainly two types of lysimeter are there

(i) Non-weighing type – volumetric, manometric, field method

(ii) Weighing type

Non weighing lysimeters give less accurate results compared to weighing type. To get more accurate results as well as short period estimates, weighing type lysimeters have been developed.

The soil and crop conditions in the lysimeter should be close to the natural conditions. From the irrigation point of view, weighing lysimeters are set up to enable the operator to measure the water balances : water added, water retained by the soil, and water lost through all sources – evaporation, transpiration and deep percolation. These measurements involve weighing which may be made with scales or by floating the lysimeters in water on a suitably heavy liquid, in which case the change in the liquid displacement is computed against water loss from the tank. The technique yields a measurement of total water loss and is useful as an indicator of field water loss, provided suitable precautions are taken.

Lysimeters, though provide the means of precise and direct measurement of the amount of water supplied to and lost by the crop, often encounter a number of problems. The major limitations are the reproduction of physical conditions such as temperature, water table, soil texture and density etc., within the lysimeter comparable to those outside in the field.

(2) Field Experimental Plots

Measurements of water supplies to the field and changes in soil moisture contents of the field plots are dependable for computing seasonal water requirements of crops. The seasonal water requirements are computed by adding measured quantities of irrigation water, the effective rainfall received during the season and the contribution of moisture from the soil.

The method requires that the amount of water applied to a field is measured accurately. This method, though satisfactory for computing seasonal water requirements, does not provide information on intermediate soil moisture conditions, short term use, profile use, deep percolation losses and peak use rate of crop.

(3) Soil Moisture Depletion Studies

The soil moisture depletion method is usually employed to determine the consumptive use of irrigated field crops grown on fairly uniform soils when the depth of the ground water is such that it will not influence the soil moisture fluctuation within the root zone. These studies involve measurement of soil moisture from various depths at a number of times throughout the growth period.

Greater the number of measurements, more is the information obtained from such studies. Consumptive use (CU) is calculated from the change in soil water content in successive samples from the following relationship :

$$u = \sum_{i=1}^{n} \frac{M_{1i} - M_{2i}}{100} * A_i * D_i$$

in which,

u = Water use from the root zone for successive sampling periods or within one irrigation cycle, mm

n = No. of soil layers sampled in the root zone depth D

M_{1i} = Soil moisture percentage at the time of the first sampling in the i^{th} layer

M_{2i} = Soil moisture percentage at the time of the second sampling in the i^{th} layer

A_i = Apparent specific gravity of the i^{th} layer of the soil.

D_i = Depth of the i^{th} layer of the soil, mm.

Seasonal consumptive use (CU = Σu) is calculated by summing the consumptive use values of each sampling interval.

(4) Water Balance Method

The water balance method, also called the inflow-outflow method, is suitable for large areas (watersheds) over long periods. It may be represented by the following hydrological equation :

Precipitation = Evapotranspiration + Surface runoff + Sub-surface drainage + Change in soil water contents

This method necessitates adequate measurements of all factors, except evapotranspiration. The value of evapotranspiration is computed from the measured data.

All the methods based on direct measurements yield very reliable values of evapotranspiration, provided elaborate installations and precise measurements are made. The methods are however costly, laborious and time consuming.

2.2.2 Methods Based on Evaporation Data

It has been observed that a close relationship exists between the rate of consumptive use by crops and the rate of evaporation from a properly located evaporation pan. The standard US Weather Bureau Class A open pan evaporimeter or the Sunken screen open pan evaporimeter can be used for the measurement. The relation between evapotranspiration and pan evaporation is given by the crop factor.

Evapotranspiration = Pan evaporation x Crop factor

The value of crop factor for any crop depends on foliage characteristics, stage of growth, environment and geographical location. Consumptive use values are very low during the early stage of growth and increases as the plant approaches maturity.

There is a general decline during the later periods. The values for a particular crop at a location should be determined experimentally.

2.2.3 Methods Based on Climatological Data

(1) Thornthwaite Formula

Thornthwaite assumed that an exponential relationship existed between mean monthly temperature and mean monthly consumptive use. The relationship was based largely on experience in the central and eastern United States. No allowance was made for different crops or varying land uses.

Thornthwaite proposed the following formula :

$$PET = 1.6\ (10\ t/I)^a$$

in which,

PET = Unadjusted potential evapotranspiration, cm per month.

t = Mean air temperature, °C.

I = Annual or seasonal heat index, the summation of 12 values of monthly heat indices (i) when,

$$i = (t/5)^{1.514}$$

a = An empirical exponent computed by the equation

$$a = 0.000000675I^3 - 0.0000771\ I^2 + 0.01792\ I + 0.49239$$

The unadjusted values of PET are corrected for actual daylight hours and days in a month.

The Thornthwaite formula gives a reasonable estimate of potential evapotranspiration in temperature, continental climate of North America where the formula was originally derived because there the temperature and radiation are strongly correlated with PET.

(2) Christiansen Method

Christiansen proposed an empirical formula, to estimate pan evaporation from climatic data when reliable measured pan evaporation data are not available for estimation of evapotranspiration.

The following is the Christiansen's revised equation developed at Logan (Utah), USA for estimation of pan evaporation :

$$E_v = K_{ev} . R . C_t . C_W . C_h . C_s . C_e . C_m$$

in which,

E_v is the computed pan evaporation equivalent to class A pan evaporation.

K_{ev} is a dimensionless empirically developed constant, the value of which is given by Christiansen as 0.473.

R is extraterrestrial radiation in the same evaporation units as E_v and C_t , C_w, C_h, C_s and C_e are coefficients for temperature, wind velocity, relative humidity, percent of possible sunshine and elevation respectively.

C_m is the monthly coefficient or factor by which all the basic formulae would have to be multiplied to obtain the measured evaporation and averaged to obtain the mean monthly values of C_m.

The values of C_m mostly ranges between 0.90 to 1.10 and vary from latitude to latitude.

Each coefficient is represented by an equation which may be either a linear, second degree or possibly a third or fourth degree equation, if such an equation provide a better fit for the data from which they were developed. The coefficients are dimensionless.

The simplified and non-dimensionless equations for different coefficients are given below :

$$C_t = 0.393 + 0.02796T_c + 0.0001189\, T_c^2$$

in which, T_c is the mean monthly temperature in °C.

$$C_w = 0.708 + 0.00339W - 0.0000039W^2$$

in which, W is the wind speed in km/day at 0.6 m height.

$$C_{hn} = 1.25 - 0.87H_n + 0.75H_n^2 - 0.85\, H_n^4$$

in which, H_n is the mean monthly relative humidity at noon expressed decimally

or $$C_{hm} = 1.25 - 3.37H_m - 0.60\, H_m^5$$

in which, H_m is the mean relative humidity for the month expressed decimally.

The approximate relationship between the H_n and H_m is given by

$$H_n = 0.40\, H_m + 0.60H_m^2$$

$$C_s = 0.542 + 0.80S - 0.78S^2 + 0.62S^3$$

in which, S is the mean sunshine percentage expressed decimally.

$$C_e = 0.970 + 0.0000984\, E$$

in which, E is the elevation in metres.

For estimating evaporation, each coefficient may be once determined and tabulated for a full range of values. The values of R may also be tabulated for each month as a function of latitude.

To obtain an estimate of the pan evaporation for a given month, mean value of each factor are tabulated. From the tables, the values of coefficient are next determined. The computation is then simply a matter of multiplying coefficients.

(3) Lowry-Johnson Formula

Lowry-Johnson has given a formula to determine consumptive use which is as follows :

$$CU = 0.00015H + 0.8$$

where

CU = Consumptive use or water requirements

H = Accumulated degree days during the growing season computed from the maximum temperature above 32°F.

The above formula is used to estimate consumptive use for agriculture in valley with the aid of linear relationship between effective heat and consumptive use. Consumptive use in a valley or a drainage area involves water losses from non-agricultural areas also.

Lowry-Johnson method requires the determination of an "equivalent valley area" of an agricultural land in order to arrive at the annual consumptive use of the area in question.

(4) Hargreaves Formula

Hargreaves suggested a formula for the determination of evaporation E_p, from which evapotranspiration (E_T) can be found out using the relation $E_T = K.E_p$, in which K is a crop factor or crop coefficient.

The formula suggested for evaporation E_p in metric units is as follows :

$$E_p = 17.4\, D \,.\, T_c\, (1.0 - H_n)$$

in which,

E_p = Class A pan evaporation in cms per month

D = Monthly day time coefficient.

H_n = Monthly relative humidity at noon expressed in decimal form.

T_c = Mean monthly temperature in °C.

The above formula can be rewritten with modifications for the effect of wind, sunshine and elevation as

$$E_p = 17.4\, D \,.\, T_c \,.\, F_H \,.\, F_W \,.\, F_S \,.\, F_E$$

where ,

$F_H = 0.59 - 0.55{H_n}^2$

$F_W = 0.75 + 0.255 \sqrt{W_{kd}}$

or $F_W = 0.75 + 0.125 \sqrt{W_{kh}}$

$F_S = 0.478 + 0.58S$

$F_E = 0.95 + 0.0001E$

W_{kd} and W_{kh} are the mean wind velocities per day and per hour respectively in kilometres observed at 2 m height, S is the sunshine percentage expressed decimally and E is elevation in metres.

(5) Blaney-Criddle Method

This method is suggested for areas where available climatic data cover air temperature only. The recommended formula in this method gives reference crop evapotranspiration (E_{TO}) from which crop evapotranspiration (E_{TC}) can be obtained using the relationship $E_{TC} = K \times E_{TO}$, in which K is crop coefficient.

The recommended relationships to determine reference crop evapotranspiration (E_{TO}) is expressed as :

$$E_{TO} = c\,[p\,(0.46T + 8)] \text{ mm/day}$$

where,

E_{TO} = Reference crop evapotranspiration in mm/day for the month considered.

T = Mean daily temperature in °C over the month considered.

p = Mean daily percentage of total annual daytime hours.

c = Adjustment factor which depends upon minimum relative humidity, sunshine hours and daytime wind estimates.

Since the empiricism involved in any ET prediction method using a single weather factor is invariably high, this method should only be used when temperature data are then only measured weather data available.

(6) Radiation Method

The radiation method is essentially an adaption of the Makkink formula. This method is suggested for the areas where available climatic data include measured air temperature and sunshine, coudiness or radiation, but not measured wind and humidity. Knowledge of general levels of humidity and wind is required and these are to be estimated using published weather descriptions, extrapolation from nearby areas or from local sources.

The relationship recommended is expressed as :

$$E_{TO} = c\,(W \times R_S)\ \text{mm/day}$$

where,

E_{TO} = Reference crop evapotranspiration in mm/day for the periods considered.

R_S = Solar radiation in equivalent evaporation in mm/day.

W = Weighing factor which depends on temperature and altitude.

C = Adjustment factor which depends on mean humidity and daytime wind.

R_S can be measured directly but is frequently not available for the area of investigation. In this case, R_S can be obtained from measured sunshine duration records as follows :

$$R_S = (0.25 + 0.50\ n/N)\ R_a$$

where, n/N is the ratio between actual measured bright sunshine hours and maximum possible sunshine hours. Data for n should be available locally. Both n and N are expressed in mean daily values, in hours. Values of R_a in mm/day for different months and latitudes may be obtained from the Table No. 2 given in the FAO publication No. 24 (1992 publication) at page no. 12.

Calculations should preferably be made for each month or period of each year of record rather than using mean radiation and mean temperature data based on several years of record.

A value of E_{TO} can then be obtained to ensure that water requirements will be met with a reasonable degree of certainty.

(7) Penman Method

For areas where measured data on temperature, humidity, wind and sunshine duration or radiation are available, adoption of the Penman method is suggested. Compared to the other methods, this method provide the most satisfactory result.

The original Panman equation predicted evaporation losses from an open water surface. Later on modified Panman method was suggested to determine E_{TO} involving revised wind function term. Therefore this method is also called as "Modified Panman Method" for determination of E_{TO}, i.e., reference crop evapotranspiration. Using this E_{TO}, the crop evapotranspiration E_{TC} can be obtained using the relationship $E_{TC} = K.E_{TO}$, where K is the crop coefficient.

The recommended relationship in the Modified Panman Method can be expressed as :

$$E_{TO} = C\,[\underbrace{W.R_n}_{\text{Radiation term}} + \underbrace{(1-W).f(u).(e_a - e_d)}_{\text{Aerodynamic term}}]$$

where,

E_{TO} = Reference crop evapotranspiration in mm/day

W = Temperature related weighing factor

R_n = Net radiation in equivalent evaporation in mm/day

f(u) = Wind related function

$(e_a - e_d)$ = Difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in mbar.

C = Adjustment factor to compensate for the effect of day and night weather conditions.

The relationship expressed above consists of two terms namely radiation term and aerodynamic term. The relative importance of each term varies with climatic conditions. The radiation term depends upon mean temperature and altitude while aerodynamic term is related with wind and humidity.

The modified Panman method would offer the best results among all the methods mentioned above with minimum possible error of plus or minus 10% in summer and upto 20 percent under low evaporative conditions.

2.3 FACTORS AFFECTING THE CROP WATER REQUIREMENTS

Many factors operate singly or in combination in influencing the amount of crop water required for the crop growth. These effects may differ with locality and fluctuate from time to time. The important factors which influence water requirements of crops are climate, water supply, plant growth, rate of percolation in the soil and method of irrigation system adopted, type of crop grown and the type of soil.

2.3.1 Climatic Factors

(i) Precipitation

The amount and rate of precipitation has an effect on the amount of crop water consumptively used during any season. Sometimes precipitation may come in frequent light showers. Such showers may add little or nothing to the soil moisture for use by the plants through transpiration but do decrease the withdrawal from stored moisture. The precipitation may be largely lost by evaporation directly from the surface of the plant foliage and from the land surface. Some of the precipitation from heavy storms may be lost by surface runoff, deep percolation or both. Other storms may be of such intensity and amount that a large percentage of precipitation will enter the soil and become available for plant transpiration. Such a condition materially reduces the amount of crop water needed.

(ii) Temperature

The rate of consumptive use of water by crops in any particular locality is probably affected more by temperature, which for a long time period is a good measure of solar radiation, then by any other factor. Abnormally low temperature may retard plant growth and unusually high temperature may produce dormancy. Consumptive use may vary even in years of similar temperatures because of derivations from the normal seasonal distribution.

(iii) Humidity

Evaporation and transpiration are accelerated on the days of low humidity and slowed down during periods of high humidity. If the average relative humidity percentage is low during the growing season, greater use of water by vegetation may be expected.

(iv) Wind Movement

Evaporation of water from land and plant surface takes place more rapidly when there is moving air than under calm air conditions. Hot dry winds and other unusual wind conditions during the growing season will affect the amount of water consumptively used. However, there is a limit in the amount of water that can be utilised. As soon as the land surface is dry, evaporation practically stops and transpiration is limited by the ability of plants to extract and convey the soil moisture through the plants.

(v) Advection

Crops grown in irrigation areas surrounded by large areas of arid or semi-arid climate can receive additional energy for evaporation of water by advection. A high percentage of net solar radiation received in arid areas is used in heating the atmosphere. As this warm air mass moves over irrigated areas that are generally cooler, energy contained in the air is as sensible heat which can be used to evaporate water by vertical turbulent transfer. Thus an "oasis" effect is created.

This evaporation of water by vertical turbulent transfer may cause a considerable increase in normal consumptive use in arid areas. It is not to be of significance in humid areas.

(vi) Latitude and Sunlight

Because of the earth's movement and axial inclination the hours of daylight during the summer are much greater in higher altitudes than at the equator. Since the sun is the source of all energy used in crop growth and evaporation of water, the longer day may allow plant transpiration to continue for a longer period in the day and to produce an effect similar to that of lengthening the growing period.

Clouds or dust in the atmosphere can reduce the amount of sunlight (solar energy) that reaches the plant. Elevation may also affect the amount of energy received, since at higher elevations there is less absorption of energy by the atmosphere.

(vii) Plant Growth Stages and Growing Season

The growing season has a major effect on the seasonal use of water by plants, actual dates of planting and crop maturity are important in determining crop water requirements.

Other factors being equal, the stage of a crop's growth has a very considerable influence on its consumptive use rate. This is aprticularly true for annual crops which have generally four distinct stages of growth.

(a) Germination stage (Initial stage)

(b) Crop development stage

(c) Vegitation stage (mid season stage)

(d) Crop maturing stage (late season stage).

Thus according to growth stages the crop water requirement varies. At the initial stage it is low and as the stage advances the requirement increases and it is highest at vegetative stage and then it reduces when the crop is at maturity stage.

(viii) Types of Crop Grown

The crop water requirements depends upon the types of crop grown. Individual crops will have different water requirements.

(ix) Irrigation System

Depending upon the irrigation system adopted, the water application efficiency will also differ and as such the total water requirement will also depend upon irrigation system adopted.

(x) Percolation and Runoff Losses

Soil conditions particularly permeability have important influence on water requirements, in as much as they affect losses and wastage. Highly permeable soils such as some sandy types are difficult to irrigate without losses by percolation.

Impermeable soils such as heavy clay types are difficult to irrigate without the waste by surface runoff.

2.4 CROPPING SYSTEMS

Cropping system is a sequence of crops grown on a given piece of land over a period of time. It varies from region to region at macrolevel and from farmer to farmer at microlevel, and governed by complexities of socio-economic and ecoedaphic factors. Approximations, however, are possible to identify major cropping systems in a region or zone through available area estimates.

2.4.1 Important Cropping Systems

On the basis of district-wise area under different crops during Kharif (rainy) and Rabi (winter) seasons, crops occupying largest area in respective seasons for each district were identified. The most prevalent cropping systems in the country are 30. These could be categorised as rice-based, cotton-based, pearl millate-based, sugarcane-based, groundnut-based, sorghum-based, and soybean-based. The cropping systems, their area and contribution to national food grains production for few are listed below :

Cropping System	Area (Million Ha)	Contribution (%)
Rice-wheat	9.77	25.0
Rice-rice	2.12	5.0
Cotton-wheat	1.39	2.36
Pearl millet-sorghum	1.35	1.68
Maize-wheat	1.29	2.25
Pearl millet-wheat	1.03	1.72
Sorghum-sorghum	0.74	1.65
Rice-gram	0.59	0.80
Sugarcane-wheat	0.54	0.86
Maize-gram	0.54	0.65

2.4.2 Objectives of Cropping System

The main objectives for the selection of a cropping system may be

(i) To improve the quality and yield of crops

(ii) To introduce diversity of crops to supply raw materials to several industries such as (a) sugar industries, (b) textile industry, (c) milk schemes, etc., without affecting balance of food crops in the area.

(iii) Economic utilisation of irrigation supplies thus controlling the contribution of seepage water to the subsoil as a preventive measure.

(iv) To suit the soil, irrigation water and the climatic conditions of the area with optimum benefits from agriculture.

2.4.3 Factors Affecting Cropping System

The various factors which may affect the cropping systems in the project area are :

(i) Availability of land for sowing the crop.

(ii) Rainfall in the area and its distribution.

(iii) Whether the scheme is productive or protective.

(iv) Suitability of the soils and the irrigation water for growing particular type of crops.

(v) Natural drainage of the area.

(vi) Cropping adopted under existing rainfed cultivation and under well irrigation.

(vii) Size of holding and family members.

(viii) Subsoil water table.

(ix) Dietic habits of the people.

(x) The demand of industrial establishment for the particular raw material.

In case of major irrigation projects the advise of leading agricultural experts is to be sought in deciding the cropping systems in the project area taking into consideration of the dependable water resources, the climatic factors of the area and the policy of the state whether to protect the rain fed crops from failure of rains or to achieve maximum efficiency in irriculture from the available water in the project.

In this study, the reference project taken up is Kolar project, Distt. Sehore of M.P., which is also a major project. So the cropping systems adopted in the project are as suggested by the Agriculture Department of M.P.

2.5 PROJECT PLANNING

In the planning of an irrigation project, the production objectives must be related to the physical resource base, particularly climate, soil and water supply in order to ensure that production proposed and yields predicted can be achieved and maintained. Also, several technical, economic and organisational factors must be considered to arrive at a technically sound, managerially workable, economically and financially viable project which is at the same time in accordance with the development and production objectives.

An important element in the evaluation of crop production under irrigation is the available and required water supply over time and acreage. When available water supply is adequate and fully meets crop water requirements, the production is maximum and the required supply depends upon the crop selected, the length of growing season and the irrigated acreage. When available water supply is limited, production is determined by the extent to which full water requirements can be met by the available water supply over the total growing season.

The cropping systems of the project (e.g. crops, crop intensity, crop rotation) and the efficiency with which production resources can be used are essential input considerations in the overall project planning. Selection of cropping systems must be carefully consider the climate, soil and water requirements of crops. The length of the growing season and the climatic conditions within the growing season dictate the type of crops and the cropping systems that can be considered. These must also match the available soil and water resources.

Planning of an irrigation project is a very complex one that too the estimation of project irrigation water requirements. Since it involves the collection and computation of data on the cropping system adopted, the growing periods of the crops, the evapotranspiration requirements of the crops, the precipitation, special needs of the crop, water application losses, etc.

All these factors varies from region to region and thus every project is a separate entity.

DESCRIPTION OF PROJECT

3.1 GENERAL

Kolar project is an irrigation cum water supply project for providing irrigation to 45087 Ha of land in Budhni and Nasarullaganj Tehsils of Sehore district of Madhya Pradesh and water supply to the tune of 34 million gallons per day to Bhopal town. The project area is situated in the Sehore district of M.P. The dam is constructed on Kolar river a tributory of Narmada river and it is about 1 km from the village Lawakhedi.

The dam site is approachable by road and it is about 32 km from Bhopal. The command area of Kolar project lies between 22°36′ and 22°53′ latitude and 77°17′ and 77°33′ longitude.

The project comprises of construction of an earthen dam on the Kolar river. The total length of dam is 1340.50 m with a maximum height of 49.50 m. A masonry gated spillway of length 141 m having a maximum height of 14.70 m upto crest level is provided on the right flank to pass the designed peak flood of 8605 cumecs. The gated structure of spillway would comprise of 8 radial gates of size 15 m x 8 m.

The reservoir has a gross storage capacity of 270 M Cum and live storage capacity of 265 M Cum. Canal system of this project takes off from a barrage 30 km down stream of the dam. The total length of barrage is 1195 m with a maximum height of 15.5 m.

Two canal systems, one on the right bank and other on left bank of the barrage are constructed to cover a total area of 45087 Ha. Right bank canal covers 18515 ha and left bank canal covers an area of 26572 ha of the command. The command area is predominantly Rabi and principal Rabi crop is wheat. Kharif is also sown but with inferior crops like jowar, soybean, etc. Intensity of irrigation is adopted as 135%.

The right bank canal and left bank canal are designed to carry a discharge of 16.40 Cumecs and 18.60 Cumecs respectively and both are lined canals.

