Design of Micro-Irrigation System for Artificial Glacier

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(2014-AE-16-M)

Division of Agricultural Engineering

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Dedicated

To my

Beloved

Grandmother

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Horticulture, Division of Agricultural Engineering

Certificate – I

This is to certify that the thesis entitled, **"Design of Micro-Irrigation System for Artificial Glacier"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Technology in Agricultural Engineering (Soil and Water Engineering)**, to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Er. Basit Afzal Najar (Regd. No. 2014-AE-16-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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ABSTRACT

For sustainable agriculture a permanent water source is a prerequisite condition. A study was conducted in a village of district Leh to study the method for making artificial glacier, after analysis of temperature data of 4 years, which can supply and act as water source for new plantation in the months of spring to when there is acute shortage of water in the cold desert, Ladakh, the glacier were constructed with the maximum height of 65 feet and with a capacity of 1937500 litres of water and threadbare details of various components of artificial glacier which include study of all plate form, source pipe line, the central dome and the vertical pipe section. The study also covers design of drip irrigation system, which include peak water requirement calculations of willow which came to be 4 litres/day/plant followed by designing and selection of 4 LPH dripper, 16mm lateral 63mm main/submain and filtration system for the Willow plantation which were planted near the site of glacier. Studies also cover the cost comparison of artificial glacier with cost of construction of earthen LLDPE farm pond and R.C.C. tank. it was revealed that the construction cost in case of RCC tank were highest 199 paisa per litre while in case of LLDPE earthen farm pond it came to be 22.8 paisa per litre and in case of artificial it was the least as 17.1 paisa per litre

Key words: Artificial glacier, Drip Irrigation, Water Storage, Ice formation.

Signature of Student
Dated____________

Signature of Major Advisor
Dated _________________

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Basit Afzal Najar

Place: Shalimar, Srinagar

Date: _______________

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Chapter – 1

INTRODUCTION

1.1 General

Agriculture was the key development in the rise of human civilization, whereby farming of domesticated species created food surpluses that nurtured the development of society. The history of agricultural development can be traced back ten thousands of years, and its technological advances has been driven and defined by greatly different climates, cultures, and geographies. However, all farming generally relies on techniques that seek to expand and maintain lands suitable for raising domesticated species.

For plants, this usually requires the development of irrigation systems (dry land farming is also available, however the description of such techniques are beyond the scope of this research). Many agricultural advances have been developed to support the sustainment of livestock. Livestock are raised in a combination of grassland-based and landless systems, in an industry that covers almost one-third of the world's ice- and water-free area.

Agricultural advancements have hence been a major factor in changing landscapes and ecological systems. A growing concern is being currently raised with regards to the preservation of natural resources and their sustainment. A growing tendency in the developed world, is the encouragement of sustainable agriculture, including permaculture and organic agriculture, looking at technological advancement in the area from the viewpoint of the environment's future.

1.2 Glaciers

More than one sixth of the world's population lives in glacier-fed and snow-fed water basins (Stern, 2007). As global temperatures are increasing, snow-cover is decreasing in most regions of the world. There is a melt-off and mass loss for the majority of the world's glaciers and ice caps that changes the hydrology of glacier fed water basins (Bates *et al.*, 2008). As glaciers melt due to global warming, river discharges for glacier fed rivers increases in the short term but is expected to decrease over the next few decades, as ice storage gradually diminishes (Kundzewicz *et al.*, 2007).

This study focuses on the western part of the Himalayas, which has very low annual precipitation, a short growing season and relies heavily on glacial melt water for agricultural production to sustain livelihoods. The climate of the Himalayas is highly variable because its wide range of geographical factors such as elevation and rain-shadow effects, contributing to variations in temperature and precipitation (Young and Hewitt 1990). For these reasons water-harvesting techniques have been developed in these areas over centuries as a way of decreasing vulnerability in periods of water scarcity.

The quantity of the water harvested by different techniques varies depending on the water-use purposes, particularly whether it is for domestic (e.g. drinking water) or for agricultural use.

Because climate change is increasing, the water stress in regions that are already dry is severing (Houghton, 2009). There is an urgent need for improvement and implementation of water management techniques, as well as the spread of knowledge of existing solutions. The cold deserts of the Himalayas, with which this research is occupied, falls under such category.

The question which leads this research is twofold: firstly, this research aims to review and analyze the glacial response to climate change in the Himalayas. Then it looks to review the ways in which village-populations are currently coping with water scarcity and identify possible issues in water supply management. The final purpose of this research is to provide a sustainable agricultural solution that could serve these communities and solve the problems identified, using traditional irrigation and water preservation techniques.

To answer these questions, the research explores and examines the agriculture of Ladakh, taking into account that it is inseparable from the social and boulder structure of the villages. Ladakh here is taken as a case study in exploring the general possible application of renovating water preservation and irrigation techniques in similar, other geographical locations.

The climate of Ladakh is considered harsh due to long winters that are devoid of rainfall, whereas temperatures may fall below -30^{o}C. At altitudes of 3,000 to 4,300 m (9,800 to 14,100 ft), the growing season is only a few months long, similar to agricultural cycles found in countries situated in the north hemisphere of the earth.

As a result, the land of Ladakh is treeless and seemingly barren, with crazily canted rocky slopes. The fields in the Ladakh territory are mostly terraced, built with elegant stone walls, and most skillfully arranged. Fields prepared for agricultural cultivation are mostly miniature lands and are not suitable for broad scale agriculture.

The agriculture of Ladakh is predominantly dependent on irrigation. Sometimes, channels are artificially made to divert water for agriculture. In such fields, little soil dams are created or breached in the drains, using long handled spades to distribute the water in a gentle and even flow. The water for agriculture of Ladakh comes from the Indus River, which runs low in March and April when crops have the greatest need for irrigation.

With the rise of global warming, Ladakh had also suffered changes in water supply, as water hardly seem to be available in spring. While Ladakh has been enjoying a fluent supply of glacier water in previous years, an abundant amount of water is being lost to the river in the form of flash floods, occurring due to the rapid melting of glaciers. This is a fact that had prevented farmers from sowing seeds in earlier months and give up what could have been a valuable growing season.

A concept of artificial glaciers might seem to solve this issue. The glacier is constructed by exploring the extreme climatic conditions in Ladakh's winter, and thus produce an artificial water body near farms. Taking advantage of the changing temperatures between winter and spring, the same glacier can therefore provide an additional supply of water that will enable the sowing and cultivation of new plantations that may produce crops throughout spring and summer months. The possibility of further nurturing agricultural activities in currently dormant months, may help not only in water conservation but also in the preservation and improvement of the soil.

1.3 Research objectives

The main objectives of the study shall be the following:

- The making of an artificial glacier.
- Design of micro-irrigation system for artificial glacier.
- Cost analysis of artificial glacier with other water storage structures.

1.4 Chapter plan

The dissertation has been divided into five chapters.

Chapter 1: General introduction; background; problem definition and objectives.

Chapter 2: Literature review of Glacier studies Micro-irrigation studies

Chapter 3: Discusses the methodology adopted for the study to achieve the objectives.

Chapter 4: Discusses the results obtained in the study.

Chapter 5: Contains summary and conclusions from this research. It also highlights recommendations for follow-up research.

