DESIGN OF SPRINKLER IRRIGATION SYSTEM FOR AN AREA AND ITS COST COMPARISON WITH THE CANAL IRRIGATION SYSTEM

Session 2019

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DEDICATION

Dedicated to all those who kept us going when we wanted to give up.

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Firstly, we are extremely grateful to Almighty Allah for the good health, knowledge, and strength to complete this project. He gave us courage and showed us the right path.

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Faria Ejaz

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ABSTRACT

The use of a water efficient method for irrigation is important as it has become necessary to save the scarcely available water and irrigate more area, especially in a country like Pakistan where the water resources are becoming insufficient and population is growing enormously with a huge need of water resources. therefore, sprinkler irrigation system is considered one of the most water saving system as it can be considered as an alternative option of canal irrigation system. In the current study, sprinkler irrigation system for a particular area is designed and its cost comparison is done with the already existing canal irrigation system. The area selected was Shaffi distributary of Pakpattan main canal originating from upper Chenab. The culturable command area was 3040 acres with an already existing canal irrigation system for the area. The current study is based on the estimation of crop water requirement which came out to be 1440.3 mm for Rabi season,4294.6 mm for Kharif season and the design discharge of 29.80 cusecs considering the cropping pattern. Similarly, taking the main components canal irrigation system and the cost of material by standard market rates, the cost of canal irrigation system has been calculated. Then, sprinkler irrigation system was designed considering the various components like main line, sub mains, laterals, sprinklers, pumps etc. and the results of the design show that design of sprinkler irrigation system requires 48 pumps for the total area, water will be taken via lift irrigation. The diameter of main is 3”, sub main is 2” and lateral is1.5”.There are 6 sprinklers per acre. The cost was estimated for the sprinkler irrigation system as well, which is higher than the canal irrigation system but water saving is much more than canal irrigation system so in this way it can be used for preserving water.

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CHAPTER 1

INTRODUCTION

The introduction includes basic definitions and types of irrigation systems. The characteristics of our study area have been mentioned. Further, the need of study of this research and scope is mentioned. Also, a brief discussion on the utilizations and limitations is also included.

1.1 BACKGROUND OF PROJECT

Pakistan has severe water shortage issues, especially in dry and semi-arid areas. Comparing sprinkler systems to conventional flood irrigation or canal systems, the former offer a more efficient use of water. By lowering evaporation, runoff, and deep percolation, they can aid in water resource conservation by ensuring that the available water is utilized efficiently. Sprinkler systems give farmers the ability to expand the types of crops they can grow and increase agricultural output. A greater variety of crops, including fruits, vegetables, and high-value commercial crops, can be grown with more controlled and exact water application. As a result, food security is improved and agricultural variety is encouraged. Flood irrigation is one of the traditional irrigation techniques that can cause soil erosion and deterioration. Conversely, sprinkler systems reduce soil erosion and runoff by applying gentle water pressure. This contributes to sustainable agricultural practices by preserving soil fertility, minimizing nutrient loss, and preserving soil structure.

1.2 IRRIGATION

Irrigation is the art of applying water to the land by artificial means to fulfill the water requirement of crops in the areas where rainfall is insufficient.

1.2.1 Advantages of irrigation

The main advantages of irrigation are:

- More food can be produced.
- Jobs can be created.
- Better environment / greenery can be produced.
- Hydel power generation can be done.
- Floods can be controlled.

1.2.2 Disadvantages of irrigation

The main disadvantages of irrigation are:

- Water logging can occur.
- Salinity can be produced.
- It causes humid environment near reservoir.

1.2.3 Methods of irrigation

Irrigation can be done by following methods:

- Drip irrigation system
- Canal irrigation system
- Sprinkler irrigation system

1.2.4 Drip irrigation system

Drip Irrigation drops water onto the soil at very low rates (2-20 liters/hour). Water is only applied onto soil close to plant roots so only that part of soil is wetted which is close to the root. Drip irrigation is most favorable for vegetables and soft fruits. Generally, very high value crops are considered for drip irrigation because of high cost. Drip irrigation is adaptable to any farmable slope. Normally the crop would be planted along contour lines and the water supply pipe. This is done to minimize changes in emitter discharge as a result of land elevation. Drip irrigation is suitable for all soils. For clay soils water applied slowly to avoid surface runoff. In sandy soils water discharges in higher rate to adequate the lateral wetting of the soil. The main problem with drip irrigation is blockage of emitters because emitters are of very small size. So, water must be free of sediments and must use clean water for drip irrigation. The water savings that can be made using drip irrigation are the reductions in deep percolation, in surface runoff and in evaporation from the soil. These savings, it must be remembered, depend as much on the user of the equipment as on the equipment itself. In the figure 1.1 process of drip irrigation ins shown. Drip irrigation is not a substitute for other proven methods of irrigation. It is just another way of applying water. It is best suited to areas where water quality is marginal, land is steeply sloping or undulating and of poor quality, where water or labor are expensive, or where high value crops require frequent water applications.

Figure 1.1. Drip Irrigation System

Figure 1.1 shows the application of drip irrigation system and shows that how water can be delivered to plants in small drops.

1.2.5 Advantages of drip irrigation system

The benefits of drip irrigation system are:

- High water application efficiency and lower labor costs
- Minimized fertilizer/nutrient loss due to localized application and reduced leaching
- Ability to irrigate irregular shaped fields. Levelling off the field is not necessary
- Allows safe use of recycled (waste-) water
- Moisture within root zone can be maintained at field capacity and minimized soil erosion
- Soil type plays less important role in frequency of irrigation
- Highly uniform distribution of water i.e., controlled by output of each nozzle
- Usually operated at lower pressure than other types of pressurized irrigation, reducing energy costs

1.2.6 Disadvantages of drip irrigation system

The drawbacks of drip irrigation system are:

- Expensive initial cost can be more than overhead systems (commercial system) The sun can affect the tubes used for drip irrigation, shortening their usable life

- If water is not properly filtered, equipment not properly maintained, it results in clogging
- Drip irrigation might be unsatisfactory if herbicides or top dressed fertilizers need sprinkler irrigation for activation
- Waste of water, time & harvest, if not installed properly
- Systems require careful study of all the relevant factors like land topography, soil, water, crop and agro-climatic conditions, and suitability of drip irrigation system and its components
- Without sufficient leaching (most drip systems are designed for high efficiency, meaning little or no leaching fraction), salts applied with the irrigation water may build up in the root zone

1.3 RESEARCH OBJECTIVES

The canal is an artificial waterway constructed to allow the passage of boats or ships inland or to convey water for irrigation, power generation, etc.

1.3.1 Types of canals

There are 6 types of canal-based on various factors

- Based on the financial output
- Based on discharge
- Based on canal alignment
- Based on the nature of the supply source
- Based on functions
- Based on the type of boundary surface

1.3.2 Based on discharge

1.3.2.1 Main canal

Water in the main canal takes off directly from a river or reservoir. Main Canal feeds the branch canals. Due to the conveying of more discharge through the main canal, it is not suggested to do direct irrigation from it.

1.3.2.2 Branch canal

Water in the branch canal takes off from the main canals at regular intervals.

1.3.2.3 Major distributary canal

Water in Major Distributary Canal takes off from the branch canal or in few cases from the main canal.

1.3.2.4 Minor distributary canal

Water in Minor Distributary Canal takes off from major distributaries and directly from branch canals depending upon the discharge of canals.

1.3.2.5 Field channels

Field channels are small water channels that are excavated by cultivators in the irrigation field. It is also called watercourses. These channels are feed by the distributary canals and branch canals through canal outlets.

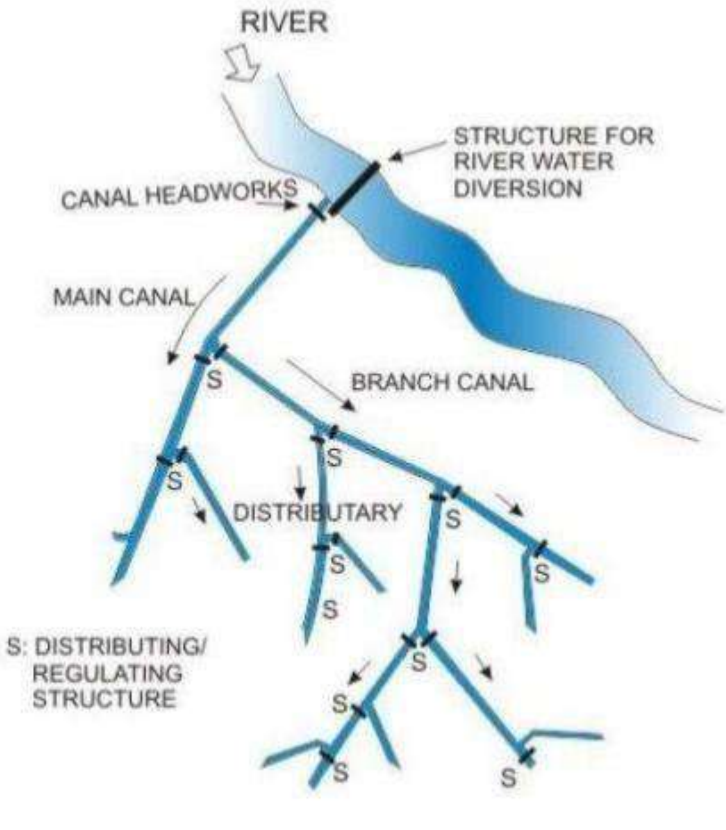


Figure 1.2. Irrigation Network

Figure 1.2 shows types of network of canal system and shows different types of canals based on discharge and different components of canal system.

1.4 CANAL IRRIGATION SYSTEM

Irrigation canal is an artificial channel that is the main waterway that brings irrigation water from a water source to the area to be irrigated. In the figure 1.2 canal irrigation system is shown. Canals are classified into different types based on factors such as nature of supply source, functions, type of boundary surface, financial output, discharge capacity and alignment of the canal as shown in the figure.1.3.

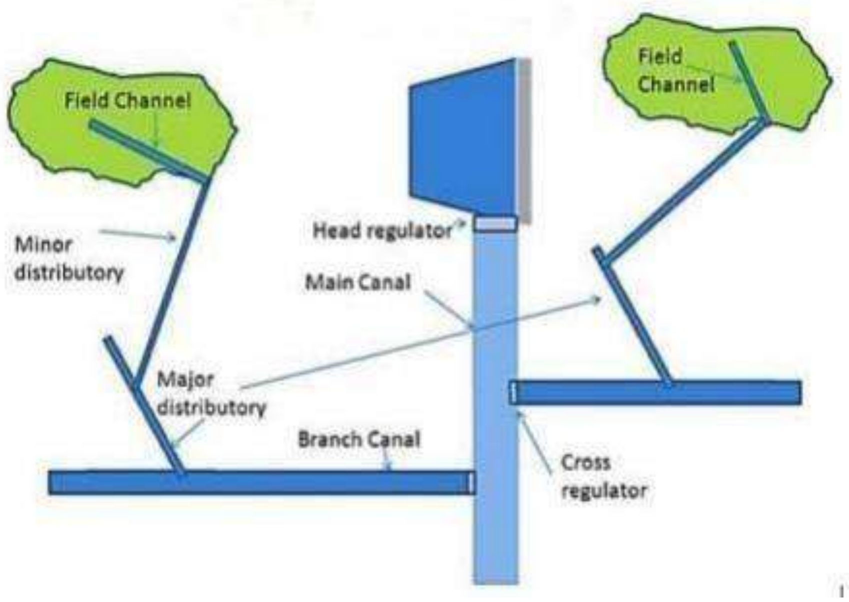


Figure 1.3. Canal Irrigation System

Figure 1.3 shows different types of canals and different structures to regulate canal and river water to regulate discharge.

1.4.1 Advantages of canal irrigation system

The main advantages of canal irrigation system are:

- Un-irrigated wastelands can be developed by canal irrigation, which would increase the quantity of biomass in the area.
- Economic development can be expedited by avoiding dangerous droughts. Dependence on rainfall can be minimized through canal development.

- Canals are fed by rain water received by rivers, and the water is used for irrigation. Production of crops needing more water is also possible through canals. As compared to un-irrigated soils, higher productivity per hectare is also possible due to canals.
- Canal system is a permanent structure, hence only maintenance is required for getting its benefits for a long time.
- Canals are multi-purpose where apart from irrigation hydro electricity generation, navigation, drinking water supply and fishery development is also done.
- Groundwater level does not go down on account of canal irrigation, but on the contrary water level increases, which facilitates digging of wells.
- Canals are also becoming a source of tourist attraction these days.

1.4.2 Disadvantages of canal irrigation system

The main drawbacks of canal irrigation system are:

- Due to imbalance in distribution of canal water, a situation of scarcity somewhere and water logging in other areas is caused due to collection of water there. It makes the soil unproductive as harmful underground salts and alkalis come to the surface level due to water logging. Land can also become marshy there.
- Many diseases are caused due to spread of mosquitoes, worms and insects on account of stationary water in canals.
- Sometimes efficient canal management results in excessive production of crops, due to which the farmers are not able to get suitable price for their product in the market.
- Due to shortage of water in inundation canals, crops are destroyed for want of water for irrigation.
- Regular maintenance of canals is not done, due to which sediments are collected resulting in reduction of capacity of canals.
- Due to excessive economic investment, it is not practicable to provide canal irrigation to all areas. Construction of canals also takes more time.
- Many types of social evils are generated in canal areas. Sometimes, disputes arise for water distribution etc. resulting in murders and throwing of dead bodies by the bank of a canal.

1.5 SPRINKLER IRRIGATION SYSTEM

The application of irrigation water which is distributed through system of pipes usually by pumping. Water is sprayed into air in the form of droplets and thus falls on crops and ground in a uniform way.

Figure 1.4. Sprinkler Irrigation System

Figure 1.4 shows a sprinkler irrigation system in wheat crop

1.5.1 Advantages of sprinkler irrigation system

Fertilizer application is more easy and there are less chances of leaching away

- There is no loss of productive land area. As high as 16 percent area can be loss in making of earthen conveyance channels and irrigation levees. Mechanical equipment can be used.
- Soil erosion chances eliminated
- The problem of soil salinity can be controlled. It encourages connective as well as diffusive transport of salts from soil.
- Sprinkler irrigation system minimizes loses such as runoff, deep percolation and conveyance losses. Seepage losses which are high as 35% in earthen channels are eliminated in sprinkler irrigation. If available water is expensive and less water is available, then sprinkler technology might helpful. With the help of sprinkler irrigation system, the irrigation land can be increases up to 1.5% as compared to surface irrigation. Over irrigation is completely eliminating with the help of sprinkler irrigation.

- Surface irrigation method depend on well-prepared land and stabilized diches (channels). Proper channels are necessary but in case of sprinkler no proper levelling is required and suitable to any type of land available. With the help of sprinkler irrigation micro-organisms work to their maximum extent and as a result soil fertility is improved. Insects and pests are discouraged duo to frequent sprinkler irrigation.
- Sprinkler irrigation minimize labor costs and very easy to manage. It is one man job to dismantle and remove the equipment from one place to another. It does not require same labor as canal irrigation required.
- For uniform water application no leveling required due to this the top fertile layer is not affected. Respectively due to canal irrigation the top layer effected due to leveling operation.
- The fertilizers and chemicals required are injected in main pipes so fertilizers are easily applied to the plants. In this way, the two operations mainly irrigation and fertilization are done simultaneously with the help of sprinkler irrigation.

1.5.2 Disadvantages of sprinkler irrigation system

- High therefore recommended for cash crops
- Local pump industry producing pump at a cost of around 10000 per acre for system not less than5 acres. The UV stabilized pipes of black carbon polythene cost 50 percent less than galvanized pipes. Out of reach of farmers until rouni (after harvesting the wheat crop the field is first irrigated artificially and then the rice seeds are sown) irrigation is linked.
- This sprinkler system is not suitable for crops having high requirements of water as rice and sugarcane. This system is designed to be lower than the infiltration rate of soil. Thus water does not infiltrate as it reaches the soil surface.
- Saline irrigation water damages the leaves of crops salts are deposited on leaves as water evaporates in continuous wetting and drying cycles of sprinkler leaving only salts deposition on leaves
- Unavailability of design components of the physical system.
- Lack of proper machinery and poor quality material availability in local areas of market
- Skilled labor is not available

- Modern technology usage is not so much adapted by the designers. proper education is needed for designing efficient systems

1.6 OBJECTIVES

1. Estimation of crop water requirement for an area
2. Cost estimation of already existed canal using current market rates
3. Design of sprinkler irrigation system and its approximate cost
4. Cost comparison of canal and sprinkler irrigation system

1.7 STUDY AREA

We selected a canal (Shafi Distributary) in district Pakpattan, Punjab. Our project is basically design of sprinkler irrigation system for that command area which is served by Shafi Distributary. After the design of sprinkler system we have estimated its cost and checked whether we can replace the sprinkler system with canal system.

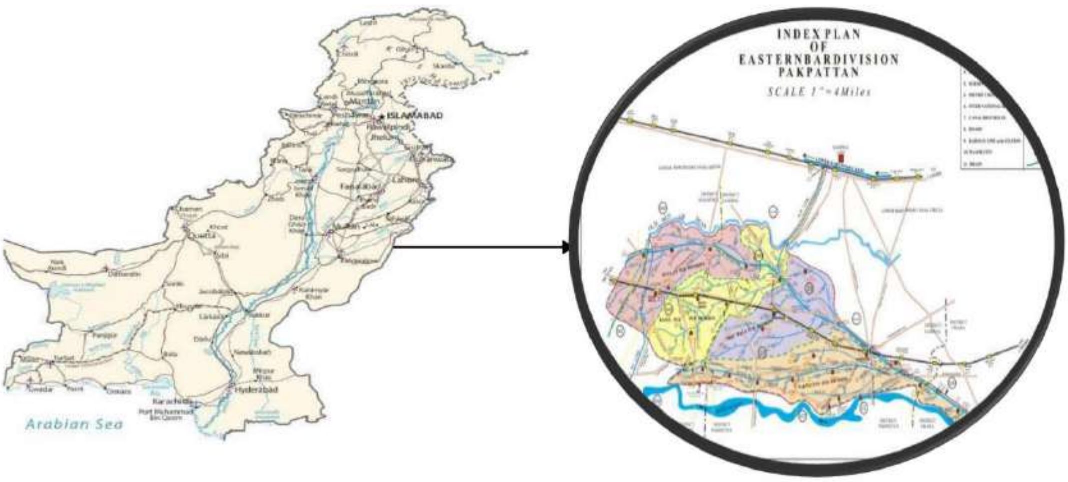


Figure 1.5. Map of Pakistan and Index Plan of Eastern Bar Division Pakpattan

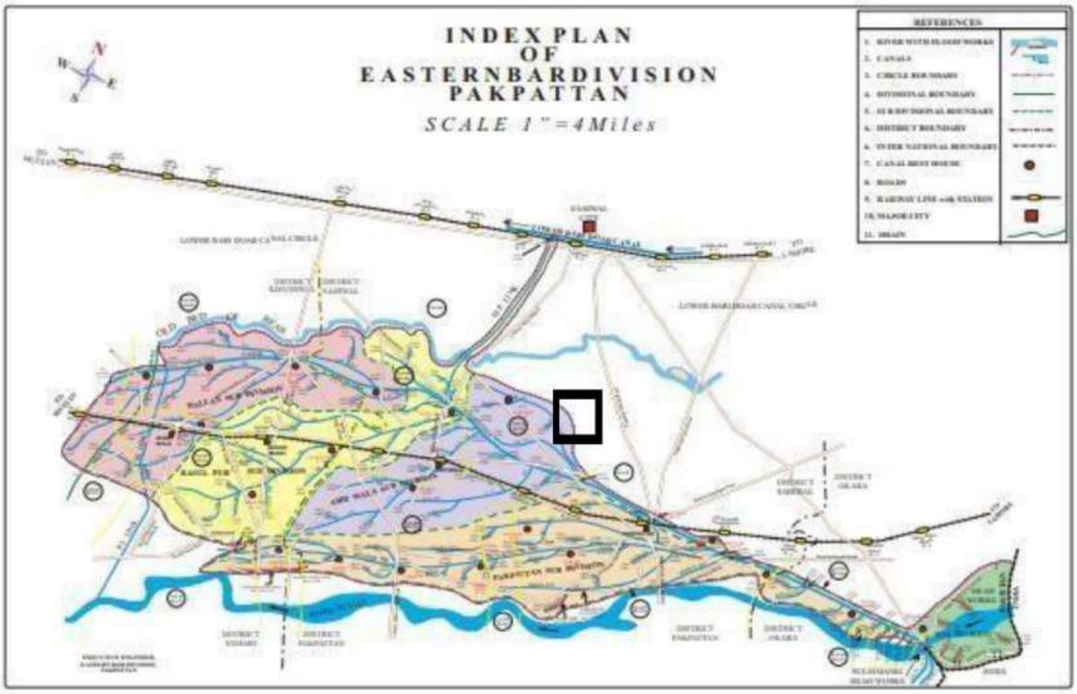


Figure 1.6. Enlarged View of Index Plan Of Eastern Bar Division Pakpattan

The map of Pakistan and index plan of eastern bar division Pakpattan is shown in the figure1.5. The figure 1.6. shows the enlarged view of index plan of eastern bar division Pakistan.

The different parameters of Shaffi distributary are shown in the table 1.1.

Table 1.1. Detail of Shafi Distributory Data

Name of Channel	**Shaffi Distributary**
Sub-division	Arifwala
Section	Pakpattan
District	Pakpattan
Tehsil	Arifwala
Latitude	30.67
Longitude	73.2
Elevation	565 feet
Authorized Discharge	10 Cs.
Off-taking RD	200818 P.C.
Tail RD	9730

Length	1.95 Miles
Gross Command Area	3155 Hectares
Culturable Command Area	3050 Hectares
No. of outlets	8
No. of Tail Outlets	3
Designed Tail Gauge	1

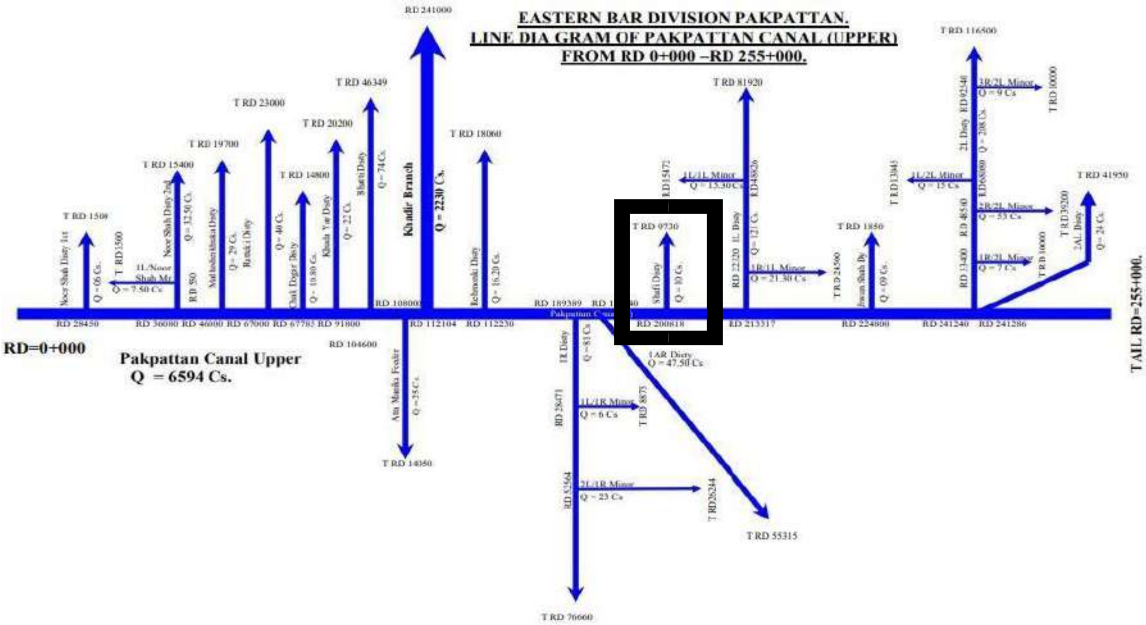


Figure 1.7. Map of Distributaries and Minors with their Respective RD

The map of distributaries and minors along with their respective running distances is shown in the figure 1.7.