The other important salient features of the Kolar project are as follows :

Location :

(i)	State	:	Madhya Pradesh
(ii)	District	:	Sehore
(iii)	Latitude	:	22°58'N
(iv)	Longitude	:	77°21' E
(v)	River	:	Kolar
(vi)	Location	:	Dam site is about 1 km from Lawakhedi village.

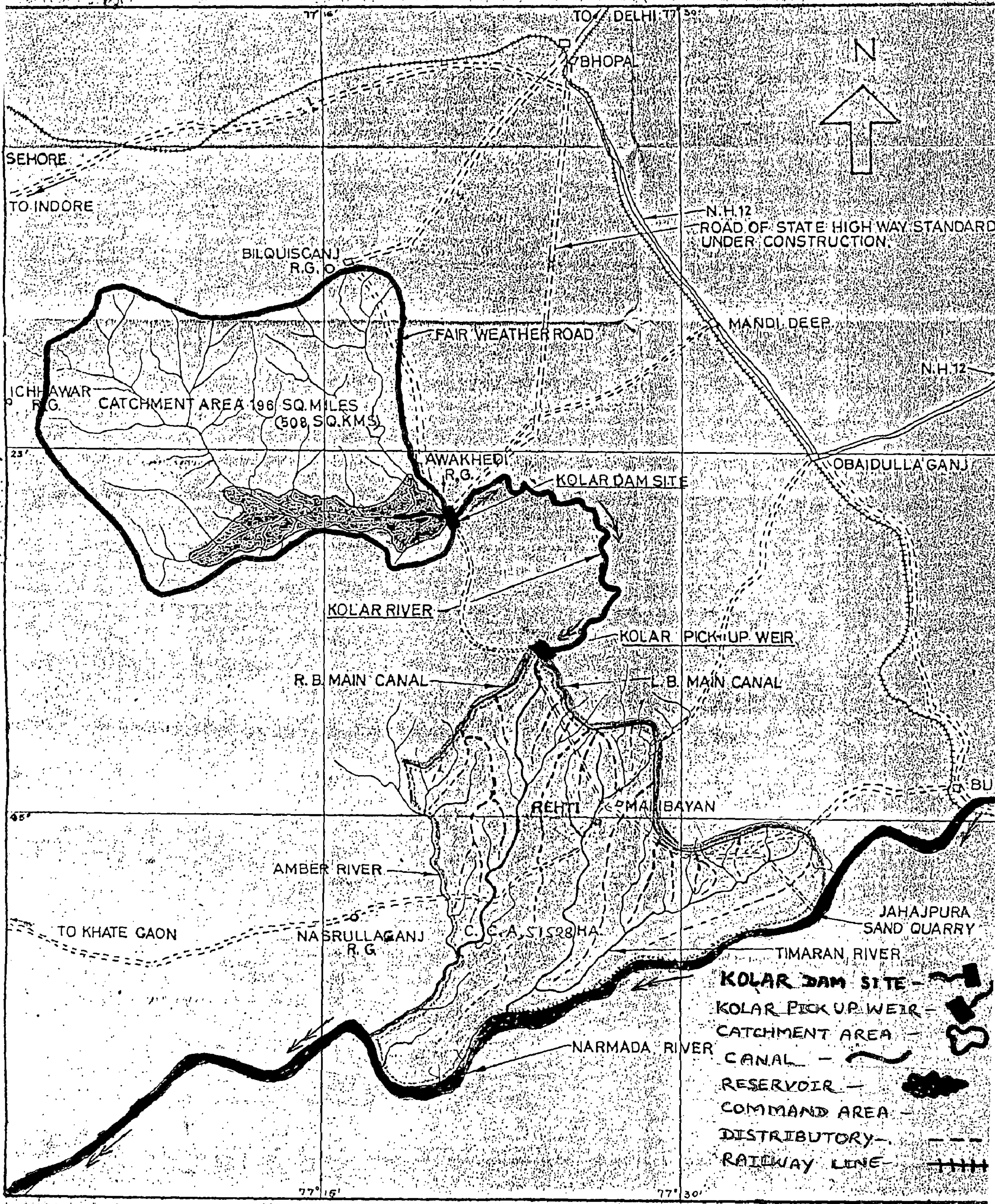
An index map of the Kolar project is shown at Fig. 1. Page No. 26.

Hydrology

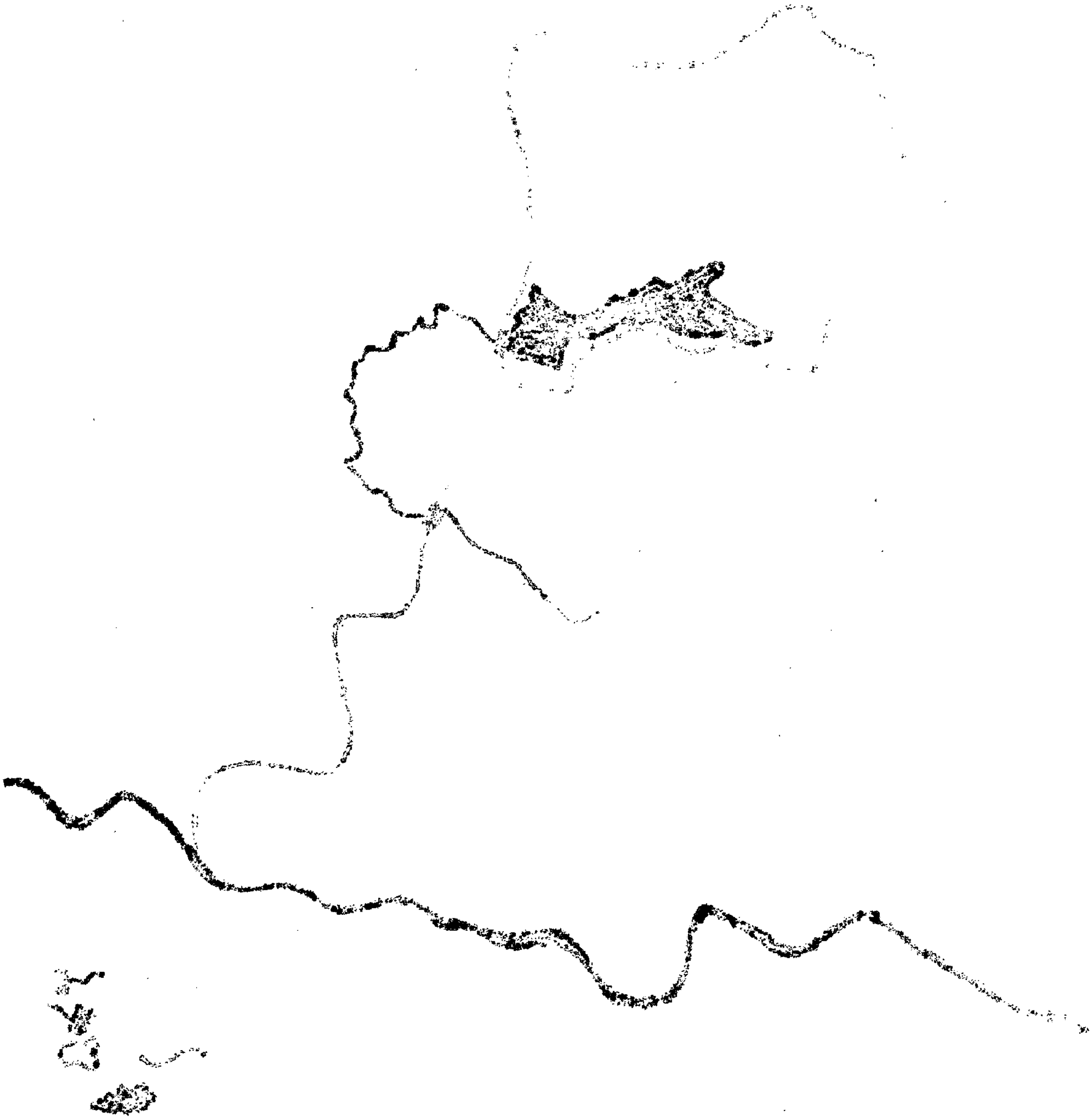
(i)	Catchment area		
	Upto dam site	:	508 sq. km
	Between dam and barrage	:	251.23 sq. km
(ii)	Maximum rainfall	:	2164 mm
(iii)	Minimum rainfall	:	495 mm
(iv)	Average annual rainfall	:	1230.50 mm

Reservoir Data

(i)	Top bank level (TBL)	:	465.50 m
(ii)	Maximum water level (MWL)	:	463.30 m
(iii)	Full reservoir level (FRL)	:	462.20 m
(iv)	Minimum draw down level (MDDL)	:	432.93 m
(v)	Water spread at FRL	:	2503 Ha



INDEX MAP OF KOLAR PROJECT



(vi)	Gross storage at FRL	:	270 MCum
(vii)	Live storage	:	265 M Cum
(viii)	Dead storage	:	5 M Cum

Dam Details

(i)	Total length of dam	:	1340.50 m
(ii)	Length of overflow portion	:	141 m
(iii)	Length of earthen dam	:	1199.50 m
(iv)	Length of spillway	:	141 m
(v)	Maximum height of spillway upto crest	:	14.70 m
(vi)	Crest level	:	453.70 m
(vii)	Number and size of spillway gates	:	8 No. (15 m x 8 m)
(viii)	Designed discharge of spillway	:	6450 Cumecs
(ix)	Sluice gate number and size	:	2 No. (2.25 m x 2.25 m)
(x)	Designed discharge through sluice gates	:	35 Cumecs

Barrage Details

(i) Location : 30 km downstream of the main dam near village Jholiyapur, Tehsil Budhni Distt. Sehore.

(ii)	Total length of barrage	:	1195 m
(iii)	Length of masonry portion	:	157 m
(iv)	Length of earthen portion	:	1038 m
(v)	Height of barrage	:	15.5 m
(vi)	Number and size of gates provided	:	9 No., 15 m x 90 m
(vii)	Designed discharge of barrage	:	8314 Cumecs

Canal Systems

		Left bank canal	**Right bank canal**
(i)	Type	Lined	Lined
(ii)	Bottom width	2.70 m	2.52 m

(iii)	Full supply depth	2.25 m	2.10 m
(iv)	Side slopes	1:1.5	1:1.5
(v)	Bed gradient	1:2050	1:1900
(vi)	Discharge	18.60 Cumecs	16.40 Cumecs
(vii)	Length	29.50 km	24.72 km
(viii)	Area of irrigation	26572 ha	18515 ha

3.2 CROPPING PATTERN OF KOLAR PROJECT

At the initial stage of planning of the Kolar project, the cropping pattern is adopted as suggested by Agriculture Department of Madhya Pradesh. Using this suggested cropping pattern, the crop water requirements were computed and the capacity of canal systems and storage capacity of the reservoir are fixed.

The cropping pattern consists of Kharif as well as Rabi irrigation. The suggested cropping pattern is described below.

S. No.	Crop	Date of Planting	Duration (Days)	Area of Irrigation (Ha)
	KHARIF			
1	Soyabean – 1KH	15th – 30th June	105	4509
2	Soyabean – 2KH	1st – 15th July	105	6763
3	Jowar – 1KH	15th – 30th June	105	4509
4	Jowar – 2KH	1st – 15th July	105	4509
5	Cotton – 2KH	15th – 30th June	180	2254
			Total Kharif	22544
	RABI			
1	Wheat – 0MV	16th – 30th Oct	135	11272
2	Wheat – 1MV	1st – 15th Nov	135	5410
3	Wheat – 2MV	16th – 30th Nov	135	11271
4	Gram – S2RA	16th – 31st Oct	120	9017
5	Potato/Vegetables	1st – 15th Nov	105	451
6	Berseem	1st – 15th Nov	165	902
			Total Rabi	38324

Grand Total (Kharif + Rabi) 60868 Ha

The total area of Kharif and Rabi crops is 60868 Ha which is 135% of the net CCA 45087 Ha. Thus the cropping intensity adopted at planning stage is 135%.

The crop water requirement is computed using aforesaid cropping pattern for 20 years (1960 to 1980) and monthly average water requirement is calculated. The total of the monthly average water requirement gives the quantum of water needed to be stored. The maximum water requirement in a particular month is the base for the design of the capacities of canal system.

The monthly average water requirement for the entire command area, i.e., 45087 Ha as computed at the initial planning stage is tabulated below :

Months	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Water require-ment in M Cum	9.21	14.59	0.739	16.14	29.98	49.50	50.31	47.76	33.61	8.77	-	-

The total water requirement (June to March) comes out as 260.60 M Cum. So the live capacity of the reservoir is kept as 265 M Cum, where additional 5 M Cum are kept for losses due to evaporation and transmission between reservoir and the barrage as they are about 30 km apart.

The maximum water requirement comes to 57.55 M Cum in the month of November 1960 which corresponds to an outlet factor as 0.77 litres/sec/ha.

As the Kolar project was World Bank aided, so as per the guidelines suggested by the Wold Bank the canals were designed to carry their capacity on the basis of an outlet factor as 0.7 litres/sec/ha or 1428.57 ha/cumecs.

Thus an outlet factor of 1428.57 Ha/cumecs is adopted in the design of left bank canal and right bank canal which ultimately yields their discharging capacities as 18.60 cumecs and 16.40 cumecs respectively.

METHODOLOGY

4.1 GENERAL

The basic idea of this study is to observe the variation that occurs in the crop water requirements due to changes in climatic conditions if any which takes place in the command area of the project. The initial planning of any irrigation project begins with the computations of crop water requirements and this is computed on the basis of previous climatological data available at the planning stage. On the basis of these crop water requirements, the net irrigation requirements and gross irrigation requirements considering certain project efficiency are found out.

Thus the computed gross water requirements are useful to fix the discharging capacities of the canal system and the storage capacities of the reservoirs in the cases of storage irrigation projects.

As the crop water requirements are closely related with the climatic conditions. So, any change observed in the climate will directly affect the crop water requirements and ultimately the discharging capacity of the canal system and the area to be irrigated. Considering this concept, an attempt is made to collect the climatological data of 16 years (1984 to 1999) of the Hoshangabad station, which is the nearest IMD station to the command area of the Kolar project, and this data is processed to compute the crop water requirements.

Thus the computed crop water requirements will ultimately help to determine the gross irrigation requirements and to finalise the carrying capacity of the canal system.

The methodology adopted to achieve the aforesaid goal consisting of the following steps :

(i) Collection of climatological data like maximum temperature, minimum temperature, RH maximum, RH minimum, cloud cover, wind speed, monthly rainfall etc. for the Hoshangabad station from the Indian Meteorological Department of India.

(ii) Computations of reference crop evapotranspiration (E_{TO}) by modified Panman method.

(iii) Selection of crop coefficients for the various crops suggested under a cropping system.

(iv) Computation of consumptive use and gross consumptive use.

(v) Computations of net irrigation requirement.

(vi) Computations of gross irrigation requirement.

(vii) Monthly estimated crop water requirements and total water requirement for the entire command.

(viii) Computation of outlet factor, i.e., area irrigated per unit volume of water and to fix canal carrying capacities.

Each step is described in details as below.

4.1.1 Collection of Climatological Data

The command area of Kolar project lies between 22°36′ and 22°53′ latitude, and 77°17′ and 77°33′ longitude. There is no climate observatory in the command area. The nearest climatological observatory is at Hoshangabad having a latitude of 22°46′ and longitude of 77°46′E. This observatory is maintained by Indian Meterological Department, Govt. of India. The monthwise climatological data from 1984 to 1999 related with max. temperature, min. temperature, max. relative humidity (RH_{max}), min. relative humidity (RH_{min}), monthly rainfall, cloud cover, wind speed, etc. for the Hoshangabad station are collected from their regional office at Nagpur.

These monthwise climatological data are at Annexure No. 1. Page No. 84-95.

4.1.2 Computation of Reference Crop Evapotranspiration (E_{TO}) by Modified Panman Method

As already mentioned in the Chapter II of this study that for the areas where measured data on temperature, humidity, wind and sunshine duration or radiations are available the modified Panman method is accepted to give the satisfactory result. This method would offer minimum possible error of $\pm 10\%$ in summer and upto 20% under low evaporative conditions.

Due to this reason, the Modified Panman method is adopted in this study.

The relationship recommended in the Modified Panman method is given by

$$E_{TO} = c\,[W.R_n + (1-W)\,.\,f(u)\,.\,(e_a - e_d)\,]$$

where,

E_{TO} = Reference crop evapotranspiration in mm/day

W = Temperature-related weighing factor

f(u) = Wind related function

$(e_a - e_d)$ = Difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in m bar.

c = Adjustment factor to compensate for the effect of day and night weather conditions.

4.1.2.1 Description of Variables

(a) Vapour Pressure ($e_a - e_d$)

Air humidity affects E_{TO}. Humidity is expressed as saturation vapour pressure deficit ($e_a - e_d$), i.e., the difference between the mean saturation water vapour pressure (e_a) and the mean actual water vapour pressure (e_d).

Air humidity data are reported as relative humidity (RHmax and RHmin in percentage) and its time of measurement is important. In our case, the relative humidity measured at 8.30 is considered as 'RHmax' while the same measured at

17.30 hrs is considered as 'RHmin'. These timings of measurements of relative humidity are being followed by the IMD at their observatory stations all over the country.

(b) Wind Function f(u)

The effect of wind on E_{TO} has been studied for different climates resulting in a wind function [f(u)] given by an expression as

$$f(u) = 0.27 (1 + U/100)$$

where U is 24 hr wind run in km/day at 2m height.

Where wind data is not collected at 2 m height then appropriate corrections to be applied to the expression given for f(u) as above. But in our case the wind data is measured at 2 m height so no correction factor is needed to apply.

(c) Weighting Factor (1-W)

(1-W) is a weighting factor for the effect of wind and humidity on E_{TO}. Values and (1-W) as related to mean temperature and altitude are available in the ready reckoner table given in FAO-24.

(d) Weighting Factor (W)

W is the weighting factor for the effect of radiation on E_{TO}. Values of W as related to mean temperature and altitudes are available in the ready reckoner table given in FAO-24.

(e) Net Radiation (Rn)

Net radiation (Rn) is the difference between all incoming and outgoing radiation. It can be measured, but such data are seldom available. Rn can be calculated from solar radiation or sunshine hours (or degree of cloud cover), temperature and humidity data.

Following relationships are recommended and may be used in the determination of net radiation (Rn).

$$R_n = R_{ns} - R_{nl}$$

$$R_{ns} = 0.75\ R_s$$

$$R_s = (0.25 + 0.5\ n/N)\ Ra$$

and $R_{nl} = f(T) \times f(e_d) \times f(n/N)$

where,

R_{ns} is net shortwave radiation

R_s is solar radiation

R_a is extra terrestrial radiation in mm/day and dependent on latitude and time of the year only.

n/N is the ratio of actual (n) to maximum possible (N) sunshine hours

R_{nl} is net longwave radiation and can be determined from available temperature (T), vapour pressure (e_d) and ratio n/N.

f(T), f(e_d) and f(n/N) are the functions of temperature, vapour pressure and ratio n/N and can be determined from the tables available.

(f) Adjustment Factor (c)

The Penman equation given assumes the most common conditions where radiation is medium to high, maximum relative humidity is medium to high and moderate daytime wind about double the night time wind. However, these conditions are not always met.

Therefore correction to Panman equation is required. This correction is made by applying adjustment factor (c) to the Panman equation.

A table is available showing values of c for different conditions of RH_{max}, R_s, U_{day} and U_{day}/U_{night}.

4.1.2.2 Procedure of Computation and Sample Calculation

The procedure laid down in "Guidelines for predicting crop water requirements – FAO-24, publication 1992" for the modified Panman method to compute evapotranspiration (E_{TO}) is followed in this study. The tables given in the aforesaid guidelines are used in the calculations.

A sample calculation is illustrated below for the month Nov. 1984.

The climatic data of Nov. 1984 is shown at Annexure No. 1, Page No. 94. and this data is used to calculate E_{TO}.

Steps of Calculations

(1) Maximum air temperature in °C = 27.5 (from climatic data)

(2) Minimum air temperature in °C = 14.7 (from climatic data)

(3) Mean air temperature in °C = (27.5 +14.7)/2 = 21.1 (calculated)

(4) Saturation vapour pressure (e_a) in mbar corresponding to mean temperature of 21.1°C = 25.05 (from Table No. 5)

(5) Maximum relative humidity (RHmax%) = 60 (from climatic data)

(6) Minimum relative humidity (RHmin%) = 46 (from climatic data)

(7) Mean relative humidity (RHmean%) = (60+46)/2 = 53 (calculated)

(8) Actual vapour pressure (e_d) = (e_a x RHmean)/100
= (25.05x53)/100 = 13.27 (calculated)

(9) Vapour pressure deficit (e_a-e_d) = 25.05-13.27 = 11.78 (calculated)

(10) Weighing factor W corresponding to mean temperature 21.1°C and altitude 302 m = 0.707 (from Table No. 9)

(11) 1 – W = 1 – 0.707 = 0.293 (calculated)

(12) Cloud cover in oktas = 2.2 (from climatic data)

(13) Ratio n/N corresponding to cloud cover 2.2 = 0.73 (from Table No. 7-A)

(14) Extra terrestrial radiation (R_a) corresponding to latitude 22°46′ N and month November in northern hemisphere = 10.948 (From Table No. 10)

(15) Short wave radiation R_s = (0.25 + 0.5 n/N) R_a = 6.733 (calculated)

(16) R_{ns} = 0.75R_s = 0.75 x 6.733 = 5.049 (calculated)

(17) Function of temperature f(T) corresponding to mean temperature 21.1°C = 14.82 (from Table No. 13)

(18) Function of vapour pressure $f(e_d)$ corresponding to

e_d = 13.27 = 0.183 (from Table No. 14)

(19) Function of sunshine duration f(n/N) corresponding

to n/N = 0.073 = 0.76 (from table no. 15)

(20) Net longwave radiation $R_{nl} = f(T) \times f(e_d) \times f(n/N)$ = 2.061 (calculated)

(21) Net radiation $R_n = R_{ns} - R_{nl}$ = 2.988 (calculated)

(22) Average wind speed in km/day (u) = 69.6 (climatic data)

(23) Average wind speed in m/sec = 0.80 (calculated)

(24) Wind function f(u) = 0.27 (1 + u/100) = 0.45 (calculated)

(25) Adjustment factor 'C' corresponding to RHmax = 60%, R_s = 6.733,

Uday = 0.80 and Uday/Unight = 1 = 0.965 (from Table No. 16)

(26) $W \times R_n$ (mm/day) = 2.112 (calculated)

(27) $(1 - W) \times f(u) \times (e_a - e_d)$ = 1.553 (calculated)

(28) $E_{TO} = C [W \times R_n + (1-W) \times f(u) \times (e_a-e_d)]$ in mm/day = 3.53 (calculated)

(29) Monthly E_{TO} (mm/month) = 105.9 (calculated)

Thus, monthly E_{TO} is calculated for each month of the year from 1984 to 1999. The yearwise E_{TO} calculated are at Table No. 1, Page No. 46-61.