Chapter – 2

LITERATURE OF REVIEW

Water is a precious natural resource, a basic human need and a prime national asset. Water, the most vital element for survival on earth, has become one of the emerging environmental issues our ecosystem is facing today. The issue of water quality, quantity and availability are the three major concerns in this regard, and in this sense, they are vital to the existence of life on the earth.

The oceans occupy about 70.8% of the earth surface and only 29.2% is land. About 97.5% of the world water resource is in the ocean and is saline. Of the remaining, 2.5% of the global water resource, about 2% is in ice cap and glaciers and is generally not available for the requirements of mankind. A major part of the balance amount of water occurs as ground water, of which about half the volume lies in water bearing formation deeper than 800 m below ground surface and is not ordinarily available for economic development. (UNESCO World Water Report, 2013).

Human use of water has increased more than 35 folds over the past three centuries. Globally, 3240 km^3 of fresh water are withdrawn and used annually. Of this total, 69 per cent is used for agriculture, 23 per cent for industries and 8 per cent for domestic use. Water use varies considerably around the world (UNESCO World Water Report, 2013).

Fresh water resources are depleting very fast in recent years. Sharp increases in population together with its resulting spurt in water demand for agriculture, industrial and urban purposes, require careful planning and management. Irrigation is the application of water to soil to assists in production of crops. Irrigation water is supplied to supplement the water available from rainfall, soil moisture and the capillary rise of ground water. In many areas of the world, the amount and timing of rainfall are not adequate to meet the moisture requirement of crops. Hence, successful crop production often requires adequate provision for irrigation.

2.1 Glacier studies

Baker *et al*. (1981) observed that the study of outburst floods is important to the hydrology and geomorphology of glaciated areas. They reported that a glacier flood can initiate migration of the river channel, channel erosion, flood plain inundation, and increase sediment load. In populated areas they may also threaten human life, property, bridges, and roads. Evidence of the destructive nature of outburst floods is exposed in the "Channeled Scablands", a landscape that stretches across Montana, Idaho, Oregon and Washington.

Taylor (1985) had studied and implemented a number of different open snow and ice storage techniques, where snow/ice is stored in ponds or pits with low or non-permeable sides and bottom. The idea of cooling sprayed water with winter cold was patented in the USA 1836.

MacCracken and Silvetti (1987) noted that ice storage for cooling was used already in ancient Greece. Ice was harvested from lakes and rivers and stored in barns that were thermally insulated by sawdust (Taylor, 1985). This technique was common in Europe and North America until the beginning of the 20th century, when cooling machines were introduced.

David and Knebel (1995) examined the ice harvesting method for thermal energy storage systems. They also discuss the operating characteristics of ice-harvesting equipment using heat-initiated defrost cycles, the process of ice formation, a simplified model for predicting ice-making performance, and defrost energy requirements.

Iijima *et al.* (1999) had explored that possibility of applying an air system for the management of snow cover. In the Japanese All-Air-System that they have explored, air is used as the cold carrier. Warm air is blown through holes in the snow. The snow is covered with a thin water layer that absorbs particles and gases, i.e. the air is cleaned during cooling. The hole spacing is about one meter and the snow lies on a steel grid.

FAO (1976) define land suitability as the fitness of land for a specified kind of use. This suitability of land is a function of crop requirements and soil/land characteristics and refers to use of land on a sustainable basis. It means that land suitability evaluation should take account of the hazards of soil erosion and other types of soil degradation (FAO, 1983). The sustainable land use should have maximum suitability and minimum vulnerability (de la Rosa *et al.*, 2000).

Shin *et al.* (2000) conducted experiments to produce ice particle by the process of spraying water in a vacuum chamber. The theoretical aspect of the experiments was investigated by the diffusion- controlled evaporation model. The cool energy storage increased almost proportionally to the number of spray nozzles. From the experimental result, they found the size of particles by spraying water droplets at ambient temperature in the vacuum chamber, where pressure was maintained below the freezing point of water. It was found that the spray flow rate influences the performance of the system more than the position of spray nozzle.

Vigneault (2000) reports on a 270 m^3 ice pond, 9m x 15m x 2m (Length, Width, Depth), made in soil of low hydraulic permeability for 200 tons of ice. The pond was filled with water during the autumn and kept free from snow to increase ice production. At the end of the winter the pond was insulated with 0.065 m Styrofoam and a light color tarpaulin. Cold bottom water was pumped to a cooling battery via a filter and then back into the pond. The cold was used for potato storage. The average cooling load was 27.4 kW and the estimated coefficient of performance (COP) was 2-4 times better than for a conventional system.

British Glaciological Society (2003) investigated the distribution of the glaciers and rivers and the total water stored from accumulated snow and ice and other matters. Their findings are used here to help the expansion of agriculture, afforestation, and livestock breeding in this region. In one part of Western

Sinkiang, where rainfall is plentiful, a glacier 20 miles long (32 km) has caused floods every year. It has blocked the only passage between north and south and damaged crops in the area.

Michelle and Cunico (2003) reported that ice storage builds ice by chiller or refrigeration plant during off-peak hours to serve part or the entire on-peak cooling requirement. The latent heat of fusion of water (144 Btu/lb) is the highest among common materials, that is melting or freezing of one pound of ice at 32^{o}F absorbs or releases 144 Btu of heat. The coolant which is circulated through the ice tanks to make ice is at a temperature of 15 to 26 ^{o}F.

Because of the rain shadow effect of the Himalayan Range, the mean annual precipitation in Leh (3506 m) is less than 100 mm in total, and there is high inter-annual variability. Whereas the average summer rainfall between July and September reaches 37.5 mm, the average winter precipitation between January and March amounts to 27.3 mm and falls almost entirely as snow (Archer and Fowler, 2004).

Hossain (2004) noted that in the case of conventional ice storage air-conditioning systems i.e. ice on coil or ice harvesting system, the efficiency of ice formation tends to decrease with increasing ice layer, which acts as an insulator.

Kjell Skogsberg (2005) explored the air temperature and relative humidity (after the snow cooling) in the All Air System, and found that these vary with airflow rate, inlet temperature and length of the snow holes, but depend only slightly on the diameter of the hole. In the All-Air-System, temperature and humidity to the user part can be controlled.

Norphel (2009) reported that in the so-called rain shadow of the Himalayas, Ladakh receives just 5 centimeters of rainwater a year, about the same quantity found at the Sahara desert. Ladakh’s population is entirely dependent on waters deriving from melting of glaciers and snow, which had been supporting these communities’ agricultural endeavors for centuries. However, global warming has hit this region in particularly hard: the tree line has risen more than 150 meters during his lifetime, and glaciers have retreated by as much as 10 kilometers.

Archer *et al.* (2010) examined the functioning and transformation of glacier-fed and snow-fed irrigation systems in the semiarid Trans-Himalayan and Karakoram Ranges. They have found that these have become a prominent research topic in recent years. Particular attention has been paid to the hydrological potentials and limitations of these “Asian water towers”.

Bhandari *et al.* (2014) applied GIS and remote sensing technology for land capability classification and crop suitability assessment in Tons river watershed of Dehradun. Based on the slope map, land characteristics of each physiographic unit and land capability criteria for land qualities, land capability classes and sub-classes were assigned. These were translated into a land capability map. From this map, a slope suitability map was generated, which was combined with land characteristics and crop suitability criteria to generate crop suitability maps for mango and wheat. For this study, GIS and image processing software ARCGIS10 and ILWIS9.3 were used.