1.7.1 Cropping pattern

The cropping pattern for rabi season is shown in the table 1.2.

Table 1.2. Cropping Pattern For Rabi Season

Rabi Season								
Sr. No.#	**Crop Type**	**Kc Initial**	**Kc Mid Season**	**Kc Late**	**Etc (mm/day)**	**Etc(mm)**	**Crop Percentage (%)**	**Area (Acres)**

1	Wheat	0.3	1.15	0.3	10.21	477.5	52.625	1630.32
2	Potatoe	0.5	1.15	0.75	12.15	547.75	24.375	755.13
3	Barley	0.3	1.15	0.25	8.79	415.05	12.625	391.12

The cropping pattern of kharif season is shown in the table.1.3.

Table 1.3. Cropping Pattern for Kharif Season

Kharif Season								
Sr. No. #	**Crop Type**	**Kc Initial**	**Kc Mid Season**	**Kc Late**	**Etc (mm/day)**	**Etc(mm)**	**Crop Percentage (%)**	**Area (Acres)**
1	Cotton	0.35	1.2	0.6	13.17	1033.9	1	30.98
2	Sugarcane	0.4	1.25	0.75	9.769	1855.26	1	30.98
3	Maize	0.3	1.2	0.35	10.32	495.25	38.5	1192.73
4	Rice	1.05	1.2	0.9	13.718	609.7	30.75	952.635
5	Millet	0.3	1	0.3	7.39	300.05	101	3128.98

1.8 SCOPE OF STUDY

- The scope of the current study includes estimation of crop water requirement by CropWat.
- The cost estimation of the existing canal system considering its various components and using the MRS 1st BI-ANNUAL-2023 of Pakpattan district.
- The design of sprinkler irrigation system including the main, submain laterals, pumps etc.
- The cost estimation of the sprinkler irrigation system.

1.9 PROBLEM STATEMENT

According to the United Nations**,** water scarcity already affects every continent. Water shortages have drawn the attention of the development community to the necessity of achieving more efficient use of limited water resources, especially in agriculture to increase crop production and to achieve global food security in a sustainable way. Pakistan is an agricultural country which is facing severe shortage of water. According to PCRWR, Pakistan will reach a level of absolute scarcity by 2025.So, there are efforts needed to put in the field of agriculture to develop efficient ways of irrigation .For this purpose ,a sprinkler irrigation system would be designed for the Shaffi distributary in Pakpattan to check the economy and feasibility of replacing the canal irrigation system with sprinkler irrigation system.

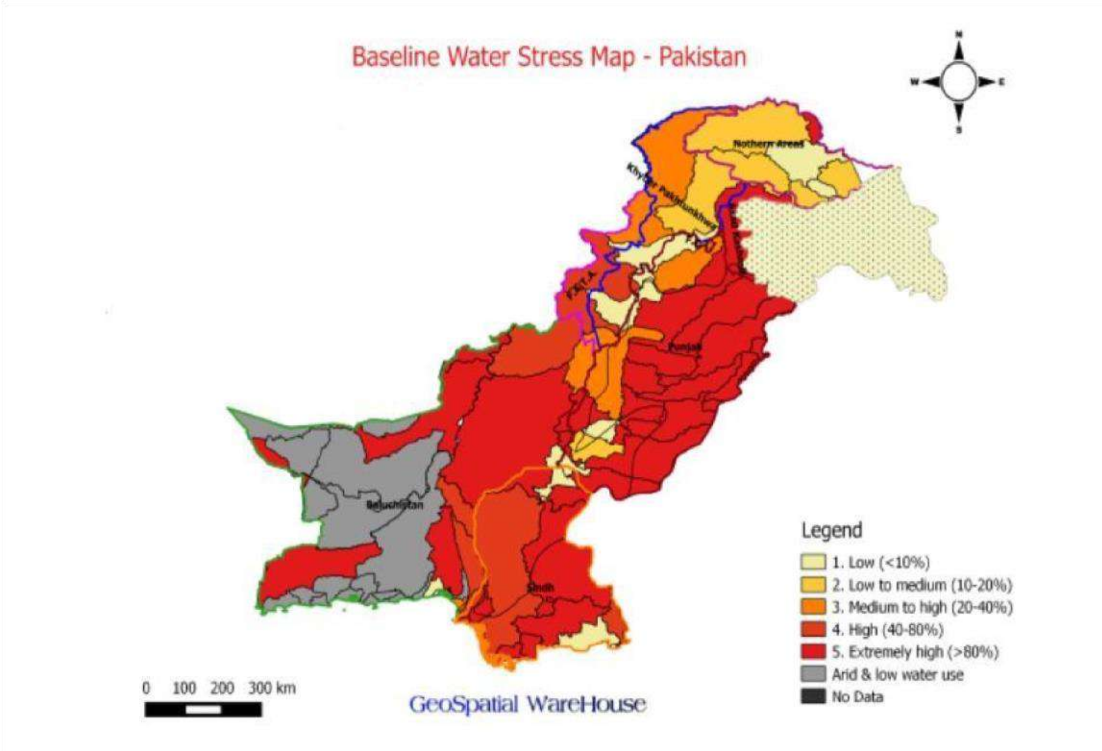


Figure 1.8. Baseline Water Stress Map of Pakistan

The baseline water stress map of Pakistan is shown in the figure 1.8.

1.10 UTILIZATION OF STUDY

An efficient system can be developed for irrigation purposes using this study keeping the losses to be minimum. The data was collected from meteorological department as well as the Punjab Irrigation department. This data was further analyzed and used in the crop evapotranspiration calculation from the Crop wat software. The necessary data necessary for Pakpattan distributary was collected from the gauging stations and relevant departments.

1.11 ORGANIZATION OF THESIS

Chapter 1 describes the introduction of irrigation systems, research objectives, study area, scope of study, need of the study, different utilizations and limitations.

Chapter 2 presents the literature review on the design of sprinkler irrigation system, cost efficiency of canal irrigation system, various case studies of canal and sprinkler irrigation researches etc.

Chapter 3 highlights the methodology adopted for the design of sprinkler irrigation system and the cost comparison of canal and sprinkler irrigation systems.

Chapter 4 includes the major results and discussions of the design as well as the cost estimations of canal and sprinkler irrigation systems.

Chapter 5 presents the conclusions and recommendations based on the research and results of project.

CHAPTER 2

LITERATURE REVIEW

This particular area includes the study of various case studies, research papers and articles related to canal and sprinkler irrigation systems, their designs, advantages and disadvantages and the cost as well.

(Waqar A. et al., 2009/2010-2010/2011) conducted a study to evaluate the water use efficiency and economic viability of sprinkler irrigation system for growing Wheat crop. The treatments consisted of two sprinkler irrigation systems, solid set sprinklers (S_1) and hand move laterals (S_2), and three irrigation frequencies (IF_1: once per week; IF_2: twice per week, IF_3: three times per week). Total irrigation amount values varied from 3924.373 to 4081.3 m^3 ha^{-1} in 2009-2010 and 4313.6 to 4486.2 m^3 ha^{-1} in 2010-2011. In 2009–2010, the total irrigation volume ranged from 3924.37 to 4081.3 m3 ha-1, while in 2010–2011, it ranged from 4313.6 to 4486.2 m3 ha^{-1}. The S2IF3 treatment produced the maximum seasonal ET (5417.1 m3 ha^{-1}), while the S1IF1 treatment produced the lowest value (4513.0 m3 ha^{-1}) in 2009-2010. The largest grain yield, on average, came from the S1IF3 treatment (5832.5 kg ha^{-1}), while the lowest grain yield came from the S2IF1 treatment. Thus, the findings indicated that the maximum value of net revenue happened under a solidly designed sprinkler irrigation system and irrigation frequency. The recommended sprinkler system and irrigation frequency for winter wheat in the ElNubaria are solid set sprinkler (S1) and irrigation three times per week (IF3).[1]

(Aqeel A. et al., 2015)) carried the research to estimate the water saving by sprinkler irrigation system in Iraq area. The simulation models have been utilized in this research for two specific areas inside the Maysan and Wasit provinces in Iraq, which have been taken as a case study to redesign and replace the current open channels network with sprinkler system. As a result, the planned sprinkler system may be utilized to water several crop kinds, including wheat, barley and corn. Through the use of the software Epanet and CROPWAT to estimate water needs. Based on comparisons, the conclusions drawn were that due to the usage of sprinkler irrigation systems rather than surface irrigation systems, the agricultural area was extended by at least 25% and the designed sprinkler system capacity in the study was 113m3/hr. Designs were created to take into account the worst case scenarios, which included places with relatively high wind speeds that impaired the uniformity of water distribution, sluggish soil infiltration rates, and high irrigation water requirements for plants. (Zhoa X. et al., 2015) performed an experiment to investigate how well smartphones performed as a dynamic testing tool for cable-type constructions.[2]

(Gal et al., 2009) in Morocco and in the oasis area in Southern Tunisia suggests that appropriate relationship between irrigated schemes, farms and agro food processors can be effective for improving food productivity. In general, if the canal water supply is inadequate, groundwater use is comparatively higher. Additionally, this issue has been researched in the Algerian-Mitidja and Morocco, respectively, by (Imache et al., 2009) and (Bekkar et al., 2009). They claim that the surface irrigation system only supplies a small percentage of the irrigation water needed by farmers, who primarily rely on groundwater.[3]

(Ghumman et al., 1990) concluded that the system is not self-sustaining because only 77.7% of the cost is recovered in the form of Abiana compared to the system's overall distribution cost. The yield of the wheat crop is 16.79% higher at the head than the tail. Due to the utilization of expensive groundwater, the rice crop output at the head is also higher than that at the tail.[4]

In 2018, the agricultural mechanization research institute Faisalabad used a mobile sprinkler rain gun for the Chickpea crop and as a result this system saved 72% water with higher yield output in crop and 67% amount was less consumed in the operational costs. Hence the sprinkler rain gun was found effective than canal irrigation.[5]

(Dhawan B.D. et al., 1992) observed due to significant inefficiencies in project implementation and canal operating, canal irrigation is an expensive endeavor. In terms of fixed and variable costs, the nation spent Rs. 2,277 in 1992–1993 to irrigate one agricultural hector with canal water. Only 5% of this expense was recovered by farmers through irrigation fees. The following three items made up the unit cost of large-scale irrigation on a per-hectare basis. Interest costs make up the greatest single component of the canal irrigation cost structure, as is to be expected. This averaged Rs 1,179 for 1992–1993. As a result, the cost of interest was more than half of the unit price of canal irrigation. What's more alarming is that, even accounting for price inflation, the marginal cost of canal irrigation has recently tended to increase by 8% annually. With the use of National Accounts Statistics, the so-called White Paper of the Central Statistical Organization, the author has estimated the variable and fixed costs of such irrigation. The widely endorsed idea that farmers must pay a canal fee that supports:

1. Variable cost of canal operation.
2. One percent of capital cost of developing canal irrigation would meet the above criteria for the users' fee provided the cost. As against the desired tariff of Rs 1,100 per hectare Indian farmers hardly paid Rs 151 per hectare during 1992-93. This is the evidence of raising canal rates by a factor of seven. Unless the irrigation planners can convincingly demonstrate that the rise in marginal cost of developing new canal irrigation is wholly due to genuine causes, notions of high corruption in canal irrigation would continue to persist in public mind.[6]

(Ghani A. et al., 1990) wrote article related to problems and potentials of Sprinkler Irrigation System in Pakistan. According to them water is scarce in both rainfed and most irrigated areas of Pakistan. The irrigated areas in the country have mostly a thin fresh groundwater layer underlain by brackish water. The limited water supply in both rainfed and irrigated areas could be efficiently utilized by sprinkler irrigation system. Irrigation efficiency for sprinkler system could be improved to 85%. Sprinkler irrigation system increases crop yield, reduces labor cost, require no leveling, eliminate soil erosion, provide crop cooling and frost control. Sprinkler irrigation system is feasible option in Pakistan but however its introduction requires local manufacturing to reduce the cost. The main problems adopting sprinkler irrigation system includes high initial investments, non-availability of its components, material quality, lack of proper expertise for its design, installation and maintenance costs. The private sector in collaboration with government sector could provide a breakthrough for the wide-scale adoption of sprinkler irrigation system and could play an effective way in solving the problems related to sprinkler irrigation system.[7]

(Zakari et al., 1999) proposed a study for the design, construction and installation of sprinkler system. The designed was based on using a rotating sprinkler irrigation system. The size of the plot was small and proper water scheduling was adopted. The study was conducted for four crops but tomato was considered with irrigation interval of five days. A sprinkler system to suit the conditions of a particular site is especially designed to achieve high efficiencies in its performance and economy. The required discharge of the sprinkler was determined from Michael (1995). The system designed has net irrigation requirement of 36.58mm, gross irrigation requirement of 56.28mm, irrigation interval of five days and time required per irrigation is 1.05 hours. The results revealed that there was an equal discharge of 2.144 lit/sec on each sprinkler which can be used to determine the total discharge of the system. Zakari et al. recommended that benefit-cost analysis between sprinkler and other system was carried out before the installation of the system. (Singh et al., 2019) provides an overview of the design considerations for sprinkler irrigation systems. It discusses factors such as field size, crop type, soil characteristics, water source, and topography. The review also explores different design parameters, including sprinkler head selection, spacing, pipe sizing, and pressure requirements.[8]

(Anjum et al., 2017) compares the design, performance, and cost aspects of sprinkler and canal irrigation systems. It analyzes the water distribution efficiency, water savings, crop yield, and overall cost-effectiveness of both systems. The review also considers factors such as water availability, land suitability, and operational requirements.[9]

(Hassan et al., 2020) compares the design and performance of sprinkler irrigation systems with conventional flood irrigation systems. It evaluates elements including agricultural production, soil moisture distribution, water use efficiency, and energy needs. The economic components of the study are also taken into account, including installation and operating costs.[10]

(Tuncer et al., 2017) provides an economic analysis of sprinkler irrigation systems in agriculture. It examines the investment costs, operational costs, and potential benefits, such as increased crop yield and water savings. The study also considers the payback period and cost-effectiveness of sprinkler systems compared to other irrigation methods.[11]

2.1 SPRINKLER IRRIGATION SYSTEM

Application of irrigation water which is distributed through system of pipes usually by pumping. Water is sprayed into air in the form of droplets and thus falls on crops and ground in a uniform way.

2.1.1 Suitable crops

It is suitable to most row, field and tree crops but large sprinklers are not recommended in case of delicate crops such as lettuce as it can result in their damage.

2.1.2 Suitable soils

Sandy soils with high infiltration rates (however adaptable to most soils).

2.1.3 Application rate (mm/hr.)

The average application rate from the sprinklers is always chosen to be less than the basic infiltration rate of the soil so that surface ponding and runoff can be avoided. Sprinklers are not suitable for soils which easily form a crust.

2.1.4 Suitable irrigation water

- Good supply of clean water
- Water should be free of suspended sediments as it can cause nozzle blockage along with the coating of plants with sediments

2.1.5 Sprinkler system layout

A typical sprinkler irrigation system consists of the following components:

- Pump unit
- Mainline and sometimes sub mainlines
- Laterals
- Sprinklers

2.1.6 Pump unit

- The pump unit is usually a centrifugal pump
- It takes water from the source
- It provides adequate pressure for delivery into the pipe system

2.1.7 Mainline and sub-mainline

- The mainline - and sub mainlines - are pipes which deliver water from the pump to the laterals.
- In some cases these pipelines are permanent and are laid on the soil surface or buried below ground.
- In other cases they are temporary, and can be moved from field to field.
- The main pipe materials used include asbestos cement, plastic or aluminum alloy

2.1.8 Lateral

- The laterals deliver water from the mainlines or sub mainlines to the sprinklers.
- They can be permanent but more often they are portable and made of Aluminium alloy or plastic so that they can be moved easily.
- The lateral pipe is located in the field until the irrigation is complete.
- The pump is then switched off and the lateral is disconnected from the mainline and moved to the next location
- The lateral can be moved one to four times a day

2.1.9 Sprinkler

They are used to sprinkle water.

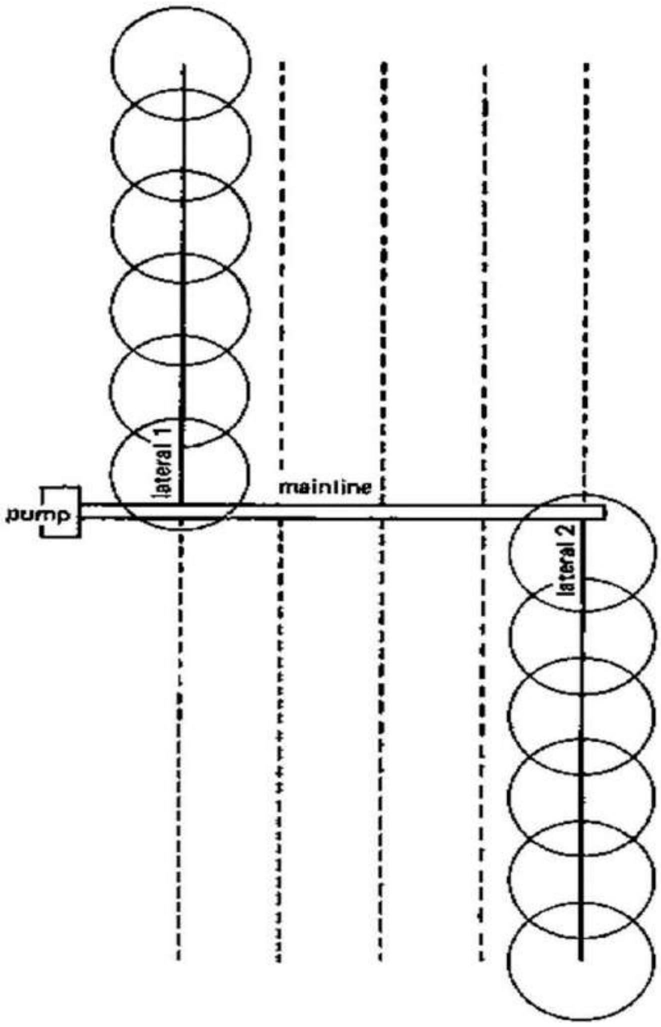


Figure 2.1. Components of Sprinkler System

The components of sprinkler system is shown in figure 2.

CHAPTER 3

METHODOLOGY

In methodology chapter, we are discussing that how we are going to proceed in our project and how are we going to analyze data. Basically, we are going to briefly discuss all the design parameters and methods in this chapter. A thesis' methodology part is crucial because it directs the research process, strengthens the study's validity and credibility, tackles ethical issues, and enables replication. A sound methodology offers a stable foundation for doing research, guaranteeing that the findings are solid, trustworthy, and add to the body of knowledge already known in a particular sector.

The flowchart shown in the figure 3.1. shows the methodology adopted for our project.

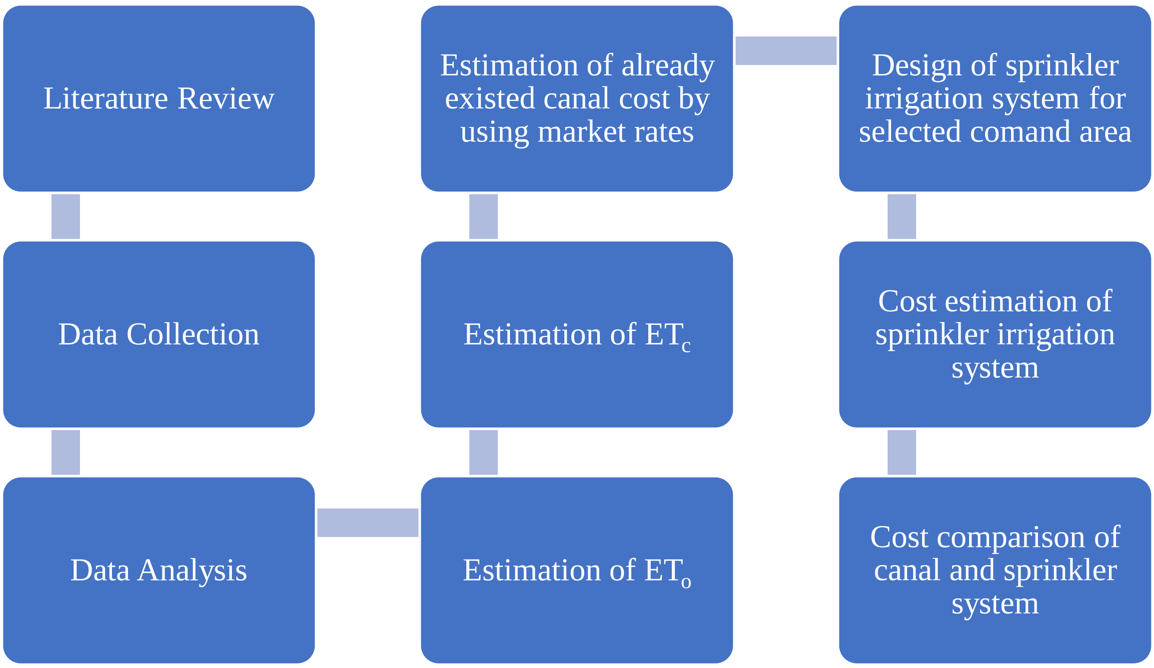


Figure 3.1. Methodology Flowchart

3.1 DATA COLLECTION

We collected data from metrological department. The data which we have collected from met department includes temperature, humidity, sunshine hours, rain and wind speed.

The data was collected from the Meteorological Department Lahore for Shafi distributary of Sahiwal for the year 2006 to 2021 as mentioned in the table.3.1.

Table 3.1. Data Collection

Source	**Station**	**Duration**
Meteorological Department Lahore	Sahiwal (Shafi Distributary)	2006-2021

The table.3.2. shows that the data included maximum and minimum monthly temperatures, humidity for two different times 8.00 am and 5.00 pm, rainfall, sunshine hours and wind speed for two different times 8am and 5pm.

Table 3.2. Data Type

Sr. No	**Data Type**
1	Maximum monthly temperatures
2	Minimum monthly temperatures
3	Humidity at 8am and 5pm
4	Rainfall
5	Sunshine hours
6	Wind speed at 8am and 5pm

3.2 DATA ANALYSIS

The next step is to analyze data which we have collected from metrological department. The purpose of data analysis is to use data of temperature, humidity and wind speed in further calculations of crop water requirement. The data which we have collected from Metrological Department comprised of 20 years. The purpose of data analysis is to select year for evapotranspiration calculations.