An abstract titled "Computed yearly reference crop evapotranspiration (E_{TO}) by Modified Panman method" is also prepared which is at Table No. 2, Page No. 62.

Monthly average E_{TO} and daily E_{TO} are derived from the aforesaid monthly average E_{TO}, which are shown in Table No. 2, Page No 62.

These computed daily E_{TO} values for different months are then used to compute the crop evapotranspiration (ET_{crop}) which will be described in the coming paras.

4.1.3 Selection of Crop Coefficients for Various Crops Suggested Under a Cropping System

The crop coefficient K_c establishes the relationship between crop evapotranspiration (ET_{crop}) and the reference crop evapotranspiration (E_{TO}). Thus knowing crop coefficient K_c and E_{TO} one can calculate the crop evapotranspiration (ET_{crop}) which is nothing but the water requirement of the crop.

Mathematically, the relationship between ET_{crop}, E_{TO} and K_c is given by

$$ET_{crop} = K_c \times E_{TO}$$

The values of K_c varies with the development stages of the crop. Usually four stages occur till the full development of any crop. These are

(i) Initial stage

(ii) Crop development stage

(iii) Mid-season stage, and

(iv) Late-season stage.

The value of K_c varies with the development stages of crop.

Under this study, the values of K_c for the different crops adopted in the cropping pattern are taken from FAO paper no. 33 on the "Yield response to water" published by Food and Agriculture organisation of the united Nations – Rome 1979.

The K_c values for different crops adopted in this study are tabulated below.

S. No.	Crops	Values of K_c			
		Initial stage	Crop development stage	Mid season stage	Late season stage
1	Soybean	0.40	0.80	1.15	0.80
2	Jowar (sorghum)	0.40	0.75	1.15	0.80
3	Cotton	0.40	0.70	1.05	0.80
4	Wheat	0.30	0.70	1.05	0.65
5	Gram	0.26	0.94	1.00	0.55
6	Potato/vegetables	0.40	0.70	1.05	0.85
7	Berseem	0.38	1.01	1.10	1.05

4.1.4 Computation of Consumptive Use and Gross Consumptive Use, (4.1.5) Computation of net irrigation Requirement, and (4.1.6) Computation of gross irrigation Requirement

All the aforesaid computations mentioned at 4.1.4, 4.1.5 and 4.1.6 are carried out on a single sheet for each crop. Thus there are 11 sheets prepared for crops namely soybean-1KH, soybean-2KH, jowar-1KH, jowar-2KH, cotton-2KH, wheat-0MV, wheat-1MV, wheat-2MV, gram-S2RA, potato/vegetables and berseem.

These computation sheets titled "Estimation of crop water requirement" are at Table No. 3, Page No. 63-73.

The duration of each crop is divided into growth stages and the number of days in each stage are distributed into successive months starting from the sowing month.

For example : Crop-soybean-1KH has its duration as 105 days, growth stages (days) – 20/30/30/25 and sowing time 16th – 30th June. Then its duration is divided as follows :

June	July		August		September	
16th – 30th	1st – 5th	6th – 31st	1st – 4th	5th – 31st	1st – 3rd	4th – 28th
15 days	5 days	26 days	4 days	27 days	3 days	25 days
Growth stage (days) 20 days		30 days		30 days		25 days

The computation sheet at Page No. 63. shows this type of distribution of the duration of crop soybean-1KH. The distribution is necessary because the crop coefficient (K_c) varies with the growth stage.

Such type of distribution of duration according to growth stages is carried out for each crop and shown at the respective sheet for that crop (Page No. 63-73).

Step by step computations carried out in these sheets are explained below :

The computation sheet of crop soybean-1KH at Page No. 63 is taken as example sheet for the explanation of each step.

Step at S. No. 1 :

E_{TO} (mm) = Daily E_{TO} x No. of days

Here, daily E_{TO} refers to daily E_{TO} (mm/day) for particular month obtained from the abstract sheet at Page No. 62, and

No. of days are taken according to growth stage as explained just above in the distribution of duration of crop.

e.g. E_{TO} = 6.76 x 15 = 101.40 mm in the month of June.

Here, 6.76 is the daily E_{TO} for the month of June, and

15 is the no. of days according to growth stage.

Step at S. No. 2 :

K_c = Crop factor, adopted according to growth stage as mentioned at 4.1.3 selection of crop coefficient at Page No. 37.

e.g. K_c = 0.4 in the month of June according to initial stage of growth.

Step at S. No. 3 :

Consumptive use (E_{TC}) = E_{TO} x K_c

e.g., E_{TC} = 101.4 x 0.4 = 40.56 in the month of June.

Step at S. No. 4 :

Presowing : Water required for softening the soil and preparing the fields by ploughing is termed as presowing. Usually for Kharif crops it is adopted as 75 mm and for Rabi crops it is adopted as 60 mm. In this study the same values are adopted. This amount of water is applied before sowing.

In the example sheet of soybean-1KH presowing is taken as 75 mm as it is a Kharif crop.

Step at S. No. 5 :

Soil Moisture Adjustment : Soil moisture may be available if all the water received from rainfall or previous irrigation is not used by plants and not fully lost in deep percolation. This soil moisture is equal to the consumptive use (E_{TC}) during the last one or two fortnights before harvest.

The irrigation is cut-off or discontinued during this period. So soil moisture adjustment is deductible from the gross consumptive use.

In the example sheet of soybean-1KH, the soil moisture adjustment comes as 53.86 mm in the month of Sept. which is equal to the consumptive use of irrigation cut off days before harvest of 15 days and it is a negative figure.

The soil moisture adjustment for other crops in this study are computed using following irrigation cut off days before harvest and consumptive use for these irrigation cut days.

S. No.	Crop	Irrigation cut off days before harvest
1	Soyabean-1KH	15
2	Soyabean-2KH	15
3	Jowar-1KH	15
4	Jowar-2KH	15
5	Cotton-2KH	30
6	Wheat – 0MV	30
7	Wheat – 1MV	30
8	Wheat – 2 MV	30
9	Gram – S2RA	40
10	Potato/vegetables	25
11	Berseem	15

The above crop wise irrigation cut off days before harvest are taken from Annexure no. 1 of the "Design series technical circular no. 25 on Estimation of crop water requirement and irrigation requirement" published by Madhya Pradesh irrigation Department (1990).

Step at S. No. 6 :

Gross Consumptive Use : This is equal to algebraic sum of step at S. No. 3, 4 and 5.

e.g.,	40.56	+	75	+	0	=	115.56
	At S. No. 3		At S. No. 4		At S. No. 5		At S. No. 6

Step at S. No. 7 :

Rainfall : This is the monthly rainfall occurred. It is observed from the climatological data collected. In this study, it is taken as the average of years 1984 to 1999 monthwise.

For the example sheet of soybean-1KH, the rainfall value for the june month is 92.9 mm, adopted from the climatological data for the June month at page no.89

Step at S. No. 8 :

Effective Rainfall : The fraction of rainfall, which is effective and usefully available for the plant use is termed as effective rainfall and is smaller than the measured amount of rainfall in the area.

FAO, Irrigation and drainage paper no. 25 (1975) provided a table to compute the effective rainfall using the mean monthly rainfall and mean monthly consumptive use data. This table is used to compute the effective rainfall by interpolation technique under this study.

For the example sheet of soyabean-1KH, the mean monthly rainfall of 92.9 mm of June and mean consumptive use of 40.65 mm of June yields the effective rainfall as 40.65 mm by interpolation and mentioned in the aforesaid sheet.

Step at Sheet No. 9 :

Net Irrigation Requirement : This is equal to gross consumptive use minus effective rainfall, i.e., S. No. 6 – S. No. 8.

e.g. 115.56 – 40.56 = 75 mm in the month of June.

Step at S. No. 10 :

Gross Irrigation Requirement : This is equal to Net irrigation requirement divided by the project efficiency. In this study, the project efficiency in the Kharif season is adopted as 42% while in the Rabi season, it is adopted as 58%.

For example, sheet of soyabean-1KH being it a Kharif crop, the gross irrigation requirement (GIR) is given by

GIR = NIR/0.42 = 75/0.42 = 178.57 mm for the month of June.

Step at S. No. 11 :

Water Requirement for Sowing Area (Ha-m) : This indicates the water requirement for the sowing area of the crop in Ha-m.

For the example sheet of soyabean-1KH the sowing area is 4509 Ha. So water requirement is

= (178.57/1000) x 4509 = 805.17 Ha-m for the month of June.

Step at S. No. 12 :

Water Requirement for Sowing Area (M Cum) : This is the water requirement for the sowing area of the crop in million cubic meter (M Cum). It is simply a conversion of figures in Ha-m obtained in the step at S. No. 11 into million cubic meter (MCum).

It is obtained by dividing the Ha-m by 100.

For the example sheet of soyabean-1KH, it is given by

805.17/100 = 8.0517 M Cum for the month of June.

In this way estimation of crop water requirement for each crop suggested under a cropping pattern is computed out monthwise for its duration.

4.1.7 Monthly Estimated Crop Water Requirements and Total Water Requirements for the Entire Command

As already mentioned above that, water requirement for each crop is computed monthwise for its duration. Based on these an abstract titled, "Monthly estimated crop water requirements" is prepared which is at Table No. 4, Page No. 74.

The table shows month wise crop water requirements for all the crops.

The sum of water requirements of all crops for all the months gives the total water requirement for the entire command area of project. In this study, it comes as 287.343 M Cum as shown in the above mentioned Table No. 4 at page No. 74.

4.1.8 Computation of outlet Factor, i.e., Area Irrigated per Unit Volume of Water and to Check Canal Carrying Capacities

The outlet factor is defined as the area irrigated per unit volume of the water released for irrigation. This outlet factor is useful in deciding the carrying capacity of the canal system.

The abstract of monthly estimated crop water requirements at Table No. 4 shows that the maximum water requirements occur in the month of November having a magnitude of 68.195 M Cum. The area irrigated in the month of November is 40578 Ha.

$$\text{So, outlet factor} = \frac{40578}{68.195 \times 10^{6} / 30 \times 24 \times 60 \times 60}$$

$$= 1542.31 \text{ Ha / Cumecs}$$

The carrying capacities of the canal system of Kolar project is to be worked out using the outlet factor as 1542.31 Ha/cumecs computed above.

As mentioned in the chapter of 'Description of Project' that Kolar project has two canal system namely left bank canal and right bank canal designed for the capacities of 18.60 cumecs and 16.40 cumecs respectively.

These canal systems has area of irrigation as 26572 Ha and 18515 Ha. So adopting outlet factor as 1542.31 Ha/cumecs, the capacities of left bank and right bank canal systems are :

Capacity of left bank canal = 26572/1542.31 = 17.22 cumecs

Capacity of right bank canal = 18515/1542.31 = 12.00 cumecs

Thus the left bank canal capacity and the right bank canal capacity are adequate to meet out the increased water requirements.

RESULTS AND DISCUSSIONS

5.1 RESULTS

The various results obtained after the completion of the study are described below :

(1) The reference crop evapotranspiration (E_{TO}) for each month of the years 1984 to 1999 is computed by 'Modified Panman Method' using the climatological data of this period. These computations are at Table No. 1, Page No. 46-61.

(2) Based on the monthly E_{TO}s computed as mentioned above, an abstract titled 'computed yearly reference crop evapotranspiration (E_{TO}) by modified Panman method is prepared which is at Table No. 2, Page No. 62. This abstract shows monthly average E_{TO} s as well as daily E_{TO} (mm/day) for each month.

(3) Using the daily E_{TO} values worked out in the above step, the estimation of crop water requirement for each crop is worked out. These computation sheets are at Table No 3, Page No. 63-73.

(4) Based on above computation sheets of 'estimation of crop water requirement' for all crops, an abstract titled 'monthly estimated crop water requirement' is prepared which is at Table No. 4, Page No. 74.

(5) The abstract at Table No. 4, Page No. 74 as mentioned above, shows that the total water requirement for the entire command area is worked out 287.343 M Cum.

(6) The water requirement calculated at the initial planning stage was 260.70 M Cum. Thus there is an increase of 26.643 M Cum in the water requirement is obtained which is about 10.21%.

TABLE NO. 1

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD
FOR THE YEAR - 1984

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.700	26.600	35.100	38.600	40.400	37.100	29.900	29.500	27.800	29.300	27.500	23.900
2	Min. air temperature in o C.	10.900	10.500	17.500	21.500	25.100	24.900	22.900	22.900	21.900	18.200	14.700	9.300
3	Mean air temperature in o C.	18.300	18.550	26.300	30.000	32.750	31.000	26.400	26.200	24.850	23.750	21.100	16.600
4	Saturation vapour pressure (ea) in mbar	21.000	21.300	34.230	42.400	49.620	44.900	34.440	34.020	31.410	29.370	25.050	18.920
5	Max.relative humidity (RH Max.%)	61.000	43.000	23.000	22.000	34.000	63.000	87.000	88.000	93.000	70.000	60.000	53.000
6	Min.relative humidity (RH Min.%)	38.000	25.000	12.000	13.000	24.000	42.000	77.000	78.000	83.000	55.000	46.000	37.000
7	Mean.relative humidity (RH Mean.%)	29.500	34.000	17.500	17.500	29.000	52.500	82.000	83.000	88.000	62.500	53.000	45.000
8	Actual vapour pressure (ed) = ea*RHMean/100	10.390	7.240	5.990	7.420	14.380	23.570	28.240	28.230	27.640	18.350	13.270	8.510
9	Vapour pressure dedicit (ea-ed) in mbar	10.610	14.060	28.240	34.980	35.240	21.330	6.200	5.790	3.770	11.020	11.780	10.410
10	Weighing factor (W)	0.670	0.670	0.750	0.786	0.811	0.796	0.760	0.758	0.744	0.733	0.707	0.652
11	(1-W)	0.330	0.330	0.250	0.214	0.189	0.204	0.240	0.242	0.256	0.267	0.293	0.348
12	Cloud cover in oktas	2.900	1.600	0.900	1.500	2.700	4.200	7.800	7.600	7.800	3.100	2.200	2.300
13	Ratio n/N	0.660	0.790	0.860	0.800	0.680	0.530	0.300	0.060	0.030	0.640	0.730	0.720
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.476	16.438	15.800	14.562	12.848	10.948	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.090	7.830	9.570	10.050	9.630	8.485	4.356	4.424	3.858	7.323	6.733	6.106
16	Rns = 0.75 Rs	4.560	5.870	7.170	7.530	7.220	6.360	3.267	3.318	2.893	5.492	5.049	4.579
17	Function of temperature f(T).	14.260	14.310	15.960	16.700	17.380	16.950	15.980	15.940	15.610	15.350	14.820	13.920
18	Function of vapour pressure f(ed).	0.198	0.223	0.232	0.222	0.176	0.122	0.108	0.108	0.111	0.148	0.183	0.214
19	Function of sunshine duration f(n/N)	0.698	0.811	0.878	0.820	0.710	0.580	0.130	0.158	0.130	0.680	0.760	0.750
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	1.970	2.588	3.250	3.040	2.170	1.199	0.224	0.272	0.225	1.544	2.061	2.234
21	Net radiation Rn = Rns-Rnl in mm/day	2.590	3.282	3.920	4.490	5.050	5.161	3.043	3.046	2.668	3.948	2.988	2.345
22	Average wind speed in km/day	105.600	105.600	117.600	129.600	165.600	184.800	158.400	139.200	108.000	69.600	69.600	88.800
23	Average wind speed in m/sec	1.220	1.220	1.360	1.500	1.910	2.130	1.830	1.610	1.250	0.800	0.800	1.020
24	Wind function f(u) =0.27(1+u/100)	0.550	0.550	0.580	0.629	0.717	0.768	0.697	0.645	0.561	0.450	0.450	0.500
25	Adjustment factor 'c'	1.004	0.976	0.924	0.922	0.986	1.022	0.942	0.945	0.963	1.046	0.965	0.941
26	W*Rn mm/day	1.735	2.198	2.940	3.529	4.095	4.108	2.312	2.308	1.984	2.893	2.112	1.528
27	(1-W)*f(u)*(ea-ed)	1.921	2.551	4.094	4.633	4.775	3.341	1.037	0.903	0.541	1.324	1.553	1.811
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.670	4.630	6.490	7.520	8.740	7.610	3.150	3.060	2.430	4.410	3.530	3.140
29	**Monthly Eto (mm/month)**	**113.770**	**129.640**	**201.190**	**225.600**	**270.940**	**228.300**	**97.650**	**94.860**	**72.900**	**136.710**	**105.900**	**97.340**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR -1985

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	24.500	27.700	32.500	37.600	40.700	37.800	31.200	27.300	29.500	30.400	27.300	25.400
2	Min. air temperature in o C.	8.200	12.400	16.100	20.900	24.800	26.100	23.400	22.600	21.800	16.000	14.200	11.700
3	Mean air temperature in o C.	16.350	20.050	24.300	29.250	32.750	31.950	27.300	24.950	25.650	23.200	20.750	18.550
4	Saturation vapour pressure (ea) in mbar	18.620	23.470	30.370	40.675	49.620	47.460	36.330	31.600	32.930	28.440	24.520	21.300
5	Max.relative humidity (RH Max.%)	55.000	62.000	41.000	38.000	38.000	57.000	82.000	88.000	86.000	45.000	44.000	65.000
6	Min.relative humidity (RH Min.%)	32.000	32.000	21.000	22.000	20.000	32.000	72.000	78.000	73.000	42.000	33.000	44.000
7	Mean.relative humidity (RH Mean.%)	43.500	47.000	31.000	30.000	29.000	44.500	77.000	83.000	79.500	38.500	38.500	54.500
8	Actual vapour pressure (ed) = ea*RHMean/100	8.090	11.030	9.410	12.200	14.380	21.110	27.970	26.220	26.170	10.940	9.440	11.600
9	Vapour pressure dedicit (ea-ed) in mbar.	10.530	12.440	20.960	28.473	35.240	26.350	8.360	5.380	6.760	17.500	15.080	9.700
10	Weighing factor (W)	0.649	0.696	0.739	0.782	0.811	0.805	0.769	0.745	0.752	0.728	0.703	0.670
11	(1-W)	0.351	0.304	0.261	0.218	0.189	0.195	0.231	0.255	0.248	0.272	0.297	0.330
12	Cloud cover in oktas	0.800	1.600	2.600	1.300	2.500	4.400	6.800	7.770	6.600	1.400	2.400	3.600
13	Ratio n/N	0.870	0.790	0.690	0.820	0.700	0.510	0.180	0.040	0.210	0.810	0.710	0.590
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.476	16.438	15.800	14.562	12.848	10.948	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	7.199	7.830	8.377	10.203	9.798	8.320	5.588	4.266	5.169	8.415	6.623	5.455
16	Rns = 0.75 Rs	5.399	5.872	6.282	7.652	7.348	6.240	4.191	3.199	3.876	6.311	4.967	4.091
17	Function of temperature f(T).	13.870	14.600	15.475	16.550	17.387	17.187	16.160	15.637	15.812	15.240	14.750	14.310
18	Function of vapour pressure f(ed).	0.219	0.194	0.205	0.189	0.176	0.134	0.110	0.118	0.119	0.195	0.205	0.192
19	Function of sunshine duration f(n/N)	0.886	0.811	0.722	0.840	0.730	0.560	0.264	0.140	0.290	0.830	0.740	0.632
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.691	2.297	2.290	2.627	2.233	1.289	0.469	0.258	0.545	2.466	2.237	1.736
21	Net radiation Rn = Rns-Rnl in mm/day	2.708	3.575	3.992	5.025	5.115	4.951	3.722	2.941	3.331	3.845	2.730	2.355
22	Average wind speed in km/day	112.800	96.000	122.400	134.400	170.400	189.600	153.600	144.000	120.000	74.400	79.300	96.000
23	Average wind speed in m/sec	1.300	1.110	1.410	1.550	1.970	2.190	1.770	1.660	1.380	0.860	0.910	1.110
24	Wind function f(u) =0.27(1+u/100)	0.574	0.529	0.600	0.632	0.730	0.781	0.684	0.658	0.594	8.470	0.483	0.529
25	Adjustment factor 'c'	0.956	1.036	0.982	1.003	0.986	0.951	0.969	0.949	0.979	1.003	0.958	0.998
26	W*Rn mm/day	1.757	2.488	2.950	3.929	4.148	3.985	2.862	2.191	2.504	2.799	1.919	1.577
27	(1-W)*f(u)*(ea-ed)	2.121	2.000	3.282	3.922	4.862	4.012	1.320	0.902	0.995	2.237	2.163	1.693
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.700	4.640	6.110	7.870	8.880	7.600	4.050	2.930	3.420	5.050	3.910	3.260
29	**Monthly Eto (mm/month)**	**114.700**	**129.920**	**189.410**	**236.100**	**275.280**	**228.000**	**125.550**	**90.830**	**102.600**	**156.550**	**117.300**	**101.060**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1986