Krishna and Regil (2014) used RS and GIS for agricultural land suitability analysis in Anjarakandi Watershed, Kerala. Satellite data were used for preparing land use. Drainage and contour maps were extracted from the topographic map of Survey of India. Secondary data like soil, geology, and landform were obtained from survey. Weighted overlay methodological approach was used to integrate all thematic layers in a GIS environment. Results indicated that 30% area of the basin is lying under moderate to high suitable areas. Both account for 65% of the total area of the Anjarakandi River basin.

2.2 Micro-irrigation studies

The crop coefficient represents crop-specific water use and is required for accurate estimation of irrigation requirements. Doorenbos and Pruitt (1977) suggested that the K_c values need to be derived empirically for each crop based on lysimeters data and local climatic conditions. Crop coefficient values for a number of crops grown under different climatic conditions were also suggested.

Wright (1982) also presented crop coefficients for a few crops. Since, localized K_c values are not always available in many parts of India and due to lack of locally determined crop water use data, the values of K_c as suggested by Food and Agricultural Organisation of the United Nations (Allen *et al.*, 1998; Doorenbos and Kassam, 1979) are being widely used to estimate crop water requirement.

Phene *et al.* (1994) noted that the excessive application of water generally entails losses because of surface run-off from the field and deep percolation below the root zone within the field. Both run-off and deep percolation losses are difficult to control under furrow irrigation system, where a large volume of water is applied at a single instance. An alternative water application method such as the drip irrigation method allow for much more uniform distribution as well as more precise control of the amount of water applied and also decreases nutrient leaching.

Molden *et al.* (1998), studied field application efficiency in most traditional irrigation methods and found that it is still very low. Typically less than 50% (sprinkler irrigation) and often as low as 30% (surface irrigation).

The Water Conservation Factsheet (2001) published by The British Columbia Ministry of Agriculture, Food and Fisheries, provides information on selecting the crop coefficient that should be used. Crop coefficients for tree fruits and grapes have been segregated into months. The absence of a cover crop will lower the crop coefficients. The cover crop draws water from the soil storage reservoir and therefore increases water use. If there is no cover crop or grass between the tree or plant rows the crop coefficients will be about 10% lower in May, September and October and 20% lower in June, July and August.

Raes *et al.* (2002) concluded that irrigation system and schedules are mostly designed to cover irrigation requirements during the peak period, when crop evapotranspiration is high and rainfall is scarce. Outside this peak period, irrigation scheduling needs to be adapted to the prevailing weather conditions. The unreliability of the rainfall and the absence of guidelines at a short time step often complicate decision making during these irregular periods.

Drip irrigation is an efficient method for minimizing the water used in agricultural and horticultural crop production. Frequency of water application is one of the most important factors in drip irrigation management because of its effect on soil water regime, root distribution around the drip holes, the amount of water uptake by roots and water percolating beyond the root zone. The water requirement of a crop must be satisfied to achieve potential yields. The crop water requirement is also called crop evapotranspiration and is usually represented as ET_c, evapotranspiration is a combination of two processes- evaporation of water from the ground surface or wet surfaces of plants; and transpiration of water through the stomata of leaves. The water requirement can be supplied by stored soil water, precipitation and irrigation. Irrigation is required when ET_c (crop water demand) exceeds the supply of water from soil water and precipitation. As ET_c varies with plant development stage and weather conditions, both the amount and timing of irrigation are important (Coelho and Or 1999; Wang *et al.,* 2007.)

In combination with animal husbandry, agriculture forms the basis of livelihood and food security in the permanent settlements of Ladakh (Dollfus *et al.*, 2009; Dame and Nusser, 2011). Agriculture depends entirely on gravity controlled irrigation and concentrates on the cultivation of the staple crops: barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*). Peas, mustard, potatoes, carrots, turnip, radish, green leafy vegetables, and alfalfa (*Medicago* spp) are also regularly cultivated on terraced fields, accompanied by apple and apricot trees. Furthermore, plantations of poplars (*Populus* spp) and willows (*Salix* spp) are characteristic elements of the irrigated areas, covering the local demand for fuel and timber wood.

These values are commonly used in places where local data are not available. However, they emphasized the strong need for local calibration of crop coefficients under given climatic conditions (Shankar, 2007; Shankar *et al.*, 2012).

Kumar *et al.* (2012) suggest that efficient water management of crops requires accurate irrigation scheduling which, in turn, requires the accurate measurement of crop water requirement. Irrigation is applied to replenish depleted moisture for optimum plant growth. Reference evapotranspiration plays an important role for the determination of water requirements for crops and irrigation scheduling. Various models/approaches varying from empirical to physically base distributed are available for the estimation of reference evapotranspiration. Mathematical models are useful tools to estimate the evapotranspiration and water requirement of crops, which is essential information required to design or choose best water management practices.

Chapter – 3

MATERIALS AND METHODS

This research was undertaken to initiate an artificial glacier and drip irrigation system for the water stored in the form artificial glacier. It aims to compare cost effectiveness of the construction and use of an artificial glacier with other water storage structures, which are already carried out in the Phyang village in Leh, Ladakh region of Jammu and Kashmir. The study was done in collaboration with Sigmol School during the year 2015 and 2016. The details of raising, designing of the drip irrigation system and cost analysis are followed and materials used during the construction are presented below.

3.1 Data collection

3.1.1 Study area

The field experiment was conducted at the land of Phyang monastery in village of Phyang, Leh. It was chosen for this due to its relative proximity to natural glaciers and their outflow stream. This proximity meant that water can be readily channelized, and the glacier is almost accessible by road.

Phyang is situated at 34^{o} 11′N, 77^{o} 29′E with an altitude of 3595 meters from mean sea level. The area is barrel with minimal vegetation which is due to minute annual precipitation. However a fair amount of vegetation, mainly willows, has made their existence on the peripheries of the flowing fresh water streams which comes from the melting of nearby glaciers. The flowing water thus join with the Indus River. By reducing water use efficiency of fresh water, the topography of the area is undulation with a gradual slope toward the glaciers which results in considerable elevation difference between the outlet of the glacier to the site of artificial glacier.

3.1.2 Soils

The top soil at the site is desert brown sandy loam. No humus is present in the soil. Phyang is sandy to sandy loam in texture, with poor water holding capacity. Soil pH is 7.82, slightly alkaline in nature, electric conductivity is 197.7 ~Scm^{-1}, sodium adsorption ratio (SAR) values is 0.69, total dissolved solids (TDS) is 94.6 ppm mean soluble sodium percentage (SSP) is 16.3 and residual sodium carbonate (RSC) 0.30 mel^{-1}. 90% soils are low in available phosphorus but high in potassium with availability depending upon the other parameters of the soil. Micronutrient status (zinc, iron, copper and manganese) are found to be below critical level and majority of soil samples have shown deficiency in its content. However, copper content is found normal in 65% of area (Somen *et al.* 2011).

The soil of high-altitude-cold-desert originate from weathered rocks. They are immature and with large proportion of sand gravel and stone in them (Dwivedi *et al.,* 2005). In the present study, sand fraction found increasing along the altitude, whereas silt fraction was in reverse order indicating the dominance of sand forming minerals in parent materials. Hence, findings indicate that the cold arid soils are dominated by sand alike the hot arid soils, and this relative high proportions of sand in these soil fragments are the cause of the sandy loam textural class in this region. Climate and parent material profoundly influence soil characteristics (Schinner, 1982; Yang *et al.,* 2008). Hence, the soils of the studied region have more proportion of coarse grained soil particles, which indicates the slow process of soil formation. This may be due to the climatic conditions (low temperature, higher snowfall, availability and movement of water along the altitude and wind).