3.2.1 Time (year) vs humidity

The data for plot between time and humidity is shown in the table 3.3.

Table 3.3. Data for Plot Between Time and Humidity

Year	Humidity (%)
2006	59.71
2007	61.58
2008	58.87
2009	61.29
2010	60.46
2011	63.33
2012	60.42
2013	63.17
2014	61.46
2015	64.17
2016	61.46
2017	60.58
2018	59.54
2019	64.08
2020	64.83
2021	63.83

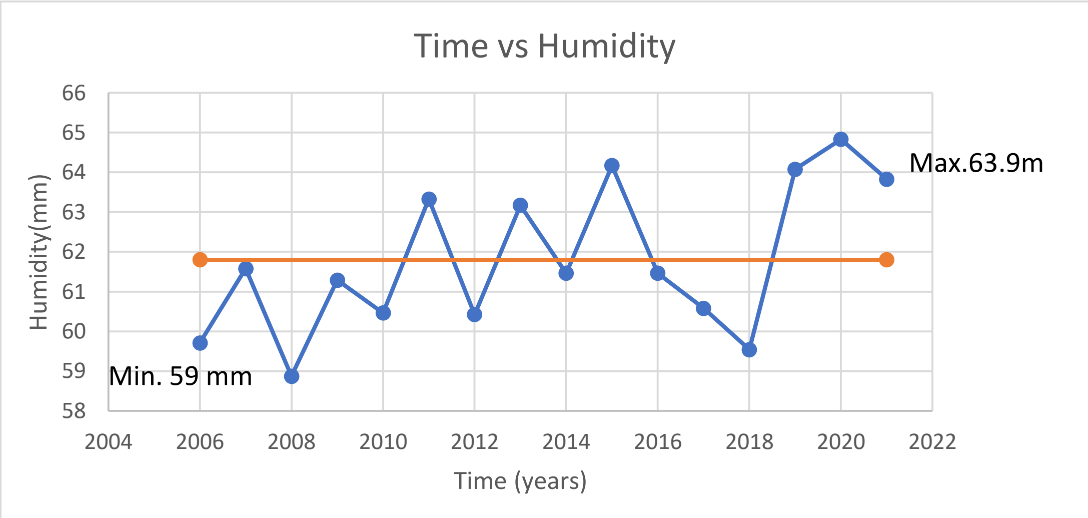


Figure 3.2. Plot Between Time and Humidity

The figure 3.2. shows that average humidity data lies between 61 and 62 so we have to choose which year which have humidity value lies between 61 and 62 and also satisfies other data for further calculation of evapotranspiration (Et_o).

3.2.2 Time (year) vs minimum temperature

The data for plot between time and minimum temperature is shown in the table 3.4.

Table 3.4. Data for Plot Between Time and Minimum Temperature

Year	**Min. Temp(°C)**
2006	18.48
2007	17.76
2008	17.71
2009	17.67
2010	17.9
2011	17.01
2012	16.41
2013	17.42
2014	16.36
2015	17.01
2016	17.84
2017	17.68
2018	18.45
2019	18.23
2020	18.13
2021	18.53

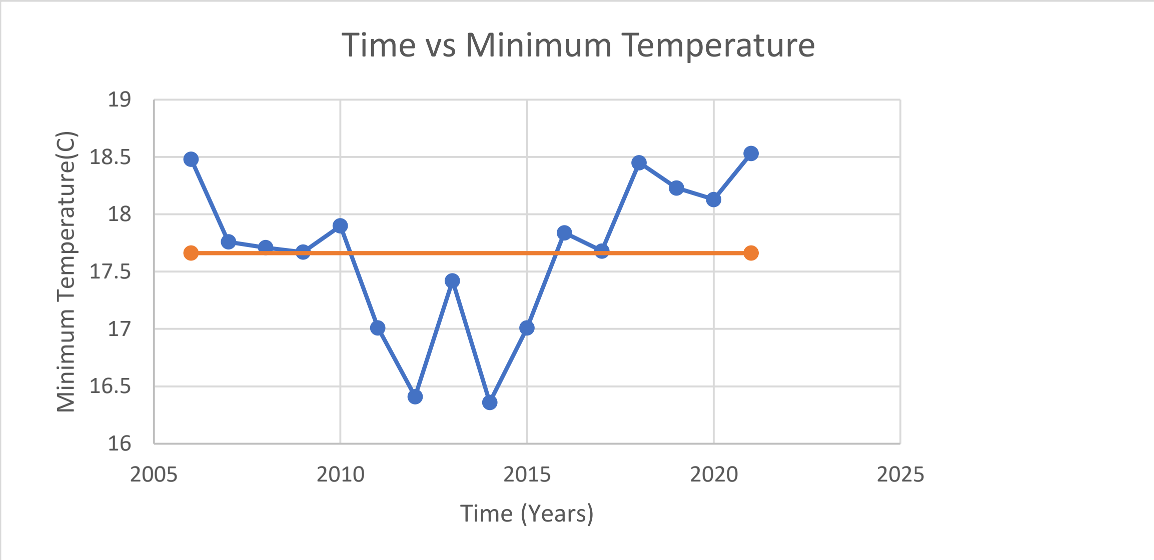


Figure 3.3. Plot Between Time and Minimum Temperature

The figure 3.3 shows the graph between time and minimum temperature. Average year in which most of data lies between 2010 to 2015. The purpose of this is to check average year which we further used in the calculation of ET_o and ET_c.

3.2.3 Time (year) vs maximum temperature

The data for Plot between time and max temperature is shown in the table 3.5.

Table 3.5. Data for Plot between Time and Max Temperature

Year	Max.Temp(C°)
2006	31.7
2007	31.52
2008	31.23
2009	31.86
2010	31.97
2011	31.18
2012	31.11
2013	31.45

2014	30.89
2015	30.9
2016	32.5
2017	31.73
2018	31.85
2019	30.53
2020	30.55
2021	31.55

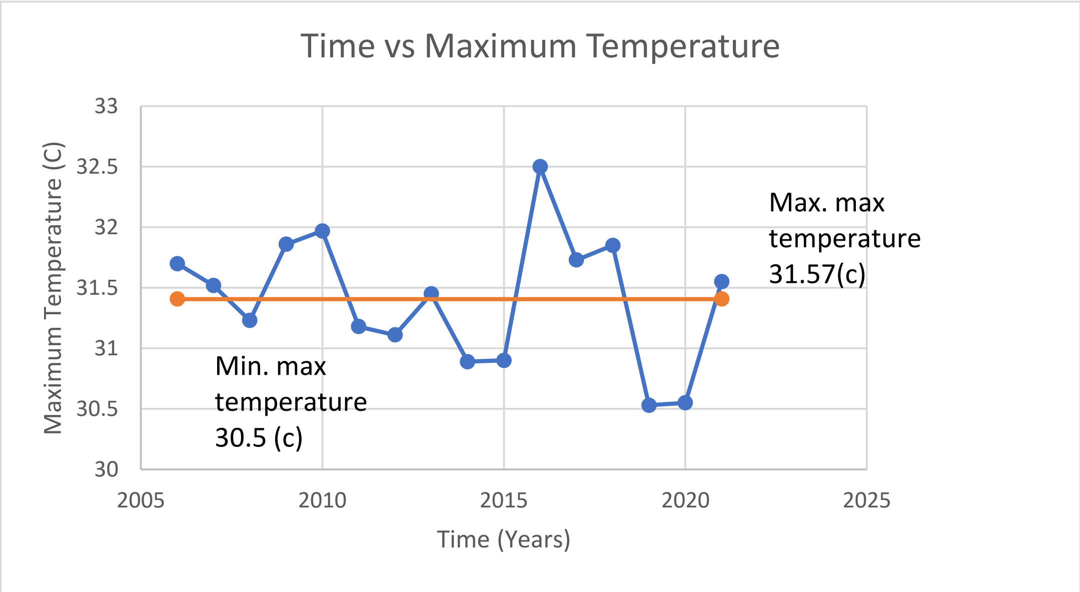


Figure 3.4. Plot Between Time and Maximum Temperature

The figure 3.4 shows the graph between time and maximum temperature which depicts that the average year lies between 2010 to 2015. Basically, we have data of 16 years and in our calculation of evapotranspiration we use data of one year. We have to set limit for data.

3.2.4 Time (year) vs wind speed

The data for plot between time and wind speed is shown in the table 3.6.

Table 3.6. Data for Plot Between Time and Wind Speed

Year	**Wind(Km/day)**
2006	94.08

2007	81.12
2008	93.9
2009	90.19
2010	71.3
2011	88.53
2012	65.56
2013	67.96
2014	81.67
2015	61.67
2016	67.47
2017	67.96
2018	79.45
2019	111.12
2020	92.22
2021	85.56

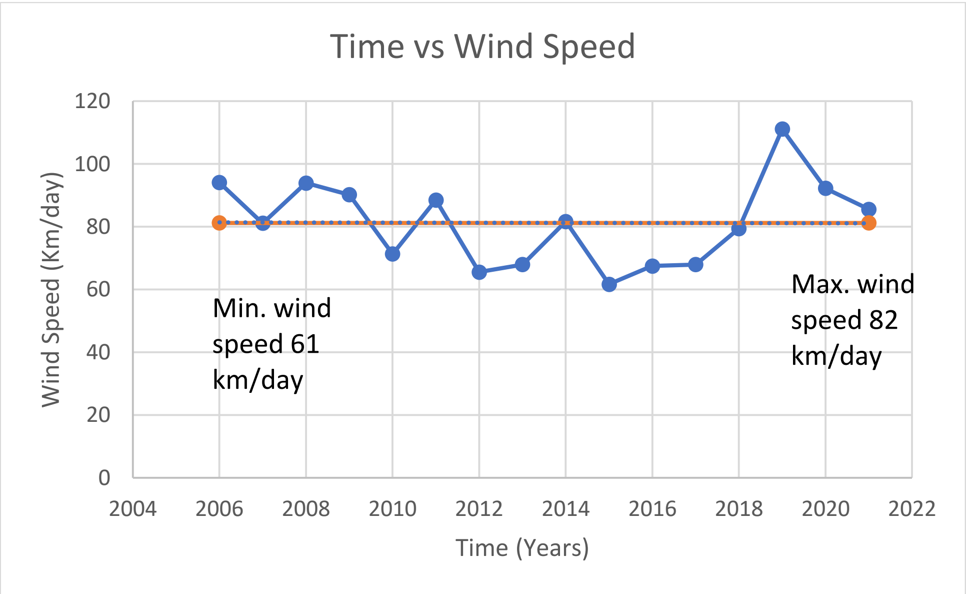


Figure 3.5. Plot Between Time and Wind Speed

The figure 3.5. shows the plot between time and wind speed according to the given data by meteorological department.

3.3 ESTIMATION OF CROP WATER REQUIREMENT

The amount of water required for a particular crop to grow and develop to its full potential is referred to as the crop's water demand. It is an important factor in agricultural water management and determines whether irrigation is necessary. Numerous variables such as crop type, development stage, climate, soil conditions, and management techniques, affect how much water crops need. Effective irrigation scheduling and water saving depend on accurately estimating and satisfying crop water needs. There are several methods to estimate crop water requirement.

3.3.1 Evapotranspiration methods

ET methods stands for the total amount of water lost by transpiration from crops and soil evaporation. Different methods can be used to estimate ET, including reference evapotranspiration (ETo) based on weather information and crop coefficient (Kc) to account for crop-specific characteristics. The Penman-Monteith equation, which takes into account weather elements like temperature, humidity, wind speed, and sun radiation, is the ET approach that is most frequently employed. For that purpose, CROPWAT is used for estimation of crop water requirement. We are going to use Penman-Monteith equation for calculation of crop water requirement.

It is important to note that crop water requirements can vary significantly depending on factors such as climate, crop variety, soil type, and management practices. Localized factors and real-time monitoring of soil moisture levels may also be considered to fine-tune irrigation scheduling and optimize water use efficiency.

3.3.2 Cropwat

The Food and Agriculture Organization of the United Nations (FAO) created the software program CROPWAT to help with irrigation planning and to estimate crop water requirements. Based on climate, crop attributes, and soil data, CROPWAT offers a user-friendly interface and integrates a number of approaches to determine crop water requirements. Users of the CROPWAT software can enter information about the weather (temperature, humidity, wind speed, and solar radiation), crops (type, planting date, and growth stages), soils (texture, depth, and water-holding capacity), and irrigation systems (efficiency, application rate, and scheduling). The software then makes use of this data to calculate the amount of water that crops will need and to create irrigation schedules. CROPWAT utilizes various methods, including the FAO Penman-Monteith method, to calculate reference evapotranspiration. ETo is a measure of the evaporative demand of the atmosphere and serves as a baseline for estimating crop water requirements. Agricultural experts, researchers, and irrigation planners frequently use CROPWAT to aid in decision-making on irrigation management. It encourages sustainable water management practices in agriculture and helps to maximize water use, increase crop yields, and do so.

It's crucial to remember that CROPWAT is a standalone application created by the FAO and is accessible without charge. The FAO's official website or other online platforms can be used to access the most recent version of CROPWAT and related documents.

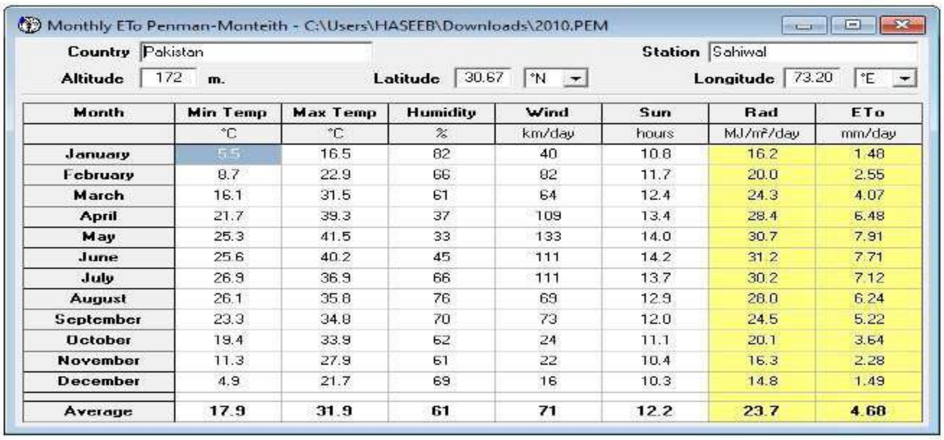
3.3.3 Reference evapotranspiration (ET_o)

Reference Evapotranspiration (ETo) is a measure of the rate at which water is lost from a reference surface (usually a well-watered grass or crop) through evaporation from the soil surface and transpiration from the vegetation. It serves as a starting point for calculating agricultural water needs and represents the evaporative demand of the atmosphere.

Weather-related information, such as temperature, humidity, wind speed, and sun radiation, are used to calculate ETo. The widely used Penman-Monteith equation, created by the Food and Agriculture Organization of the United Nations (FAO), accounts for these meteorological variables as well as additional elements including net radiation and aerodynamic resistance.

ETo is expressed in units of length per time, such as millimeters per day (mm/day) or inches per day (in/day). In agricultural water management and irrigation planning, ETo is a key variable. Farmers and irrigation planners can optimize irrigation scheduling and water usage efficiency by predicting ETo to calculate the quantity and time of irrigation needed to meet the water needs of various crops.

The FAO Penman-Monteith approach, the Hargreaves method, and the Thornthwaite method are just a few of the models and methodologies that can be used to estimate ETo. It's important to note that ETo is a reference value and may need to be adjusted by crop coefficients (Kc) to account for the specific crop's water requirements at different growth stages. The combination of ETo and crop coefficients provides a comprehensive estimation of crop water requirements, aiding in efficient irrigation planning and management.



Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	5.5	16.5	82	40	10.8	16.2	1.48
February	8.7	22.9	66	82	11.7	20.0	2.55
March	16.1	31.5	61	64	12.4	24.3	4.07
April	21.7	39.3	37	109	13.4	28.4	6.48
May	25.3	41.5	33	133	14.0	30.7	7.91
June	25.6	40.2	45	111	14.2	31.2	7.71
July	26.9	36.9	66	111	13.7	30.2	7.12
August	26.1	35.8	76	69	12.9	28.0	6.24
September	23.3	34.8	70	73	12.0	24.5	5.22
October	19.4	33.9	62	24	11.1	20.1	3.64
November	11.3	27.9	61	22	10.4	16.3	2.28
December	4.9	21.7	69	16	10.3	14.8	1.49
Average	**17.9**	**31.9**	**61**	**71**	**12.2**	**23.7**	**4.68**

Figure 3.6. ETo Calculation from CROPWAT

The calculation of reference evapotranspiration (Eto) using the CROPWAT software is shown in the figure 3.6.

3.3.4 Penman-monteith equation

Penman-Monteith equation is used by CROPWAT for the calculation of crop water requirement.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

where	ET_o	reference evapotranspiration [mm day^{-1}],
	R_n	net radiation at the crop surface [MJ m^{-2} day^{-1}],
	G	soil heat flux density [MJ m^{-2} day^{-1}],
	T	mean daily air temperature at 2 m height [°C],
	u_2	wind speed at 2 m height [m s^{-1}],
	e_s	saturation vapour pressure [kPa],
	e_a	actual vapour pressure [kPa],
	e_s-e_a	saturation vapour pressure deficit [kPa],
	Δ	slope vapour pressure curve [kPa °C^{-1}],
	γ	psychrometric constant [kPa °C^{-1}].

Figure 3.7. Penman Monteith Equation

Figure 3.7 shows different parameters involved in Penman-Monteith Equation.

3.4 CROP COEFFICIENT CURVE

Crop Coefficient (Kc) curve, also known as the Crop Water Requirement Curve, represents the relationship between the crop coefficient (Kc) and the growth stage of a specific crop over time. For effective irrigation scheduling, the Kc curve aids in determining the crop's water requirements during various growth stages. It details how much reference evapotranspiration (ETo) the crop needs at each stage of growth.

Typically, the Kc curve begins with a low value early in the crop's development when its needs for water are minimal. The Kc value rises as the crop moves through several growth phases, signaling an increase in water requirement. The Kc curve's peak value often reflects the crop's highest water needs during the reproductive or fruiting stages. As the crop matures and requires less water after reaching its peak, the Kc value gradually declines.

For various crops, the form of the Kc curve varies and is influenced by elements like crop type, climate, and management techniques. It frequently relies on actual data gathered through field research or observation.

It's important to note that the Kc curve is specific to each crop and region. Local climate conditions, soil characteristics, and management practices may influence the shape and values of the Kc curve. Therefore, it is recommended to consult local agricultural experts or references specific to the region to obtain accurate Kc values and develop appropriate irrigation plans based on the crop's water requirements.

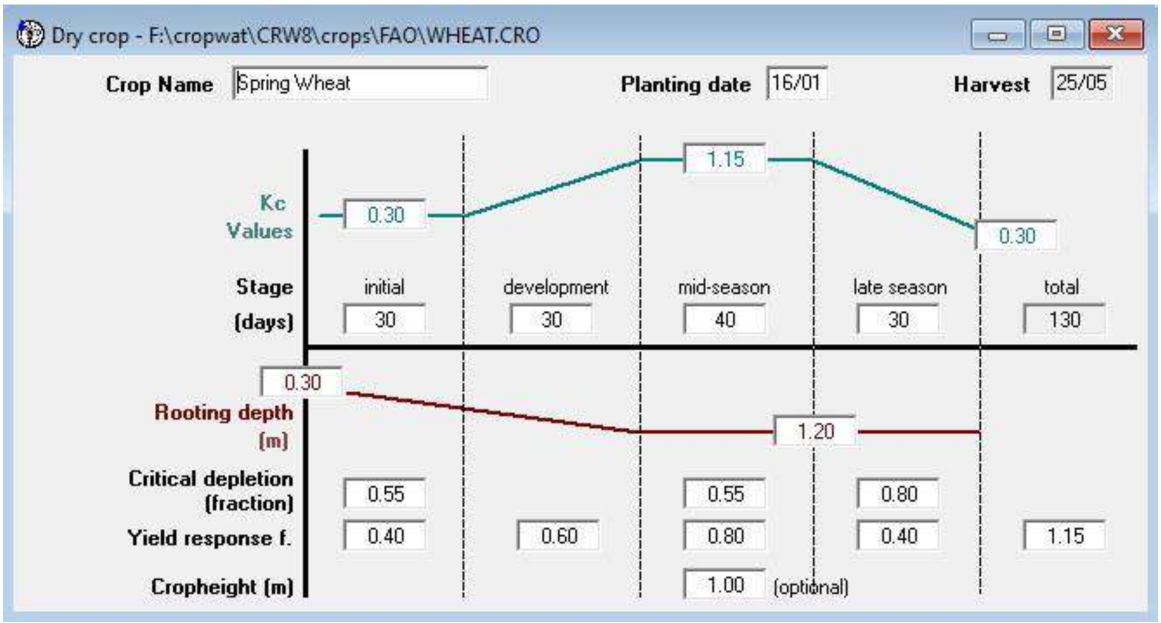


Figure 3.8. Crop Coefficient Curve Calculation From Cropwat

The calculation of crop coefficient curve for spring wheat using cropwat is shown in the figure 3.8.

3.5 EVAPOTRANSPIRATION UNDER STANDARD CONDITION (ET_C)

Evapotranspiration under standard conditions (ETc) refers to the reference evapotranspiration calculated for a hypothetical standardized crop with specific characteristics, under ideal or standard conditions. It is used as a reference value to estimate the water requirements of actual crops in a given location. ETc is determined for a standardized crop with particular qualities, in contrast to ETo, which is commonly calculated for a reference surface like well-watered grass or a crop.

The standardized crop used for ETc calculations is often referred to as the "short crop" or "grass reference crop" because it represents a hypothetical crop with characteristics similar to well-maintained, actively growing grass. The grass reference crop is assumed to have specific characteristics such as a fixed crop height, leaf area index, and surface resistance.

ETc calculations consider various meteorological factors such as temperature, humidity, wind speed, and solar radiation, similar to the calculation of ETo. The most widely accepted method for estimating ETc is the FAO Penman-Monteith method, which incorporates these meteorological variables along with additional factors such as net radiation and aerodynamic resistance.

ETc is used as a benchmark figure to calculate the water needs for actual crops in a specific area. The Etc value can be modified to determine the real crop evapotranspiration (ETc) by using crop coefficients (Kc) unique to the crop that is being cultivated. The ETc aids in scheduling and planning irrigation by providing an estimation of the crop's water requirements.

It's crucial to keep in mind that while ETc offers a standardized reference figure for predicting agricultural water requirements, the actual water needs of particular crops may vary based on factors including crop type, development stage, regional climate, soil conditions, and management practices. To achieve accurate estimates of agricultural yield, it is crucial to take into account crop-specific information and modify the ETc value using the proper crop coefficients. The evapotranspiration of different crops is shown in the table 3.7.