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	24.500	30.300	33.300	37.400	40.300	37.300	31.300	28.700	30.400	31.900	29.900	25.900
2	Min. air temperature in o C.	9.100	13.500	16.500	20.600	24.900	25.100	23.500	22.800	21.000	18.400	16.600	10.900
3	Mean air temperature in o C.	16.800	21.900	24.900	29.000	32.600	31.200	27.400	25.750	25.700	25.150	23.250	18.400
4	Saturation vapour pressure (ea) in mbar	19.160	26.250	31.510	40.100	49.220	45.440	36.540	33.120	33.030	31.985	28.520	21.160
5	Max.relative humidity (RH Max.%)	51.000	51.000	33.000	34.000	30.000	64.000	83.000	91.000	78.000	60.000	60.000	55.000
6	Min.relative humidity (RH Min.%)	32.000	27.000	16.000	21.000	17.000	42.000	67.000	81.000	61.000	39.000	45.000	34.000
7	Mean.relative humidity (RH Mean.%)	41.500	39.000	24.500	27.500	23.500	53.000	75.000	86.000	69.500	49.500	52.500	44.500
8	Actual vapour pressure (ed) = ea*RHMean/100	7.950	10.230	7.710	11.020	11.560	24.080	27.400	28.480	22.950	15.832	14.973	9.416
9	Vapour pressure dedicit (ea-ed) in mbar	11.210	16.010	23.791	29.080	37.660	21.360	9.140	4.640	10.080	16.153	13.547	11.744
10	Weighing factor (W)	0.654	0.715	0.745	0.781	0.810	0.798	0.770	0.753	0.753	0.747	0.728	0.672
11	(1-W)	0.346	0.285	0.255	0.219	0.190	0.202	0.230	0.247	0.247	0.253	0.272	0.328
12	Cloud cover in oktas	2.100	1.600	1.500	3.200	2.300	5.700	7.400	7.500	4.800	3.200	2.800	2.900
13	Ratio n/N	0.740	0.790	0.800	0.630	0.720	0.340	0.090	0.070	0.470	0.630	0.670	0.660
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.476	16.438	15.800	14.562	12.848	10.948	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.510	7.830	9.152	8.734	9.961	6.919	4.849	4.503	7.062	7.259	6.404	5.805
16	Rns = 0.75 Rs	4.880	5.870	6.864	6.550	7.470	5.189	3.636	3.377	5.296	5.444	4.803	4.353
17	Function of temperature f(T).	13.960	14.980	15.620	16.500	17.350	16.730	16.180	15.837	15.825	15.687	15.250	14.280
18	Function of vapour pressure f(ed).	0.220	0.198	0.221	0.194	0.192	0.120	0.113	0.107	0.125	0.161	0.170	0.205
19	Function of sunshine duration f(n/N)	0.770	0.811	0.820	0.670	0.750	0.410	0.182	0.166	0.526	0.670	0.706	0.698
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.364	2.405	2.830	2.144	2.498	0.823	0.332	0.281	1.040	1.692	1.830	2.043
21	Net radiation Rn = Rns-Rnl in mm/day	2.516	3.465	4.034	4.406	4.972	4.366	3.304	3.096	4.256	3.752	2.973	2.310
22	Average wind speed in km/day	124.800	100.800	120.000	124.800	160.800	180.000	163.200	148.800	105.600	64.800	60.000	100.800
23	Average wind speed in m/sec	1.440	1.160	1.380	1.440	1.860	2.080	1.880	1.720	1.220	0.750	0.690	1.160
24	Wind function f(u) =0.27(1+u/100)	0.606	0.540	0.594	0.600	0.700	0.756	0.710	0.670	0.550	0.440	0.430	0.540
25	Adjustment factor 'c'	0.934	0.977	1.000	0.989	0.902	0.985	0.948	0.951	1.023	0.980	0.961	0.960
26	W*Rn mm/day	1.645	2.477	3.000	3.441	4.027	3.484	2.544	2.332	3.204	2.802	2.164	1.552
27	(1-W)*f(u)*(ea-ed)	2.350	2.463	3.603	3.821	5.008	3.261	1.492	0.767	1.369	1.798	1.584	2.080
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.730	4.820	6.603	7.180	8.140	6.640	3.820	2.940	4.670	4.500	3.600	3.480
29	**Monthly Eto (mm/month)**	**115.630**	**134.960**	**204.690**	**215.400**	**252.340**	**199.200**	**118.420**	**91.140**	**140.100**	**139.500**	**108.000**	**107.880**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1987

S.No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.300	29.100	35.700	37.700	40.700	37.400	30.200	27.000	30.400	32.400	27.200	26.300
2	Min. air temperature in o C.	8.800	12.100	18.600	23.300	23.700	24.400	22.100	21.800	21.400	18.300	12.000	10.200
3	Mean air temperature in o C.	17.050	20.600	27.150	30.500	32.200	30.900	26.150	24.400	25.900	25.350	19.600	18.250
4	Saturation vapour pressure (ea) in mbar	19.460	24.300	36.000	43.650	48.140	44.650	33.910	30.560	33.410	32.360	22.840	20.950
5	Max.relative humidity (RH Max.%)	50.000	39.000	27.000	27.000	34.000	56.000	86.000	88.000	82.000	51.000	39.000	46.000
6	Min.relative humidity (RH Min.%)	28.000	21.000	15.000	16.000	15.000	39.000	70.000	80.000	69.000	35.000	28.000	30.000
7	Mean.relative humidity (RH Mean.%)	39.000	30.000	21.000	21.500	24.500	47.500	78.000	84.000	75.500	43.000	33.500	38.000
8	Actual vapour pressure (ed) = ea*RHMean/100	7.589	7.290	7.560	9.380	11.790	21.200	26.440	25.670	25.220	13.910	7.650	7.960
9	Vapour pressure dedicit (ea-ed) in mbar	11.871	17.010	28.440	34.270	36.350	23.450	7.470	4.890	8.190	18.450	15.190	12.990
10	Weighing factor (W)	0.656	0.702	0.767	0.791	0.807	0.795	0.757	0.740	0.755	0.749	0.690	0.669
11	(1-W)	0.344	0.298	0.233	0.209	0.193	0.205	0.243	0.260	0.245	0.251	0.310	0.331
12	Cloud cover in oktas	1.400	1.800	1.000	1.300	1.500	4.800	7.300	7.500	6.300	2.400	2.000	0.500
13	Ratio n/N	0.810	0.770	0.850	0.820	0.800	0.470	0.100	0.070	0.250	0.710	0.750	0.900
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.476	16.438	15.800	14.562	12.848	10.948	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.884	7.708	9.504	10.203	10.614	7.990	4.972	4.503	5.460	7.773	6.842	7.000
16	Rns = 0.75 Rs	5.163	5.781	7.128	7.652	7.960	5.990	3.729	3.377	4.095	5.829	5.131	5.250
17	Function of temperature f(T).	14.010	14.720	16.130	16.825	17.250	16.925	15.930	15.500	15.875	15.737	14.520	14.250
18	Function of vapour pressure f(ed).	0.222	0.223	0.222	0.206	0.191	0.134	0.117	0.120	0.120	0.180	0.221	0.220
19	Function of sunshine duration f(n/N)	0.830	0.796	0.870	0.840	0.820	0.526	0.190	0.166	0.330	0.740	0.780	0.910
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.581	2.612	3.115	2.911	2.701	1.192	0.354	0.308	0.628	2.096	2.502	2.852
21	Net radiation Rn = Rns-Rnl in mm/day	2.582	3.169	4.013	4.741	5.259	4.798	3.375	3.069	3.467	3.733	2.629	2.398
22	Average wind speed in km/day	105.600	105.600	124.800	139.200	168.000	187.200	168.000	129.600	124.800	72.000	69.600	76.800
23	Average wind speed in m/sec	1.220	1.220	1.440	1.610	1.940	2.160	1.940	1.500	1.440	0.830	0.800	0.880
24	Wind function f(u) =0.27(1+u/100)	0.550	0.550	0.606	0.645	0.723	0.775	0.723	0.619	0.606	0.464	0.457	0.477
25	Adjustment factor 'c'	0.952	0.972	0.918	0.918	0.995	0.944	0.948	0.962	0.982	0.989	0.967	0.968
26	W*Rn mm/day	1.693	2.224	3.077	3.750	4.240	3.814	2.554	2.271	2.617	2.796	1.814	1.604
27	(1-W)*f(u)*(ea-ed)	2.245	2.787	4.015	4.619	5.072	3.725	1.312	0.786	1.215	2.148	2.151	2.050
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.740	4.870	6.510	7.680	9.260	7.110	3.660	2.940	3.760	4.880	3.830	3.530
29	**Monthly Eto (mm/month)**	**115.940**	**136.360**	**201.810**	**230.400**	**287.060**	**213.300**	**113.460**	**91.140**	**112.800**	**151.280**	**114.900**	**109.430**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD
FOR THE YEAR - 1988

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	26.500	28.800	32.900	37.400	39.800	38.200	32.000	31.400	31.100	33.700	29.900	25.200
2	Min. air temperature in o C.	11.800	11.800	16.400	21.400	24.800	25.800	23.100	22.500	21.000	18.600	14.700	11.100
3	Mean air temperature in o C.	19.150	20.300	24.650	29.400	32.300	32.000	27.550	26.950	26.050	26.150	22.300	18.150
4	Saturation vapour pressure (ea) in mbar	22.210	23.850	31.030	41.020	48.410	47.600	36.850	33.590	33.700	33.910	26.910	20.810
5	Max.relative humidity (RH Max.%)	52.000	39.000	26.000	35.000	27.000	59.000	83.000	83.000	76.000	50.000	52.000	62.000
6	Min.relative humidity (RH Min.%)	33.000	23.000	15.000	26.000	18.000	36.000	58.000	64.000	55.000	32.000	39.000	47.000
7	Mean.relative humidity (RH Mean.%)	42.500	31.000	20.500	30.500	22.500	47.500	70.500	73.500	65.500	41.000	45.500	54.500
8	Actual vapour pressure (ed) = ea*RHMean/100	9.439	7.390	6.360	12.510	10.890	22.610	25.970	24.680	22.070	13.900	12.240	11.340
9	Vapour pressure dedicit (ea-ed) in mbar	12.771	16.460	24.670	28.510	37.520	24.990	10.880	8.910	11.630	20.010	14.670	9.470
10	Weighing factor (W)	0.683	0.699	0.742	0.783	0.808	0.806	0.771	0.765	0.756	0.757	0.719	0.668
11	(1-W)	0.317	0.301	0.258	0.217	0.192	0.194	0.229	0.235	0.244	0.243	0.281	0.332
12	Cloud cover in oktas	3.700	0.900	1.700	2.700	1.800	4.100	7.000	6.100	4.100	0.600	1.400	2.500
13	Ratio n/N	0.580	0.860	0.780	0.680	0.770	0.540	0.150	0.280	0.540	0.890	0.810	0.700
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	5.675	8.255	9.011	9.121	10.369	8.564	5.339	6.162	7.571	8.923	7.165	6.000
16	Rns = 0.75 Rs	4.256	6.191	6.758	6.840	7.770	6.423	4.000	4.621	5.678	6.692	5.373	4.500
17	Function of temperature f(T).	14.430	14.660	15.562	16.580	17.275	17.200	16.240	16.090	15.900	15.930	15.060	14.230
18	Function of vapour pressure f(ed).	0.205	0.223	0.120	0.187	0.195	0.126	0.120	0.120	0.130	0.180	0.188	0.193
19	Function of sunshine duration f(n/N)	0.624	0.878	0.804	0.710	0.796	0.590	0.240	0.354	0.590	0.902	0.830	0.730
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	1.845	2.870	1.501	2.201	2.681	1.278	0.466	0.683	1.219	2.586	2.349	2.000
21	Net radiation Rn = Rns-Rnl in mm/day	2.411	3.321	5.257	4.639	5.089	5.145	3.534	3.938	4.459	4.106	3.024	2.500
22	Average wind speed in km/day	120.000	98.400	115.200	120.000	172.800	192.000	148.800	134.400	112.800	67.200	67.200	81.600
23	Average wind speed in m/sec	1.380	1.130	1.330	1.380	2.000	2.220	1.720	1.550	1.300	0.770	0.770	0.940
24	Wind function f(u) =0.27(1+u/100)	0.594	0.530	0.580	0.594	0.730	0.788	0.671	0.632	0.574	0.451	0.451	0.490
25	Adjustment factor 'c'	0.919	0.989	0.920	1.000	0.900	0.956	0.966	0.990	1.031	1.019	0.976	1.016
26	W*Rn mm/day	1.646	2.321	3.900	3.632	4.110	4.146	2.724	3.012	3.371	3.108	2.174	1.670
27	(1-W)*f(u)*(ea-ed)	2.404	2.650	3.691	3.674	5.258	3.820	1.671	1.323	1.628	2.192	1.859	1.540
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.720	4.910	6.980	7.300	8.430	7.610	4.240	4.290	5.150	5.400	3.930	3.260
29	**Monthly Eto (mm/month)**	**115.320**	**142.390**	**216.380**	**219.000**	**261.330**	**228.300**	**131.440**	**132.990**	**154.500**	**167.400**	**117.900**	**101.060**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1989

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.700	30.800	33.100	38.400	40.200	37.200	33.500	28.900	31.400	34.800	29.100	25.900
2	Min. air temperature in o C.	10.600	14.000	15.900	21.300	25.200	25.500	24.200	22.400	20.600	18.800	16.200	10.300
3	Mean air temperature in o C.	18.150	22.400	24.500	29.850	32.700	31.350	28.850	25.650	26.000	26.800	22.650	18.100
4	Saturation vapour pressure (ea) in mbar	20.810	27.080	30.750	42.050	49.490	45.840	39.750	32.930	33.600	35.280	27.500	20.740
5	Max.relative humidity (RH Max.%)	59.000	47.000	29.000	25.000	37.000	59.000	76.000	86.000	68.000	38.000	56.000	49.000
6	Min.relative humidity (RH Min.%)	39.000	25.000	18.000	17.000	17.000	43.000	59.000	74.000	53.000	24.000	42.000	31.000
7	Mean.relative humidity (RH Mean.%)	49.000	36.000	23.500	21.000	27.000	51.000	67.500	80.000	60.500	31.000	49.000	40.000
8	Actual vapour pressure (ed) = ea*RHMean/100	10.190	9.740	7.220	8.830	13.360	23.370	26.830	26.340	20.320	10.930	13.470	8.290
9	Vapour pressure dedicit (ea-ed) in mbar	10.620	17.340	23.530	33.220	36.130	22.470	12.920	6.590	13.280	24.350	14.030	12.444
10	Weighing factor (W)	0.668	0.720	0.741	0.794	0.810	0.789	0.780	0.752	0.756	0.764	0.722	0.667
11	(1-W)	0.332	0.280	0.259	0.206	0.190	0.211	0.220	0.248	0.244	0.236	0.278	0.333
12	Cloud cover in oktas	1.900	1.300	1.000	2.000	1.300	4.500	6.600	7.100	3.300	1.500	2.900	1.800
13	Ratio n/N	0.760	0.820	0.850	0.750	0.820	0.500	0.210	0.130	0.620	0.800	0.660	0.770
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.621	8.012	9.504	9.662	10.777	8.235	5.832	4.977	8.153	8.346	6.345	6.356
16	Rns = 0.75 Rs	4.965	6.000	7.128	7.246	8.082	6.176	4.374	3.732	6.114	6.259	4.758	4.767
17	Function of temperature f(T).	14.230	15.080	15.525	16.670	17.375	17.037	16.470	15.812	15.900	16.060	15.130	14.230
18	Function of vapour pressure f(ed).	0.199	0.202	0.223	0.211	0.183	0.123	0.115	0.118	0.138	0.195	0.182	0.217
19	Function of sunshine duration f(n/N)	0.788	0.840	0.870	0.780	0.840	0.550	0.290	0.220	0.660	0.820	0.698	0.796
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.231	2.558	3.012	2.743	2.670	1.152	0.549	0.410	1.448	2.567	1.922	2.457
21	Net radiation Rn = Rns-Rnl in mm/day	2.734	3.442	4.116	4.503	5.412	5.024	3.825	3.322	4.666	3.692	2.836	2.310
22	Average wind speed in km/day	108.000	103.200	120.000	124.800	165.600	177.600	158.400	139.200	105.600	69.600	72.000	93.600
23	Average wind speed in m/sec	1.250	1.190	1.380	1.440	1.910	2.050	1.830	1.610	1.220	0.800	0.830	1.080
24	Wind function f(u) =0.27(1+u/100)	0.561	0.548	0.594	0.606	0.710	0.749	0.697	0.645	0.550	0.450	0.460	0.520
25	Adjustment factor 'c'	0.944	0.981	0.922	0.920	0.998	0.954	0.970	0.964	1.045	1.004	0.954	0.945
26	W*Rn mm/day	1.826	2.478	3.049	3.575	4.383	3.963	2.983	2.498	3.527	2.820	2.047	1.540
27	(1-W)*f(u)*(ea-ed)	1.977	2.660	3.619	4.147	4.873	3.551	1.981	1.054	1.782	2.585	1.794	2.154
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.590	5.040	6.140	7.100	9.230	7.160	4.810	3.420	5.540	5.420	3.660	3.490
29	**Monthly Eto (mm/month)**	**111.290**	**141.120**	**190.340**	**213.000**	**286.130**	**214.800**	**149.110**	**106.020**	**166.200**	**168.020**	**109.800**	**108.190**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD - FOR THE YEAR - 1990

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.100	31.600	32.400	37.400	41.100	37.300	31.200	28.200	29.400	33.000	30.400	25.300
2	Min. air temperature in o C.	8.000	13.300	16.800	20.600	24.600	25.200	23.500	22.100	21.000	17.800	14.900	14.900
3	Mean air temperature in o C.	16.550	22.450	24.600	29.000	32.850	31.250	27.350	25.150	25.200	25.400	22.650	20.100
4	Saturation vapour pressure (ea) in mbar	18.860	27.160	30.940	40.100	49.890	45.570	36.430	31.980	32.080	32.460	27.500	23.550
5	Max.relative humidity (RH Max.%)	42.000	32.000	47.000	27.000	27.000	61.000	83.000	90.000	80.000	45.000	43.000	83.000
6	Min.relative humidity (RH Min.%)	23.000	16.000	28.000	12.000	12.000	43.000	67.000	80.000	65.000	28.000	27.000	62.000
7	Mean.relative humidity (RH Mean.%)	32.500	24.000	37.500	19.500	19.500	52.000	75.000	75.000	72.500	36.500	35.000	72.500
8	Actual vapour pressure (ed) = ea*RHMean/100	6.120	6.510	11.600	7.810	9.720	23.690	27.320	23.980	23.250	11.840	9.620	17.070
9	Vapour pressure dedicit (ea-ed) in mbar	12.740	20.650	19.340	32.290	40.170	21.880	9.110	8.000	8.830	20.620	17.880	6.480
10	Weighing factor (W)	0.651	0.720	0.742	0.781	0.811	0.798	0.769	0.747	0.748	0.750	0.722	0.697
11	(1-W)	0.349	0.280	0.258	0.219	0.189	0.202	0.231	0.253	0.252	0.250	0.278	0.303
12	Cloud cover in oktas	0.600	0.500	3.300	1.200	0.300	4.600	7.400	7.800	5.500	1.500	1.600	5.200
13	Ratio n/N	0.890	0.900	0.620	0.830	0.920	0.490	0.090	0.030	0.370	0.800	0.790	0.420
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.476	16.438	15.800	14.562	12.848	10.948	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	7.304	8.498	7.884	10.280	11.594	8.155	4.849	4.187	6.334	8.351	7.061	4.604
16	Rns = 0.75 Rs	5.478	6.373	5.913	7.710	8.695	6.116	3.636	3.140	4.750	6.263	5.295	3.453
17	Function of temperature f(T).	13.910	15.090	15.550	16.500	17.410	17.012	16.170	15.687	15.700	15.750	15.130	14.620
18	Function of vapour pressure f(ed).	0.229	0.227	0.192	0.220	0.202	0.121	0.113	0.120	0.123	0.190	0.203	0.154
19	Function of sunshine duration f(n/N)	0.902	0.910	0.660	0.850	0.930	0.540	0.182	0.130	0.436	0.820	0.811	0.480
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.873	3.117	1.970	3.085	3.270	1.111	0.332	0.244	0.841	2.453	2.490	1.080
21	Net radiation Rn = Rns-Rnl in mm/day	2.605	3.256	3.943	4.625	5.425	5.005	3.304	2.896	3.909	3.810	2.805	2.373
22	Average wind speed in km/day	112.800	124.800	122.400	134.400	170.400	180.000	170.400	134.400	112.800	79.200	74.400	84.000
23	Average wind speed in m/sec	1.300	1.440	1.410	1.550	1.970	2.080	1.970	1.550	1.300	0.910	0.860	0.970
24	Wind function f(u) =0.27(1+u/100)	0.570	0.600	0.600	0.630	0.730	0.750	0.730	0.630	0.570	0.480	0.470	0.496
25	Adjustment factor 'c'	0.959	0.984	0.969	0.921	0.921	1.015	0.944	0.953	1.005	1.000	0.970	0.991
26	W*Rn mm/day	1.695	2.344	2.925	3.612	4.390	3.993	2.540	2.163	2.920	2.857	2.025	1.653
27	(1-W)*f(u)*(ea-ed)	2.534	3.469	2.993	4.455	5.542	3.314	1.536	1.275	1.268	2.474	2.336	0.962
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	4.050	5.710	5.730	7.420	9.140	7.410	3.840	3.270	4.200	5.330	4.230	2.590
29	**Monthly Eto (mm/month)**	**125.550**	**159.880**	**177.630**	**222.600**	**283.340**	**222.300**	**119.040**	**101.370**	**126.000**	**165.230**	**126.900**	**80.290**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1991

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	23.700	26.700	32.000	37.200	40.100	32.000	31.100	28.000	33.100	31.700	27.200	26.400
2	Min. air temperature in o C.	10.700	11.000	18.800	21.000	24.100	25.700	22.900	21.700	22.100	16.700	12.800	10.500
3	Mean air temperature in o C.	17.200	18.850	25.400	29.100	32.100	28.850	27.000	24.850	27.600	24.200	20.000	18.450
4	Saturation vapour pressure (ea) in mbar	19.640	21.790	32.460	40.330	47.870	39.750	35.700	31.410	36.960	30.180	23.400	21.230
5	Max.relative humidity (RH Max.%)	69.000	45.000	36.000	25.000	24.000	54.000	85.000	85.000	72.000	54.000	42.000	45.000
6	Min.relative humidity (RH Min.%)	39.000	26.000	12.000	15.000	10.000	31.000	73.000	74.000	54.000	27.000	30.000	30.000
7	Mean.relative humidity (RH Mean.%)	54.000	35.500	24.000	20.000	17.000	42.500	79.000	79.500	63.000	40.500	36.000	37.500
8	Actual vapour pressure (ed) = ea*RHMean/100	10.600	7.730	7.790	8.060	8.130	16.890	28.200	24.970	23.280	12.220	8.420	7.960
9	Vapour pressure dedicit (ea-ed) in mbar	9.040	14.060	24.670	32.270	39.740	22.860	7.500	6.440	13.680	17.960	14.990	13.270
10	Weighing factor (W)	0.658	0.678	0.750	0.781	0.806	0.780	0.766	0.744	0.772	0.738	0.696	0.672
11	(1-W)	0.342	0.322	0.250	0.219	0.194	0.220	0.234	0.256	0.228	0.262	0.304	0.328
12	Cloud cover in oktas	2.400	2.100	1.100	2.700	0.700	5.000	7.600	7.200	5.100	1.700	2.200	1.200
13	Ratio n/N	0.710	0.740	0.840	0.680	0.880	0.450	0.060	0.120	0.430	0.780	0.730	0.830
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.358	7.526	9.433	9.121	11.267	7.823	4.600	4.898	6.770	8.217	6.733	6.656
16	Rns = 0.75 Rs	4.768	5.644	7.074	6.841	8.450	5.867	3.450	3.673	5.077	6.162	5.049	4.992
17	Function of temperature f(T).	14.040	14.370	15.750	16.520	17.225	16.470	16.100	15.610	16.220	15.450	14.600	14.290
18	Function of vapour pressure f(ed).	0.197	0.221	0.221	0.220	0.218	0.155	0.109	0.120	0.123	0.188	0.215	0.220
19	Function of sunshine duration f(n/N)	0.740	0.770	0.860	0.710	0.894	0.510	0.158	0.210	0.490	0.804	0.760	0.850
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.046	2.445	2.993	2.580	3.357	1.301	0.277	0.393	0.977	2.335	2.385	2.672
21	Net radiation Rn = Rns-Rnl in mm/day	2.722	3.199	4.081	4.261	5.093	4.566	3.173	3.280	4.100	3.827	2.664	2.320
22	Average wind speed in km/day	100.800	120.000	122.400	129.600	163.200	189.600	172.800	144.000	100.800	60.000	64.800	88.800
23	Average wind speed in m/sec	1.160	1.380	1.410	1.500	1.880	2.190	2.000	1.660	1.160	0.690	0.750	1.020
24	Wind function f(u) =0.27(1+u/100)	0.540	0.590	0.600	0.610	0.710	0.780	0.730	0.650	0.540	0.430	0.440	0.500
25	Adjustment factor 'c'	1.012	0.962	1.000	0.911	0.919	0.938	0.938	0.961	1.020	1.000	0.967	0.954
26	W*Rn mm/day	1.791	2.168	3.060	3.327	4.104	3.561	2.430	2.440	3.165	2.824	1.854	1.559
27	(1-W)*f(u)*(ea-ed)	1.669	2.671	3.700	4.310	5.473	3.922	1.281	1.071	1.684	2.023	2.003	2.176
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.500	4.650	6.760	6.950	8.800	7.010	3.480	3.370	4.940	4.840	3.720	3.560
29	**Monthly Eto (mm/month)**	**108.500**	**130.200**	**209.560**	**208.500**	**272.800**	**210.300**	**107.880**	**104.470**	**148.200**	**150.040**	**111.600**	**110.360**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1992