It is also assumed that the lack of smaller size particles shows the slow process of weathering in this region. Therefore, slow process of soil formation along the altitude results in very low content of clay particles which may cause low content of available mineral nutrients in this soil (Brady and Weil, 1999).

3.1.3 Climate

Leh's climatic characteristics are quite unique in relation to the rest of the Indian subcontinent due to the mountain ranges that surround it. Summer in Leh lasts from May through August, after which the winter sets in and lasts until April. The town receives minimal rainfall (90-120 mm/year), mostly during the months of July and August. Therefore, the region of Ladakh is referred to as a cold mountain desert (National Informatics Center, Leh District, Ladakh 2010).

Leh receives high solar radiation due to its high altitude, and consequently, even though temperature in the summer rarely exceeds $28^{o}C$, the rain fed atmosphere considerably enhances the sun's intensity (Singh 2006). When not covered in snow, the topography in Ladakh consists of rocky, barren, granite mountains, with very little vegetation. The air in Leh is very dry, with relative humidity ranging from 6-24% (Tetra Tech, 2009).

3.1.4 Vegetation

The region of Ladakh is mostly barren, and agricultural activities performed by villagers is the only vegetation noticeable, apart from a few willow and popular trees which are grown alongside irrigation streams. The main crop is grim (naked barley - *Hordeum vulgare* L. var. nudum Hook. f., which is an ancient form of domesticated barley with a hull easier to remove). This form of barley is the main ingredient in the staple food made in Ladakh. Water for the agriculture of Phyang comes from glaciers, which run in late May when barley fields have the greatest need for irrigation

3.1.5 Meteorological data

Before the formation of the artificial glacier, efforts were made to record the weather data which includes temperature and precipitation of the area. This was done so that the data can be used for various calculations with regards to ice formation in winter and the melting of the glacier during spring time, when the water is needed most. In order to fulfil the water requirement, quantities and times of the artificial glacier's melting-water were recorded in both tabulated form as we well as graphical form.

Table 3.1: Monthly temperate, relative humidity, total precipitation data of Leh from 2012 to 2015 Defense Institute of High Altitude Research (DIHAR, 2016)

Month	Average temperature (^{o}C)		Temperature (^{o}C) limits		Relative humidity (%)		Total precipitation (mm/cm)
	Day	Night	Day	Night	Min.	Max.	
2012							
January	0.1	-15.4	4.5	-20.0	57	19	15 mm (S)
February	0.6	-10.7	7.5	-17.5	59	21	70 mm (S)
March	9.2	-2.3	14.5	-8.5	53	20	10 mm (S)
April	12.7	1.5	16.5	-3.5	57	20	10 mm (S)
May	15.53	2.67	18.5	-2.5	61	20	Nil
June	18.6	7.53	26.0	3.0	61	20	19.6 mm (R)
July	26.59	13.87	29.5	9.0	41	20	1.9 mm (R)
August	26.0	13.29	31.0	10.0	53	20	9.1 mm (R)
September	20.51	7.6	26.5	2.0	59	20	1 mm (R)
October	11.77	-1.74	17.0	-6.0	50	20	Nil
November	7.72	-5.05	13.5	-11.5	57	20	Nil
December	1.56	-12.5	4.5	-16.5	56	24	Nil
2013							
January	3.0	-10.5	7.5	-18.5	55.8	31.9	39 mm (S)
February	1.6	-10.2	7.5	-17.5	53.0	31.4	46 mm (S)
March	8.5	-4.8	11.5	-11.5	39.3	26.4	Nil
April	12.6	-0.2	16.0	-6.0	37.5	24.9	10.0 mm (R)
May	16.5	3.8	23.0	-1.5	37.5	22.6	Nil
June	23.4	9.5	30.5	3.0	35.8	21.5	15.7 mm (R)
July	26.8	13.6	31.0	9.5	30.1	20.1	22.0 mm (R)
August	26.1	12.7	32.0	8.5	25.8	20.3	24.2 mm (R)
September	21.3	7.0	26.5	2.0	27.3	20.7	2.9 mm (R)
October	15.6	-0.0	23.0	-5.0	31.8	21.8	7.6 mm (R)
November	13.8	-8.3	10.0	-12.0	35.0	25.7	Nil
December	2.9	-12.4	10.0	-17.5	36.8	25.9	4 mm (S)

Contd…

Table 3.1 contd…

Month	Average temperature (^oC)		Temperature (^oC) limits		Relative humidity (%)		Total precipitation (mm/cm)
	Day	Night	Day	Night	Min.	Max.	
2014							
January	0.0	-13.5	3.0	-18.5	37.4	30.7	60 mm (S)
February	0.8	-9.9	9.0	-13.5	37.8	28.2	4 mm (S)
March	7.1	-5.2	11.5	-12.0	33.2	27.4	Nil
April	12.3	-0.5	18.0	-6.5	31.1	25.0	Nil
May	17.0	3.4	21.0	0.0	28.5	22.7	Nil
June	20.7	9.3	26.5	3.5	26.4	20.9	Nil
July	26.2	13.4	32.0	8.5	24.5	20.3	29.0 mm (R)
August	24.5	12.0	30.0	6.0	24.8	20.3	2.6 mm (R)
September	18.8	6.7	25.0	2.0	28.7	21.7	45.4 mm (R)
October	14.6	0.0	20.0	-5.0	31.2	22.5	Nil
November	8.4	-8.1	11.5	-12.5	34.3	26.6	Nil
December	2.9	-11.7	10.0	-17.0	36.3	29.2	18 mm (S)
2015							
January	0.8	-13.0	5.5	-17.0	36.5	30.3	5 mm (S)
February	3.3	-8.5	9.5	-15.0	35.0	29.3	6 mm (S)
March	7.0	-4.9	14.5	-11.5	33.1	27.4	36 mm (S)
April	12.5	-0.2	17.5	-5.0	31.2	24.7	8.5 mm (R)
May	16.7	4.1	20.0	0.5	28.8	22.6	0.2 mm (R)
June	19.5	7.6	22.0	6.0	27.0	21.3	11.2 mm (R)
July	25.1	11.5	28.5	7.5	25.5	20.3	61.8 mm (R)
August	25.1	12.3	29.0	8.5	25.9	20.2	57.4 mm (R)
September	18.9	6.0	22.5	1.0	28.1	21.7	23.4 mm (R)
October	14.5	0.2	19.0	0.0	31.0	23.5	0.6 mm (R)
November	9.1	-5.2	15.0	-9.0	33.1	26.5	Nil
December	2.2	-10.8	10.0	-16.5	36.2	29.6	9 mm (S)

The meteorological data on temperature, humidity and rainfall, was collected from Defense Institute of High Altitude Research, which was then processed further.

3.1.6 GIS mapping

GIS mapping of the study area, including the pipe line was conducted from the source to the location of artificial glacier in Phyang and in the Indus Valley. The area was mapped using arc GIS 10.2 with active online resources. High resolution base map imagery, (Bing imagery) was used to demarcate the stream line (blue) along with the pipe line (red) (as shown in Fig. 3.1), along with the location of artificial glacier (17^{th} July 2015).