Table 3.7. Evapotranspiration of Different Crops

Sr. No. #	**Crop Type**	**Kc Initial**	**Kc Mid Season**	**Kc Late**	**Etc (mm/day)**
1	Wheat	0.3	1.15	0.3	10.21
2	Potato	0.5	1.15	0.75	12.15
3	Barley	0.3	1.15	0.25	8.79
4	Cotton	0.35	1.2	0.6	13.17
5	Sugarcane	0.4	1.25	0.75	9.769
6	Maize	0.3	1.2	0.35	10.32

3.6 DESIGN DISCHARGE

We calculated design discharge for different crops of Rabi and Kharif season as mentioned in the table.3.8 The design discharge for kharif season is maximum. The purpose of design discharge calculation is to calculate total water requirement of crops because we need to know how much water is required by crops in our selected command area. This amount of water is needed by sprinkler to fulfill the water requirement of crops in our selected area.

Table 3.8. Design Discharge

Rabi Season						
Sr. no	Crop type	Crop %	Area	Volume	Cropping period	Design discharge
		(%)	(Acre)	(Acre ft)	(Days)	(cusecs)
1	Wheat	52.625	1630.322	2554.06494	130	9.90
2	Potato	24.375	755.1375	1357.42538	130	5.26
3	Barley	12.625	391.1225	532.596435	120	2.23
						∑=17.40
Kharif season						
1	Cotton	1	30.98	105.0860	195	0.27
2	Sugarcane	1	30.98	188.569	183	0.51
3	Maize	38.5	1192.73	1937.99	125	7.81
4	Rice	30.75	952.63	1905.5825	150	6.40
5	Millet	101	3128.98	3080.2180	105	14.78
						∑=29.80

3.7 COST OF CANAL IRRIGATION SYSTEM

The cost of canal irrigation system is approximately 30 million rupees which is calculated using the standard market rates. It includes the cost of total number of outlets, estimating the concrete lining, detail of earthwork original channel, permanent outlet structures, weight of iron block for tail outlet, distance marks, painting and writing data board and dismantling works as shown in the table.3.9.

Table 3.9. Summary of Cost of Canal Irrigation System

Cost Changes	New detailed cost (Rs)	New cost per km (Rs)	New cost per ft (Rs)
cost of total Number of Outlets	105225	35481	11
Estimate for Concrete Lining of Shaffi Distributary Reach RD 0 to 9730 (Tail)	6913048.791	2330998	711
detail of earthwork original channel	6324448.323	2132529	650
Concrete Lining of Shaffi Distributary Reach RD 0 to 9730 (Tail)	16353479.55	5514199	1681
providing permanent outlet structures	67643	22809	7
Analysis for calculating weight of iron block for tail outlet	4572	1542	1
Providing and fixing distance marks	11820	3986	2
Analysis for calculating weight of iron block for Outlet	17998	6069	2
Providing Painting & Writing Data Board	110555	37278	12
Abstract of cost for dismantling works	123975	41803	13
Final	30032764.66	10126690	3087

3.8 DETAIL OF EARTHWORK

The estimate for concrete lining and detail of earthwork diversion channel is shown in the table.3.10. It includes the cost of excavation, compaction of earthwork, earthwork excavation in irrigation channels, rehandling of earthwork up to a lead 50ft.

Table 3.10. Cost Of Earthwork Diversion Channel

<table>
<tr><td colspan="5">Estimate for Concrete Lining of Shaffi Distributary Reach RD 0 to 9730 (Tail)</td></tr>
<tr><td colspan="5">Detail of Earthwork Diversion Channel</td></tr>
<tr><td>1</td><td colspan="2">Barrow pit Excavation lead up to 100 feet undressed in ordinary soil</td><td>0</td><td>Cft</td></tr>
<tr><td>2</td><td colspan="2">Compaction of earthwork with power road roller, including ploughing mixing,
moisture content in layered. complete 85% maximum modified AASHTO dry density.</td><td>41000</td><td>Cft</td></tr>
<tr><td>3</td><td colspan="2">Earth work excavation in irrigation channels, drains etc. to design sections, grads,
and profiles, excavated material disposed off and undressed within 50 ft lead in ordinary soil.</td><td>774670</td><td>Cft</td></tr>
<tr><td>4</td><td>Rehandling of earth work up to a lead
50 ft.</td><td>36000 (70 %)</td><td>25200</td><td>Cft</td></tr>
</table>

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3.9 ABSTRACTION OF COST

The abstraction of cost is shown in the table.3.11. It includes the borrow pit excavation, compaction of earthwork, earthwork excavation in irrigation channels and rehandling of earthwork up to a lead of 50ft.

Table 3.11. Abstraction of Cost

Abstraction of cost

Sr. #	Quantity	Description of item	Rate		Amount (Rs)
1	0	Borrow pit Excavation lead up to 100 feet undressed in ordinary soil. Chap: #3 Item #4 a	7761.6	Cft	0
2	36000	Compaction of earthwork with power road roller, including ploughing, mixing, moisture content in layer ,etc. complete 85% maximum modified AASHTO dry density. Chap:#3 Item #25 (iii)	1038.9	Cft	37400.4
3	763190	Earth work excavation in irrigation channels, drains etc. to design sections, grads, and profiles, excavated material disposed off and undressed within 50 ft. lead in ordinary soil. Chap: #3 Item #10 (i)	8880.95	Cft	6777852.231
4	25200	Rehandling of earth work up to a lead 50 ft. Chap:#3 Item #13 b	3880.8	Cft	97796.16
Total					6913048.791

3.10 SPRINKLER DESIGN

We have to design the sprinkler irrigation system for culturable command area of 3040 acres. We designed the sprinkler irrigation system for 25-acre (1 Murabba) area.

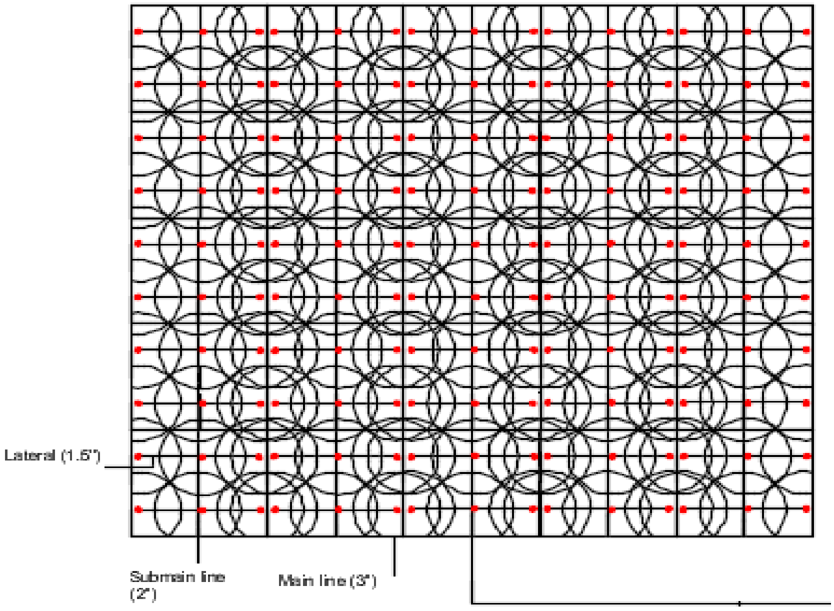

Figure 3.9. Sprinkler Irrigation System Scheme

We have initially calculated the crop evapotranspiration. The crop evapotranspiration of largest crop was selected. Based on that we calculated the design discharge of the system for selected unit area that came out to be 137.42 m^3/hr.

The table 3.12. shows the design discharge for selected unit area for the concerned sprinkler irrigation scheme

Table 3.12. Design Discharge for Selected Unit Area

Design a Sprinkler Irrigation System		
REF: DARA and Raghuvanshi (1999)		
Soil	Deep Light Sandy Loam	
Topography	Undulating	
Slope	5-8%	
Water Source	Tube well	
Power Source	Electricity	
Crop	Rice	
Wind	7-10 km/hr.	
Size of field		
Length	335	M
Width	305	M

Area	10.2175	Ha
Area	25	Acres
Irrigation Schedule and Volume		
Irrigation Schedule when	70%	AMC is depleted
Peak consumption for Rice	13.718	mm/day
Moisture Holding Capacity of Soil	1.083	mm/cm
Root Depth	100	Cm
Operation hours per day (H)	12	hr./day
AMC=Moisture Cap x Root depth	108.3	Mm
Depth of irrigation required (d)	75.81	Mm
Irrigation Interval (f) =	5.526315789	Days
Vol	7745.88675	m3
Efficiency	0.85	%
Vol	9112.807941	m3
Discharge if System if it runs H hours per day for 5.5 days		
For 25 Acres	137.42	m3/hr.
	38.2	l/sec

After that the head loss was calculated for the longest distance point. The total head loss for 1.5”,2” and 3” came out to be 10.69m. That head loss was converted into psi using a factor of 1m of head =1.42 psi. The nozzle was selected which was to maintain pressure of 4 bars (58.02 psi). The suction length was considered 0. Then tank depth was calculated. The factor of 0.433 is used to calculate the depth of water in a tank required for a sprinkler irrigation system.

This factor is derived from the formula for the volume of a cylinder, which is given by:

$$V = \pi r^2 h \qquad 3.1$$

where V is the volume of the cylinder, r is the radius of the cylinder, and h is the height of the cylinder.

For a cylindrical tank used in a sprinkler irrigation system, the volume of water required to fill the tank to a certain depth is given by

$$V = \pi r^2 d \qquad 3.2$$

where d is the depth of water in the tank.

To convert this volume to a height, we need to divide by the area of the tank's base, which is πr^2. This gives us:

$$h = \frac{V}{\pi r2} = \frac{\pi r2\ d}{\pi r2} = d \qquad 3.3$$

Therefore, the height of water in the tank is equal to the depth of water in the tank. However, sprinkler irrigation systems typically require a certain pressure to operate effectively. To achieve this pressure, the water in the tank needs to be at a certain height above the sprinklers. The formula for the pressure of a column of water is given by:

$$P = \rho g h \qquad 3.4$$

where P is the pressure, ρ is the density of water, g is the acceleration due to gravity, and h is the height of the column of water.

For a sprinkler irrigation system, a pressure of around 2-3 bar (29-44 psi) is usually required. To calculate the height of water required to achieve this pressure, we can rearrange the formula as follows:

$$h = \frac{P}{\rho g} \qquad 3.5$$

Plugging in the values for water density and the acceleration due to gravity, we get:

$$h = \frac{P}{1000 * 9.81} = \frac{P}{9810} \qquad 3.6$$

For a pressure of 2-3 bar, this gives us a height h = 2-3 bar / 9810 = 0.000203 - 0.000305 meters. Multiplying this height by the factor of 1000/ρg (where ρ is the density of water and g is the acceleration due to gravity) gives us the depth of water in the tank required to achieve the necessary pressure. Therefore, the factor of 0.433 is simply a conversion factor that combines the density of water and the acceleration due to gravity to give the depth of water in meters required to achieve a pressure of 2-3 bar in a sprinkler irrigation system.

The recommended height of water for a sprinkler irrigation system depends on a number of factors, such as the crop being grown, soil type, and climate conditions. Generally, the recommended depth of water for irrigating most crops is around 1 inch (25.4 mm) per week, which is equivalent to 0.0254 meters. For a 25-acre area, we need to calculate the volume of water required to cover the area with a depth of 0.0254 meters.

1 acre = 4046.86 square meters (approximately)

25 acres = 25 x 4046.86 = 101171.5 square meters

Volume of water required = area x depth = 101171.5 x 0.0254 = 2569.7561 cubic meters

To calculate the height of water required to achieve a pressure of 2-3 bar (29-44 psi), we need to divide the volume of water by the area of the tank's base, which is πr^2, where r is the radius of the tank.

Assuming a cylindrical tank with a diameter of 3 meters (approximately) and a height-to diameter ratio of 1:2, the radius of the tank is 1.5 meters and the area of the base is:

πr^2 = π x 1.5^2 = 7.07 square meters (approximately) Dividing the volume of water by the area of the base, we get:

Height of water required = volume of water / area of base = 2569.7561 / 7.07 = 363.47 meters

Multiplying this height by the conversion factor of 0.433 gives us the pressure required to achieve this height:

Pressure required = height x 0.433 = 363.47 x 0.433 = 157.38 psi (approximately)

Therefore, the recommended height of water for a 25-acre area is around 0.0254 meters, which when multiplied by the conversion factor of 0.433, gives a pressure of approximately 157.38 psi. It's important to note that this is an approximate calculation and the actual pressure required may vary depending on specific factors such as the type of sprinkler and the layout of the irrigation system.

Fitting losses were taken as 20 % of total head loss. After that total head loss was calculated. After that the required HP of pumps was calculated by using the BHP formula.

3.10.1 Pipe losses

The pipe losses are shown in the table 3.13

Table 3.13. Pipe Losses

Pipe Losses		
Pipe size	Pipe length (m)	Head Loss(m)
1 inch	-	-
1.5 inch	610	8.16
2 inch	305	3.06
3 inch	399	2.66
Head Loss		13.89

The head losses are mentioned in the table 3.14.

Table 3.14. Head Losses

Head Losses					
Pressure (Psi)	Suction length (Psi)	Tank Depth (Psi)	Pipe losses (Psi)	Fitting losses (Psi)	Total Head Loss (PSI)
58.0152	0	157.38	19.72	2.77	237.87

The Horse power of pump is shown in the table.3.15.

Table 3.15. Pump Horse Power(HP)

Pump Horse Power (HP)				
Total Flow (gpm)	Total Head Loss (ft)	Constant Factor	Pump efficiency	Required HP
606	549.4926042	3960	0.85	98.92825851

The different design schemes are shown in the figure 3.10 and figure 3.11 and 3.12 (recommended by field).

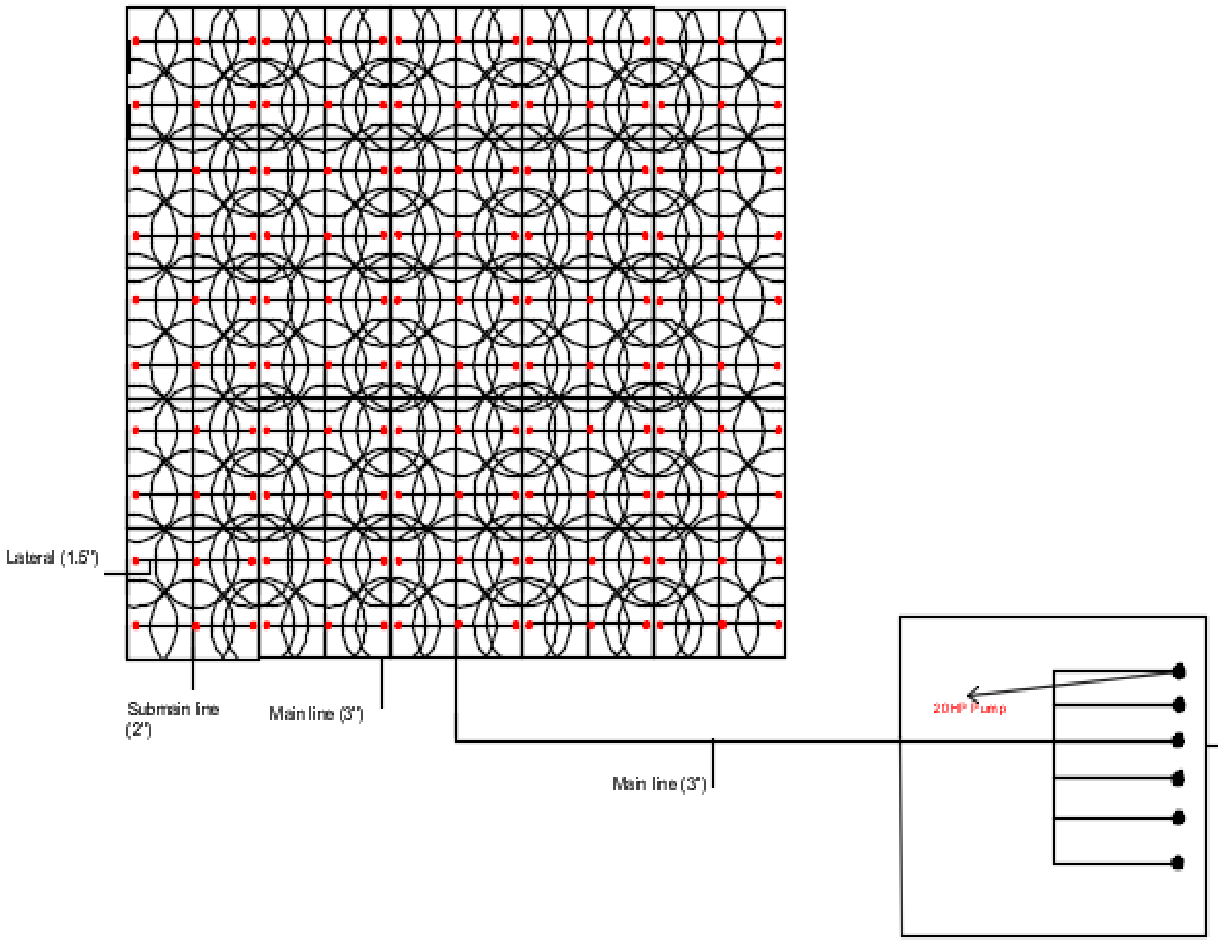

Figure 3.10. Showing Enlarged View of Pumping Station Linked with Sprinkler Irrigation Scheme

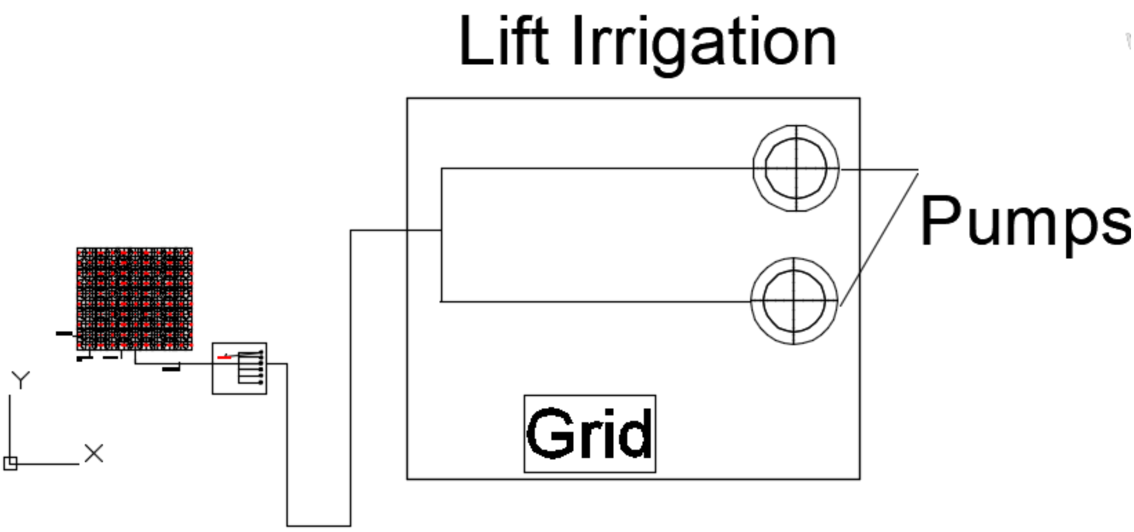

Figure 3.11. Enlarged View of Lift Irrigation System

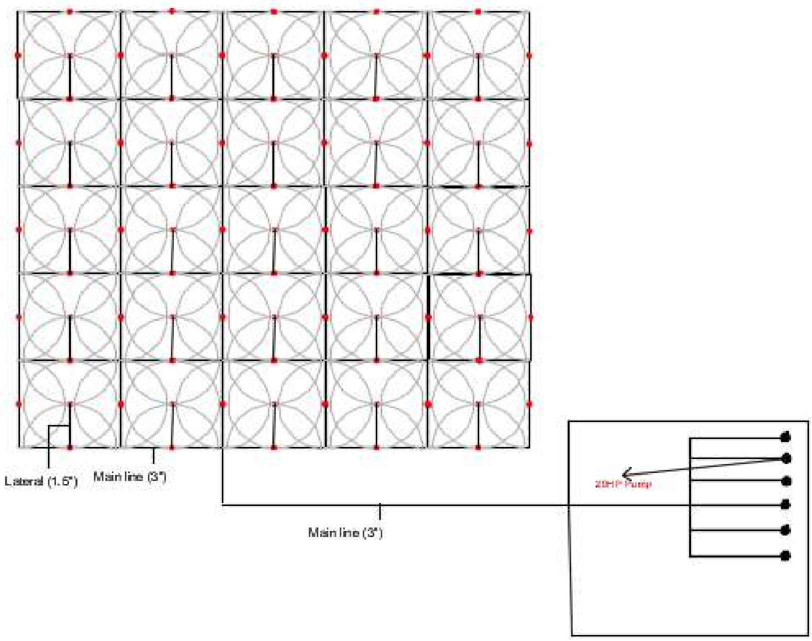

Figure 3.12. Recommended Design Scheme by Field

The pipe losses are shown in the table 3.16

Table 3.16. Pipe Losses

Pipe Losses		
Pipe size	Pipe length (m)	Head Loss(m)
1 inch	-	-
1.5 inch	-	-
2 inch	1231.5	12.35
3 inch	265	3.55
	Head Loss	14.56

The head losses are mentioned in the table 3.17.

Table 3.17. Head Losses

Head Losses					
Pressure (Psi)	Suction length (Psi)	Tank Depth (Psi)	Pipe losses (Psi)	Fitting losses (Psi)	Total Head Loss (PSI)
45.5	0	157.38	22.59	4.5	228.01

The pump HP is mentioned in the table 3.18 and the result of this table validates our theoretical design.

Table 3.18. Pump Horse Power (HP)

Pump HP				
Total Flow	Total Head Loss	Constant Factor	Pump efficiency	Required HP
606	526.7059126	3960	0.85	94.82584167

CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter describes the results and discussions. The design of sprinkler as well as cost comparison of both the canal irrigation and sprinkler irrigation system is discussed in this chapter.

The cost changes for various components of the project are presented in the following table

4.1 ET_C FOR KHARIF AND RABI SEASON

Table 4.1. shows the ETc for Kharif and Rabi season respectively

Table 4.1. ETc for Kharif and Rabi season

ETc	Mm
Kharif	4294.16
Rabi	1440.3

4.2 COST CHANGES

The table 4.2. reflects the cost increase regarding various components of distributary. The cost of total number of outlets has significantly increased from 47,794 to 105,224.3, indicating the scale of the project. The estimate for concrete lining of Shaffi distributary has also witnessed a substantial increase from 2,105,769 to 6,913,048.791. Similarly, the cost for other components such as earthwork, providing permanent outlet structures, analysis for calculating weight of iron block, and providing painting and writing data board has increased significantly

Table 4.2. Cost Changes

Cost Changes	**Old**	**New**
Cost of total Number of Outlets	47,794	105,224.30

Estimate for Concrete Lining of Shaffi i Distributary Reach RD 0 to 9730 (Tail)	2,105,769	6,913,048.79
Detail of earthwork original channel	388,912.68	6,324,448.32
Concrete Lining of Shaffi Distributary Reach RD 0 to 9730 (Tail)	7,284,068	16,353,479.55
Providing permanent outlet structures	31,159.73	67,642.66
Analysis for calculating weight of iron block for tail outlet	3,075.38	4,571.35
Providing and fixing distance marks	7,780	11,819.31
Analysis for calculating weight of iron block for outlet	5,156.57	17,997.40
Providing Painting & Writing Data Board	45,877.52	110,554.87
Abstract of cost for dismantling works	122,875	123,975
Final	10,042,468	30,032,761.56

4.3 DEPTH OF IRRIGATION REQUIRED

The depth of irrigation required for the project is determined to be 75.81 mm.