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	26.600	30.300	36.300	39.300	40.900	39.100	31.100	28.100	30.100	33.400	29.300	25.200
2	Min. air temperature in o C.	9.900	12.800	18.400	21.600	25.300	25.600	22.300	21.400	20.900	17.600	16.400	10.500
3	Mean air temperature in o C.	18.250	21.550	27.350	30.450	33.100	32.350	26.700	24.750	25.500	25.500	22.850	17.850
4	Saturation vapour pressure (ea) in mbar	20.950	25.720	36.430	43.520	50.590	48.540	35.070	31.220	32.650	22.650	27.840	20.420
5	Max.relative humidity (RH Max.%)	51.000	44.000	28.000	20.000	26.000	56.000	87.000	88.000	84.000	49.000	58.000	53.000
6	Min.relative humidity (RH Min.%)	29.000	27.000	18.000	10.000	11.000	34.000	75.000	79.000	70.000	28.000	43.000	34.000
7	Mean.relative humidity (RH Mean.%)	40.000	35.500	23.000	15.000	18.500	45.000	81.000	83.500	77.000	38.500	50.500	43.500
8	Actual vapour pressure (ed) = ea*RHMean/100	8.380	9.130	8.370	6.520	9.350	21.840	28.400	26.070	25.140	12.570	14.060	8.880
9	Vapour pressure dedicit (ea-ed) in mbar	12.570	16.590	28.060	37.000	41.240	26.700	6.670	5.150	7.510	20.080	13.780	11.540
10	Weighing factor (W)	0.669	0.711	0.769	0.790	0.813	0.808	0.763	0.743	0.751	0.751	0.724	0.664
11	(1-W)	0.331	0.289	0.231	0.210	0.187	0.192	0.237	0.257	0.249	0.249	0.276	0.336
12	Cloud cover in oktas	2.200	2.400	2.300	1.100	2.400	5.300	7.700	7.100	5.800	1.000	4.100	2.400
13	Ratio n/N	0.730	0.710	0.720	0.840	0.710	0.400	0.040	0.130	0.330	0.850	0.540	0.710
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.460	7.340	8.580	10.350	9.870	7.410	4.430	4.970	6.040	8.667	5.688	6.056
16	Rns = 0.75 Rs	4.845	5.505	6.435	7.762	7.402	5.557	3.322	3.727	4.530	6.500	4.266	4.542
17	Function of temperature f(T).	14.250	14.910	16.170	16.810	17.470	17.287	16.040	15.587	15.775	15.775	15.170	14.170
18	Function of vapour pressure f(ed).	0.216	0.208	0.216	0.227	0.206	0.130	0.108	0.120	0.120	0.187	0.180	0.211
19	Function of sunshine duration f(n/N)	0.760	0.740	0.750	0.860	0.740	0.460	0.140	0.220	0.400	0.870	0.590	0.740
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.339	2.294	2.611	3.281	2.663	1.033	0.242	0.411	0.757	2.566	1.611	2.212
21	Net radiation Rn = Rns-Rnl in mm/day	2.506	3.211	3.816	4.481	4.739	4.524	3.080	3.316	3.773	3.934	2.655	2.330
22	Average wind speed in km/day	120.000	100.800	129.600	132.000	175.200	184.800	146.400	153.600	120.000	64.800	60.000	91.200
23	Average wind speed in m/sec	1.380	1.160	1.500	1.520	2.020	2.130	1.690	1.770	1.380	0.750	0.690	1.050
24	Wind function f(u) =0.27(1+u/100)	0.590	0.540	0.610	0.620	0.740	0.760	0.660	0.680	0.590	0.440	0.430	0.510
25	Adjustment factor 'c'	0.935	0.966	0.895	0.924	0.892	0.930	0.951	0.957	0.996	1.014	0.948	0.939
26	W*Rn mm/day	1.676	2.283	2.934	3.539	3.852	3.655	2.350	2.463	2.833	2.954	1.922	1.547
27	(1-W)*f(u)*(ea-ed)	2.454	2.589	3.953	4.817	5.706	3.896	1.043	0.900	1.103	2.199	1.635	1.977
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.860	4.700	6.160	7.720	8.520	2.020	3.220	3.210	3.920	5.220	3.370	3.300
29	**Monthly Eto (mm/month)**	**119.660**	**136.300**	**190.960**	**231.600**	**264.120**	**210.600**	**99.820**	**99.510**	**117.600**	**161.820**	**101.100**	**102.300**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1993

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.200	27.500	32.600	38.900	41.600	34.600	33.100	28.800	29.700	32.300	28.600	26.600
2	Min. air temperature in o C.	11.200	12.200	16.500	22.600	26.400	24.400	22.900	22.900	21.900	18.200	11.900	9.800
3	Mean air temperature in o C.	18.200	19.850	24.550	30.750	34.000	29.500	28.000	25.850	25.800	25.250	20.250	18.200
4	Saturation vapour pressure (ea) in mbar	20.880	23.190	34.840	44.270	53.200	41.250	37.800	33.310	33.220	32.170	23.770	20.880
5	Max.relative humidity (RH Max.%)	70.000	58.000	40.000	19.000	33.000	75.000	82.000	90.000	86.000	54.000	39.000	46.000
6	Min.relative humidity (RH Min.%)	39.000	27.000	21.000	11.000	19.000	52.000	67.000	82.000	73.000	36.000	25.000	26.000
7	Mean.relative humidity (RH Mean.%)	54.500	42.500	30.500	15.000	26.000	63.500	74.500	86.000	79.500	45.000	32.000	36.000
8	Actual vapour pressure (ed) = ea*RHMean/100	11.370	9.850	9.400	6.640	13.830	26.190	28.160	28.650	26.400	14.470	7.600	7.510
9	Vapour pressure dedicit (ea-ed) in mbar	9.510	13.340	21.440	37.630	39.370	15.060	9.640	4.660	6.820	17.700	16.170	13.370
10	Weighing factor (W)	0.669	0.693	0.742	0.793	0.820	0.783	0.776	0.754	0.754	0.748	0.698	0.669
11	(1-W)	0.331	0.307	0.258	0.207	0.180	0.217	0.224	0.246	0.246	0.252	0.302	0.331
12	Cloud cover in oktas	1.700	2.500	1.700	3.000	1.800	6.600	6.700	7.700	7.000	0.900	0.400	0.200
13	Ratio n/N	0.780	0.700	0.780	0.650	0.770	0.210	0.190	0.040	0.150	0.860	0.910	0.930
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.720	7.280	9.010	8.880	10.360	5.840	5.660	4.260	4.730	8.730	7.710	7.150
16	Rns = 0.75 Rs	5.040	5.460	6.750	6.660	7.770	4.380	4.240	3.190	3.540	6.540	5.780	5.360
17	Function of temperature f(T).	14.240	14.570	15.530	16.880	17.700	16.600	16.300	15.860	15.850	15.710	14.650	14.240
18	Function of vapour pressure f(ed).	0.193	0.201	0.206	0.226	0.180	0.119	0.109	0.106	0.118	0.175	0.222	0.222
19	Function of sunshine duration f(n/N)	0.804	0.730	0.804	0.690	0.796	0.290	0.272	0.140	0.240	0.878	0.920	0.940
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.209	2.137	2.572	2.632	2.536	0.572	0.483	0.235	0.448	2.413	2.992	2.971
21	Net radiation Rn = Rns-Rnl in mm/day	2.831	3.323	4.178	4.028	5.234	3.808	3.757	2.955	3.092	4.127	2.788	2.389
22	Average wind speed in km/day	124.800	112.800	129.600	139.200	168.000	182.400	144.000	148.800	124.800	74.700	79.200	86.400
23	Average wind speed in m/sec	1.440	1.300	1.500	1.610	1.940	2.110	1.660	1.720	1.440	0.860	0.910	1.000
24	Wind function f(u) =0.27(1+u/100)	0.600	0.570	0.610	0.640	0.720	0.760	0.650	0.670	0.600	0.470	0.480	0.500
25	Adjustment factor 'c'	1.007	0.959	0.995	0.898	0.993	0.957	0.975	0.945	0.969	1.011	0.984	0.967
26	W*Rn mm/day	1.893	2.302	3.100	3.194	4.291	2.981	2.915	2.228	2.331	3.086	1.946	1.590
27	(1-W)*f(u)*(ea-ed)	1.888	2.334	3.374	4.985	5.102	2.483	1.403	0.768	1.006	2.096	2.344	2.212
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.800	4.440	6.440	7.340	9.320	5.220	4.210	2.830	2.270	5.230	4.220	3.670
29	**Monthly Eto (mm/month)**	**117.800**	**124.320**	**199.640**	**220.200**	**288.900**	**156.600**	**130.510**	**87.730**	**68.100**	**162.130**	**126.600**	**113.770**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1994

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	24.600	28.500	33.200	38.800	39.300	32.700	27.700	29.000	30.200	29.800	28.400	25.000
2	Min. air temperature in o C.	9.800	11.800	16.600	22.500	24.900	23.600	22.300	22.400	20.800	18.600	12.800	8.100
3	Mean air temperature in o C.	17.200	20.150	24.900	30.650	32.100	28.150	25.000	25.700	25.500	24.200	20.600	16.550
4	Saturation vapour pressure (ea) in mbar	19.640	23.620	31.510	44.020	37.870	38.140	31.700	33.030	32.650	30.180	24.300	18.860
5	Max.relative humidity (RH Max.%)	57.000	35.000	23.000	30.000	42.000	81.000	88.000	87.000	79.000	71.000	48.000	51.000
6	Min.relative humidity (RH Min.%)	30.000	19.000	11.000	16.000	22.000	59.000	78.000	80.000	66.000	49.000	30.000	29.000
7	Mean.relative humidity (RH Mean.%)	43.500	27.000	17.000	23.000	32.000	70.000	83.000	83.500	72.500	60.000	39.000	40.000
8	Actual vapour pressure (ed) = ea*RHMean/100	8.540	6.370	5.350	10.120	15.310	26.700	26.310	27.580	23.670	18.100	9.470	7.540
9	Vapour pressure dedicit (ea-ed) in mbar	11.100	17.250	26.160	33.900	32.560	11.440	5.390	5.450	8.980	12.080	14.830	11.320
10	Weighing factor (W)	0.658	0.697	0.745	0.792	0.806	0.776	0.746	0.753	0.751	0.738	0.702	0.651
11	(1-W)	0.342	0.303	0.255	0.208	0.194	0.224	0.254	0.247	0.249	0.262	0.298	0.349
12	Cloud cover in oktas	2.500	1.200	1.200	0.900	1.600	6.400	7.700	7.700	5.100	3.500	1.500	0.900
13	Ratio n/N	0.700	0.830	0.830	0.860	0.790	0.240	0.040	0.040	0.430	0.600	0.800	0.860
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.310	8.070	9.360	10.510	10.530	6.093	4.430	4.260	6.770	7.060	7.110	6.800
16	Rns = 0.75 Rs	4.720	6.050	7.020	7.880	7.890	4.560	3.320	3.190	5.070	5.290	5.330	5.100
17	Function of temperature f(T).	14.040	14.630	15.620	16.860	17.225	16.330	15.650	15.825	15.770	15.450	14.720	13.910
18	Function of vapour pressure f(ed).	0.214	0.228	0.230	0.199	0.166	0.116	0.118	0.112	0.121	0.149	0.205	0.222
19	Function of sunshine duration f(n/N)	0.730	0.850	0.850	0.878	0.811	0.320	0.140	0.140	0.490	0.640	0.820	0.878
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.193	2.835	3.053	2.945	2.318	0.606	0.258	0.248	0.935	1.473	2.474	2.711
21	Net radiation Rn = Rns-Rnl in mm/day	2.527	3.215	3.967	4.935	5.572	3.954	3.062	2.942	4.135	3.817	2.856	2.389
22	Average wind speed in km/day	103.200	108.000	117.600	120.000	165.600	187.200	158.400	124.800	103.200	72.000	69.600	96.000
23	Average wind speed in m/sec	1.190	1.250	1.360	1.380	1.910	2.160	1.830	1.440	1.190	0.830	0.800	1.110
24	Wind function f(u) =0.27(1+u/100)	0.540	0.560	0.580	0.590	0.710	0.770	0.690	0.600	0.540	0.460	0.450	0.520
25	Adjustment factor 'c'	0.939	0.981	0.922	0.933	0.995	0.960	0.943	0.960	1.019	1.039	0.974	0.954
26	W*Rn mm/day	1.661	2.240	2.955	3.908	4.491	3.068	2.284	2.215	3.105	2.816	2.004	1.555
27	(1-W)*f(u)*(ea-ed)	2.049	2.926	3.869	4.160	4.484	1.973	0.944	0.800	1.207	1.455	1.988	2.054
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.480	5.060	6.290	7.520	8.930	4.830	3.090	2.890	4.390	4.430	3.880	3.440
29	**Monthly Eto (mm/month)**	**104.400**	**141.680**	**194.990**	**225.600**	**276.830**	**144.900**	**95.790**	**89.590**	**131.700**	**137.330**	**116.400**	**106.640**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1995

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	26.000	26.600	34.800	37.200	40.900	38.900	32.000	28.400	30.500	32.200	29.100	26.600
2	Min. air temperature in o C.	9.200	9.900	17.800	20.700	24.800	25.900	23.300	22.200	19.500	17.500	13.800	11.600
3	Mean air temperature in o C.	17.600	18.250	26.300	28.950	32.850	32.400	27.650	25.300	25.000	24.850	21.450	19.100
4	Saturation vapour pressure (ea) in mbar	20.120	20.950	34.230	39.980	49.890	48.680	37.060	32.270	31.700	31.410	25.570	22.140
5	Max.relative humidity (RH Max.%)	53.000	44.000	29.000	28.000	33.000	77.000	81.000	88.000	72.000	53.000	59.000	59.000
6	Min.relative humidity (RH Min.%)	25.000	21.000	17.000	20.000	17.000	27.000	66.000	79.000	54.000	37.000	41.000	36.000
7	Mean.relative humidity (RH Mean.%)	39.000	32.500	23.000	24.000	25.000	52.000	73.500	83.500	63.000	45.000	50.000	47.500
8	Actual vapour pressure (ed) = ea*RHMean/100	7.840	6.800	7.870	9.590	12.470	25.310	27.230	26.940	19.970	14.130	12.780	10.510
9	Vapour pressure dedicit (ea-ed) in mbar	12.280	14.150	26.360	30.390	37.420	23.370	9.830	5.330	11.730	17.280	12.790	11.630
10	Weighing factor (W)	0.662	0.669	0.750	0.780	0.811	0.808	0.772	0.749	0.746	0.744	0.710	0.682
11	(1-W)	0.338	0.331	0.250	0.220	0.189	0.192	0.228	0.251	0.254	0.256	0.290	0.318
12	Cloud cover in oktas	2.300	1.700	1.700	1.600	2.700	7.000	6.300	7.600	3.800	3.300	0.900	1.800
13	Ratio n/N	0.720	0.780	0.780	0.790	0.680	0.150	0.250	0.060	0.570	0.620	0.860	0.770
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.410	7.760	9.010	9.970	9.630	5.350	6.160	4.420	7.780	7.190	7.430	6.350
16	Rns = 0.75 Rs	4.800	5.820	6.750	7.470	7.220	4.010	4.620	3.310	5.830	5.390	5.570	4.760
17	Function of temperature f(T).	14.120	14.250	15.960	16.490	17.410	17.300	16.230	15.720	15.650	15.610	14.890	14.420
18	Function of vapour pressure f(ed).	0.220	0.226	0.220	0.204	0.187	0.120	0.113	0.115	0.140	0.178	0.186	0.197
19	Function of sunshine duration f(n/N)	0.750	0.804	0.804	0.811	0.710	0.240	0.330	0.158	0.616	0.660	0.878	0.796
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.329	2.589	2.823	2.728	2.311	0.498	0.600	0.285	1.349	1.833	2.431	2.261
21	Net radiation Rn = Rns-Rnl in mm/day	2.471	3.231	3.927	4.742	4.909	3.512	4.020	3.025	4.481	3.557	3.139	2.499
22	Average wind speed in km/day	98.400	120.000	124.800	124.800	170.400	184.800	158.400	129.600	98.400	67.200	67.200	98.400
23	Average wind speed in m/sec	1.130	1.380	1.440	1.440	1.970	2.130	1.830	1.500	1.130	0.770	0.770	1.130
24	Wind function f(u) =0.27(1+u/100)	0.530	0.590	0.600	0.600	0.730	0.760	0.690	0.610	0.530	0.450	0.450	0.530
25	Adjustment factor 'c'	0.944	0.968	0.913	0.924	0.984	0.946	0.977	0.960	1.041	0.977	0.983	0.943
26	W*Rn mm/day	1.635	2.161	2.945	3.698	3.981	2.837	3.103	2.265	3.342	2.646	2.228	1.704
27	(1-W)*f(u)*(ea-ed)	2.199	2.763	3.954	4.010	5.162	3.410	1.546	0.816	1.579	1.990	1.669	1.960
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.610	4.760	6.290	7.120	8.990	5.900	4.540	2.950	5.120	4.520	3.830	3.450
29	**Monthly Eto (mm/month)**	**111.910**	**133.280**	**194.990**	**213.600**	**278.680**	**177.000**	**140.740**	**91.450**	**153.600**	**140.120**	**114.900**	**106.950**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1996

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.900	29.100	33.700	40.500	42.100	36.500	28.200	28.700	28.200	31.000	28.400	23.700
2	Min. air temperature in o C.	9.900	13.400	16.600	23.000	26.800	25.500	22.500	22.600	21.800	17.900	12.600	11.100
3	Mean air temperature in o C.	17.900	21.250	25.150	31.750	34.450	31.000	25.350	25.650	25.000	24.450	20.500	17.400
4	Saturation vapour pressure (ea) in mbar	20.480	25.270	31.980	46.920	54.550	44.900	32.360	32.930	31.700	30.650	24.150	19.880
5	Max.relative humidity (RH Max.%)	50.000	47.000	25.000	22.000	31.000	61.000	81.000	90.000	88.000	61.000	45.000	65.000
6	Min.relative humidity (RH Min.%)	29.000	23.000	14.000	14.000	13.000	42.000	71.000	80.000	78.000	40.000	27.000	46.000
7	Mean.relative humidity (RH Mean.%)	39.500	35.000	19.500	18.000	22.000	51.500	76.000	85.000	83.000	50.500	36.000	55.500
8	Actual vapour pressure (ed) = ea*RHMean/100	8.080	8.840	6.230	8.440	12.000	23.120	24.590	27.990	26.310	15.480	8.690	11.030
9	Vapour pressure dedicit (ea-ed) in mbar	12.400	16.430	25.750	38.480	42.550	21.780	7.770	4.940	5.390	15.170	15.460	8.850
10	Weighing factor (W)	0.665	0.708	0.747	0.803	0.823	0.796	0.749	0.752	0.746	0.740	0.701	0.660
11	(1-W)	0.335	0.292	0.253	0.197	0.177	0.204	0.251	0.248	0.254	0.260	0.299	0.340
12	Cloud cover in oktas	1.300	2.400	0.400	1.200	0.900	6.300	7.800	7.600	6.800	2.700	0.400	3.100
13	Ratio n/N	0.820	0.710	0.910	0.830	0.860	0.250	0.030	0.060	0.180	0.680	0.910	0.640
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.930	7.340	9.920	10.280	11.100	6.170	4.350	4.420	4.950	7.570	7.710	5.700
16	Rns = 0.75 Rs	5.190	5.500	7.440	7.710	8.320	4.620	3.260	3.310	3.710	5.670	5.780	4.270
17	Function of temperature f(T).	14.180	14.850	15.680	17.130	17.790	16.950	15.730	15.810	15.650	15.510	14.700	14.080
18	Function of vapour pressure f(ed).	0.220	0.211	0.228	8.215	0.190	0.124	0.120	0.110	0.118	0.165	0.213	0.195
19	Function of sunshine duration f(n/N)	0.840	0.740	0.920	0.850	0.870	0.330	0.130	0.150	0.260	0.710	0.920	0.680
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.620	2.310	3.280	3.130	2.940	0.690	0.240	0.260	0.480	1.810	2.880	1.860
21	Net radiation Rn = Rns-Rnl in mm/day	2.570	3.190	4.160	4.580	5.380	3.930	3.020	3.050	3.230	3.860	2.900	2.410
22	Average wind speed in km/day	105.600	105.600	127.200	134.400	172.800	196.800	168.000	139.200	105.600	69.600	72.000	79.200
23	Average wind speed in m/sec	1.220	1.220	1.470	1.550	2.000	2.270	1.940	1.610	1.220	0.800	0.830	0.910
24	Wind function f(u) =0.27(1+u/100)	0.550	0.550	0.610	0.630	0.730	0.800	0.720	0.640	0.550	0.450	0.460	0.480
25	Adjustment factor 'c'	0.953	0.963	0.922	0.921	1.000	0.958	0.936	0.954	0.984	1.049	0.987	1.012
26	W*Rn mm/day	1.709	2.258	3.100	3.677	4.420	3.128	2.261	2.293	2.409	2.834	2.032	1.590
27	(1-W)*f(u)*(ea-ed)	2.284	2.638	3.970	4.775	5.490	3.554	1.404	0.784	0.752	1.774	2.126	1.440
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.800	4.710	6.510	7.780	9.910	6.400	3.430	2.930	3.110	4.830	4.100	3.060
29	**Monthly Eto (mm/month)**	**117.800**	**136.590**	**201.810**	**233.400**	**307.210**	**192.000**	**106.330**	**90.830**	**93.300**	**149.730**	**123.000**	**94.860**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1997