Supported by the field investigations, the orthorectified high spatial resolution imagery allowed for the bi-temporal mapping of small-scale land use structures and infrastructure elements. In order to analyze the pipeline path and location of the artificial glacier Basin, 8 GPS spot were integrated to the mark pipe line from the stream (marked red, Fig. 3.2). This approach allowed the identification of the area suitable for construction of the artificial glacier and area for cultivation.

Satellite images provided information about the stored natural water reserve in the form of natural glacier and was also helpful in marking the pipe line with less hindrance and obstacles. GPS were processed and superimposed on Google Earth to estimate pipe length and other important aspect of the project. This way, showing the location of various parts of the artificial glacier on a satellite sky-view of Phyang valley, was made possible. The glacial source of the Phyang Tokpo stream can also be seen in these mapping images.

3.2 Glacier formation

3.2.1 Plate form

The first step was the preparation of a site for the glacier: a platform of 100m by 35m was mounted on land by mechanical means in order to achieve a horizontal leveled surface. A special type of earth which is relatively less

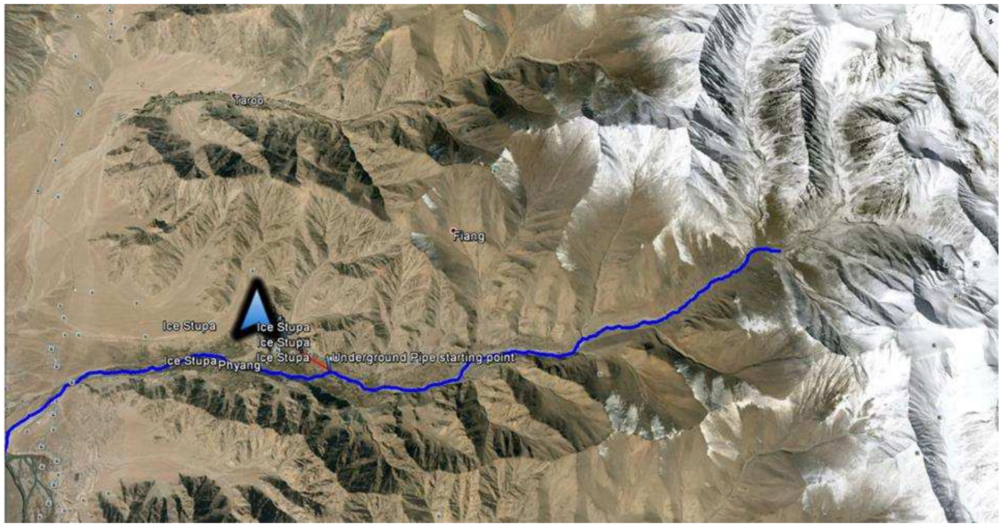

Fig. 3.1: Mechanical excavation for source pipe line

Fig. 3.2: Mechanical excavation for source pipe line

permeable due to high clay content presence, was spread on the platform, so that melting water would be guided in to collection chamber rather than percolate down in soil profile. This was implemented in response to the mostly sandy soil.

3.2.2 Source pipe line

In parallel, a survey of the Phyang valley had been performed, where the 2.5 Km pipeline was laid. The pipe line was laid in November after several occasions of climbing and descending the length of the valley to mark the pipeline's route. The route is 2.5 km long, and a drop in head (difference in height from inlet and outlet) of 65 m was finally achieved. The pipe line was made of HDPE of different sizes, varying from 110 mm for 10 meters, then followed by 90 mm HDPE pipe of 1.5 km then 75 mm HDPE pipe line were used.

There were four main reasons for the choice of a telescopic pipe line: one was to reduce frictional loses through the pipe line, second was to increase the intake flow from the source, third was to ease the process of siphoning and finally, the telescopic pipeline was chosen as to maintain the proper velocity of the water through the pipeline

The pipe line was laid in a 6 feet deep and 2 feet wide trench which was made by manual as well as mechanical means with an aim of protecting the pipeline and water from freeing during winter. However, this could not tackle the issue of the freezing main line, an issue which persists to this day.

Vertical head difference was measured to be enough for the production of a 35 m of artificial glacier taking into account that an extra amount of head can be used by the villager for other various innovative purposes. The same head difference can be used in summer to run hundreds of sprinklers and produce an artificial rain effect in the desert.

There were a few reasons for using the HPDE pipe: Firstly, HPDE is light-weight and is known for its long life: As the site was tough and was not fully approachable by vehicle, there was a need of light weight and yet durable pipes.

Plate 3.1: Mechanical excavation for source pipe line

Secondly, the main advantage of HDPE pipe is that it resistant to U.V radiation, which is, as mentioned before, very high in Ladakh and is major source material degradation in the region.

HPDE has excellent resistance to chemicals, salts and solvents: Water coming from glaciers is pure, however the same water comes in contact with rocks and minerals, and hence might dissolve a wide range of salts which may have an impact on the pipe material. The fourth reason has to do with HPDE's excellent flexibility and strength: the property of flexibility works in favor of this project, and thanks to the pipe's flexibility, a good quantity of bellows and fitting s were saved, which in turn prevented head lose due to fittings and also saved time during installation.

HPDE is a high abrasion resistant: flowing water possess considerable amount of sand and abrasive particles, in order to preserve pipe line for such damage HDPE pipe was preferred. In addition, this type of pipe does not have any conveyance loses. Compared to any other type of pipe, HDPE pipe has a negligible water conveyance loses. It is available in various pressure ratings and sizes. In this type of project, pressure rating pipes had a major role to play in order to sustain the pressure head of at least 40 meter and HDPE pipe does possess these characteristics. Finally, diathermic in nature, in HDPE pipes water flowing can be prevented by freezing in chilling nights of winter when mercury falls below -30^{o}C.

3.2.3 The central dome

An artificial glacier is designed so that a central ice dome (reception hall) is raised at the heart of the glacier and an ice tunnel leading to that dome. (Igloo shaped) The dome and the tunnel are first made in light iron pipes and clad with plastic sheets. It has a base diameter of 3.65 meter and a central height of 2.13 meter.

On top of this formwork, the ice starts forming slowly burying the dome and the tunnel into solid ice. But the solidification of ice is not a process which is easily started, as water, even if already cold, needs a relatively extensive surface area to quickly freeze with exposure to the cold air. Otherwise, there is a risk that the water would flow down and seep into the sand.

To approach this issue, the execution team, came up with the idea of using sea-buck thorn bushes. The thorn bushes act as water-flow speed breakers and decreased kinetic energy of water while allowing it to freeze without being wasted to ground.

The glacier was constructed gradually. Every time the glacier reached the jet, another pipe was added from the base of the glacier. In this way, the height of the glacier increased.

The glacier does not usually possess any discrete shape as it is formed by the process of crystallization. Shapes of the artificial glaciers depend on various factors such as the placement of the water shower, the general flow of water and the freezing pattern which was observed during the process of its creation.

At the end of the season, a conical pyramid of artificial glacier was raised and measured approximately 20 meters tall, with a base radius of 10 meters.