4.4 IRRIGATION INTERVAL

The irrigation interval is calculated by dividing the depth of one irrigation (75.81 mm) by the peak irrigation requirement. The result is an irrigation interval of 5.5 days.

4.5 DISCHARGE CAPACITY OF THE PUMP REQUIRED

The discharge capacity of the pump required is calculated using the formula:

$$Q = \left(\frac{d*a}{f*h*E}\right) \times 2780 \qquad 4.1$$

Where: Q = Discharge capacity of the pump (Lit/sec), d = Depth of irrigation required (mm) a = Area (ha), f = Irrigation interval (days) ,H = Number of working hours in a day and E = Application efficiency.

Based on the given values and calculations, the discharge capacity of the pump required is determined to be 38.2 l/sec or 954.2733184 m3/hr.

4.6 OPTIMUM APPLICATION RATE

The optimum application rate depends on the type of soil and slope. It should be less than the infiltration capacity. The specific values can be obtained from Table 3.4 or 3.7a in DARA and Raghuvanshi (1999).

4.7 PIPE LOSSES

The head losses for different pipe sizes are determined based on the given pipe lengths. The table 4.3. shows the head losses for each pipe size

4.8 HEAD LOSSES

The total head losses are calculated by considering the pressure, suction length, tank depth, pipe losses, and fitting losses. The table 4.3. below presents the head losses:

Table 4.3. Head Loss

Pipe size	Pipe length (m)	Head Loss (m)
1 inch	0.00	-
1.5 inch	305.00	4.08
2 inch	305.00	3.06
3 inch	399.02	3.56

4.9 TOTAL HEAD LOSSES

The table 4.4. shows the total head losses.

Table 4.4. Total Head Losses

Pressure (PSI)	Suction length (PSI)	Tank Depth (PSI)	Pipe losses (PSI)	Fitting losses (PSI)	Total Head Loss (PSI)
58.02	0	363.47	15.2	2.14	438.82

4.10 PUMP HORSE POWER (HP)

The pump HP required is determined based on the total flow, total head loss, constant factor, pump efficiency, and the formula:

$$Required\ HP = \frac{Total\ flow * total\ head\ loss * Constant\ factor}{1000 * 60 * Pump\ efficiency} \quad 4.2$$

Based on the given values and calculations, the required pump HP is determined to be 98.93.

4.11 COST OF SPRINKLER SYSTEM

The cost of the sprinkler system is calculated based on different components and their respective costs per unit. The table 4.5 shows the cost breakdown for a 25-acre and 3,050acre area.

Table 4.5. Cost of Sprinkler System

COST OF SPRINKLER SYSTEM				
Item		25 Acre		3040 Acres
		Cost (Rs.) per unit	Cost (Million Rs.)	Cost (Million Rs.)
3" PVC Pipe (399m)		378.5	0.15	18.43
2" PVC Pipe (1525 m)		164	0.25	30.5
1.5 " PVC Pipe (1525 m)		164	0.25	61
6 (20 Hp) Pumps		200,000	0.2	9.6
Pump House		_	1	122
Nozzles cost		380	0.06	6.95
T cost	3"	3150	0.02	1.9
	2"	3300	0.33	30.3
Valves Cost	3"	23650	0.11	14.4

	2"	23100	0.5775	70.5
Grand Total (Million Rupees)				375.6

4.12 LIFT IRRIGATION

For lift irrigation, various components and their associated costs are considered. The table 4.6 presents the cost breakdown.

Table 4.6. Cost of Lift Irrigation Scheme

Lift Irrigation	
Item	**Amount (Million Rs.)**
Construction of head regulator	10
Construction of Pond and tank	5
Provision of pumps for lift irrigation	30
Provision of electricity connection and transformer	10
Construction of pump house and super visionary staff	7.5
Unforeseen and contingent expenses	1
Grand Total (Million Rupees)	60

4.13 GRAND TOTAL

The grand total of whole scheme is mentioned in the table 4.7.

Table 4.7. Grand Total

Total Cost (Million rupees)	435.6

The estimated cost for the lift irrigation system is 60 million Rs.

4.14 CONCLUSION

The analysis provides insights into the cost changes for various components of the project, the water requirements and design parameters for different crop types during the Rabi and Kharif seasons, the depth of irrigation required, irrigation interval, discharge capacity of the pump required, optimum application rate, pipe losses, head losses, pump HP required, cost of the sprinkler system, and the cost of the lift irrigation system. These calculations and cost breakdowns are essential for planning and implementing an effective irrigation project.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

- The crop water requirement of the study area was estimated by CROPWAT and it came out to be 1440.3mm for Rabi season and 4294.16mm for Kharif season and the design discharge for the scheme was estimated as 38.2 liter per second.
- For the existing canal system in the study area the original estimated cost was about 10 million rupees and with the current rates the cost came out to be about 30 million rupees only.
- The design of sprinkler irrigation system has been done for the area which includes main line 3inch diameter, sub main line of 2inch diameter, lateral of 1.5inch diameter. The total no of sprinklers came out to be 18300.
- The spacing along main is 31m and the spacing along lateral is also 31m.
- To run the system for the whole area it is determined that 2 pumps are required to lift water from the canal and to carry water from the pond to the field 6 pumps of 20 hp are required to irrigate 10 large squares (10 murabbas) of land according to decided interval of 5.5 days for each 1 Murabba of land including 1 pump as a factor of safety.
- The cost of the overall sprinkler system came out to be approximately 435.6 million rupees which is 15 times more than the cost of canal irrigation system.

5.2 RECOMMENDATIONS

- Based on the study we conducted the use of sprinkler system is not recommended for wider area. For developing countries like Pakistan the cost of sprinkler components is very high because we are importing these components. However, for smaller areas like lawns, orchards and parks sprinkler system can be recommended.
- The cost of sprinkler may further be calculated by adding the cost of filter and pipe material like PVC, concrete etc.
- Benefit cost analysis should also be done for both canal and sprinkler system for better comparison.

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APPENDICES

Table 1: Metrological data of Shaffi distributary for year 2006

Year 2006											
Latitude						30.67					degrees
Longitude						73.2					degrees
Elevation						565					ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day		
81	47	64	5.2	19.6	0.5	22.2	1.6	71.1	46.7	10.8
84	51	67.5	11.8	26.5	0.5	22.2	2.7	120.0	71.1	11.7
76	45	60.5	14.3	27.5	1.5	66.7	3.1	137.8	102.2	12.4
49	24	36.5	19.9	36.7	2.3	102.2	3.4	151.1	126.7	13.4
52	29	40.5	26.4	41.7	2.3	102.2	4.2	186.7	144.5	14
57	37	47	25.2	39.3	2.6	115.6	2.7	120.0	117.8	14.2
72	51	61.5	27.7	38.1	3.3	146.7	3.7	164.5	155.6	13.7
78	61	69.5	26.5	36.3	1.3	57.8	2.7	120.0	88.9	12.9
78	50	64	23.5	35.1	1.3	57.8	3	133.3	95.6	12
77	48	62.5	19.7	32.9	0.8	35.6	3.3	146.7	91.1	11.1
83	56	69.5	14.2	26	0.6	26.7	1.4	62.2	44.4	10.4
88	59	73.5	7.4	20.7	0.5	22.2	1.5	66.7	44.4	10.3

Table 2: Metrological data of Shaffi distributary for year 2007

Year 2007											
Latitide					30.67						degrees
Longitude					73.2						degrees
Elevation					565						ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			mm
82	48	65	5.2	20.1	0.3	13.3344	2.4	106.6752	60	10.8	0
89	65	77	9.6	21.4	0.6	26.6688	2.2	97.7856	62.23	11.7	30.3
82	56	69	13.4	26.2	0.3	13.3344	2.1	93.3408	53.34	12.4	18.3
57	31	44	20.1	37.9	0.4	17.7792	1.7	75.5616	46.67	13.4	0
49	28	38.5	24.7	40.3	2.3	102.2304	2.5	111.12	106.7	14	1.5
67	45	56	26.7	38.9	3.1	137.7888	3	133.344	135.6	14.2	186.6
78	59	68.5	26.6	36.4	3	133.344	3.3	146.6784	140	13.7	130.6
77	55	66	27.1	37	2.5	111.12	3.5	155.568	133.3	12.9	17.7
79	53	66	24.2	35.7	1.3	57.7824	3.7	164.4576	111.1	12	22.6
77	32	54.5	16.5	34.4	0.7	31.1136	1.6	71.1168	51.12	11.1	0
83	48	65.5	12.8	28.9	0.6	26.6688	1	44.448	35.56	10.4	0
86	52	69	6.2	21	0.5	22.224	1.2	53.3376	37.78	10.3	13

Table 3: Metrological data of Shaffi distributary for year 2008

Year 2008											
Latitude						30.67					degrees
Longitude						73.2					degrees
Elevation						565					ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			mm
83	47	65	4.3	17.7	0.4	17.7792	2.1	93.3408	55.56	10.8	16.6
80	41	60.5	6.1	21.4	1	44.448	3.9	173.3472	108.9	11.7	5.2
77	38	57.5	14.9	31.4	1.3	57.7824	1.7	75.5616	66.67	12.4	0
63	31	47	19.2	34	1.3	57.7824	2.7	120.0096	88.9	13.4	33.1
54	31	42.5	23.6	38.5	3.2	142.2336	3.2	142.2336	142.2	14	56.6
71	48	59.5	27.1	38.6	3.3	146.6784	3.5	155.568	151.1	14.2	111.3
73	50	61.5	27.8	38	2.6	115.5648	3.4	151.1232	133.3	13.7	29
83	63	73	25.8	35.4	2.6	115.5648	3.4	151.1232	133.3	12.9	248.6
81	53	67	23.2	34.6	2	88.896	3.2	142.2336	115.6	12	38
83	46	64.5	19.9	34.1	1.4	62.2272	1.1	48.8928	55.56	11.1	0
81	44	62.5	12	28.5	1	44.448	0.9	40.0032	42.23	10.4	0
90	60	75	8.6	22.5	0.5	22.224	1	44.448	33.34	10.3	14.6

Table 4: Metrological data of Shaffi distributary for year 2009

Year 2009											
Latitide					30.67						Degrees
Longitude					73.2						Degrees
Elevation					565						Ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			Mm
90	54	72	6.7	20.5	0.4	17.7792	1.9	84.4512	51.12	10.8	26.6
85	48	66.5	9.8	23.7	0.7	31.1136	2.5	111.12	71.12	11.7	12.9
77	42	59.5	14	28.4	1.4	62.2272	3.6	160.0128	111.1	12.4	15.9
58	28	43	18.8	34.6	2.4	106.6752	3.5	155.568	131.1	13.4	30
50	27	38.5	24.6	40.5	2.8	124.4544	3.2	142.2336	133.3	14	4.4
53	31	42	25.8	40.8	2.3	102.2304	5	222.24	162.2	14.2	7.3
74	51	62.5	27.1	38.3	1.9	84.4512	3.5	155.568	120	13.7	105.7
78	56	67	26.7	37.1	3.7	164.4576	4.3	191.1264	177.8	12.9	29.6
81	50	65.5	23.4	35.6	0.7	31.1136	1.4	62.2272	46.67	12	3.6
79	38	58.5	17	33.7	1.5	66.672	0.5	22.224	44.45	11.1	1.9
83	48	65.5	11.4	26.3	0.3	13.3344	0.4	17.7792	15.56	10.4	_
85	47	66	6.7	22.8	0.3	13.3344	0.5	22.224	17.78	10.3	_

Table 5: Metrological data of Shaffi distributary for year 2010

Year 2010											
Latitide						30.67					degrees
Longitude						73.2					degrees
Elevation						565					ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			Mm
96	67	81.5	5.5	16.5	0.6	26.6688	1.2	53.3376	40	10.8	1.2
83	49	66	8.7	22.9	1.1	48.8928	2.6	115.5648	82.23	11.7	5.9
81	40	60.5	16.1	31.5	0.6	26.6688	2.3	102.2304	64.45	12.4	9.6
51	23	37	21.7	39.3	1.9	84.4512	3	133.344	108.9	13.4	1.4
46	20	33	25.3	41.5	2.6	115.5648	3.4	151.1232	133.3	14	4.8
57	33	45	25.6	40.2	2.3	102.2304	2.7	120.0096	111.1	14.2	30
77	55	66	26.9	36.9	2.1	93.3408	2.9	128.8992	111.1	13.7	129.6
84	68	76	26.1	35.8	1.4	62.2272	1.7	75.5616	68.89	12.9	116.3
84	55	69.5	23.3	34.8	1.3	57.7824	2	88.896	73.34	12	14.1
81	42	61.5	19.4	33.9	0.6	26.6688	0.5	22.224	24.45	11.1	0
83	39	61	11.3	27.9	0.1	4.4448	0.9	40.0032	22.22	10.4	0
87	50	68.5	4.9	21.7	0.2	8.8896	0.5	22.224	15.56	10.3	1

Table 6: Metrological data for year 2011

Year 2011											
Latitide						30.67					Degrees
Longitude						73.2					Degrees
Elevation						565					Ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			Mm
86	52	69	3.6	17	0.6	26.6688	1.9	84.4512	55.56	10.8	0
84	55	69.5	8.7	21.9	0.9	40.0032	2.4	106.6752	73.34	11.7	41.2
80	39	59.5	12.6	28.4	1	44.448	2.8	124.4544	84.45	12.4	3
63	29	46	17.3	33.8	2.4	106.6752	3.7	164.4576	135.6	13.4	17.5
53	28	40.5	24.3	40.7	2.6	115.5648	2.9	128.8992	122.2	14	41
66	39	52.5	26.4	40.2	4.2	186.6816	2.8	124.4544	155.6	14.2	50
78	56	67	26.5	37.3	2.9	128.8992	3.2	142.2336	135.6	13.7	40.2
84	66	75	25.8	35.7	2.5	111.12	2.5	111.12	111.1	12.9	120.7
90	71	80.5	23.1	33.4	1.1	48.8928	2.3	102.2304	75.56	12	297.5
83	43	63	17.5	33.6	1	44.448	1.4	62.2272	53.34	11.1	_
89	50	69.5	13.1	29.4	0.3	13.3344	0.5	22.224	17.78	10.4	_
86	50	68	5.2	22.8	1.2	53.3376	0.7	31.1136	42.23	10.3	0

Table 7: Metrological data for year 2012

Year 2012												
Latitide							30.67					degrees
Longitude							73.2					degrees
Elevation							565					ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			mm
88	53	70.5	3.2	18.7	1.1	48.8928	1.7	75.5616	62.23	10.8	0.8
76	39	57.5	5.3	21	1.8	80.0064	3.2	142.2336	111.1	11.7	2.7
72	35	53.5	11.5	28.2	1.5	66.672	2.9	128.8992	97.79	12.4	0.3
69	37	53	18.5	34	2.1	93.3408	3.3	146.6784	120	13.4	8.2
48	24	36	23.4	39.7	2.2	97.7856	2.1	93.3408	95.56	14	3.8
54	32	43	26.5	41.3	0.3	13.3344	0.4	17.7792	15.56	14.2	1
72	49	60.5	27.2	39.3	2.1	93.3408	2.7	120.0096	106.7	13.7	98.6
82	58	70	25.7	36.4	1.6	71.1168	2.3	102.2304	86.67	12.9	134.3
89	62	75.5	23	34.3	0.1	4.4448	0.1	4.4448	4.445	12	226
84	45	64.5	16.4	32.4	0.6	26.6688	1	44.448	35.56	11.1	_
87	49	68	10.6	27.5	0.3	13.3344	0.5	22.224	17.78	10.4	0
90	56	73	5.6	20.5	0.6	26.6688	0.9	40.0032	33.34	10.3	8

Table 8: Metrological data for year 2013

Year 2013											
Latitide					30.67						Degrees
Longitude					73.2						Degrees
Elevation					565						Ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			Mm
90	51	70.5	4.1	18.3	1	44.448	1.5	66.672	55.56	10.8	0
89	63	76	8.4	21.1	1.2	53.3376	2	88.896	71.12	11.7	113.2
86	46	66	13.2	28.4	0.8	35.5584	1.3	57.7824	46.67	12.4	6.2
72	33	52.5	18.6	34	1.3	57.7824	2	88.896	73.34	13.4	8
55	25	40	22.6	40.3	1.9	84.4512	2.4	106.6752	95.56	14	3.3
64	38	51	26	40.4	2.3	102.2304	2.7	120.0096	111.1	14.2	52
73	50	61.5	27.2	39.3	1.8	80.0064	3	133.344	106.7	13.7	5
84	62	73	25.7	36.2	1.4	62.2272	2.4	106.6752	84.45	12.9	156.7
80	50	65	23.8	36.6	1.1	48.8928	2	88.896	68.89	12	0
83	48	65.5	19.8	34.3	0.6	26.6688	1	44.448	35.56	11.1	0
85	46	65.5	10.5	26.8	0.5	22.224	0.8	35.5584	28.89	10.4	4
88	55	71.5	6.6	21.8	0.6	26.6688	1.1	48.8928	37.78	10.3	0

Table 9: Metrological data for year 2014

Year 2014											
Latitide					30.67						degrees
Longitude					73.2						degrees
Elevation					565						ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			mm
90	52	71	3.8	19.7	1	44.448	1.9	84.4512	64.45	10.8	_
87	53	70	6.6	20.9	1.4	62.2272	2.2	97.7856	80.01	11.7	29
83	50	66.5	12.1	26	0.8	35.5584	2.3	102.2304	68.89	12.4	58
66	33	49.5	17.4	33.5	1.7	75.5616	2.2	97.7856	86.67	13.4	44
58	32	45	22.1	37.9	1.9	84.4512	2.3	102.2304	93.34	14	30
55	32	43.5	26.3	42	2.7	120.0096	3.4	151.1232	135.6	14.2	16
70	48	59	26.4	38.6	3	133.344	2.9	128.8992	131.1	13.7	76
74	50	62	25.9	38.2	1.8	80.0064	3.5	155.568	117.8	12.9	_
82	57	69.5	22.8	34.9	1.5	66.672	2.7	120.0096	93.34	12	64
80	47	63.5	18	32.8	0.8	35.5584	1.9	84.4512	60	11.1	1
83	40	61.5	10.1	27.7	0.5	22.224	0.6	26.6688	24.45	10.4	_
91	62	76.5	4.8	18.5	0.4	17.7792	0.7	31.1136	24.45	10.3	0

Table 10: Metrological data for year 2015

Year 2015											
Latitide						30.67					Degrees
Longitude						73.2					Degrees
Elevation						565					Ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			Mm
96	68	82	5.4	16.4	0.7	31.1136	1	44.448	37.78	10.8	9
88	58	73	9.3	19.2	1	44.448	2	88.896	66.67	11.7	22.2
85	54	69.5	12.6	25.3	1.1	48.8928	1.9	84.4512	66.67	12.4	59.2
71	39	55	18.9	34.2	1.5	66.672	2.5	111.12	88.9	13.4	23
53	25	39	23.3	40	2.1	93.3408	2.7	120.0096	106.7	14	-
60	37	48.5	25	39.2	1.5	66.672	2.1	93.3408	80.01	14.2	21
78	48	63	25.4	36.5	1.9	84.4512	2.1	93.3408	88.9	13.7	163
81	60	70.5	25.8	35.7	1.5	66.672	1.9	84.4512	75.56	12.9	94
80	60	70	22.6	35.3	0.6	26.6688	1.4	62.2272	44.45	12	84
82	49	65.5	18	32.8	0.7	31.1136	1	44.448	37.78	11.1	2
83	46	64.5	11.6	27	0.6	26.6688	1	44.448	35.56	10.4	-
88	51	69.5	6.3	22	0.1	4.4448	0.4	17.7792	11.11	10.3	0

Table 11: Metrological data for year 2016

Year 2016											
Latitide						30.67					Degrees
Longitude						73.2					Degrees
Elevation						565					Ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			Mm
93	68	80.5	6.6	17.7	0.8	35.5584	1.5	66.672	51.12	10.8	9
88	45	66.5	6.9	23.7	0.6	26.6688	2.3	102.2304	64.45	11.7	3
83	48	65.5	14.3	28.2	1.4	62.2272	2.1	93.3408	77.78	12.4	45.2
59	28	43.5	19.6	35.9	1.7	75.5616	2.8	124.4544	100	13.4	8
50	27	38.5	24.9	41.5	2.1	93.3408	2.1	93.3408	93.34	14	2
60	33	46.5	28	42	2.3	102.2304	2.5	111.12	106.7	14.2	13.2
75	52	63.5	26.8	38.6	2.6	115.5648	1.9	84.4512	100	13.7	61
81	60	70.5	25.7	36.6	1.5	66.672	1.9	84.4512	75.56	12.9	122.4
79	50	64.5	23.7	37.7	1.8	80.0064	1.7	75.5616	77.78	12	1
80	42	61	18.2	35.1	0.3	13.3344	0.9	40.0032	26.67	11.1	0
83	44	63.5	11.4	28.8	0.4	17.7792	0.1	4.4448	11.11	10.4	2
90	57	73.5	8	24.2	0.7	31.1136	0.5	22.224	26.67	10.3	0

Table 12: Metrological data for year 2017

Year 2017											
Latitide					30.67						Degrees
Longitude					73.2						Degrees
Elevation					565						Ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			Mm
92	67	79.5	6.2	17.5	0.6	26.6688	2	88.896	57.78	10.8	6
79	43	61	8.7	24.2	0.8	35.5584	2.1	93.3408	64.45	11.7	3.2
76	38	57	13	28.5	0.9	40.0032	1.9	84.4512	62.23	12.4	1
55	26	40.5	19.1	37.6	1.3	57.7824	1.9	84.4512	71.12	13.4	29
53	28	40.5	24.7	40.2	2.3	102.2304	2	88.896	95.56	14	18.2
66	44	55	25.3	38.5	1.9	84.4512	2.9	128.8992	106.7	14.2	107.8
74	56	65	26.9	38	2.1	93.3408	2.5	111.12	102.2	13.7	55
76	54	65	26.5	37.8	2.1	93.3408	2.3	102.2304	97.79	12.9	17
78	50	64	23.5	36.7	1.3	57.7824	1.5	66.672	62.23	12	44
78	41	59.5	18.6	35.4	0.5	22.224	0.5	22.224	22.22	11.1	0
90	56	73	12.2	24.3	0.8	35.5584	0.8	35.5584	35.56	10.4	-1
84	50	67	7.5	22	0.5	22.224	1.2	53.3376	37.78	10.3	11