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.000	27.400	35.500	38.800	40.000	37.400	30.500	28.600	33.200	31.200	28.200	25.100
2	Min. air temperature in o C.	9.000	11.300	18.500	22.900	25.100	25.600	23.100	22.200	22.000	19.400	11.800	9.700
3	Mean air temperature in o C.	17.000	19.350	27.000	30.850	32.550	31.500	26.800	25.400	27.600	25.300	20.000	17.400
4	Saturation vapour pressure (ea) in mbar	19.400	22.490	35.700	44.520	49.080	46.250	35.280	32.460	36.960	32.270	23.400	19.880
5	Max.relative humidity (RH Max.%)	47.000	38.000	30.000	21.000	33.000	61.000	84.000	88.000	69.000	67.000	46.000	57.000
6	Min.relative humidity (RH Min.%)	26.000	20.000	15.000	13.000	20.000	30.000	71.000	75.000	51.000	54.000	33.000	38.000
7	Mean.relative humidity (RH Mean.%)	36.500	29.000	22.500	17.000	26.500	45.500	77.500	81.500	60.000	60.500	39.500	47.500
8	Actual vapour pressure (ed) = ea*RHMean/100	7.080	6.520	8.030	7.560	13.000	21.040	27.340	26.450	22.170	19.520	9.240	9.440
9	Vapour pressure dedicit (ea-ed) in mbar	12.320	15.970	27.670	36.960	36.080	25.210	7.940	6.010	14.790	12.750	14.160	10.440
10	Weighing factor (W)	0.656	0.686	0.766	0.794	0.809	0.801	0.764	0.750	0.772	0.749	0.696	0.660
11	(1-W)	0.344	0.314	0.234	0.206	0.191	0.199	0.236	0.250	0.228	0.251	0.304	0.340
12	Cloud cover in oktas	0.500	0.800	0.900	1.600	1.900	4.700	7.100	7.000	4.500	3.800	0.300	1.600
13	Ratio n/N	0.900	0.870	0.860	0.790	0.760	0.480	0.130	0.150	0.500	0.570	0.920	0.790
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	7.350	8.310	9.570	9.970	10.280	8.070	5.170	5.130	7.280	6.860	7.760	6.450
16	Rns = 0.75 Rs	5.510	6.230	7.170	7.470	7.710	6.050	3.870	3.850	5.460	5.140	5.820	4.830
17	Function of temperature f(T).	14.000	14.470	16.100	16.910	17.330	17.070	16.060	15.750	16.220	15.720	14.600	14.080
18	Function of vapour pressure f(ed).	0.224	0.227	0.220	0.222	0.185	0.135	0.113	0.117	0.129	0.142	0.207	0.205
19	Function of sunshine duration f(n/N)	0.910	0.880	0.870	0.810	0.780	0.530	0.220	0.240	0.550	0.610	0.930	0.810
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.860	2.890	3.080	3.040	2.500	1.220	0.390	0.440	1.150	1.360	2.810	2.330
21	Net radiation Rn = Rns-Rnl in mm/day	2.650	3.340	4.090	4.430	5.210	4.830	3.480	3.410	4.310	3.780	3.010	2.500
22	Average wind speed in km/day	100.800	124.800	120.000	129.600	163.200	172.800	148.800	141.600	100.800	60.000	64.800	81.600
23	Average wind speed in m/sec	1.160	1.440	1.380	1.500	1.880	2.000	1.720	1.630	1.160	0.690	0.750	0.940
24	Wind function f(u) =0.27(1+u/100)	0.540	0.600	0.590	0.610	0.710	0.730	0.670	0.650	0.540	0.430	0.440	0.490
25	Adjustment factor 'c'	0.960	0.970	0.920	0.920	0.990	1.010	0.960	0.960	1.030	1.040	0.990	0.950
26	W*Rn mm/day	1.730	2.290	3.130	3.510	4.210	3.860	2.650	2.550	3.320	2.830	2.090	1.650
27	(1-W)*f(u)*(ea-ed)	2.280	3.000	3.820	4.640	4.890	3.660	1.250	0.970	1.820	1.370	1.890	1.730
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.840	5.130	6.390	8.150	9.000	7.590	3.740	3.370	5.290	4.360	3.940	3.210
29	**Monthly Eto (mm/month)**	**119.040**	**143.640**	**198.090**	**244.500**	**279.000**	**227.700**	**115.940**	**104.470**	**158.700**	**135.160**	**118.200**	**99.510**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1998

S. No.	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	24.000	27.500	32.700	39.300	40.700	35.600	29.800	29.300	29.700	31.100	27.800	26.100
2	Min. air temperature in o C.	8.400	11.700	15.700	22.000	26.000	25.400	22.600	22.800	22.000	19.600	11.600	9.400
3	Mean air temperature in o C.	16.200	19.600	24.200	30.650	33.350	30.500	26.200	26.050	25.850	25.350	19.700	17.750
4	Saturation vapour pressure (ea) in mbar	18.440	22.840	30.180	44.020	51.310	43.650	34.020	33.700	33.310	32.360	22.980	20.300
5	Max.relative humidity (RH Max.%)	62.000	51.000	33.000	18.000	31.000	64.000	87.000	88.000	83.000	75.000	49.000	53.000
6	Min.relative humidity (RH Min.%)	32.000	29.000	15.000	12.000	15.000	47.000	76.000	79.000	72.000	57.000	32.000	38.000
7	Mean.relative humidity (RH Mean.%)	47.000	40.000	24.000	15.000	23.000	55.500	81.500	83.500	77.500	66.000	40.500	45.500
8	Actual vapour pressure (ed) = ea*RHMean/100	8.660	9.130	7.240	6.600	11.800	24.220	27.720	28.130	25.810	21.350	9.300	9.230
9	Vapour pressure dedicit (ea-ed) in mbar	9.780	13.710	22.940	37.420	39.510	19.430	6.300	5.570	7.500	11.010	13.680	11.070
10	Weighing factor (W)	0.648	0.690	0.738	0.792	0.815	0.791	0.758	0.756	0.754	0.749	0.691	0.663
11	(1-W)	0.352	0.310	0.262	0.208	0.185	0.209	0.242	0.244	0.246	0.251	0.309	0.337
12	Cloud cover in oktas	2.000	2.000	2.200	0.700	1.700	4.700	7.100	7.400	5.900	3.600	0.600	1.000
13	Ratio n/N	0.750	0.750	0.730	0.880	0.780	0.480	0.130	0.090	0.310	0.590	0.890	0.850
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.560	7.580	8.650	10.660	10.450	8.070	5.170	4.660	5.890	6.990	7.600	6.750
16	Rns = 0.75 Rs	4.920	5.680	6.480	7.990	7.830	6.050	3.870	3.490	4.410	5.240	5.700	5.060
17	Function of temperature f(T).	13.840	14.520	15.450	16.860	17.530	16.820	15.940	15.900	15.860	5.730	14.540	14.150
18	Function of vapour pressure f(ed).	0.213	0.208	0.223	0.227	0.191	0.120	0.111	0.109	0.120	0.133	0.207	0.207
19	Function of sunshine duration f(n/N)	0.780	0.780	0.760	0.890	0.800	0.530	0.220	0.180	0.380	0.630	0.900	0.870
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.290	2.350	2.610	3.400	2.670	1.060	0.380	0.310	0.720	1.310	2.700	2.540
21	Net radiation Rn = Rns-Rnl in mm/day	2.630	3.330	3.870	4.590	5.160	4.990	3.490	3.180	3.690	3.930	3.000	2.520
22	Average wind speed in km/day	96.000	112.800	115.200	139.200	168.000	187.200	158.400	136.800	103.200	79.200	74.400	81.600
23	Average wind speed in m/sec	1.110	1.300	1.330	1.610	1.940	2.160	1.830	1.580	1.190	0.910	0.860	0.940
24	Wind function f(u) =0.27(1+u/100)	0.520	0.570	0.580	0.640	0.720	0.770	0.690	0.630	0.540	0.480	0.470	0.490
25	Adjustment factor 'c'	1.010	0.960	0.990	0.920	0.990	1.000	0.950	0.960	1.000	1.030	0.980	0.960
26	W*Rn mm/day	1.700	2.290	2.850	3.630	4.200	3.940	2.640	2.400	2.780	2.940	2.070	1.670
27	(1-W)*f(u)*(ea-ed)	1.790	2.420	3.480	4.980	5.260	3.120	1.050	0.850	0.990	1.320	1.980	1.820
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.520	4.520	6.260	7.920	9.360	7.060	3.500	3.120	3.770	4.380	3.960	3.350
29	**Monthly Eto (mm/month)**	**109.120**	**126.560**	**194.060**	**237.600**	**290.160**	**211.800**	**108.500**	**96.720**	**113.100**	**135.780**	**118.800**	**103.850**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD
FOR THE YEAR - 1999

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.900	29.000	33.700	38.000	40.500	35.000	31.700	29.300	30.600	33.800	28.600	26.000
2	Min. air temperature in o C.	11.100	12.400	17.100	21.300	25.700	24.300	23.300	22.500	21.100	18.800	12.200	9.500
3	Mean air temperature in o C.	18.500	20.700	25.400	29.650	33.100	29.650	27.500	25.900	25.850	26.300	20.400	17.750
4	Saturation vapour pressure (ea) in mbar	21.300	24.450	32.460	41.590	50.590	41.590	36.750	33.410	33.310	34.230	24.000	20.300
5	Max.relative humidity (RH Max.%)	63.000	60.000	51.000	35.000	43.000	70.000	85.000	88.000	83.000	45.000	61.000	65.000
6	Min.relative humidity (RH Min.%)	39.000	34.000	43.000	20.000	24.000	54.000	70.000	77.000	64.000	29.000	48.000	45.000
7	Mean.relative humidity (RH Mean.%)	51.000	47.000	47.000	27.500	33.500	62.000	77.500	82.500	73.500	37.000	54.500	55.000
8	Actual vapour pressure (ed) = ea*RHMean/100	10.860	11.490	15.250	11.430	16.940	25.780	28.480	27.560	24.480	12.660	13.080	11.160
9	Vapour pressure dedicit (ea-ed) in mbar	10.440	12.960	17.210	30.160	33.650	15.810	8.270	5.850	8.830	21.570	10.920	9.140
10	Weighing factor (W)	0.673	0.703	0.750	0.784	0.813	0.784	0.771	0.755	0.754	0.750	0.700	0.663
11	(1-W)	0.327	0.297	0.250	0.216	0.187	0.216	0.229	0.245	0.246	0.250	0.300	0.337
12	Cloud cover in oktas	2.400	1.300	1.400	0.900	0.800	5.500	6.500	7.100	4.700	1.000	3.200	1.000
13	Ratio n/N	0.710	0.820	0.810	0.860	0.870	0.370	0.220	0.130	0.480	0.850	0.630	0.850
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.350	8.010	9.220	10.510	11.180	7.160	5.910	4.970	7.130	8.660	6.180	6.750
16	Rns = 0.75 Rs	4.760	6.000	6.910	7.880	8.380	5.370	4.430	3.730	5.340	6.490	4.630	5.060
17	Function of temperature f(T).	14.300	14.740	15.750	16.630	17.470	16.630	16.200	15.870	15.860	15.960	14.680	14.150
18	Function of vapour pressure f(ed).	0.195	0.192	0.167	0.192	0.155	0.120	0.107	0.112	0.120	0.186	0.185	0.194
19	Function of sunshine duration f(n/N)	0.740	0.840	0.830	0.870	0.880	0.430	0.300	0.220	0.530	0.870	0.670	0.870
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.060	2.370	2.180	2.770	2.380	0.850	0.520	0.390	1.000	2.580	1.810	2.380
21	Net radiation Rn = Rns-Rnl in mm/day	2.700	3.630	4.730	5.110	6.000	4.520	3.910	3.340	4.340	3.910	2.820	2.660
22	Average wind speed in km/day	103.200	105.600	120.000	120.000	165.600	192.000	165.600	139.200	96.000	69.600	69.600	96.000
23	Average wind speed in m/sec	1.190	1.220	1.380	1.380	1.910	2.220	1.910	1.610	1.110	0.800	0.800	1.110
24	Wind function f(u) =0.27(1+u/100)	0.540	0.550	0.590	0.590	0.710	0.780	0.710	0.640	0.520	0.450	0.450	0.520
25	Adjustment factor 'c'	1.010	0.980	1.000	1.010	1.000	0.980	0.960	0.960	1.030	1.010	1.020	1.020
26	W*Rn mm/day	1.810	2.550	3.540	4.000	4.870	3.540	3.010	2.520	3.270	2.930	1.970	1.770
27	(1-W)*f(u)*(ea-ed)	1.840	2.110	2.530	3.840	4.460	2.660	1.340	0.910	1.120	2.420	1.470	1.600
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.680	4.560	6.070	7.910	9.330	6.070	4.170	3.290	4.520	5.400	3.500	3.430
29	**Monthly Eto (mm/month)**	**114.080**	**127.680**	**188.170**	**237.300**	**289.230**	**182.100**	**129.270**	**101.990**	**135.600**	**167.400**	**105.000**	**106.330**

TABLE NO. 2

ABSTRACT

COMPUTED YEARLY REFERENCE CROP EVAPOTRANSPIRATION (*Eto*)

BY MODIFIED PANMAN METHOD

(All figures are in mm)

S.NO.	YEAR	JAN	FEB	MAR	APRL	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
1	1984	113.77	129.64	201.19	225.6	270.94	228.3	97.65	94.86	72.90	136.71	105.9	97.34	1774.8
2	1985	114.70	129.92	189.41	236.1	275.28	228.0	125.55	90.83	102.60	156.55	117.3	101.06	1867.3
3	1986	115.63	134.96	204.69	215.4	252.34	199.2	118.42	91.14	140.10	139.50	108.0	107.88	1827.26
4	1987	115.94	136.36	201.81	230.4	287.06	213.3	113.46	91.14	112.80	151.28	114.9	109.43	1877.88
5	1988	115.32	142.39	216.38	219.0	261.33	228.3	131.44	132.99	154.50	167.40	117.9	101.06	1988.01
6	1989	111.29	141.12	190.34	213.0	286.13	214.8	149.11	106.02	166.20	168.02	109.8	108.19	1964.02
7	1990	125.55	159.88	177.63	222.6	283.34	222.3	119.04	101.37	126.00	165.23	126.9	80.29	1910.13
8	1991	108.50	130.20	209.56	208.5	272.80	210.3	107.88	104.47	148.20	150.04	111.6	110.36	1872.41
9	1992	119.60	136.30	190.96	231.6	264.12	210.6	99.82	99.51	117.60	161.82	101.1	102.30	1835.33
10	1993	117.80	124.32	199.64	220.2	288.92	156.6	130.51	87.73	68.10	162.13	126.6	113.77	1796.32
11	1994	104.40	141.68	194.99	225.6	276.83	144.9	95.79	89.59	131.70	137.33	116.4	106.64	1765.85
12	1995	111.91	133.28	194.99	213.6	278.69	177.0	140.74	91.45	153.60	140.12	114.9	106.95	1857.23
13	1996	117.80	136.59	201.81	233.4	307.21	192.0	106.33	90.83	93.30	149.73	123.0	94.86	1846.86
14	1997	119.04	143.64	198.09	244.5	279.00	227.7	115.94	104.47	158.70	135.16	118.2	99.51	1943.95
15	1998	109.12	126.56	194.06	237.6	290.16	211.8	108.50	96.72	113.10	135.78	118.8	103.85	1846.05
16	1999	114.08	127.68	188.17	237.3	289.23	182.1	129.27	101.99	135.60	167.40	105.0	106.33	1884.15
AVERAGE.		**114.65**	**135.90**	**197.10**	**225.90**	**278.96**	**202.95**	**118.09**	**98.44**	**124.68**	**151.51**	**114.76**	**103.11**	**1866.10**
DAILY Eto (mm/day)		**3.69**	**4.85**	**6.35**	**7.53**	**8.99**	**6.76**	**3.80**	**3.17**	**4.15**	**4.88**	**3.82**	**3.32**	**5.11**

TABLE NO. 3

ESTIMATION OF CROP WATER REQUIREMENT

Crop : SOYABEAN - 1KH
Sowing time : 15 th - 30 th JUNE
Duration : 105 DAYS
Sowing area : 4509 Ha.
Growth Stages (Days) : 20/30/30/25

S.NO.	PARTICULARS	JUN	JUL		AUG		SEPT	
		16th to 30th (15 DAYS)	1st to 5th (5DAYS)	6th to 31st (26 DAYS)	1st to 4th (4 DAYS)	5th to 31st (27 DAYS)	1st to 3rd (3DAYS)	4th to 28th (25 DAYS)
1	Eto . (mm)	101.40	19.00	114.29	12.68	85.76	12.45	112.23
2	Crop factor (Kc)	0.40	0.40	0.80	0.80	1.15	1.15	0.80
3	Cosumptive Use (Etc) (mm)	40.56	7.60	91.43	10.14	98.62	14.31	89.78
4	Presowing (mm)	75.00	-	-	-	-	-	-
5	Soil Moisture Adjustment (mm)	-	-	-	-	-	-	(-)53.86
6	Gross Consumptive Use (mm)	115.56	99.03		108.76		50.23	
7	Rainfall (mm)	92.90	376.88		388.59		220.41	
8	Effective Rainfall (mm)	40.56	99.03		108.76		50.23	
9	Net Irrigation Requirement (mm)	75.00	-		-		-	
10	Gross Irrigation Requirement Considering Project Efficiency 42%	178.57	-		-		-	
11	Water Requirement for the Sowing Area - 4509 Ha (Ha-M)	805.17	-		-		-	
12	**Water Requirement for the Sowing Area - 4509 Ha (MCum)**	**8.051**	-		-		-	

ESTIMATION OF CROP WATER REQUIREMENT

Crop : SOYABEAN - 2KH
Sowing time : 1st to 15th JULY
Duration : 105 DAYS
Sowing area : 6763 Ha.
Growth Stages (Days) : 20/30/30/25

S.NO.	PARTICULARS	JUL 1st to 20th (20 DAYS)	JUL 21st to 31st (11 DAYS)	AUG 1st to 19th (19 DAYS)	AUG 20th to 31st (12 DAYS)	SEPT 1st to 18th (18 DAYS)	SEPT 19th to 30th (12 DAYS)	OCT 1st to 13th (13 DAYS)
1	Eto . (mm)	76.00	42.09	60.23	38.21	74.70	49.98	63.44
2	Crop factor (Kc)	0.40	0.80	0.80	1.15	1.15	0.80	0.80
3	Cosumptive Use (Etc) (mm)	30.40	33.67	48.18	43.94	85.90	39.98	50.75
4	Presowing (mm)	75.00	-	-	-	-	-	-
5	Soil Moisture Adjustment (mm)	-	-	-	-	-	(-)6.66	(-)50.75
6	Gross Consumptive Use (mm)	139.07		92.12		119.22		-
7	Rainfall (mm)	376.88		388.59		220.41		21.23
8	Effective Rainfall (mm)	64.07		92.12		119.22		
9	Net Irrigation Requirement (mm)	75.00		-		-		-
10	Gross Irrigation Requirement Considering Project Efficiency 42%	178.57		-		-		-
11	Water Requirement for the Sowing Area - 6763 Ha (Ha-M)	1207.66		-		-		-
12	**Water Requirement for the Sowing Area - 6763 Ha (MCum)**	**12.076**		-		-		-

ESTIMATION OF CROP WATER REQUIREMENT

Crop : JOWAR - 1KH
Sowing time : 16th to 30th JUNE
Duration : 105 DAYS
Sowing area : 4509 Ha.
Growth Stages (Days) : 20/25/35/25

S.NO.	PARTICULARS	JUN 16th to 30th (15 DAYS)	JUL 1st to 5th (5DAYS)	JUL 6th to 31st (25 DAYS)	AUG 1st to 31st (31 DAYS)	SEPT 1st to 4th (4 DAYS)	SEPT 5th to 29th (25 DAYS)
1	Eto . (mm)	101.40	19.00	99.09	98.44	16.60	103.75
2	Crop factor (Kc)	0.40	0.40	0.75	1.15	1.15	0.80
3	Cosumptive Use (Etc) (mm)	40.56	7.60	74.31	113.20	19.09	83.00
4	Presowing (mm)	75.00	-	-	-	-	-
5	Soil Moisture Adjustment (mm)	-	-	-	-	-	(-)49.8
6	Gross Consumptive Use (mm)	115.56	81.91		113.20	52.29	
7	Rainfall (mm)	92.90	376.88		388.59	220.41	
8	Effective Rainfall (mm)	40.56	81.91		113.20	102.09	
9	Net Irrigation Requirement (mm)	75.00	-		-	-	
10	Gross Irrigation Requirement Considering Project Efficiency 42%	178.57	-		-	-	
11	Water Requirement for the Sowing Area - 4509 Ha (Ha-M)	805.17	-		-	-	
12	**Water Requirement for the Sowing Area - 4509 Ha (MCum)**	**8.051**	-		-	-	

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ESTIMATION OF CROP WATER REQUIREMENT

Crop : JOWAR - 2KH
Sowing time : 1st to 15th JULY
Duration : 105 DAYS
Sowing area : 4509 Ha.
Growth Stages (Days) : 20/25/35/25

S.NO.	PARTICULARS	JUL 1st to 20th (20 DAYS)	JUL 21st to 31st (10 DAYS)	AUG 1st to 15th (15 DAYS)	AUG 16th to 31st (16 DAYS)	SEPT 1st to 19th (19 DAYS)	SEPT 20th to 30th (11 DAYS)	OCT 1st to 14th (14 DAYS)
1	Eto . (mm)	76.00	42.09	47.55	50.89	78.85	45.83	68.32
2	Crop factor (Kc)	0.40	0.75	0.75	1.15	1.15	0.80	0.80
3	Cosumptive Use (Etc) (mm)	30.40	31.56	35.66	58.52	90.67	36.66	54.65
4	Presowing (mm)	75.00	-	-	-	-	-	-
5	Soil Moisture Adjustment (mm)	-	-	-	-	-	-	(-)54.65
6	Gross Consumptive Use (mm)	136.96		94.18		127.33		-
7	Rainfall (mm)	376.88		388.59		220.41		21.23
8	Effective Rainfall (mm)	61.96		94.18		127.33		
9	Net Irrigation Requirement (mm)	75.00		-		-		-
10	Gross Irrigation Requirement Considering Project Efficiency 42%	178.57		-		-		-
11	Water Requirement for the Sowing Area - 4509 Ha (Ha-M)	805.17		-		-		-
12	**Water Requirement for the Sowing Area - 4509 Ha (MCum)**	8.0517		-		-		-

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ESTIMATION OF CROP WATER REQUIREMENT

Crop : COTTON - 2KH
Sowing time : 16th to 30th JUNE
Duration : 180 DAYS
Sowing area : 2254 Ha.
Growth Stages (Days) : 30/50/55/45