3.2.4 Vertical pipeline system Material needed

The vertical pipe system constitutes of 1.5″ diameter GI pipe placed at the center of the dome. These were placed vertically with the help of MS iron guide and came out of the top of dome. On top of the G.I pipe, a jet breaker, which is a modified pulp bob that, held inverted by an iron bridge to spray water uniformly in all directions as shown in Plate 3.3.

This modified jet has no moving parts, as moving parts are unable to perform in the harsh temperatures as found in the site. Using the jet, the water are spread at top of the dome, and onto the poly-film. This enabled waters to lose its kinetic energy and facilitated the freezing of water so that ice can accumulate and the glacier can be gradually built.

Plate 3.2: Making of iron dome

Plate 3.3: Jet assembly and breaking pattern

Once the ice reached to the nozzle height, another G.I pipe was added from the base inside the dome to increase the height of the vertical pipe line. This way, the height of the artificial glacier was increased without needing to climb on the glacier to add more pipes.

The process was repeated until the desired height of the glacier was attained. Sizes of the artificial glaciers generally depend on the amount of water that gets frozen, excluding the amount of water that is lost without freezing. However, an increased height in glaciers can be obtained by observing the elevation difference between the source and the site. The maximum height for an artificial glacier that was attained is 65 feet.

3.2.5 Glacier capacity and volume

The amount of water that was retained by the artificial glacier can be estimated by relating the structure to a certain geographical shape, hence constructed glacier resembled to conical shape, therefore volume of the glacier was calculated as.

$$V = 1/3\ \pi \times r^2 \times h$$

Where 'r' is the radius of the cone's base and 'h' is the vertical height of the cone from the center of base to the apex.

Ice water equivalent

With a known volume of ice, the water equivalent can be calculated with the formula:

$$h_w = (p_i/p_w)\ h_i$$

Where h_w is height of the melt water column, p_i is the density of ice, p_w is the density of water and h_i is the height of the icepack (Dingman, 2002).

$$h_w = (0.934/1)\ 19.81$$

$$h_w = 18.50$$


Plate 3.4: Cone shaped artificial glacier

$$V = 1/3\ \pi \times 10^2 \times 18.5$$

$$V = 1937.8\ m^3$$

$$V = 19{,}37{,}800 \text{ liters}$$

3.3 Drip irrigation system

3.3.1 Introduction

Arid regions with extensive periods of drought and inadequate rainfall contribute to the India's sub-continent's food shortage problem. While nature cannot be controlled, society does have the ability to develop and practice more efficient water usage techniques in order to improve water supply management. One type of technology that may contribute to the improvement of water supply management and the associated food crisis is drip irrigation.

Drip irrigation systems (DIS) have discharge points or sufficiently small holes in sections of hose, designed so that filtration is a primary concern (Burt and Styles, 1994). These systems commonly use low flow rates and low pressures at the emitters and are typically designed to wet only the root zone while maintaining it at or near an optimum moisture level (James, 1988). This method, therefore, may be efficient in conserving water, as there is no need in irrigating the entire field.

Obvious advantages of drip irrigation include a smaller wetted surface area, minimal evaporation and weed growth, and potentially improved water application uniformity within the crop root zone by better control over the location and volume of water application (Hoffman and Martin, 1993).

Drip systems are also commonly designed to include fertigation and automation capabilities, however in recent years, low-pressure drip irrigation (LPDI) systems have been developed for smaller farming areas. For many subsistence farmers, a standard pressurized system is too expensive and complicated, as pressurized systems are intended for large areas of land, and therefore do not match the needs of small subsistence farming (Bustan and Pasternak, 2008).

These systems are economical and fairly simple to use, and therefore are appropriate for subsistence farming in rural areas of developing countries. LPDI systems work with gravity-power and are low water pressure; there is no longer a need for operation by an outside power source, thus reducing the initial cost. With the bottom of the water reservoir sitting at 1-2 m above the ground, these systems can generate a flow of about 1 m^3/h (Phocaides, 2007).

3.3.2 Estimation of peak water requirement of crop

Before the micro-irrigation system was designed water requirement was calculated. The climate of Ladakh is pleasantly warm and dry in summer, though very cold and dry in winters. At all seasons there is abundant bright sunshine, and high radiation values thanks to the thin, clear atmosphere. This is why crops grow well in summer, and in winter man and animals can warm –up in the sun.

The winter snow-fall is sufficiently deep to cause significant difficulties in farming and is sometimes a serious hazard, however it is also the life-blood of the whole agricultural system, as it is the main source of water for irrigation. The average pan evaporation of 4.3mm day represents about 40cm over the crop growing season which must be supplied by irrigation (Crook, 2010).

A plot of land of length 225 meter and width of 60 meter were prepared for willow plantation. With a spacing of 60 centimeters plant to plant and 4.5 meters row to row. The plot was chosen just below the site of the glacier so that there will be enough head to operate a drip irrigation system without any external power source.

Reference evapotranspiration will be calculated by Pan Evaporation method (FAO, 1998).

$$PWR = \frac{ET_0\ (C_r.C_a)A}{n}$$

Where,

PWR	=	Peak water requirement [mm day^{-1}]
ET_0	=	Evapotranspiration rate [mm day^{-1}]
C_r	=	Crop factor
C_a	=	Canopy factor [up to 1]
A	=	Area of plant (Plant spacing × Row spacing) [m^{-2}]
n	=	Efficiency of Micro-irrigation system

$$PWR = \frac{4.3(0.27 \times 0.42)2.7}{0.9}$$

$$PWR = 3.9\ \text{mm/day/plant}$$

Approximately 4 liters /day/plant

3.3.3 Design and selection of drip-irrigation system

Dripper *:* The selection of type and number of drippers per plant is based on Peak water requirement of crop and soil type. Where sandy soil was prevalent, water requirement was 4 liters per day. For this reason a dripper of 4 liters per hour was chosen. Operating the system for 1 hour, it should suffice the requirement of the crop, and in future with increase in plants 'growth, and the increase of water requirement another dripper of 4 liters per hour can be added to meet the plants' demand. It is also possible to use a loop of drippers around the root zone of the plant so that uniform water distribution in root zone is achieved. Besides water requirement, the following consideration were kept in mind while selecting the dripper:

- It should be compact, serviceable and inexpensive to keep the system cost low.

- It should have relatively low discharge to ensure less deep percolation losses.
- It would not vary significantly with pressure this will give good uniformity of distribution.

Lateral *:* Lateral carries water from submain and feeds into drippers. Generally one lateral for each row of orchard plant and one lateral for two rows of vegetables is used. The size and length of lateral is dependent on the head lose in the lateral. The number of drippers on each lateral will determine the net flow the lateral and according depending upon the dipper spacing the lateral of certain diameter will be selected a with permissible head lose and can be obtained by following expression:

$$Hf = \frac{K_S L Q^{1.9} (4.1 \times 10^6) F}{D^{4.9}}$$

Where,

Hf = Total head loss due to friction [m]

K_S = Scobys coefficient

L = Length of pipe [m]

Q = Flow rate [LPS]

D = Inner diameter of pipe [mm]

F = Factor for multiple outlet pipe flow

We have

K_S = Scobey's coefficient

L= half of plot size as we running pipe in the center of the field, $\frac{60}{2}$ = 30 m

Q = flow in one lateral will be = $\frac{30}{0.6} \times \frac{4}{3600}$ = 0.055 lps

D = 14.2 mm (inner dia)

F = Factor for 20 to 40 outlet in a pipe is 0.35

$$Hf = \frac{0.4 \times 30 \times 0.55^{1.9}\ (4.1 \times 10^{6})\ 0.35}{14.2^{4.9}}$$

Where,

Hf = 0.157 m

However, frictional loses by using 16mm (outer diameter) lateral, but keeping growth into consideration, the water requirement of plant is certainly going to increase.