Table 13: Metrological data for year 2018

Year 2018											
Latitide					30.67						degrees
Longitude					73.2						degrees
Elevation					565						ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			mm
88	52	70	5.4	20.3	0.6	26.6688	1.7	75.5616	51.12	10.8	-1
82	46	64	9.5	23.8	0.9	40.0032	2.3	102.2304	71.12	11.7	4
74	40	57	15.7	30.3	1	44.448	1.5	66.672	55.56	12.4	13.2
62	28	45	20.5	36.4	1.7	75.5616	2.2	97.7856	86.67	13.4	2
49	26	37.5	24.5	39.4	2.5	111.12	2.7	120.0096	115.6	14	7
64	41	52.5	26.8	39.4	2.8	124.4544	2.5	111.12	117.8	14.2	63
77	55	66	27.6	37.3	2	88.896	2.5	111.12	100	13.7	133
74	55	64.5	27.8	37.2	2.5	111.12	2.4	106.6752	108.9	12.9	37
76	50	63	24.9	36.1	1.8	80.0064	2.5	111.12	95.56	12	-1
79	40	59.5	18.8	33.1	1	44.448	1.3	57.7824	51.12	11.1	0
81	47	64	13.1	27.1	1.5	66.672	1.1	48.8928	57.78	10.4	1
89	54	71.5	6.9	21.8	0.6	26.6688	1.3	57.7824	42.23	10.3	4

Table 14: Metrological data for year 2019

Year 2019											
Latitide					30.67						degrees
Longitude					73.2						degrees
Elevation					565						Ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			Mm
89	63	76	6.3	18.5	0.6	26.6688	2.1	93.3408	60	10.8	16
87	58	72.5	8.2	19.8	1.6	71.1168	2.9	128.8992	100	11.7	39.2
77	46	61.5	13.2	25.6	1.8	80.0064	3.4	151.1232	115.6	12.4	6
67	36	51.5	20.3	35.4	2.1	93.3408	3.8	168.9024	131.1	13.4	47.5
57	31	44	23.1	38.2	3.8	168.9024	3	133.344	151.1	14	26
55	32	43.5	27	41.7	2.7	120.0096	4.1	182.2368	151.1	14.2	6
75	54	64.5	27.7	38.1	4	177.792	5.2	231.1296	204.5	13.7	65.6
80	60	70	27.3	37	2.1	93.3408	3.6	160.0128	126.7	12.9	46.1
84	59	71.5	26.3	36.5	2.7	120.0096	2.5	111.12	115.6	12	33.2
82	49	65.5	19.5	32.5	1.4	62.2272	1.4	62.2272	62.23	11.1	4
86	53	69.5	13.3	25.9	1.7	75.5616	2.1	93.3408	84.45	10.4	3
93	65	79	6.5	17.1	0.3	13.3344	1.1	48.8928	31.11	10.3	12.8

Table 15: Metrological data for year 2020

Year 2020											
Latitide					30.67						degrees
Longitude					73.2						degrees
Elevation					565						ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			mm
91	63	77	6.2	16.2	1	44.448	2.6	115.5648	80.01	10.8	49
86	50	68	9.1	22.9	1.3	57.7824	3.3	146.6784	102.2	11.7	16
85	61	73	14.3	24.4	2.5	111.12	3.4	151.1232	131.1	12.4	120.6
68	38	53	19.7	32.9	2.1	93.3408	1.7	75.5616	84.45	13.4	22.2
58	33	45.5	23.7	37.9	3.3	146.6784	3.8	168.9024	157.8	14	29
66	44	55	27	39.4	3.6	160.0128	2.7	120.0096	140	14.2	76
77	57	67	27.4	37.8	2.8	124.4544	3.3	146.6784	135.6	13.7	103
78	62	70	28.1	37.1	2.6	115.5648	2.3	102.2304	108.9	12.9	67
82	55	68.5	25.7	36.6	1	44.448	1.7	75.5616	60	12	27
78	40	59	17.4	34.7	0.9	40.0032	0.8	35.5584	37.78	11.1	0
83	41	62	11.5	20.61	0.9	40.0032	0.6	26.6688	33.34	10.4	10
91	59	75	7.6	20.6	0.6	26.6688	1	44.448	35.56	10.3	5

Table 16: Metrological data for year 2021

Year 2021											
Latitide						30.67					degrees
Longitude						73.2					degrees
Elevation						565					ft
Relative Humidity			Temperature		Wind Speed at 8 am		Wind Speed at 5 pm		Mean	Sunshine hours	Rain
At 8 am	At 5 pm	Mean	Min. T	Max. T	Knots	Km/day	Knots	Km/day			mm
94	68	81	5.2	17.1	0.8	35.5584	1.7	75.5616	55.56	10.8	26
89	52	70.5	10.1	25.7	0.7	31.1136	1.6	71.1168	51.12	11.7	-1
78	46	62	16.3	29.7	2.5	111.12	2	88.896	100	12.4	16
63	29	46	19.3	34.5	1.8	80.0064	3.5	155.568	117.8	13.4	3.2
59	33	46	24.1	38.3	1.8	80.0064	1.8	80.0064	80.01	14	21
63	40	51.5	26.7	39.2	3.8	168.9024	3.9	173.3472	171.1	14.2	9
75	54	64.5	28.2	38.7	2.7	120.0096	3.7	164.4576	142.2	13.7	22
77	53	65	27.5	38.1	2.8	124.4544	3.3	146.6784	135.6	12.9	8.5
84	65	74.5	25.5	34.6	1.5	66.672	2.5	111.12	88.9	12	57.6
80	49	64.5	19.9	33.4	0.6	26.6688	1.7	75.5616	51.12	11.1	13
84	49	66.5	12.2	27.9	0.5	22.224	0.4	17.7792	20	10.4	0
91	57	74	7.4	21.4	0.1	4.4448	0.5	22.224	13.33	10.3	-1

Table 17: Cost of Shaffi distributary

Sr. No	Description	Amount (Rs.)
1	Earthwork for Diversion Channel	2015769
2	Earthwork for Original Channel	3888913
3	Linning of Channel	7284068
4	Temporary Outlets	47794
5	Permannt Outlets	150049
6	Tail Cluster trifurcation	53993
7	Cost of Distance Marks	7780
8	Cost of Data Board	45877.54
9	Cost of Removing Hinderances	90000.46
Sub-total		13584244
Add 2% Work Charge and Contengancies (1% + 1 %)		271684.88
Add 1% Tree Plantation		135842.44
G. Total		13991771.32
G. Total in Million (Rs.)		13.99177132

Table 18: Detail of Earthwork Diversion Channel

Estimate for Concrete Lining of shaffi Distributary Reach RD 0 to 9730 (Tail)					
Detail of Earthwork Diversion Channel					
1	Barrowpit Excavation lead upto 100 feet undressed in ordinary soil			0	Cft
2	Compaction of earthwork with power road roller,including ploughing mixing, moisture content in layer,etc. complete 85% maximum modified AASHTO dry density.			41000	Cft
3	Earth work excavation in irrigation channels,drains etc to design sections,grads, and profiles,excavated material disposed off and undressed within 50 ft lead in ordinary soil.			774670	Cft
4	Rehandling of earthworkupto a lead 50 ft.	36000	70%	25200	Cft

Table 19: Earthwork and lining cost

Abstraction of cost					
Sr. #	Quantity	Description of item	Rate	Unit (cft)	Amount (Rs)
1	0	Borrowpit Excavation lead upto 100 feet undressed in ordinary soil. Chap:#3 Item #4 a	7761.6	1000	0
2	36000	Compaction of earthwork with power road roller,including ploughing, mixing,moisture content in layer,etc. complete 85% maximum modified AASHTO dry density. Chap:#3 Item #25 (iii)	1038.9	1000	37400.4
3	763190	Earth work excavation in irrigation channels,drains etc to design sections, grads, and profiles,excavated material disposed off and undressed within 50 ft lead in ordinary soil. Chap: #3 Item #10 (i)	8880.95	1000	6777852.2
4	25200	Rehandling of earthworkupto a lead 50 ft. Chap:#3 Item #13 b	3880.8	1000	97796.16
Total					6913048.8

Estimate for Concrete Lining of shaffi Distributary Reach RD 0 to 9730 (Tail)

Detail of Earthwork Diversion Channel

RD	Earth Work Filling					Earth Work for Cutting				Excess Filling	Excess Over Cutting
		Total	Mean	Length	Contents	X-Sectional Area	Total			(+)	(-)

	X-Sectional Area							Mean	Contents		
0	0			0		67					
500	0	0	0	500	0	95	162	81	40500	0	40500
1000	0	0	0	500	0	99	194	97	48500	0	48500
1500	0	0	0	500	0	95	194	97	48500	0	48500
2000	0	0	0	500	0	96	191	95.5	47750	0	47750
2500	13	13	6.5	500	3250	74	170	85	42500	0	39250
3000	0	13	6.5	500	3250	72	146	73	36500	0	33250
3500	18	18	9	500	4500	24	96	48	24000	0	19500
4000	0	18	9	500	4500	71	95	47.5	23750	0	19250
4500	0	0	0	500	0	36	107	53.5	26750	0	26750
5000	7	7	3.5	500	1750	17	53	26.5	13250	0	11500
5500	0	7	3.5	500	1750	41	58	29	14500	0	12750
6000	0	0	0	500	0	87	128	64	32000	0	32000
6500	0	0	0	500	0	92	179	89.5	44750	0	44750
7000	0	0	0	500	0	154	246	123	61500	0	61500
7500	0	0	0	500	0	122	276	138	69000	0	69000
8000	0	0	0	500	0	123	245	122.5	61250	0	61250
8500	34	34	17	500	8500	0	123	61.5	30750	0	22250
9000	0	34	17	500	8500	145	145	72.5	36250	0	27750
9500	0	0	0	500	0	196	341	170.5	85250	0	85250
9730	0	0	0	230	0	106	302	151	34730	0	34730

Table 20: Estimate for concrete lining

Estimate for Concrete Lining of shaffi Distributary Reach RD 0 to 9730 (Tail)					
Detail of Earthwork original Channel					
1	earthwork excavation from outside borrowpits lead upto 100 ft undressed	172750	32400	205150	Cft
2	compaction of earthwork with power roadroller, including ploughing mixing, moisture ontent in layer, etc.complete 90% maximum modified AASHO dry density	269035	104380	373415	Cft
3	earthwork excavation in irrigation channels, drains etc to design section, grades and profiles, excavated material disposed off and undressed within 50 ft lead in ordinary soil	227035	95068	322103	Cft
4	transportation of earth all types lead upto 1 mile, (excessive earthwork)	130750	23088	881028	Cft

Table 21: Earthwork and lining cost

Abstract of cost					
sr #	Quantity	Description of item	Rate	Unit	Amount
1	205150	earthwork excavation from outside borrowpits lead upto 100 ft undressed	7761.6	1000 Cft	1592292.24
2		compaction of earthwork with power roadroller, including ploughing mixing , moisture content in layer, etc.complete 90% maximum modified AASHO dry density chapter # 3 item # 25 ii	1273.95	1000 Cft	475712.039
3	322103	earthwork excavation in irrigation channels, drains etc to design section, grades and profiles excavated material disposed off and undressed within 50 ft lead in ordinary soil chapter # 3 item # 10-I-18b	880.95	997 Cft	283756.638
4	881028	transportation of earth all types lead upto 1 mile, (excessive earthwork) chapter # 3 item # (a+b) +17	4509.15	1000 Cft	3972687.41
Total			6324448.32		

Table 22: Estimate of concrete lining of different cross-sections

Estimate for Concrete Lining of shaffi Distributary Reach RD 0 to 9730 (Tail)											
Detail of Earthwork original Channel											
RD	Earth Work For prism cutting					Earth Work patrol / non patrol bank filling				Excess Filling	Excess Over Cutting
	X-Sectional Area	Total	Mean	Length	Contents	X-Sectional Area	Total	Mean	Contents	(+)	(-)
0	13.44			0		9					
500	13.44	26.88	13.44	500	6720	5	14	7	3500	0	-3220
1000	13.44	26.88	13.44	500	6720	9	14	7	3500	0	-3220
1500	10.27	23.71	11.85	500	5927.5	2	11	5.5	2750	0	-3177.5
2000	10.27	20.54	10.27	500	5135	7	9	4.5	2250	0	-2885
2500	10.27	20.54	10.27	500	5135	4	11	5.5	2750	0	-2385
3000	10.27	20.54	10.27	500	5135	9	13	6.5	3250	0	-1885
3500	10.27	20.54	10.27	500	5135	37	46	23	11500	6365	0
4000	10.27	20.54	10.27	500	5135	6	43	21.5	10750	5615	0
4500	10.27	20.54	10.27	500	5135	14	20	10	5000	0	-135
5000	10.27	20.54	10.27	500	5135	14	28	14	7000	1865	0
5500	10.27	20.54	10.27	500	5135	14	28	14	7000	1865	0

6000	10.27	20.54	10.27	500	5135	4	18	9	4500	0	-635
6500	10.27	20.54	10.27	500	5135	4	8	4	2000	0	-3135
7000	7.31	17.58	8.79	500	4395	8	12	6	3000	0	-1395
7500	7.31	14.62	7.31	500	3655	5	13	6.5	3250	0	-405
8000	7.31	14.62	7.31	500	3655	9	14	7	3500	0	-155
8500	7.31	14.62	7.31	500	3655	40	49	24.5	12250	8595	0
9000	7.31	14.62	7.31	500	3655	7	47	23.5	11750	8095	0
9500	7.31	14.62	7.31	500	3655	7	14	7	3500	0	-155
9730	7.31	14.62	7.31	230	1681.3	5	12	6	1380	0	-301.3
total					95068 Cft				104380	32400	23088

Table 23: Concrete lining of shaffi distributary

Concrete Lining of shaffi Distributary Reach RD 0 to 9730 (Tail)						
Abstraction of cost						
sr #	description	Quantity	Rate	Reference	Unit	Amount
1	earth work excavation in irrigation channels, drains etc to designed ,section, grades and profiles, excavated material disposed off and undressed within 50ft .lead in ordinary soil	1272.66Cft	8188.2	chp -3/10i- 18 b	1000 Cft	10420.7
2	Cement plaster 1.5" thick ratio 1:6 in bed	32171.19Sft	4837.7	chp-14/5 a	100 Sft	1556346
3	Cement plaster 1.5"thick (10mm) ratio 1:6 on slope	69640.83Sft	5484.5	chp-14/5 b	100 Sft	3819451
4	Cement concrete lining using washed screened and graded stone aggregate ratio (1:2:4) in bed	8432.60Cft	38670.7	chp-14/10 ai	100 Cft	3260945
5	Cement concrete lining using washed screened and graded stone aggregate ratio(1:2:4) on slope	18253.97Cft	40378.8	chp-14/10 b i	100 C ft	7370734
6	Providing and placing cement,sand and bitumen joint sealant in ratio (1:2:3) 0.5"wide and 1"deep	10181.21Rft	7.49	rate analysis	1 Rft	76257.26

7	Filling expansion joints with bitumen ,sand and saw dust in ratio (1:2:2), 0.5" wide and 2 " deep	1018.12Rft	188.75	chp-6/29	1 Rft	192170.1
8	Bitumen coating to plastered or cement concrete surface 10lbs .per 100sft (4.54kg per sqm)	5090.60Sft	1319.2	chp-13/9 iii	100 Sft	67155.19
Grand Total		16353479.55				

Table 24: Cost estimation of plastic and bitumen in concrete lining

Concrete Lining of shaffi Distributary Reach RD 0 to 9730 (Tail) detail of works				
sr #	Description	Total Quantity	Deducted Quantity	Net quantity
1	earth work excavation in irrigation channels, drains etc to designed section, grades and profiles, excavated material disposed off and undressed within 50ft .lead in ordinary soil total of 03 reaches	1272.66		1272.66 Cft
2	Cement plaster 1.5" thick ratio 1:6 in bed total of 03 reaches	32171.19		32171.19 Sft
3	Cement plaster 1.5"thick (10mm) ratio 1:6 on slope total of 03 reaches	69640.83		69640.83 Sft
4	Cement concrete lining using washed screened and graded stone aggregate ratio (1:2:4) in bed total of 03 reaches	8444.93	12.33	8432.60Cft
5	Cement concrete lining using washed screened and graded stone aggregate ratio (1:2:4) in bed total of 03 reaches	18280.71	26.74	18253.97Cft

6	Providing and placing cement,sand and bitumen joint sealant in ratio (1:2:3) 0.5" wide and 1"deep total of 03 reaches	10181.21		10181.21 Rft
7	Filling expansion joints with bitumen,sand and saw dust in ratio (1:2:2), 0.5" wide and 2 " deep total of 03 reaches	1018.12		1018.12 Rft
8	Bitumen coating to plastered or cement concrete surface 10lbs .per 100sft(4.54kg per sqm) total of 03 reaches	5090.6		5090.6 Sft

Table 25: Quantity of cement and bitumen in sealant joint

Concrete Lining of Shaffi Distributary Reach RD 0 to 1412
Details of work
Total length=1412
no .of profiles 1412/10=141.20Nos(at 10ftc/c)
no. of expansion joints=1412/100=14Nos
Bed width=2ft
Full supply depth=1.8ft
Free board=1ft
Side slope=1V:1Hft/ft
Width of lip=1ft

Sr#	Description	Quantity	
1	earth work excavation in irrigation channels, drains etc to designed sections, grades and profiles, excavated material disposed off and undressed within 50 ft lead in ordinary soil profile in bed=141.20x2x0.50x0.25	35.3	Cft
		139.78	Cft

	profile in slope=2x141.20x3.96x0.50x0.25 profile in lip=2x141.20x1x0.50x0.25	35.3 210.38	Cft Cft
2	Cement plaster 1.5" thick ratio 1:6 in bed bed=1412x2 top lip =2x1412x1	 2824 2824 5648	 Sft Sft Sft
3	Cement plaster 1.5"thick (10mm) 1:6 in slope slope=2x1412x3.9	11182.47	Sft
4	Cement concrete lining using washed screened and graded stone aggregate ratio 1:2:4 in bed bed =1412x(2+2/2)x0.25 profile concreting bed 141.2x2x0.5x0.25 lip=2x14112x1x0.25 profile concrete in lip=2x141.2x1.0.5x1x0.25	 706 35.3 706 35.3	 Cft Cft Cft Cft
	Total	1482.6	Cft
5	Cement concrete lining using washed screened and graded stone aggregate 1:2:4 on slope panel=2x1412x3.96x0.25 profile=2x141.20x3.96x0.50x0.25	 2795.62 139.78	 Cft Cft
	Total	2935.4	Cft
6	Providing and placing cement,sand and bitumen joint sealant in 1:2:3 0.5 in wide and 1 in deep		

	bed=141.2x2 slope=2x141.20x3.96 top=2x141.2x1	282.4	Rft
		1118.25	Rft
		282.4	Rft
	Total	1683.05	Rft
7	Filling expansion joints with bitumen, sand and saw dust in 1:2:2 , 0.5 in wide and 2 in deep bed=14.12 x2 slope=2x14.12x3.96 lip=2x14.12x1		
		28.24	Rft
		111.82	Rft
		28.24	Rft
	Total	168.3	Rft
8	Bitumen coating to plastered or cement concrete surface 10lb/ 100sqft. Profile=141.2x(2+2(3.96+1))x0.5		
		841.52	Sft
	Total	841.52	Sft

Table 26: Aggregate, Cement and bitumen quantity in joints

Concrete Lining of Shaffi Distributary Reach RD 1412 to 6991
Details of work
Total length=5579
no .of profiles 5579/10=557.90 Nos(at 10ftc/c)
no. of expansion joints=5579/100=56 Nos
Bed width=1.35 ft
Full supply depth=1.6 ft
Free board=1ft
Side slope=1V:1H ft/ft
Width of lip=1 ft

Sr#	Description	Quantity	
1	earth work excavation in irrigation channels,drains to designed section, grades profiles, excavated material dispossed off and undressed within 50 ft		
	profile in bed=557.90x1.35x0.50x0.25	94.15	Cft
		512.84	Cft
	profile in	139.48	Cft

	slope=2x557.90x3.68x0.50x0.25 profile in lip=2x557.90x1x0.50x0.25	Total	746.47	Cft
2	Cement plaster 1.5" thick ratio 1:6 in bed bed=1x5579x1.35 top lip=2x5579x1	7531.65		Sft
		11158		Sft
		total	18689.65	Sft
3	Cement plaster 1.5"thick (10mm)1:6 on slope slope=2x5579x3.68	41027.47		Sft
		total	41027.47	Sft
4	Cement concrete lining using washed screened graded stone aggregate 1:2:4 bed=5579x(1.35+1.35)/2x0.25 profile concrete in bed=557.9x1.35x0.5x0.25 lip=2x5579x0.25 profile concrete in lip=2x557.9x1x0.5x0.25			
		1882.91		Cft
		94.15		Cft
		2789.5		Cft
		139.48		Cft
		total	4906.04	Cft
5	Cement concrete lining using washed screened graded aggregate 1:2:4 panel=2x5579x3.68x0.25 profile=2x557.9x3.68x0.50x0.25			
		10256.87		Cft
		512.84		Cft
		total	10769.71	Cft
6	Providing and placing cement,sand and bitumen joint sealant 1:2:3 , 0.5 in wide and 1 in deep bed=557.9x1.35			
		753.17		Rft
		4102.75		Rft

	slope=2x557.9x3.68 top=2x557.9x1	1115.8		Rft
		total	5971.72	Rft
7	Filling expansion joints with bitumen,sand and saw dust in 1:2:2, 0.5 in wide and 2 in deep bed=55.79x1.35 slope=2x55.79x3.68 lip=2x55.79x1			
		75.32		Rft
		410.27		Rft
		111.58		Rft
		total	597.17	Rft
8	Bitumen coating to plastered or cement concrete surface 10 lbs/100 sqft. Profile=557.9(1.35+2(3.68+1))x0.5			
		2985.86		Sft
		total	2985.86	Sft

Table 27: Total quantity of expansion and sealant joints

Description	Quantity
1. Reach RD. 0 to 1412 Total length = 1442 ft No. of profiles 1412/10 = 141.20 NOS. (at 10 ft. c/c) say 141 No. Expansion joint = 1412/100 = 14.12 say 14	
in bed sealant joint Bed = 141*2 *0.04 *0.08 =	0.9 cft
Lip = 141 * 2 * 1 * 0.04 * 0.08 =	0.9 cft
Expansion joint Bed = 14.12 * 2 * 0.04* 0.16 =	0.18 cft
Lip = 14.12 * 2 * 1 * 0.04 * 0.16 =	0.18 cft
Total	2.16 cft
On slope Sealent joint Pannel = 141 * 2 * 4 * 0.04 * 0.08	3.60 cft
Expansion Joint Pannel = 14.12 * 2 * 4 * 0.04 * 0.16	0.72 cft
Total	4.32 cft
2. Reach RD. 1412 to 6991 Total length = 5579 ft No. of profiles 5579/10 = 557.9 NOS. (at 10ft. c/c) say 558 No. Expansion joint 5579/100 =55.79 say 56	
in bed sealant joint Bed = 558*1.35*0.04*0.08 =	2.41 cft
Lip = 558*2*1*0.04*0.08 =	3.57 cft
Expansion joint Bed = 55.79*1.35*0.04*0.16 =	0.48 cft
Lip = 55.79*2*1*0.04*0.16	0.71 cft

Total	7.17 cft
On slope Sealent joint Pannel = 558*2*3.67*0.04*0.08 =	13.10 cft
Expansion joint Pannel = 55.79*2*3.67*0.04*0.16 =	2.62 cft
Total	15.72 cft
3. Reach RD. 6991 to 9730 TAIL Total length = 2739 ft No. of profiles 2739/10 = 273.9 NOS. (at 10 ft.c/c) say 274 NO. Expansion joint 2739/100 = 27.39 27 NO.	
in bed Sealent joint Bed = 274*0.86*0.04*0.08	0.75 cft
Lip = 274*2*1*0.04*0.08	1.75 cft
Expansion joint Bed = 27.39*0.86*0.04*0.16	0.15 cft
Lip = 27.39*2*1* 0.04*0.16	0.35 cft
Total	3 cft
On slope Sealent joint Pannel = 274*2*3.19*0.04*0.08	5.59 cft
Expansion joint Pannel = 27.39*2*3.19*0.04*0.16	1.11 cft
Total	6.70 cft
G. Total Deduction (in Bed)	**12.33 cft**
G.Total Deduction (on Slope)	**26.74 cft**