S.NO.	PARTICULARS	JUN	JUL		AUG	SEPT		OCT		NOV	DEC
		16th to 30th (15 DAYS)	1st to 15th (15 DAYS)	16th to 31st (16 DAYS)	1st to 31st (31 DAYS)	1st to 3rd (3 DAYS)	4th to 30th (27 DAYS)	1st to 28t (28 DAYS)	29th to 31 (3 DAYS)	1st to 30t (30 DAYS)	1st to 12th (12DAYS)
1	Eto . (mm)	101.400	57.000	61.090	98.440	12.450	112.230	136.640	14.870	114.760	39.840
2	Crop factor (Kc)	0.400	0.400	0.700	0.700	0.700	1.050	1.050	0.800	0.800	0.800
3	Cosumptive Use (Etc) (mm)	40.560	22.800	42.760	68.900	8.710	117.840	143.470	11.890	91.800	31.870
4	Presowing (mm)	75.000	-	-	-	-	-	-	-	-	-
5	Soil Moisture Adjustment (mm)	-	-	-	-	-	-	-	-	(-)55.08	(-)31.87
6	Gross Consumptive Use (mm)	115.560	65.560		68.900	126.550		155.360		36.720	-
7	Rainfall (mm)	92.900	376.880		388.590	220.410		21.230		11.410	-
8	Effective Rainfall (mm)	40.560	65.560		68.900	126.550		16.920		-	-
9	Net Irrigation Requirement (mm)	75.000	-		-	-		138.440		36.720	-
10	Gross Irrigation Requirement Considering Project Efficiency 42%	178.570	-		-	-		329.610		87.420	-
11	Water Requirement for the Sowing Area - 2254 Ha (Ha-M)	402.496	-		-	-		742.940		197.044	-
12	**Water Requirement for the Sowing Area - 2254 Ha (MCum)**	**4.0249**	-		-	-		**7.429**		**1.97**	-

ESTIMATION OF CROP WATER REQUIREMENT

Crop : WHEAT - 0MV
Sowing time : 1st to 15th OCT
Duration : 135 DAYS
Sowing area : 11272 Ha.
Growth Stages (Days) : 15/30/55/35

S.NO.	PARTICULARS	OCT 1st to 15th (15 DAYS)	OCT 16th to 31st (16 DAYS)	NOV 1st to 14th (14 DAYS)	NOV 15th to 30th (16 DAYS)	DEC 1st to 31st (31 DAYS)	JAN 1st to 8th (8 DAYS)	JAN 9th to 31st (23 DAYS)	FEB 1st to 12t (12 DAYS)
1	Eto . (mm)	73.20	78.31	53.48	61.28	103.11	29.52	85.13	58.20
2	Crop factor (Kc)	0.30	0.70	0.70	1.05	1.05	1.05	0.65	0.65
3	Cosumptive Use (Etc) (mm)	21.96	54.81	37.43	64.34	108.26	30.99	55.33	37.83
4	Presowing (mm)	60.00	-	-	-	-	-	-	-
5	Soil Moisture Adjustment (mm)	-	-	-	-	-	-	(-)43.3	(-)37.83
6	Gross Consumptive Use (mm)	136.77		101.77		108.26	43.02		-
7	Rainfall (mm)	21.23		11.41		14.45	10.88		5.20
8	Effective Rainfall (mm)	14.89		-		10.48	-		-
9	Net Irrigation Requirement (mm)	121.88		101.77		97.78	43.02		-
10	Gross Irrigation Requirement Considering Project Efficiency 58%	210.13		175.46		168.58	74.17		-
11	Water Requirement for the Sowing Area - 11272 Ha (Ha-M)	2368.58		1977.78		1900.23	834.12		-
12	**Water Requirement for the Sowing Area - 11272 Ha (MCum)**	**23.685**		**19.777**		**19.002**	**8.341**		-

ESTIMATION OF CROP WATER REQUIREMENT

Crop : WHEAT - 1MV
Sowing time : 1st to 15th NOV
Duration : 135 DAYS
Sowing area : 5410 Ha.
Growth Stages (Days) : 15/30/55/35

S.NO.	PARTICULARS	NOV 1st to 15th (15 DAYS)	NOV 16th to 30th (15 DAYS)	DEC 1st to 15th (15 DAYS)	DEC 16th to 31st (16 DAYS)	JAN 1st to 31st (31 DAYS)	FEB 1st to 8th (8 DAYS)	FEB 9th to 28th (20 DAYS)	MAR 1st to 15th (15 DAYS)
1	Eto . (mm)	57.30	57.46	49.80	53.31	114.65	38.80	97.10	95.25
2	Crop factor (Kc)	0.30	0.70	0.70	1.05	1.05	1.05	0.65	0.65
3	Cosumptive Use (Etc) (mm)	17.19	40.22	34.86	55.97	120.38	40.74	63.11	61.91
4	Presowing (mm)	60.00	-	-	-	-	-	-	-
5	Soil Moisture Adjustment (mm)	-	-	-	-	-	-	(-)47.33	(-)61.91
6	Gross Consumptive Use (mm)	117.41		90.83		120.38	56.52		-
7	Rainfall (mm)	11.41		14.45		10.88	5.20		-
8	Effective Rainfall (mm)	-		10.28		-	-		-
9	Net Irrigation Requirement (mm)	117.41		80.55		120.38	56.52		-
10	Gross Irrigation Requirement Considering Project Efficiency 58%	202.43		138.87		207.55	97.44		-
11	Water Requirement for the Sowing Area - 5410 Ha (Ha-M)	1095.14		751.28		1122.84	527.15		-
12	**Water Requirement for the Sowing Area - 5410 Ha (MCum)**	**10.951**		**7.512**		**11.228**	**5.271**		-

ESTIMATION OF CROP WATER REQUIREMENT

Crop : WHEAT - 2MV
Sowing time : 16th to 30th NOV
Duration : 135 DAYS
Sowing area : 11271 Ha.
Growth Stages (Days) : 15/30/55/35

S.NO.	PARTICULARS	NOV 16th to 30th (15 DAYS)	DEC 1st to 30th (30 DAYS)	DEC 31st (1 DAY)	JAN 1st to 31st (31 DAYS)	FEB st to 23r (23 DAYS)	FEB 4th to 28t (5 DAYS)	MAR 1st to 30t (30 DAYS)
1	Eto . (mm)	57.30	99.60	3.51	114.65	111.55	24.35	190.50
2	Crop factor (Kc)	0.30	0.70	1.05	1.05	1.05	0.65	0.65
3	Cosumptive Use (Etc) (mm)	17.19	69.72	3.68	120.38	117.12	15.82	123.82
4	Presowing (mm)	60.00	-	-	-	-	-	-
5	Soil Moisture Adjustment (mm)	-	-	-	-	-	-	(-)123.82
6	Gross Consumptive Use (mm)	77.19	73.40		120.38	132.94		-
7	Rainfall (mm)	11.41	14.45		10.88	5.20		5.36
8	Effective Rainfall (mm)	-	10.02		-	-		-
9	Net Irrigation Requirement (mm)	77.19	63.38		120.38	132.94		-
10	Gross Irrigation Requirement Considering Project Efficiency 58%	133.08	109.27		207.55	229.20		-
11	Water Requirement for the Sowing Area - 11271 Ha (Ha-M)	1499.94	1231.58		2339.29	2583.31		-
12	**Water Requirement for the Sowing Area - 11271 Ha (MCum)**	**14.999**	**12.315**		**23.392**	**25.833**		-

ESTIMATION OF CROP WATER REQUIREMENT

Crop : GRAM S2 - RA
Sowing time : 1st to 15th NOV
Duration : 120 DAYS
Sowing area : 9017 Ha.
Growth Stages (Days) : 20/25/45/30

S.NO.	PARTICULARS	NOV 1st to 20th (20 DAYS)	NOV 21st to 31st (10 DAYS)	DEC 1st to 15th (15 DAYS)	DEC 16th to 31st (16 DAYS)	JAN 1st to 29th (29 DAYS)	JAN 30th to 31st (2 DAYS)	FEB 1st to 28th (28 DAYS)
1	Eto . (mm)	76.40	38.36	49.80	53.31	107.01	7.64	135.90
2	Crop factor (Kc)	0.26	0.94	0.94	1.00	1.00	0.55	0.55
3	Cosumptive Use (Etc) (mm)	19.86	36.05	46.81	53.31	107.01	4.20	74.74
4	Presowing (mm)	60.00	-	-	-	-	-	-
5	Soil Moisture Adjustment (mm)	-	-	-	-	(-)36.9	(-)4.2	(-)74.74
6	Gross Consumptive Use (mm)	115.91		100.12		70.11		-
7	Rainfall (mm)	11.41		14.45		10.88		5.20
8	Effective Rainfall (mm)	-		10.40		-		
9	Net Irrigation Requirement (mm)	115.91		89.72		70.11		-
10	Gross Irrigation Requirement Considering Project Efficiency 58%	199.84		154.68		120.87		-
11	Water Requirement for the Sowing Area - 9017 Ha (Ha-M)	1801.95		1394.74		1089.88		-
12	**Water Requirement for the Sowing Area - 9017 Ha (MCum)**	**18.019**		**13.947**		**10.898**		-

ESTIMATION OF CROP WATER REQUIREMENT

Crop : POTATO/VEGETABLES
Sowing time : 1st to 15th NOV
Duration : 105 DAYS
Sowing area : 451 Ha.
Growth Stages (Days) : 25/30/30/20

S.NO.	PARTICULARS	NOV 1st to 25th (25 DAYS)	NOV 26TH to 31s (5 DAYS)	DEC 1st to 25th (25 DAYS)	DEC 26th to 31st (6 DAYS)	JAN 1st to 24th (24 DAYS)	JAN 25th to 31st (6 DAYS)	FEB 1st to 14th (14 DAYS)
1	Eto . (mm)	95.50	19.26	83.00	20.11	88.56	26.09	67.90
2	Crop factor (Kc)	0.40	0.70	0.70	1.05	1.05	0.85	0.85
3	Cosumptive Use (Etc) (mm)	38.20	13.48	58.10	21.11	92.98	22.17	57.71
4	Presowing (mm)	60.00	-	-	-	-	-	-
5	Soil Moisture Adjustment (mm)	-	-	-	-	(-)36.9	(-)22.17	(-)57.71
6	Gross Consumptive Use (mm)	111.68		79.21		92.98		-
7	Rainfall (mm)	11.41		14.45		10.88		5.20
8	Effective Rainfall (mm)	-		10.12		-		
9	Net Irrigation Requirement (mm)	111.68		69.09		92.98		-
10	Gross Irrigation Requirement Considering Project Efficiency 58%	192.55		119.12		160.31		-
11	Water Requirement for the Sowing Area - 451 Ha (Ha-M)	86.84		53.72		72.30		-
12	**Water Requirement for the Sowing Area - 451 Ha (MCum)**	0.868		0.537		0.722		-

ESTIMATION OF CROP WATER REQUIREMENT

Crop : BERSEEM
Sowing time : 1st to 15th NOV
Duration : 165 DAYS
Sowing area : 902 Ha.
Growth Stages (Days) : 30/45/45/45

S.NO.	PARTICULARS	NOV 1st to 30th (30 DAYS)	DEC 1st to 31st (31 DAYS)	JAN 1st to 14th (14 DAYS)	JAN 15th to 31st (17 DAYS)	FEB 1st to 28th (28 DAYS)	MARCH 1st to 31st (31 DAYS)	APRL 1st to 14th (14 DAYS)
1	Eto . (mm).	114.76	103.11	51.66	62.99	135.90	197.10	105.42
2	Crop factor (Kc)	0.38	1.01	1.01	1.10	1.10	1.05	1.05
3	Cosumptive Use (Etc) (mm)	43.60	104.14	52.17	69.28	149.49	206.95	110.69
4	Presowing (mm)	60.00	-	-	-	-	-	-
5	Soil Moisture Adjustment (mm)	-	-	-	-	-	(-)6.67	(-)110.69
6	Gross Consumptive Use (mm)	103.60	104.14	121.45		149.49	200.28	-
7	Rainfall (mm)	11.41	14.45	10.88		5.20	5.36	4.95
8	Effective Rainfall (mm)	-	10.44	-		-	-	-
9	Net Irrigation Requirement (mm)	103.60	93.70	121.45		149.49	200.28	-
10	Gross Irrigation Requirement Considering Project Efficiency 58%	178.62	161.55	209.39		257.74	345.31	-
11	Water Requirement for the Sowing Area - 902 Ha (Ha-M)	161.11	145.71	188.86		232.48	311.46	-
12	**Water Requirement for the Sowing Area - 902 Ha (MCum)**	**1.611**	**1.457**	**1.888**		**2.324**	**3.114**	-

TABLE NO. 4

ABSTRACT

MONTHLY ESTIMATED CROP WATER REQUIREMENTS

(All figures are in Mcum.)

S.N	CROPS/SOWN AREA (Ha)	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	TOTAL
	KHARIF CROPS											
1	SOYABEAN - 1KH (4509)	8.051	-	-	-	-	-	-	-	-	-	8.051
2	SOYABEAN - 2KH (6763)	-	12.076	-	-	-	-	-	-	-	-	12.076
3	JOWAR - 0KH (4509)	8.051	-	-	-	-	-	-	-	-	-	8.051
4	JOWAR - 1KH (4509)	-	8.051	-	-	-	-	-	-	-	-	8.051
5	COTTON - 2KH (2254)	4.024	-	-	-	7.429	1.97	-	-	-	-	13.423
	RABI CROPS											
1	WHEAT - 0MV (11272)	-	-	-	-	23.685	19.777	19.002	8.341	-	-	70.805
2	WHEAT - 1MV (5410)	-	-	-	-	-	10.951	7.512	11.228	5.271	-	34.962
3	WHEAT - 2MV (11271)	-	-	-	-	-	14.999	12.315	23.392	25.833	-	76.539
4	GRAM - S2RA (9017)	-	-	-	-	-	18.019	13.947	10.898	-	-	42.864
5	POTATO/VEGETABLES (451	-	-	-	-	-	0.868	0.537	0.722	-	-	2.127
6	BERSEEM (902)	-	-	-	-	-	1.611	1.457	1.888	2.324	3.114	10.394
	TOTAL (KHARIF+ RABI) WATER REQUIREMENTS FOR ENTIRE COMMAND OF 45087 Ha.	20.126	20.127	-	-	31.114	68.195	54.770	56.469	33.428	3.114	287.343

(7) An outlet factor of 1542.31 Ha/cumec is worked out to check the adequacy of the capacity of the canal system designed at the initial planning stage.

(8) Using the outlet factor of 1542.31 Ha/cumec, the discharging capacities of the left bank canal and right bank canal of the Kolar project are worked out as 17.22 cumecs and 12.00 cumecs respectively against the 18.60 cumecs and 16.40 cumecs designed at the initial planning stage.

(9) The monthwise variations occurring in the crop water requirements is also worked out for comparison. These variations are shown on a bar chart at Fig. 2 on Page No. 76.

5.2 DISCUSSIONS

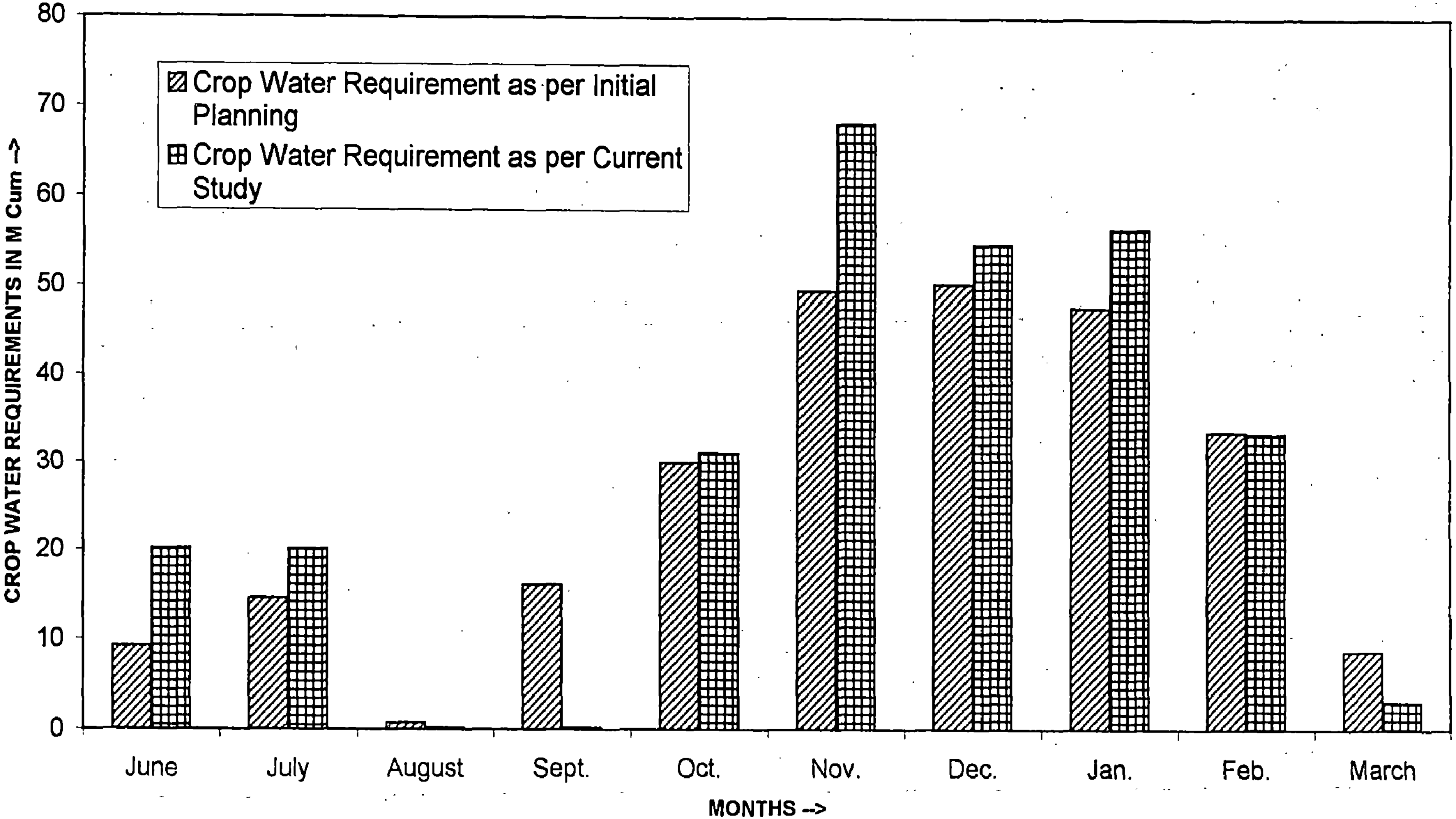
The results of the study show that the crop water requirements for the entire command of the project has increased by 26.643 M Cum as compared to that adopted at the initial planning stage. It means that to fulfil the water requirements of the entire command there will be a shortfall of the water having a quantity equal to 26.643 M Cum. Resulting to which the crop yields will decrease as available water is limited due to Kolar project being a storage project and having its storage limitations.

In such a situation to get the optimum results the only way remaining is to improve the irrigation efficiency and control the cropping pattern.

The irrigation efficiency can be improved by regular maintenance of canal system, structures, gates, etc. and by providing lining starting from distributories to water courses. A study carried out in the state of Haryana shows that by providing lining in the water courses upto 50% length reduces the seepage losses upto 80% thus increasing the irrigation efficiency substantially.

The cropping pattern may be controlled by selection of crop and reducing the area to be irrigated. When water supply is limited, crop selection, total acreage

FIGURE NO. 2 : MONTHWISE VARIATIONS IN CROP WATER REQUIREMENTS BETWEEN INITIAL PLANNING AND CURRENT STUDY



and total production are primarily determined by the extent to which the available water supply over the growing season can meet full water requirement of crops and the highest water utilization efficiency that can be obtained from the available water supply. The water allocations of limited supply would be directed towards meeting the full requirements of the crop during the most sensitive growth period for water deficit rather than spreading the available limited supplies to the crop equally over the total growing period.

Thus by improving the irrigation efficiency of the system and by controlling the cropping pattern, the deficit arrived in the available total water due to increased crop water requirement may be met out.

The another result of the study shows that the existing canal system of the project designed at the initial planning stage is having adequate capacities to supply the increased water requirements. In general, the inadequacy of the canal system of a reservoir project/storage project might not be arises to supply the increased water requirements due to the reason that the total water available is limited due to the storage limitations and this limited water is to be delivered for irrigation.

But in the case of diversion scheme where water is diverted directly from the river having sufficient quantum of water to meet out the increased water requirement, the adequacy of the canal system might play important role. In such situations, the adequacy must be checked if increase in crop water requirements is observed.

In the study, it is also observed that the crop water requirements are computed on the basis of average values of E_{TO}s derived from the historical data and also average values of E_{TO}s were adopted at initial planning stage due to common practice. Instead of adopting average values of E_{TO}s, frequency analysis may be done for the historical climatic data (10 years or more) and the value of E_{TO} selected for crop water requirement than be based on probability of 75 or 80 percent.

By adopting E_{TO}s based on frequency analysis in any planning and design of irrigation project may reduce the failure chances.

Chapter 6

SUMMARY AND CONCLUSIONS

6.1 SUMMARY

The basic objectives of this study is to observe the variations occurred in the crop water requirements due to micro climatic changes if any has taken place in the command area of the Kolar project. As the crop water requirements are closely related with climatic conditions so any change observed in the climate will directly affect the crop water requirements and ultimately the discharging capacity of the canal system and the area to be irrigated.

To obtain the aforesaid objective, analysis made are as follows :

(1) Collection of climatological data like maximum temperature, minimum temperature, RHmax, RHmin, cloud cover, wind speed, monthly rainfall of the Hoshangabad station for a period of 16 years (1984 to 1999) from the Indian Meteorological Department of India.

(2) Computations of Reference Crop Evapotranspiration (E_{TO}) by 'Modified Panman Method' as suggested in FAO Irrigation and Drainage paper No. 24.

(3) Selection of crop coefficients (K_c) for the various crops suggested under a cropping pattern.

(4) Computation of consumptive use and gross consumptive use

(5) Computations of net irrigation and gross irrigation requirements.

(6) Monthly estimated crop water requirements and total water requirements for the entire command.

(7) Computation of outlet factor, i.e., area irrigated per unit volume of water to check the adequacy of the carrying capacity of the canal system.

After carrying out the above steps, the results of the study shows that the crop water requirements for the entire command of the project has increased by 26.643 M Cum as compared to that adopted at the initial planning stage. Resulting to which the crop yields will decrease as available water is limited. The canal system has adequate capacities to meet out the increased crop water requirements.

As the Kolar project is a reservoir project so quantum of water available for irrigation is limited. In such situation, to fulfil the need of increased crop water requirements the only way remaining is to improve the irrigation efficiency and control the cropping pattern.