Sub-main/Mainline : HDPE pipes of size 63 mm × 4 kg/cm^2, were used as a Submain/main. Only one pipe line was used for main and sub main. Separate control was provided to each lateral to ensure better utilization of water, cost reduction inlying of extra pipe line and in order to enhance the ease of operation.

This technique also enables the system to cope with the variability of the melting glaciered water of which flow is a variable of climatic conditions. Hence 16mm mini control value were used as joiner as well as controller. The size of the mainline was decided by referring the HDPE friction loss equation.

The number of laterals per pipe determined the net flow of the pipe and accordingly depends upon the lateral spacing of the main/submain. 63mm diameter pipes were selected with a permissible head lose which is obtained by the same expression.

$$Hf = \frac{K_S L Q^{1.9}\ (4.1 \times 10^{6}) F}{D^{4.9}}$$

Where;

Hf = Total head loss due to friction [m]

K_S = Scobys coefficient

L = Length of pipe [m]

Q = Flow rate [LPS]

D = Inner diameter of pipe [mm]

Plate 3.5: Laterals for willow trees

F = Factor for multiple outlet pipe flow

We have

K_S = Scobey's coefficient

L= As we operating half of the area at a time, hence whole are will be covered in two hours, so whole pipe line will be divide into two,

$$\frac{225}{2} = 112.5 \text{ m}$$

$$Q = \text{flow at once} = \frac{112.5}{4.5} \times \frac{100 \times 4}{3600} \text{ lps} = 2.77 \text{ lps}$$

D = 56 mm (inner dia)

F = Factor for 20 to 40 outlet in a pipe is 3.5

$$Hf = \frac{0.4 \times 112.5 \times 2.77^{1.9} (4.1 \times 10^{6}) \, 3.5}{56^{4.9}}$$

$$Hf = 1.21 \text{ m}$$

Filtration : The filtration of the irrigation water is of major importance for the normal application of this system. The solid content in the water must be removed through effective filtration in order to avoid blockage damage to the drippers. The kind of filtration depends on the impurities contained in the water and the degree of filtration required. As the source of water in this case is glacier, after melting, water takes its course of natural stream where it absorbs sand particles and minor trash due to turbulence in water steam. After freezing the stream water in form of artificial glacier, thorn branches were used again in order to control solar radiation and the melting of the glacier. In this way melting water possesses sand vegetation and other various impurities.

The flow of the system is 2.77 liter per second (lps) which equal to 10 m^3/hr allowing us to use 12 m^3/hr screen filter of 100 micron which was used in the system to reduce the turbidity.

3.3.4 Layout and bill of quantities

After completing the design process an actual bill of quantity was made with the layout of designed drip irrigation system for the plants.

Item description	**Quantity**	**Unit**
HDPE pipe PE 80 4kg/cm^2 63 mm	300	M
4lph dripper	5500	No
16 mm Mini control valve	150	No
Poly Grommet take off 16mm	150	No
16mm poly end stop 8shaped	150	No
Poly joiner 16mm	50	No
2" GI isolation valve	2	No
1"Air release value assembly	1	No
63 mm pipe end with flange, nut and bolts	10	No
100 micron screen filter 12m^3/hr	1	No
2"Ventury with manifold	1	No
Fittings etc.	1	Set

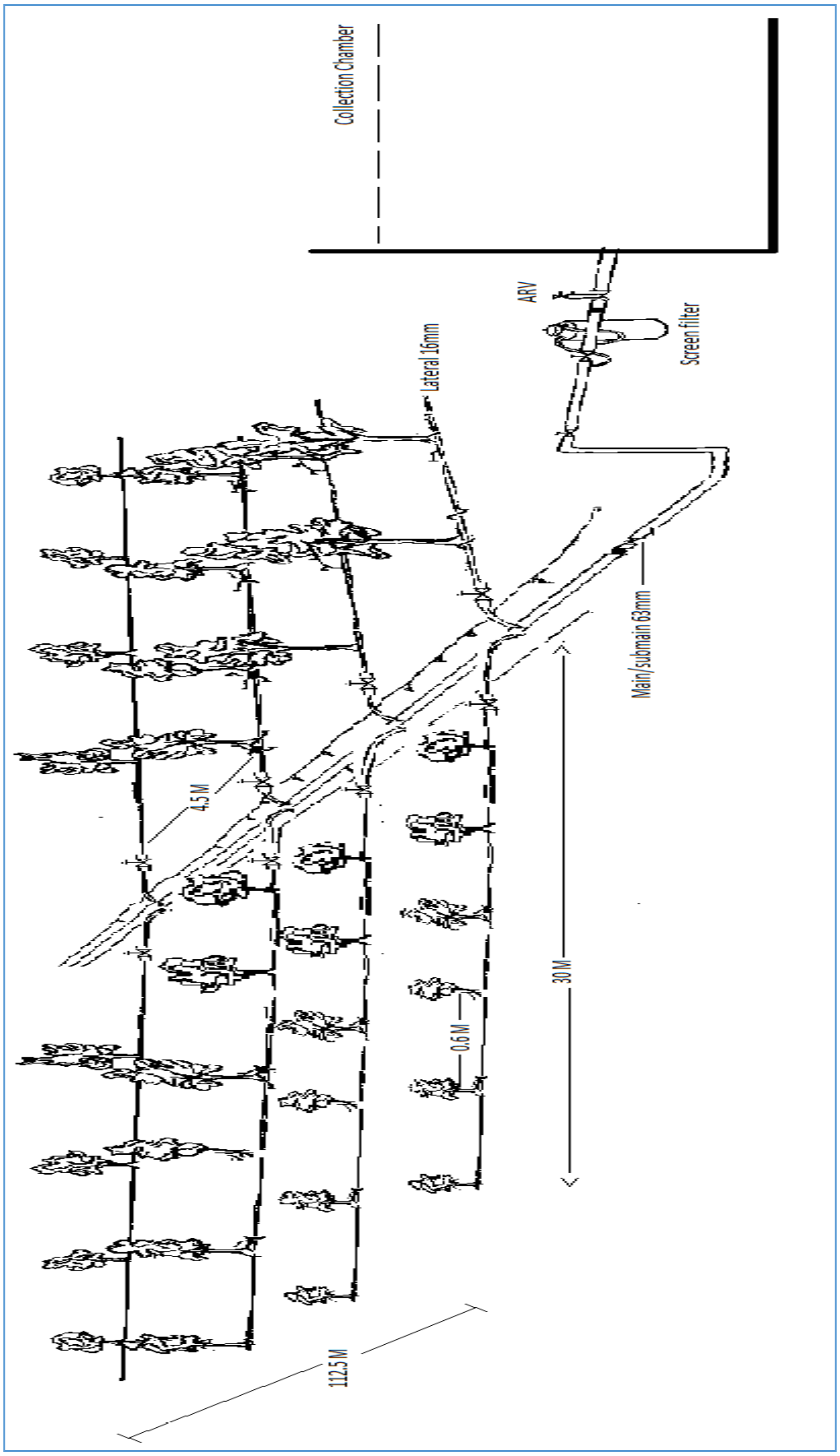

Fig. 3.3: Layout of drip irrigation system

Plate 3.6: Willow plantation with installed drip irrigation system

Chapter – 4

RESULTS AND DISCUSSIONS

The given research project is an extensive study. Before proceeding with the fabrication and layout process, the parameters involved in this compound setup needed an exhaustive study.