Table 28: Cost and quantity of temporary outlets

Providing temporary outlets							
Sr #	Description	Quantity		Rate	Reference	Unit	amount (Rs)
1	excavation in foundation of buildings, bridges and other structures including dag belling,dressing, refilling around structure with excavated earth ,watering and ramming lead upto 1 chain (30 m) and lift upto 5 ft (1.5) in ordinary soil	45.75	Cft	11658.25	chp 3 /21b	1000 Cft	533.3649375
2	cement concrete brick or stone blast 1.5" to 2 " guage in foundation and plinth ratio 1:4:8	4.5	Cft	29487.6	chp 6/3b	100 Cft	1326.942
3	pacca brick work other than building upto10' ratio1:3cement sand water	12.83	Cft	33440.9	chp-7/7 i	100 Cft	4290.46747
4	P/L RCC pipe sewers, molded with cement concrete 1:1.5 ratio 3 confirming to ASTM specification C-76-79, CLASS 2ii	20	Rft	754.65	chp 21-3i	1 Rft	15093
5	dismantling temporary outlets	1	_	2217.6	chp 17-4	1 job	2217.6
cost of 1 no outlet			Rs.	23461.37441			
cost of old material			Rs.	2416.521564			
net cost of 1 no outlet			Rs.	21044.85284			

Table 29: Quantity of concrete, mortar, bricks in temporary outlets

sr #	Description	Quantity	
1	excavation in foundation of buildings, bridges and other structures including dagbelling, refilling around structure with excavated earth, watering and ramming lead upto 1 chain (30 m) and lift upto 5 ft(1.5) in an ordinary soil		
	wall 2 3 1.5 2	18	Cft
	pipe 1 18.5 1.5 1	27.75	Cft
	total	45.75	Cft
2	cement concrete brick or stone blast 1.5" to 2 " guage in foundation and plinth 1:4:8 wall 2 3 1.5 0.5	4.5	Cft
3	pacca brick work other than building upto10' 1:3 cement sand mortar wall 2 3 0.75 2.85	12.83	Cft
4	P/L RCC pipe sewers, molded with cement concrete 1:1.5:3 confirming to ASTM C-76-79, CLASS 2 ii	20	Rft
5	dismantling temporary outlets	1	Job

sr #	Description	Quantity	
1	excavation in foundation of buildings, bridges and other structures including dagbelling, refilling around structure with excavated earth, watering and ramming lead upto 1 chain (30 m) and lift upto 5 ft(1.5) in an ordinary soil		
	wall 2 3 1.5 2	18	Cft
	pipe 1 18.5 1.5 1	27.75	Cft
	total	45.75	Cft
2	cement concrete brick or stone blast 1.5" to 2 " guage in foundation and plinth 1:4:8 wall 2 3 1.5 0.5	4.5	Cft
3	pacca brick work other than building upto10' 1:3 cement sand mortar wall 2 3 0.75 2.85	12.83	Cft
4	P/L RCC pipe sewers, molded with cement concrete 1:1.5:3 confirming to ASTM C-76-79, CLASS 2 ii	20	Rft
5	dismantling temporary outlets	1	Job

Table 30: Cost of permanent outlets

Poviding permanent outlet structures						
Sr #	Description	Quantity		Rate	Unit	Amount (Rs.)
1	dismantling outlets A.P.M or OF upto 2 ft	1	job	3465	Each	3465
2	earthwork for outlets excavation , refilling, discharge upto 50 cusecs	1	job	2310	each	2310
3	fixing APM OR OF block including supply(iron work)	42	kg	21768.35	100 kg	9142.707
4	extra labour for fixing APM or OF block including dressing of bricks for channel depth upto 3 ft	1	job	1816.3	each	1816.3
5	P/L RCC PIPE molded with cement concrete 1:1.5:3 I/C reinforcement cost	20	Rft	553.85	1 Rft	11077
6	cement concrete brick or stone ballast, 1.5 - 2 in guage in foundation and plinth 1:4:8	35.49	Cft	25659.6	100 Cft	9106.59204
7	pacca brick work other than building upto 10 ft height cement sand mortar (1:4)	85.87	Cft	35780.9	100 Cft	30725.05883
Total					Rs.	67642.65787

Credit of old material	Rs.	1150
Net cost of 1no outlet	Rs.	30009.71
Total outlets no. (5x 30009.71)	Rs.	150048.55

Table 31: Detail of permanent outlet structures

PROVIDING PERMANENT OUTLET STRUCTURES DETAIL OF WORK			
Sr.#	Description	Quantity	Unit
1	Dismantling outlets A.P.M. or O.F.,"H" upto 2.0 ft.(600 mm) (Average)	1	Job
2	Earthwork for outlets, excavation refilling ,ramming and puddling channels ,discharge upto 50 cusecs	1	Job
3	Water allowance for constructing outlets of culverts, when canal water is not flowing.	1	Job
4	Fixing APM or OF block including supplying	42	kg
5	Extra labour for fixing APM or OF block including dressing of bricks for channel depth upto 3ft.	1	Job
6	P/L RCC pipe sewers ,moulded with cement concrete ratio 1:1 1/2":3 with spigot socket or collerv joints.i/c cost of reinforcement confirming to B.S 5911 part 1 1981 class including carriage of pipe from factory to the site of work, to correct alignment and grade jointing cutting pipe where necessary finishing and testing etc. complete 225 mm 9 inch i/d	20	Rft.
7	Cement concrete brick or stone ballast 11/2" to 2" gauge in foundation and plinth ratio 1:4:8	-	-

i)	In foundation wall	7.527708	Cft.
ii)	In bed of wall	12.568	Cft.
iii)	Under Straight portion	3.0625	Cft.
iv)	Splay portion	6.3	Cft.
v)	End wall	6.048	Cft.
	Total	35.50621	
8	Pecca Brick work other than building up to 10 ft, height cement sand mortar (1:4)		
i)	For Wall	24.63413	Cft.
ii)	Under wall	2.8278	Cft.
iii)	For floor in straight position	0.42	Cft.
iv)	For straight walls	16.8	Cft.
v)	For floor in splay portion	2.8	Cft.
vi)	For Splay walls	24	Cft.
vii)	For end walls	14.4	Cft.
	Total	85.88193	Cft.

Table 32: Calculating weight of iron block

Analysis for calculating weight of iron block
H=2.00 ft B=0.25 ft. Thickness of plate =1/8 inch

i)	Side plate	16	Sft
ii)	Bed Plate	1.64	Sft
iii)	Roof Block	0.465	Sft
iv)	Side Bars	0.25	Sft
Total		18.355	Sft
Say		18.5	Sft
Weight in lbs		92.5	lbs.
Weight in Kg		41.96915	Kg

Table 33: Cost iron block

Description	Quantity	Rate	Unit	Cost
Fixing APM or OF block inclu- ding supplying (Small Iron work)	42 KG	42851.05 Chap-25/9	100 KG	17997.44

Table 34: Cost of dismantling works

Sr.#	Description	Quantity	Rate	Reference	Unit	Amount
1	Dismantling outlet Tail cluster	3	4620	Chp-17/2 f	Each	13860
2		3	2310	Chp-17/1 a	Each	6930

	Earthwork for outlets ,excavation refilling ,ramming and puddling channels ,discharge upto 50 cusecs.					
3	Water allowance for constructing outlets of culverts , when canal water is not flowing	3	2310	Chp- 17/12	Each	6930
4	Cement concrete brick or stone blast 1.5" to 2" gauge in foundation and plinth ratio 1:4:8	123.20 Cft.	25659.6	Chp-6/3 b	100 Cft.	31612.6
5	Pucca brick work other than building upto 10' height ratio 1:3 cement sand mortar	168.12 Cft.	33440.9	Chp-7/7 i	100 Cft.	56220.8
6	Fixing APM or OF block including supplying (Small Iron work)	63.0 Kg	6237	Chp-25/9	100 KG	3929.31
7	Extra labour in fixing A.P>M> and O.F. outlet blocks, including dressing of bricks for channel depth 2.0'. (600mm)	3 No.	1497.6	Chp-17/9 d	Each	4492.8
Total						123975.5

Table 35: Providing & Fixing Distance Marks

Provding & Fixing Distance Marks			
Detail of work			
Sr.#	**Description**	**Detail**	**Contents**
1	Reinforced cement concrete in roof slab,beams ,columns lintels, girders and other structural members laid in situ or precast laid in position, or prestressed members cast in situ, complete in all respects Type C (nominal mix 1:2:4) Base Top	= 1*1*0.75*1 =1((o.o75+o.25)/2)*0.75	0.75 Cft. 0.37 Cft.
2	Fabrication of mild steel reinforcement for cement concrete, including cutting, bending, laying in position, making joints and fastenings, including cost of binding wire and lobour charges for binding of steel reinforcement (also includes removal of rust)	1.12*2.13 Kg/cft	2.38 KG
3	Preparing surface and painting of new surface 3 coats emulsion Front Side Top	2*1*0.75 2((0.75+0.25)/2)*0.75 1*1*0.25	1.50 Sft 0.75 Sft 0.25 Sft Total = 2.50 Sft
4	Writing letters or figures, per letter, per inch (25 mm) height	2*3*4	24 inch
5	Carriage of small consignment for a distance for 5 Km	Each consignment	1 No

Table 36: Quantity and Cost of painting and writing data board

Providing Painting & Writing Data Board						
Abstract of Cost						
Sr.#	**Description**	**Qty**	**Rate**	**Reference**	**Unit**	**Amount**
1	Excavation in foundation of building, bridges and other structures, including dagbelling, dressing, refilling around structure with excavated earth, watering and ramming lead upto one chain (30 m) and lift upto 5 ft. (1.5 m) in ordinary soil	96.75 Cft	11658.25	Chp-3/21 b	1000 Cft	1128
2	Cement brick or stone ballast 1-1/2 " to 2" (4o mm to 50 mm) gauge, in foundation and plinth ratio 1:4:8	19.35 Cft	25659.6	Chp-6/3b	100 Cft	4965
3	Pacca brick work other than building upto 10ft. (3 m) height cement, sand mortar Ratio 1:3	142.92 Cft	33440.9	Chp-7/7 i	100 Cft	47794
4	Cement plaster 1:3 upto 20' (6.00 m) height 1/2" (13 mm) thick	210.94 Cft	3635.05	Chp-11/8 b	100 Cft	7668
5	Preparing surface & painting 3 coats	210.94 Cft	1469.75	Chp-13/5 a I + ii ii	100 Cft	3100
6	Writing letters or figures, per letter, per inch (25 mm) height	2000 No	22.95	Chp-13/10	1 No.	45900
Total						***110555***

Table 37: Detailing of painting works

Providing Painting & writing Data Board			
(one at head and one at tail)			
Detail of Work			
Sr. #	***Descriction***	***Contents***	
1	Excavation in foundation of building, bridges and other structures, including dagbelling, dressing, refilling around structure with excavated earth, watering and ramming lead upto one chain (30 m) and lift upto 5 ft. (1.5 m) in ordinary wall	2*9*2.15*2.5	96.75 Cft
2	Cement concrete brick or stone ballast 1-1/2 " to 2" (40 mm to 50 mm) gauge, in foundation and plinth ratio 1:4:8	2*9*2.15*0.5	19.35 Cft
3	Pacca brick work other than building upto 10ft. (3 m) height cement, sand mortar Ratio 1:3	2*8*1.5*2	48 Cft
		2*7*6*1.13	94.92 Cft
	Total		142.92 Cft
4	Cement plaster 1:3 upto 20' (6 m) height 1/2 " (13 mm) thick	2*2*6*7 2*2*6*1.13 2*7*1.13 Total	168 Sft 27.12 Sft 15.82 Sft 210.94 Sft
5	Preparing surface & painting 3 coats	quantity as per item # 4	210.94 Sft
6	Writing letters or figures, per letter, per inch (25 mm) height	height 2*1000 No.	2000 No.

Table 38: Comparison between old and new cost

Cost Changes	Old	New
Cost of total Number of Outlets	47794	105224
Estimate for Concrete Lining of shaffi Distributary Reach RD 0 to 9730 (Tail)	2105769	6913048
detail of earthwork original channel	388912.7	6324448
Concrete Lining of shaffi Distributary Reach RD 0 to 9730 (Tail)	7284068	16353479
providing permanent outlet structures	31159.73	67642
Analysis for calculating weight of iron block for tail outlet	3075.377	4571
Providing and fixing distance marks	7780	11819
Analysis for calculating weight of iron block for outlet	5156.571	17997
Providing Painting & Writing Data Board	45877.52	110554
Abstract of cost for dismantling works	123975	123975
Grand Total	10043568	30032761.6

Table 39: Crop Water Requirement For Rabi and Kharif Season

Rabi Season											
Sr. No.#	Crop Type	Kc Initial	Kc Mid Season	Kc Late	Etc (mm/day)	Etc(mm)	Crop (%)	Area (Acres)	Volume (acre-ft)	Cropping Period (days)	Q(Cusec)
1	Wheat	0.3	1.15	0.3	10.21	477.5	52.625	1630.3225	2554.06494	130	9.91
2	Potatoe	0.5	1.15	0.75	12.15	547.75	24.375	755.1375	1357.042538	130	5.26
3	Barley	0.3	1.15	0.25	8.79	415.05	12.625	391.1225	532.5964358	120	2.24
Summation						1440.3	Summation				17.41
Kharif Season											
Sr. No. #	Crop Type	Kc Initial	Kc Mid Season	Kc Late	Etc (mm/day)	Etc(mm)	Crop (%)	Area (Acres)			
1	Cotton	0.35	1.2	0.6	13.17	1033.9	1	30.98	105.0860302	195	0.27
2	Sugarcane	0.4	1.25	0.75	9.769	1855.26	1	30.98	188.5694055	183	0.52
3	Maize	0.3	1.2	0.35	10.32	495.25	38.5	1192.73	1937.990592	125	7.82
4	Rice	1.05	1.2	0.9	13.718	609.7	30.75	952.635	1905.582544	150	6.40
5	Millet	0.3	1	0.3	7.39	300.05	101	3128.98	3080.218009	105	14.79
Summation						4294.16	Summation				29.80

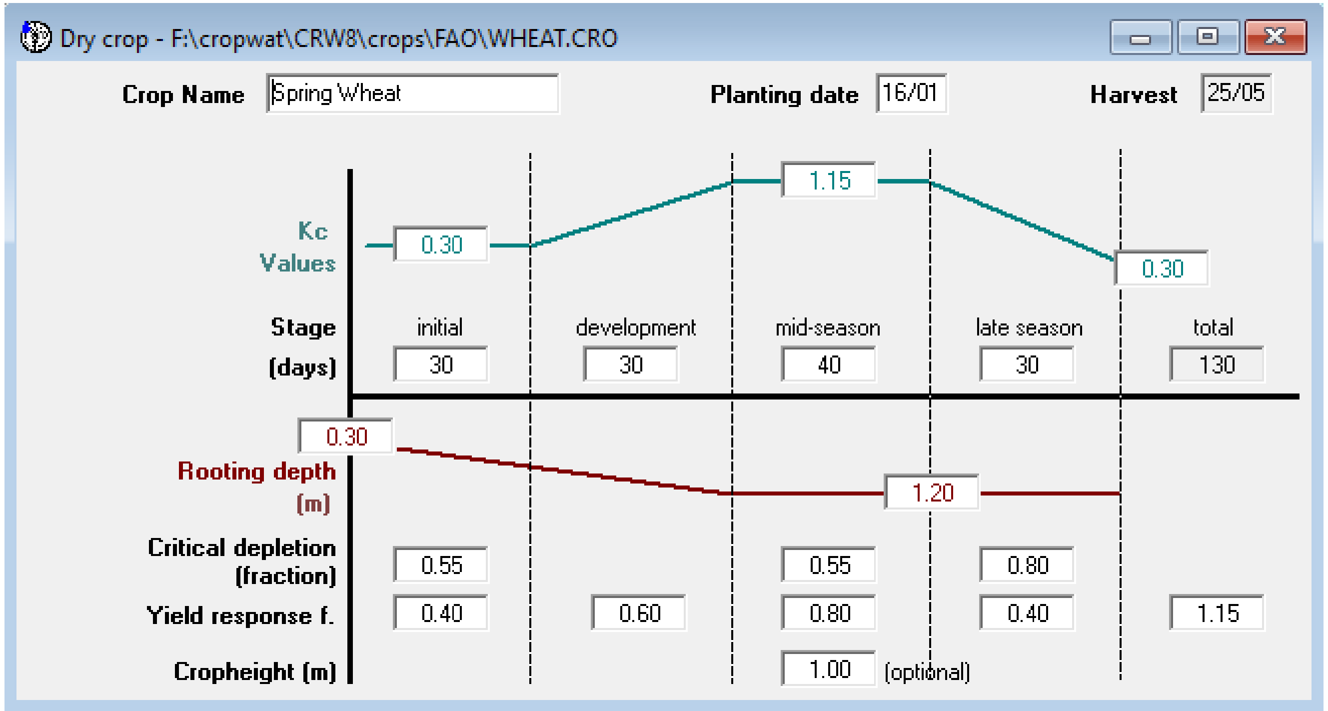

Fig 1: KC curve of Wheat crop using CROPWAT

Table 40: ETc calculations of Wheat

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	2	Init	0.3	0.41	2.1	0.1	1.9
Jan	3	Init	0.3	0.53	5.8	0.8	5
Feb	1	Init	0.3	0.66	6.6	1.4	5.1
Feb	2	Deve	0.36	0.91	9.1	1.9	7.2
Feb	3	Deve	0.6	1.82	14.6	2.3	12.2
Mar	1	Deve	0.85	3.03	30.3	3.1	27.2
Mar	2	Mid	1.1	4.49	44.9	3.7	41.2
Mar	3	Mid	1.14	5.58	61.4	2.6	58.8
Apr	1	Mid	1.14	6.57	65.7	1	64.7
Apr	2	Mid	1.14	7.53	75.3	0	75.3
Apr	3	Late	1.1	7.74	77.4	0.5	76.9
May	1	Late	0.85	6.42	64.2	0.6	63.6
May	2	Late	0.57	4.6	46	0.6	45.4
May	3	Late	0.36	2.84	14.2	1.6	12.4

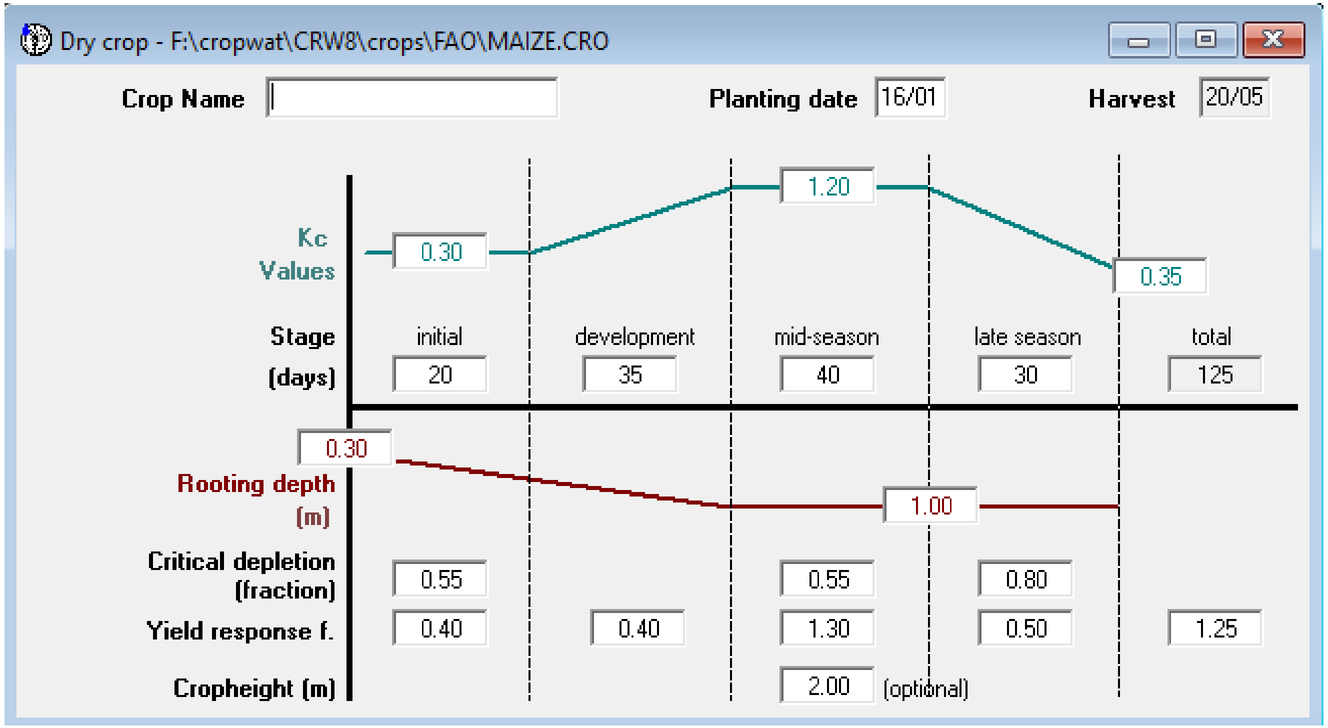

Fig 2: KC curve of Maize using CROPWAT

Table 41: ETc calculations of Maize

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	2	Init	0.3	0.41	2.1	0.1	1.9
Jan	3	Init	0.3	0.53	5.8	0.8	5
Feb	1	Deve	0.35	0.77	7.7	1.4	6.3
Feb	2	Deve	0.59	1.51	15.1	1.9	13.1
Feb	3	Deve	0.82	2.51	20.1	2.3	17.7
Mar	1	Deve	1.05	3.74	37.4	3.1	34.3
Mar	2	Mid	1.19	4.84	48.4	3.7	44.8
Mar	3	Mid	1.19	5.8	63.8	2.6	61.2
Apr	1	Mid	1.19	6.83	68.3	1	67.3
Apr	2	Mid	1.19	7.82	78.2	0	78.2
Apr	3	Late	1.04	7.27	72.7	0.5	72.2
May	1	Late	0.76	5.72	57.2	0.6	56.6
May	2	Late	0.48	3.86	38.6	0.6	38