6.2 CONCLUSIONS

The various conclusions drawn after carrying out the study are briefly described as follows :

(1) The climatic variations occurred in the command area of any irrigation project plays important role in computation of crop water requirements. Therefore, crop water requirements should be carried out time to time so that the optimum crop yields may be obtained by timely management by improving irrigation efficiency and controlling cropping pattern.

(2) In the case of increase in crop water requirements is observed, the adequacy of the canal system to supply the increased water requirements should be checked especially in the diversion schemes in which the river has sufficient water to meet out the increased water requirement.

(3) In view of even increasing food problem and the limited water resources, the accurate estimation of crop water requirements is quite essential to conserve and utilise the available water resources to the best of man kind.

(4) Planning of an irrigation project is a very complex one that too the estimation of crop water requirements of the project since it involves various parameters such as cropping pattern to be adopted, climatic data, consumptive use of crops, water application efficiency, special requirements, e.g., nursery, leaching, etc.

All these parameters vary from region to region and thus every project is a separate entity.

(5) The entire procedure laid down in the study may be helpful in planning and design of any new irrigation project.

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ANNEXURE NO. 1

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **JANUARY** Height above M.S.L. - **302 M.**

Latitude : 77^{0} 46 ' E Latitutude : 22^{0} 46' N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	25.7	10.9	61	38	45.2	2.9	4.4	105.6	1.22
2	1985	24.5	8.2	55	32	25.6	0.8	4.7	112.8	1.30
3	1986	24.5	9.1	51	32	15.1	2.1	5.2	124.8	1.44
4	1987	25.3	8.8	50	28	0.0	1.4	4.4	105.6	1.22
5	1988	26.5	11.8	52	33	3.9	3.7	5.0	120.0	1.38
6	1989	25.7	10.6	59	39	24.1	1.9	4.5	108.0	1.25
7	1990	25.1	8.0	42	23	0.0	0.6	4.7	112.8	1.30
8	1991	23.7	10.7	69	39	0.0	2.4	4.2	100.8	1.16
9	1992	26.6	9.9	51	29	5.2	2.2	5.0	120.0	1.38
10	1993	25.2	11.2	70	39	26.5	1.7	5.2	124.8	1.44
11	1994	24.6	9.8	57	30	1.5	2.5	4.3	103.2	1.19
12	1995	26.0	9.2	53	25	0.0	2.3	4.1	98.4	1.13
13	1996	25.9	9.9	50	29	0.0	1.3	4.4	105.6	1.22
14	1997	25.0	9.0	47	26	0.0	0.5	4.2	100.8	1.16
15	1998	24.0	8.4	62	32	13.2	2.0	4.0	96.0	1.11
16	1999	25.9	11.1	63	39	13.9	2.4	4.3	103.2	1.19
	AVEG:	**25.263**	**9.788**	**55.750**	**32.063**	**10.888**	**1.919**	**4.538**	**108.900**	**1.256**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **FEBRUARY** Height above M.S.L. - **302 M.**

Latitude : 77^0 46 ' E Latitutude : 22^0 46 ' N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	26.6	10.5	43	25	1.8	1.6	4.3	105.6	1.22
2	1985	27.7	12.4	62	32	22.7	1.6	4.0	96.0	1.11
3	1986	30.3	13.5	51	27	14.0	1.6	4.2	100.8	1.16
4	1987	29.1	12.1	39	21	0.0	1.8	4.4	105.6	1.22
5	1988	28.8	11.8	39	23	3.2	0.9	4.1	98.4	1.13
6	1989	30.8	14.0	47	25	0.0	1.3	4.3	103.2	1.19
7	1990	31.6	13.3	32	16	0.0	0.5	5.2	124.8	1.44
8	1991	26.7	11.0	45	26	7.6	2.1	5.0	120.0	1.38
9	1992	30.3	12.8	44	27	0.0	2.4	4.2	100.8	1.16
10	1993	27.5	12.2	58	27	13.5	2.5	4.7	112.8	1.30
11	1994	28.5	11.8	35	19	0.6	1.2	4.5	108.0	1.25
12	1995	26.6	9.9	44	21	1.4	1.7	5.0	120.0	1.38
13	1996	29.1	13.4	47	23	1.7	2.4	4.4	105.6	1.22
14	1997	27.4	11.3	38	20	0.0	0.8	5.2	124.8	1.44
15	1998	27.5	11.7	51	29	3.2	2.0	4.7	112.8	1.3
16	1999	29.0	12.4	60	34	13.6	1.3	4.4	105.6	1.22
	AVEG:	**28.594**	**12.131**	**45.938**	**24.688**	**5.206**	**1.606**	**4.538**	**109.050**	**1.258**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : MARCH Height above M.S.L. - **302 M.**

Latitude : 77^{0} 46 ' E Latitutude : 22^{0} 46 ' N

S.No.	Year	Temperature in ^{0} c. Maximum	Minimum	Humidity % At 8.30 hrs	At 17.30 hrs	Rainfall in the month (mm)	Cloud Cover in (oktas)	Wind speed in 24 Hrs (Km/hr)	(Km/day)	(m/sec)
1	1984	35.1	17.5	23	12	0.0	0.9	4.9	117.6	1.36
2	1985	32.5	16.1	41	21	7.0	2.6	5.1	122.4	1.41
3	1986	33.3	16.5	33	16	5.1	1.5	5.0	120.0	1.38
4	1987	35.7	18.6	27	15	0.8	1.0	5.2	124.8	1.44
5	1988	32.9	16.4	26	15	0.3	1.7	4.8	115.2	1.33
6	1989	33.1	15.9	29	18	7.0	1.0	5.0	120.0	1.38
7	1990	32.4	16.8	47	28	35.1	3.3	5.1	122.4	1.41
8	1991	32.0	18.8	36	12	13.1	1.1	5.1	122.4	1.41
9	1992	36.3	18.4	28	18	0.0	2.3	5.4	129.6	1.50
10	1993	32.6	16.5	40	21	16.0	1.7	5.4	129.6	1.50
11	1994	33.2	16.6	23	11	0.0	1.2	4.9	117.6	1.36
12	1995	34.8	17.8	29	17	0.0	1.7	5.2	124.8	1.44
13	1996	33.7	16.6	25	14	0.0	0.4	5.3	127.2	1.47
14	1997	35.5	18.5	30	15	0.0	0.9	5.0	120.0	1.38
15	1998	32.7	15.7	33	15	0.0	2.2	4.8	115.2	1.33
16	1999	33.7	17.1	51	43	1.5	1.4	5.0	120.0	1.38
	AVEG:	**33.719**	**17.113**	**32.563**	**18.188**	**5.369**	**1.556**	**5.075**	**121.800**	**1.405**

CLIMATOLOGICAL DATA

Station : HOSHANGABAD Month : APRIL Height above M.S.L. - 302 M.

Latitude : 77° 46' E Latitutude : 22° 46' N

S.No.	Year	Temperature in ° c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	38.6	21.5	22	13	1.4	1.5	5.4	129.6	1.50
2	1985	37.6	20.9	38	22	16.2	1.3	5.6	134.4	1.55
3	1986	37.4	20.6	34	21	2.8	3.2	5.2	124.8	1.44
4	1987	37.7	23.3	27	16	0.0	1.3	5.8	139.2	1.61
5	1988	37.4	21.4	35	26	0.0	2.7	5.0	120.0	1.38
6	1989	38.4	21.3	25	17	0.6	2.0	5.2	124.8	1.44
7	1990	37.4	20.6	27	12	10.5	1.2	5.6	134.4	1.55
8	1991	37.2	21.0	25	15	2.0	2.7	5.4	129.6	1.50
9	1992	39.3	21.6	20	10	0.0	1.1	5.5	132.0	1.52
10	1993	38.9	22.6	19	11	0.0	3.0	5.8	139.2	1.61
11	1994	38.8	22.5	30	16	25.8	0.9	5.0	120.0	1.38
12	1995	37.2	20.7	28	20	3.9	1.6	5.2	124.8	1.44
13	1996	40.5	23.0	22	14	0.0	1.2	5.6	134.4	1.55
14	1997	38.8	22.9	21	13	0.0	1.6	5.4	129.6	1.50
15	1998	39.3	22.0	18	12	0.0	0.7	5.8	139.2	1.61
16	1999	38.0	21.3	35	20	16.1	0.9	5.0	120.0	1.38
	AVEG:	**38.281**	**21.700**	**26.625**	**16.125**	**4.956**	**1.681**	**5.406**	**129.750**	**1.498**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **MAY** Height above M.S.L. - **302 M.**

Latitude : 77^{0} 46 ' E Latitutude : 22^{0} 46 ' N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	40.4	25.1	34	24	16.5	2.7	6.9	165.6	1.91
2	1985	40.7	24.8	38	20	14.1	2.5	7.1	170.4	1.97
3	1986	40.3	24.9	30	17	2.9	2.3	6.7	160.8	1.86
4	1987	40.7	23.7	34	15	8.5	1.5	7.0	168.0	1.94
5	1988	39.8	24.8	27	18	1.0	1.8	7.2	172.8	2.00
6	1989	40.2	25.2	37	17	0.0	1.3	6.9	165.6	1.91
7	1990	41.1	24.6	27	12	0.0	0.3	7.1	170.4	1.97
8	1991	40.1	24.1	24	10	0.0	0.7	6.8	163.2	1.88
9	1992	40.9	25.3	26	11	0.0	2.4	7.3	175.2	2.02
10	1993	41.6	26.4	33	19	1.8	1.8	7.0	168.0	1.94
11	1994	39.3	24.9	42	22	14.0	1.6	6.9	165.6	1.91
12	1995	40.9	24.8	33	17	6.4	2.7	7.1	170.4	1.97
13	1996	42.1	26.8	31	13	5.0	0.9	7.2	172.8	2.00
14	1997	40.0	25.1	33	20	4.2	1.9	6.8	163.2	1.88
15	1998	40.7	26.0	31	15	2.8	1.7	7.0	168.0	1.94
16	1999	40.5	25.7	43	24	12.2	0.8	6.9	165.6	1.91
	AVEG:	**40.581**	**25.138**	**32.688**	**17.125**	**5.588**	**1.681**	**6.994**	**167.850**	**1.938**

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CLIMATOLOGICAL DATA

Station : HOSHANGABAD Month : JUNE Height above M.S.L. - **302 M.**

Latitude : 77^0 46 ' E Latitutude : 22^0 46 ' N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	37.1	24.9	63	42	29.8	4.2	7.7	184.8	2.13
2	1985	37.8	26.1	57	32	13.2	4.4	7.9	189.6	2.19
3	1986	37.3	25.1	64	42	141.7	5.7	7.5	180.0	2.08
4	1987	37.4	24.4	56	39	114.6	4.8	7.8	187.2	2.16
5	1988	38.2	25.8	59	36	45.7	4.1	8.0	192.0	2.22
6	1989	37.2	25.5	59	43	125.0	4.5	7.4	177.6	2.05
7	1990	37.3	25.2	61	43	105.3	4.6	7.5	180.0	2.08
8	1991	32.0	25.7	54	31	67.7	5.0	7.9	189.6	2.19
9	1992	39.1	25.6	56	34	21.7	5.3	7.7	184.8	2.13
10	1993	34.6	24.4	75	52	215.2	6.6	7.6	182.4	2.11
11	1994	32.7	23.6	81	59	195.2	6.4	7.8	187.2	2.16
12	1995	38.9	25.9	77	27	89.6	7.0	7.7	184.8	2.13
13	1996	36.5	25.5	61	42	62.0	6.3	8.2	196.8	2.27
14	1997	37.4	25.6	61	30	45.8	4.7	7.2	172.8	2.00
15	1998	35.6	25.4	64	47	129.9	4.7	7.8	187.2	2.16
16	1999	35.0	24.3	70	54	84.1	5.5	8.0	192.0	2.22
	AVEG:	**36.506**	**25.188**	**63.625**	**40.813**	**92.906**	**5.238**	**7.731**	**185.550**	**2.143**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **JULY** Height above M.S.L. - **302 M.**

Latitude : 77^{0} 46 ' E Latitutude : 22^{0} 46' N

S.No.	Year	Temperature in ^{0} c. Maximum	Temperature in ^{0} c. Minimum	Humidity % At 8.30 hrs	Humidity % At 17.30 hrs	Rainfall in the month (mm)	Cloud Cover in (oktas)	Wind speed in 24 Hrs (Km/hr)	Wind speed in 24 Hrs (Km/day)	Wind speed in 24 Hrs (m/sec)
1	1984	29.9	22.9	87	77	367.2	7.8	6.6	158.4	1.83
2	1985	31.2	23.4	82	72	239.9	6.8	6.4	153.6	1.77
3	1986	31.3	23.5	83	67	169.2	7.4	6.8	163.2	1.88
4	1987	30.2	22.1	86	70	511.7	7.3	7.0	168.0	1.94
5	1988	32.0	23.1	83	58	453.2	7.0	6.2	148.8	1.72
6	1989	33.5	24.2	76	59	270.2	6.6	6.6	158.4	1.83
7	1990	31.2	23.5	83	67	191.2	7.4	7.1	170.4	1.97
8	1991	31.1	22.9	85	73	511.8	7.6	7.2	172.8	2.00
9	1992	31.1	22.3	87	75	375.1	7.7	6.1	146.4	1.69
10	1993	33.1	22.9	82	67	453.4	6.7	6.0	144.0	1.66
11	1994	27.7	22.3	88	78	461.2	7.7	6.6	158.4	1.83
12	1995	32.0	23.3	81	66	112.0	6.3	6.6	158.4	1.83
13	1996	28.2	22.5	81	71	776.1	7.8	7.0	168.0	1.94
14	1997	30.5	23.1	84	71	447.6	7.1	6.2	148.8	1.72
15	1998	29.8	22.6	87	76	331.7	7.1	6.6	158.4	1.83
16	1999	31.7	23.3	85	70	358.7	6.5	6.9	165.6	1.91
	AVEG:	**30.906**	**22.994**	**83.750**	**69.813**	**376.888**	**7.175**	**6.619**	**158.850**	**1.834**

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CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **AUGUST** Height above M.S.L. - **302 M.**

Latitude : 77° 46 ' E Latitutude : 22° 46 ' N

S.No.	Year	Temperature in ° c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
				At	At					
		Maximum	Minimum	8.30 hrs	17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	29.5	22.9	88	78	308.5	7.6	5.8	139.2	1.61
2	1985	27.3	22.6	88	78	217.5	7.7	6.0	144.0	1.66
3	1986	28.7	22.8	91	81	531.3	7.5	6.2	148.8	1.72
4	1987	27.0	21.8	88	80	412.8	7.5	5.4	129.6	1.50
5	1988	31.4	22.5	83	64	132.7	6.1	5.6	134.4	1.55
6	1989	28.9	22.4	86	74	131.2	7.1	5.8	139.2	1.61
7	1990	28.2	22.1	90	80	219.9	7.8	5.6	134.4	1.55
8	1991	28.0	21.7	85	74	326.0	7.2	6.0	144.0	1.66
9	1992	28.1	21.4	88	79	569.9	7.1	6.4	153.6	1.77
10	1993	28.8	22.9	90	82	519.7	7.7	6.2	148.8	1.72
11	1994	29.0	22.4	87	80	210.0	7.7	5.2	124.8	1.44
12	1995	28.4	22.2	88	79	373.7	7.6	5.4	129.6	1.50
13	1996	28.7	22.6	90	80	767.0	7.6	5.8	139.2	1.61
14	1997	28.6	22.2	88	75	722.8	7.0	5.9	141.6	1.63
15	1998	29.3	22.8	88	79	440.5	7.4	5.7	136.8	1.58
16	1999	29.3	22.5	88	77	334.0	7.1	5.8	139.2	1.61
	AVEG:	**28.700**	**22.363**	**87.875**	**77.500**	**388.594**	**7.356**	**5.800**	**139.200**	**1.608**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **SEPTEMBER** Height above M.S.L. - **302 M.**

Latitude : 77^0 46 ' E Latitutude : 22^0 46 ' N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	27.8	21.9	93	83	767.7	7.8	4.5	108.0	1.25
2	1985	29.5	21.8	86	73	387.7	6.6	5.0	120.0	1.38
3	1986	30.4	21.0	78	61	154.2	4.8	4.4	105.6	1.22
4	1987	30.4	21.4	82	69	142.6	6.3	5.2	124.8	1.44
5	1988	31.1	21.0	76	55	98.5	4.1	4.7	112.8	1.30
6	1989	31.4	20.6	68	53	70.9	3.3	4.4	105.6	1.22
7	1990	29.4	21.0	80	65	189.0	5.5	4.7	112.8	1.3
8	1991	33.1	22.1	72	54	81.3	5.1	4.2	100.8	1.16
9	1992	30.1	20.9	84	70	161.0	5.8	5.0	120.0	1.38
10	1993	29.7	21.9	86	73	317.7	7.0	5.2	124.8	1.44
11	1994	30.2	20.8	79	66	254.5	5.1	4.3	103.2	1.19
12	1995	30.5	19.5	72	54	89.5	3.8	4.1	98.4	1.13
13	1996	28.2	21.8	88	78	213.6	6.8	4.4	105.6	1.22
14	1997	33.2	22.0	69	51	32.6	4.5	4.2	100.8	1.16
15	1998	29.7	22.0	83	72	335.0	5.9	4.3	103.2	1.19
16	1999	30.6	21.1	83	64	230.9	4.7	4.0	96.0	1.11
	AVEG:	**30.331**	**21.300**	**79.938**	**65.063**	**220.419**	**5.444**	**4.538**	**108.900**	**1.256**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **OCTOBER** Height above M.S.L. - **302 M.**

Latitude : 77^{0} 46' E Latitutude : 22^{0} 46' N

S.No.	Year	erature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	29.3	18.2	70	55	121.3	3.1	2.9	69.6	0.80
2	1985	30.4	16.0	45	32	0.0	1.4	3.1	74.4	0.86
3	1986	31.9	18.4	60	39	21.7	3.2	2.7	64.8	0.75
4	1987	32.4	18.3	51	35	0.3	2.4	3.0	72.0	0.83
5	1988	33.7	18.6	50	32	0.0	0.6	2.8	67.2	0.77
6	1989	34.8	18.8	38	24	0.0	1.5	2.9	69.6	0.80
7	1990	33.0	17.8	45	28	0.0	1.5	3.3	79.2	0.91
8	1991	31.7	16.7	54	27	7.2	1.7	2.5	60.0	0.69
9	1992	33.4	17.6	49	28	0.0	1.0	2.7	64.8	0.75
10	1993	32.3	18.2	54	36	9.1	0.9	3.1	74.4	0.86
11	1994	29.8	18.6	71	49	34.9	3.5	3.0	72.0	0.83
12	1995	32.2	17.5	53	37	1.9	3.3	2.8	67.2	0.77
13	1996	31.0	17.9	61	40	10.0	2.7	2.9	69.6	0.88
14	1997	31.2	19.4	67	54	84.2	3.8	2.5	60.0	0.69
15	1998	31.1	19.6	75	57	48.7	3.6	3.3	79.2	0.91
16	1999	33.8	18.8	45	29	0.4	1.0	2.9	69.6	0.80
	AVEG:	**32.000**	**18.150**	**55.500**	**37.625**	**21.231**	**2.200**	**2.900**	**69.600**	**0.806**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** — Month : **NOVEMBER** — Height above M.S.L. - **302 M.**

Latitude : 77° 46 ' E — Latitutude : 22° 46' N

S.No.	Year	Temperature in ° c. Maximum	Minimum	Humidity % At 8.30 hrs	At 17.30 hrs	Rainfall in the month (mm)	Cloud Cover in (oktas)	Wind speed in 24 Hrs (Km/hr)	(Km/day)	(m/sec)
1	1984	27.5	14.7	60	46	16.7	2.2	2.9	69.6	0.80
2	1985	27.3	14.2	44	33	2.0	2.4	3.3	79.2	0.91
3	1986	29.9	16.6	60	45	13.9	2.8	2.5	60.0	0.69
4	1987	27.2	12.0	39	28	0.0	2.0	2.9	69.6	0.88
5	1988	29.9	14.7	52	39	0.0	1.4	2.8	67.2	0.77
6	1989	29.1	16.2	56	42	49.0	2.9	3.0	72.0	0.83
7	1990	30.4	14.9	43	27	0.0	1.6	3.1	74.4	0.86
8	1991	27.2	12.8	42	30	0.0	2.2	2.7	64.8	0.75
9	1992	29.3	16.4	58	43	100.5	4.1	2.5	60.0	0.69
10	1993	28.6	11.9	39	25	0.0	0.4	3.3	79.2	0.91
11	1994	28.4	12.8	48	30	0.0	1.5	2.9	69.6	0.80
12	1995	29.1	13.8	59	41	0.5	0.9	2.8	67.2	0.77
13	1996	28.4	12.6	45	27	0.0	0.4	3.0	72.0	0.83
14	1997	28.2	11.8	46	33	0.0	0.3	2.7	64.8	0.75
15	1998	27.8	11.6	49	32	0.0	0.6	3.1	74.4	0.86
16	1999	28.6	12.2	61	48	0.0	3.2	2.9	69.6	0.80
	AVEG:	28.556	13.700	50.063	35.563	11.413	1.806	2.900	69.600	0.806

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **DECEMBER** Height above M.S.L. - **302 M.**

Latitude : $77^0 46'$ E Latitutude : $22^0 46'$ N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	23.9	9.3	53	37	0.0	2.3	3.7	88.8	1.02
2	1985	25.4	11.7	65	44	14.7	3.6	4.0	96.0	1.11
3	1986	25.9	10.9	55	34	3.9	2.9	4.2	100.8	1.16
4	1987	26.3	10.2	46	30	0.0	0.5	3.2	76.8	0.88
5	1988	25.2	11.1	62	47	34.7	2.5	3.4	81.6	0.94
6	1989	25.9	10.3	49	31	0.0	1.8	3.9	93.6	1.08
7	1990	25.3	14.9	83	62	134.5	5.2	3.5	84.0	0.97
8	1991	26.4	10.5	45	30	0.0	1.2	3.7	88.8	1.02
9	1992	25.2	10.5	53	34	0.0	2.4	3.8	91.2	1.05
10	1993	26.6	9.8	46	26	0.0	0.2	3.6	86.4	1.00
11	1994	25.0	8.1	51	29	0.0	0.9	4.0	96.0	1.11
12	1995	26.6	11.6	59	36	2.1	1.8	4.1	98.4	1.13
13	1996	23.7	11.1	65	46	41.3	3.1	3.3	79.2	0.91
14	1997	25.1	9.7	57	38	0.0	1.6	3.4	81.6	0.94
15	1998	26.1	9.4	53	38	0.0	1.0	3.4	81.6	0.94
16	1999	26.0	9.5	65	45	0.0	1.0	4.0	96.0	1.11
	AVEG:	**25.538**	**10.538**	**56.688**	**37.938**	**14.450**	**2.000**	**3.700**	**88.800**	**1.023**