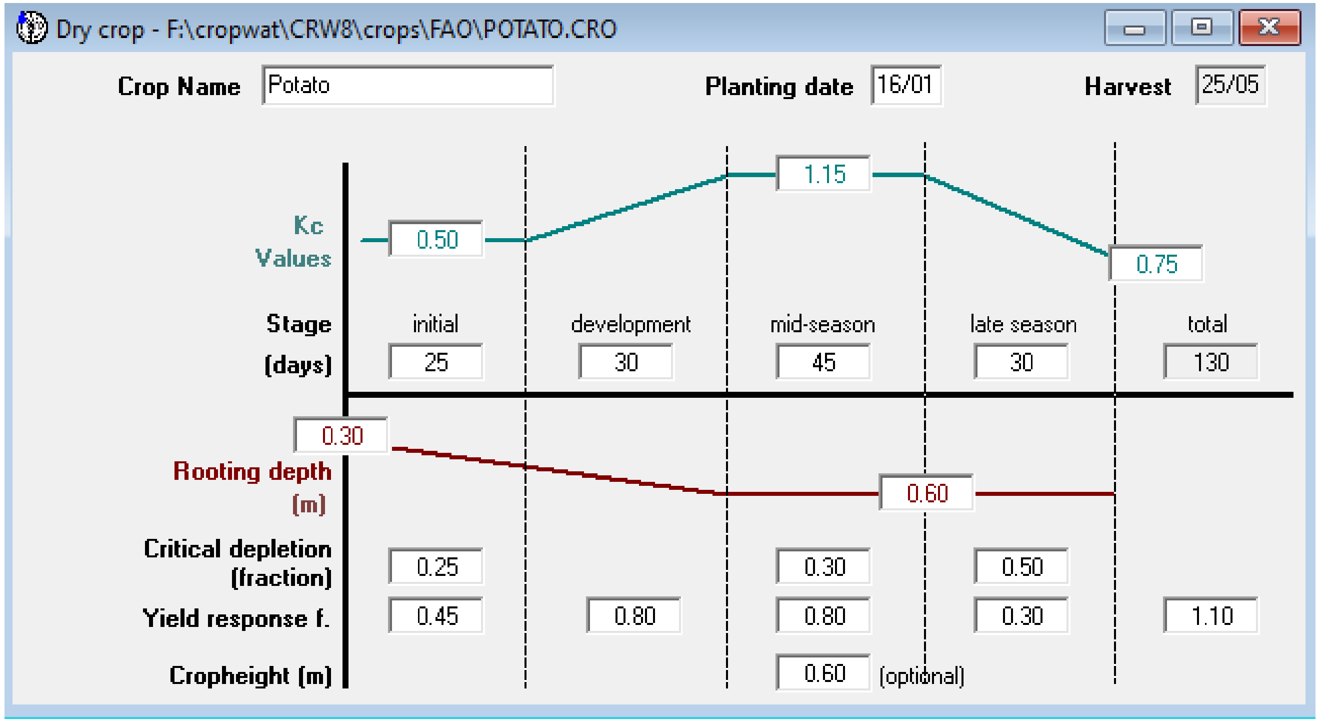

Fig 3: KC curve of Potato using CROPWAT

Table 42: ETc calculations of Potato

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	2	Init	0.5	0.69	3.4	0.1	3.3
Jan	3	Init	0.5	0.88	9.7	0.8	8.9
Feb	1	Deve	0.5	1.1	11	1.4	9.6
Feb	2	Deve	0.64	1.63	16.3	1.9	14.3
Feb	3	Deve	0.83	2.54	20.4	2.3	18
Mar	1	Deve	1.03	3.66	36.6	3.1	33.5
Mar	2	Mid	1.14	4.66	46.6	3.7	42.9
Mar	3	Mid	1.14	5.58	61.3	2.6	58.7
Apr	1	Mid	1.14	6.57	65.7	1	64.7
Apr	2	Mid	1.14	7.52	75.2	0	75.2
Apr	3	Late	1.12	7.89	78.9	0.5	78.4
May	1	Late	1.01	7.61	76.1	0.6	75.5
May	2	Late	0.87	7.1	71	0.6	70.3
May	3	Late	0.78	6.2	31	1.6	29.2

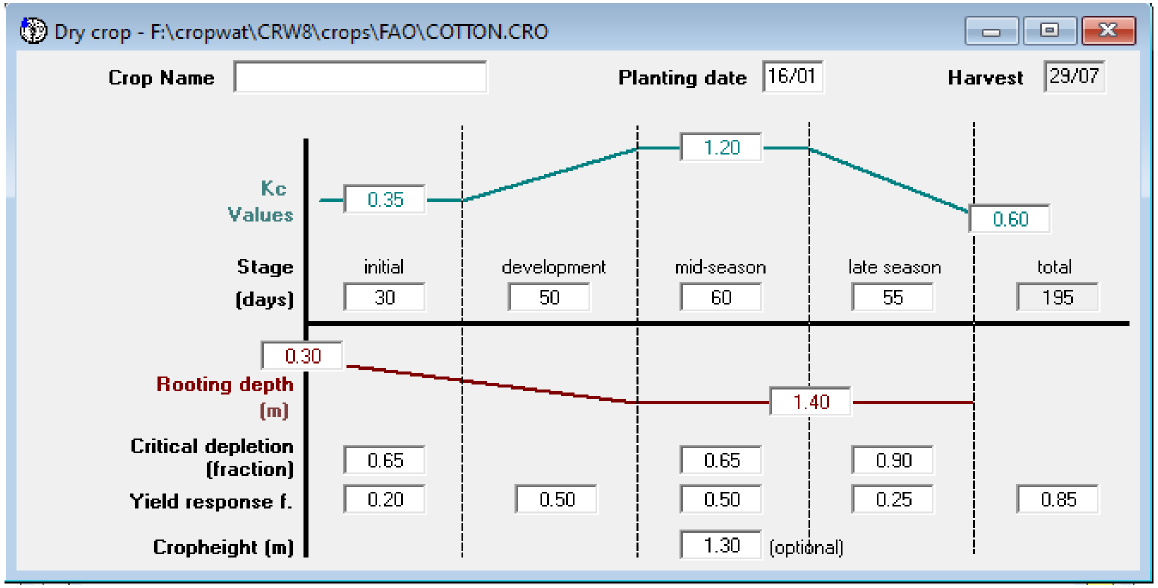

Fig 4: KC curve of Cotton by CROPWAT

Table 43: ETc calculation of Cotton

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	2	Init	0.35	0.48	2.4	0.1	2.3
Jan	3	Init	0.35	0.62	6.8	0.8	6
Feb	1	Init	0.35	0.77	7.7	1.4	6.2
Feb	2	Deve	0.39	0.98	9.8	1.9	7.9
Feb	3	Deve	0.53	1.62	12.9	2.3	10.6
Mar	1	Deve	0.68	2.43	24.3	3.1	21.2
Mar	2	Deve	0.85	3.47	34.7	3.7	31
Mar	3	Deve	1.03	5.02	55.2	2.6	52.7
Apr	1	Mid	1.18	6.8	68	1	67
Apr	2	Mid	1.2	7.9	79	0	79
Apr	3	Mid	1.2	8.43	84.3	0.5	83.8
May	1	Mid	1.2	9.08	90.8	0.6	90.2
May	2	Mid	1.2	9.74	97.4	0.6	96.7
May	3	Mid	1.2	9.57	105.3	3.6	101.7
Jun	1	Late	1.18	9.14	91.4	5.3	86.1
Jun	2	Late	1.07	8.22	82.2	7.2	75
Jun	3	Late	0.95	7.13	71.3	16.2	55.1
Jul	1	Late	0.83	6.1	61	28.6	32.4
Jul	2	Late	0.72	5.11	51.1	38.1	12.9
Jul	3	Late	0.61	4.14	37.3	29.4	1.3

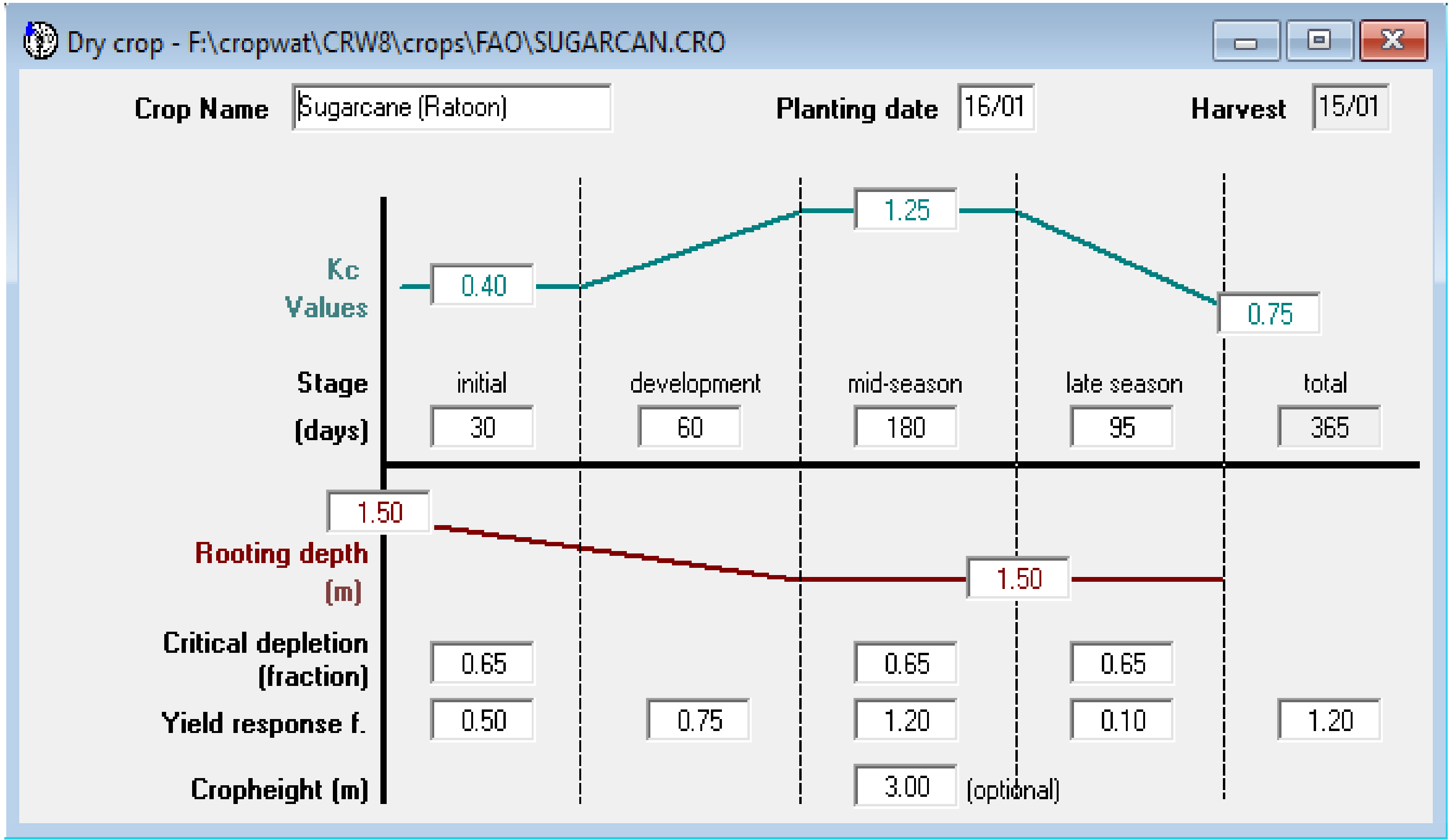

Fig 5: KC curve for Sugarcane

Table 44: ETc calculations of Sugarcane

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	2	Init	0.72	0.99	4.9	0.1	4.8
Jan	3	Init	0.4	0.71	7.8	0.8	7
Feb	1	Init	0.4	0.88	8.8	1.4	7.3
Feb	2	Deve	0.43	1.09	10.9	1.9	9
Feb	3	Deve	0.54	1.65	13.2	2.3	10.9
Mar	1	Deve	0.66	2.35	23.5	3.1	20.4
Mar	2	Deve	0.79	3.23	32.3	3.7	28.7
Mar	3	Deve	0.93	4.55	50.1	2.6	47.5
Apr	1	Deve	1.07	6.17	61.7	1	60.7
Apr	2	Mid	1.19	7.81	78.1	0	78.1
Apr	3	Mid	1.2	8.43	84.3	0.5	83.8
May	1	Mid	1.2	9.08	90.8	0.6	90.3
May	2	Mid	1.2	9.74	97.4	0.6	96.7
May	3	Mid	1.2	9.57	105.3	3.6	101.7
Jun	1	Mid	1.2	9.33	93.3	5.3	88
Jun	2	Mid	1.2	9.25	92.5	7.2	85.3
Jun	3	Mid	1.2	9.02	90.2	16.2	74
Jul	1	Mid	1.2	8.78	87.8	28.6	59.2
Jul	2	Mid	1.2	8.55	85.5	38.1	47.3
Jul	3	Mid	1.2	8.2	90.2	35.9	54.2
Aug	1	Mid	1.2	7.84	78.4	34.7	43.7
Aug	2	Mid	1.2	7.49	74.9	35	39.9
Aug	3	Mid	1.2	7.08	77.9	24.9	53.1
Sep	1	Mid	1.2	6.67	66.7	11.5	55.3

Sep	2	Mid	1.2	6.26	62.6	1.4	61.2
Sep	3	Mid	1.2	5.63	56.3	1	55.4
Oct	1	Mid	1.2	5	50	0.1	49.9
Oct	2	Late	1.18	4.31	43.1	0	43.1
Oct	3	Late	1.13	3.6	39.6	0	39.6
Nov	1	Late	1.07	2.93	29.3	0	29.3
Nov	2	Late	1.02	2.33	23.3	0	23.3
Nov	3	Late	0.97	1.95	19.5	0.1	19.4
Dec	1	Late	0.92	1.61	16.1	0.2	15.9
Dec	2	Late	0.87	1.29	12.9	0.3	12.6
Dec	3	Late	0.81	1.21	13.3	0.4	12.9
Jan	1	Late	0.76	1.07	10.7	0.3	10.4
Jan	2	Late	0.72	0.99	4.9	0.1	4.8

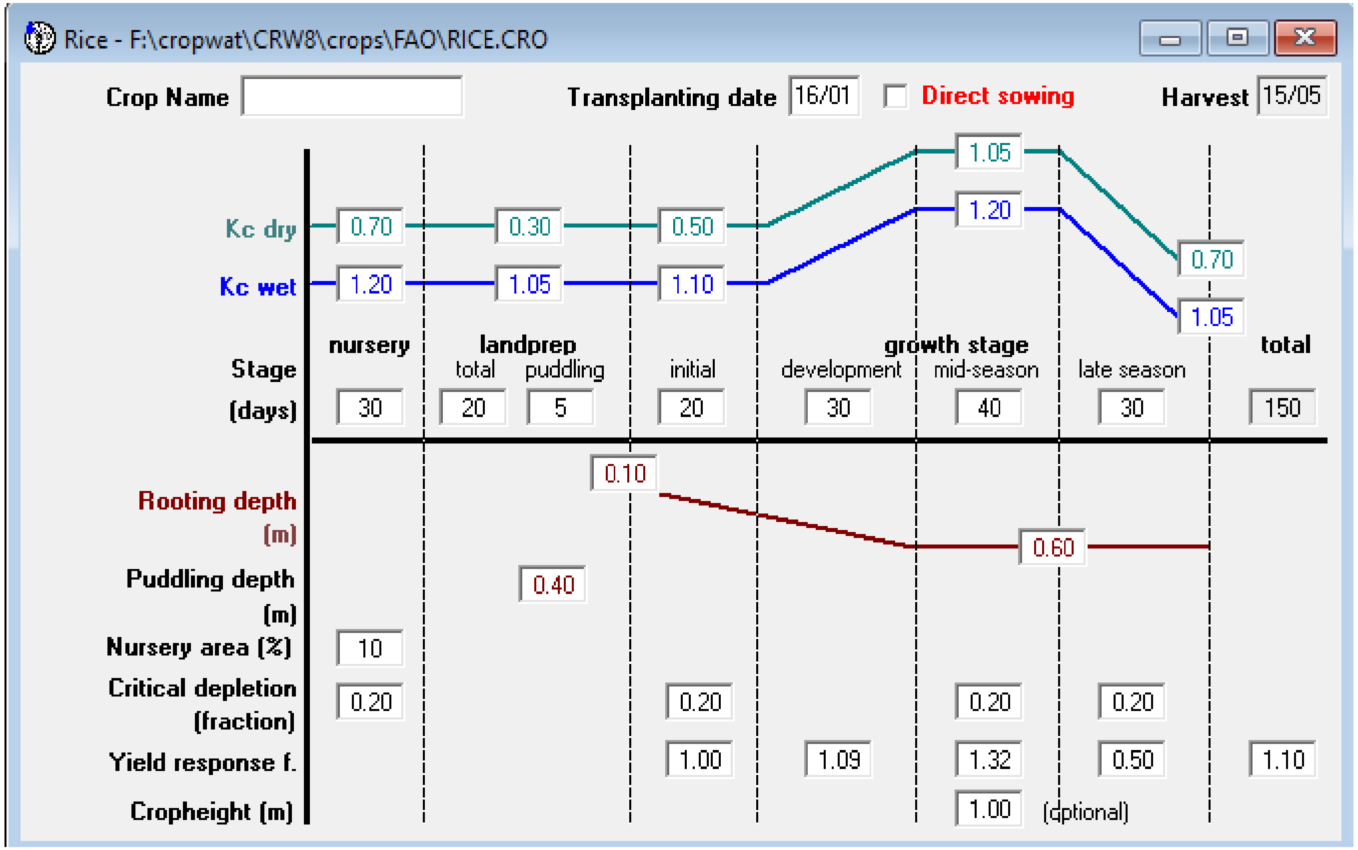

Fig 6: KC curve for Rice using CROPWAT

Table 45: ETc calculations of Rice

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	2	Nurs	1.2	0.18	0.7	0.1	0.5
Dec	3	Nurs/LPr	1.14	0.82	9	0.4	98.8
Jan	1	Nurs/LPr	1.06	1.51	15.1	0.3	14.8
Jan	2	Init	1.08	1.49	14.9	0.2	159.5
Jan	3	Init	1.1	1.94	21.4	0.8	20.6
Feb	1	Deve	1.11	2.42	24.2	1.4	22.8
Feb	2	Deve	1.13	2.89	28.9	1.9	26.9
Feb	3	Deve	1.16	3.55	28.4	2.3	26
Mar	1	Mid	1.18	4.22	42.2	3.1	39.1
Mar	2	Mid	1.19	4.84	48.4	3.7	44.8
Mar	3	Mid	1.19	5.79	63.7	2.6	61.1
Apr	1	Mid	1.19	6.83	68.3	1	67.3
Apr	2	Late	1.18	7.77	77.7	0	77.7
Apr	3	Late	1.14	8.01	80.1	0.5	79.6
May	1	Late	1.09	8.29	82.9	0.6	82.3
May	2	Late	1.06	8.6	43	0.3	42.7

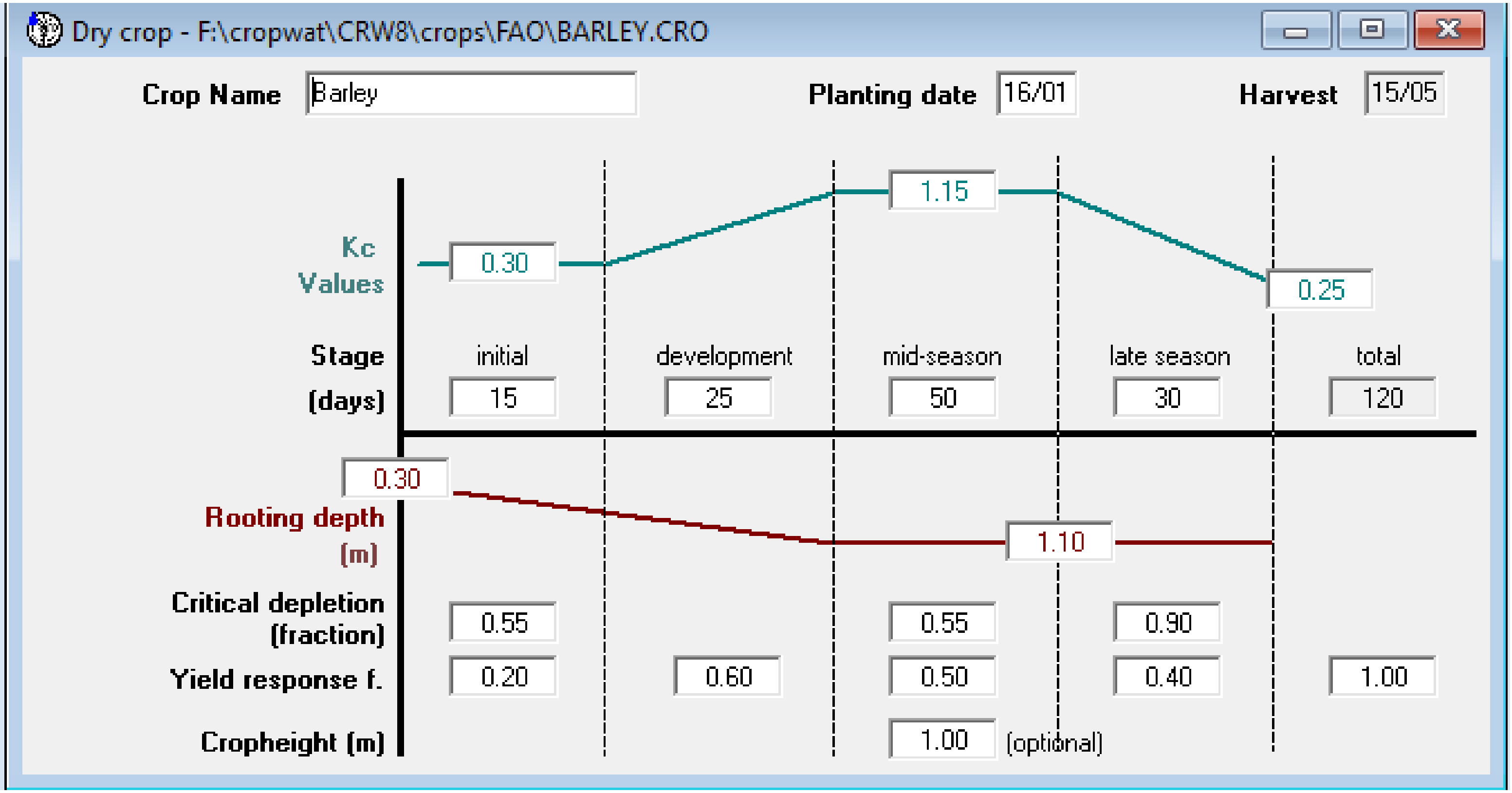

Fig 7: KC curve of Barley using CROPWAT

Table 46: ETc calculations of Barley crop

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	2	Init	0.3	0.41	2.1	0.1	1.9
Jan	3	Deve	0.3	0.54	5.9	0.8	5.1
Feb	1	Deve	0.52	1.13	11.3	1.4	9.9
Feb	2	Deve	0.85	2.17	21.7	1.9	19.8
Feb	3	Mid	1.11	3.4	27.2	2.3	24.8
Mar	1	Mid	1.14	4.05	40.5	3.1	37.4
Mar	2	Mid	1.14	4.63	46.3	3.7	42.7
Mar	3	Mid	1.14	5.54	61	2.6	58.4
Apr	1	Mid	1.14	6.53	65.3	1	64.3
Apr	2	Late	1.09	7.19	71.9	0	71.9
Apr	3	Late	0.83	5.8	58	0.5	57.5
May	1	Late	0.53	4.02	40.2	0.6	39.6
May	2	Late	0.31	2.51	12.5	0.3	12.2