The weather data of last four years of Leh district was analyzed. This included temperature, precipitation and relative humidity. The data was procured through the authentic agency. The weather data thus obtained was further analyzed such that its effect on the setup under consideration could be evaluated. The data was used to generate the monthly average temperature, monthly peak temperature of day as well as nights. Also relative humidity and monthly precipitation were also studied.

4.1 Precipitation

The precipitation data as obtained was studied for its trend over a number of years. The graphical representation of the precipitation data is given in Fig. 4.1. Precipitation showed an erratic trend, however, scarcity of precipitation persists in spring months i.e. March to June.

It was also clearly evident that when the rest of the months did not receive a constant share, this acted as a big constraint for the setup of new plantation. Furthermore, taking into account that the soil condition of the region is sandy, which has least water retention capacity, precipitation received is lost to evaporation and the other portions directly percolates down. It is thus concluded that the precipitation in the area does not contribute towards any type of cultivation practices. These aspects reinforce the suggested necessity of an alternate irrigation source.

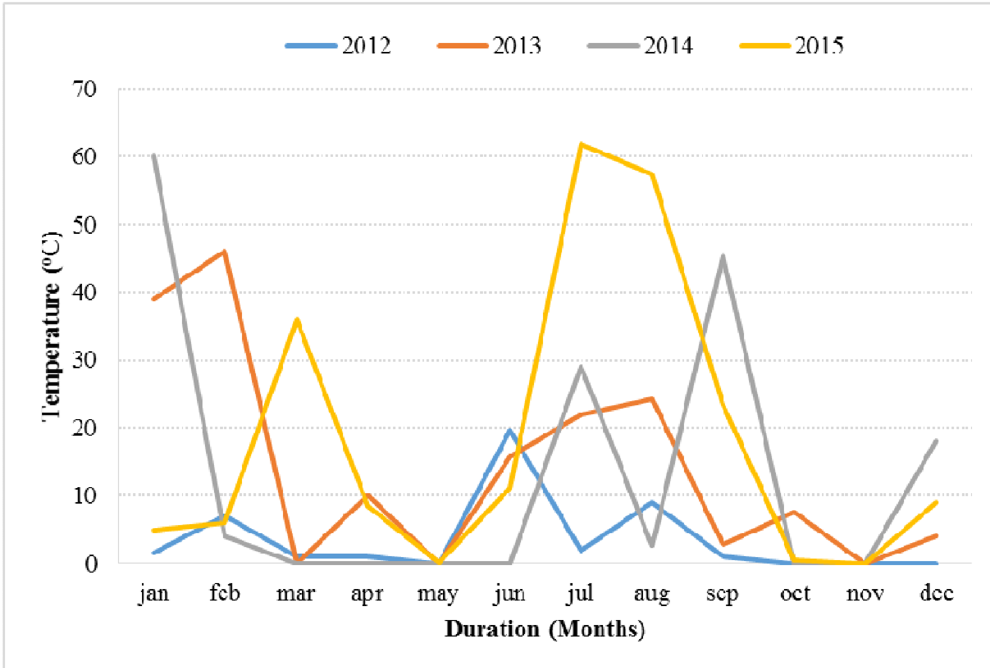

Fig. 4.1: Monthly precipitation for year 2012, 2013, 2014 and 2015

4.2 Temperature

The monthly temperature of the area was procured, Fig. 4.2 gives the maximum monthly temperature for the years 2012-2015. Fig. 4.3 gives the average monthly temperature for the given years. Although December, January and February are the coldest months and in these months glacier formation takes place. However, maximum freezing occurs from January to early February.

The process of glacier formation is substantially dependent on the night temperatures. Fig. 4.4 gives the minimum night temperatures for the years studied. Since, the consistency of night temperature is of much importance, the study of the average night temperatures as given in Fig. 4.5 was used in the projects design and implementation. Freezing takes place due to low night temperatures and the system is maintained due to the low day temperatures as well, where negligible melting were observed in the day time of winter months.

Considerable melting takes place in the spring months, gradually starting from March, Melting reaches its peak in the months of May and June and eventually arrests in the month of July. This is due to increase in temperature particularly in spring months, as shown in the graphs in Fig 4.2 and Fig 4.3.

4.3 Cost analysis

In order to make the artificial glacier, various costs were encountered during this process which were estimated and record for study and for comparison with other water storage structures. And same will be described in this chapter.

4.3.1 Cost analysis of artificial glacier

Cost estimation was done by summing up all the expenses that were made on manufacturing the artificial glacier and rising structure. These estimates do not include the water supply pipeline to the glacier. The cost estimation of the glacier was studied in comparison with cost estimation for constructing earthen water storage pond with poly lining and R.C.C water storage tank. Table 4.1 give the cost estimation of the artificial glacier.

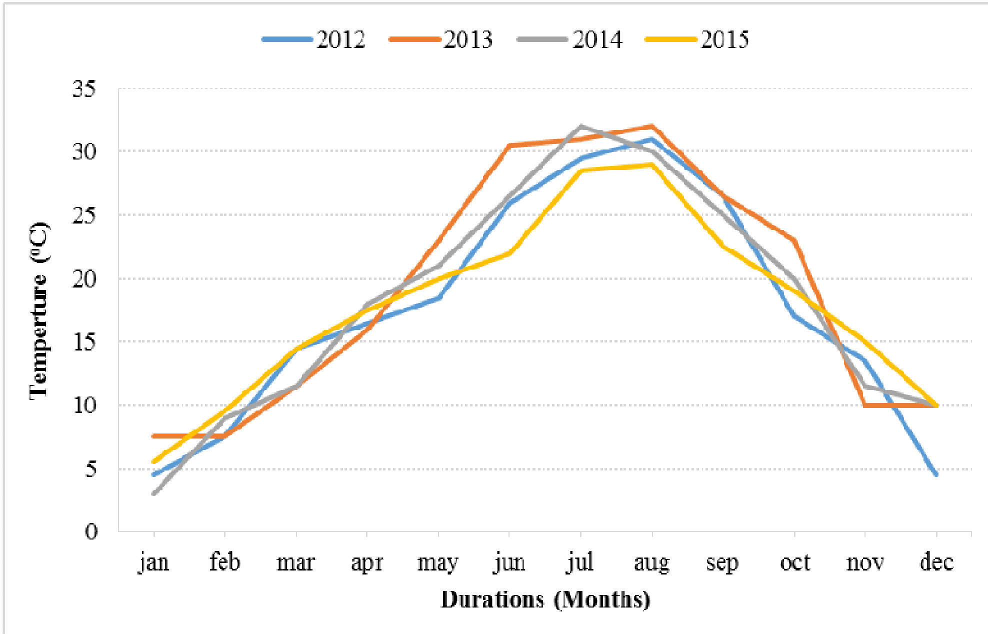

Fig. 4.2: Maximum monthly temperature for year 2012, 2013, 2014 and 2015

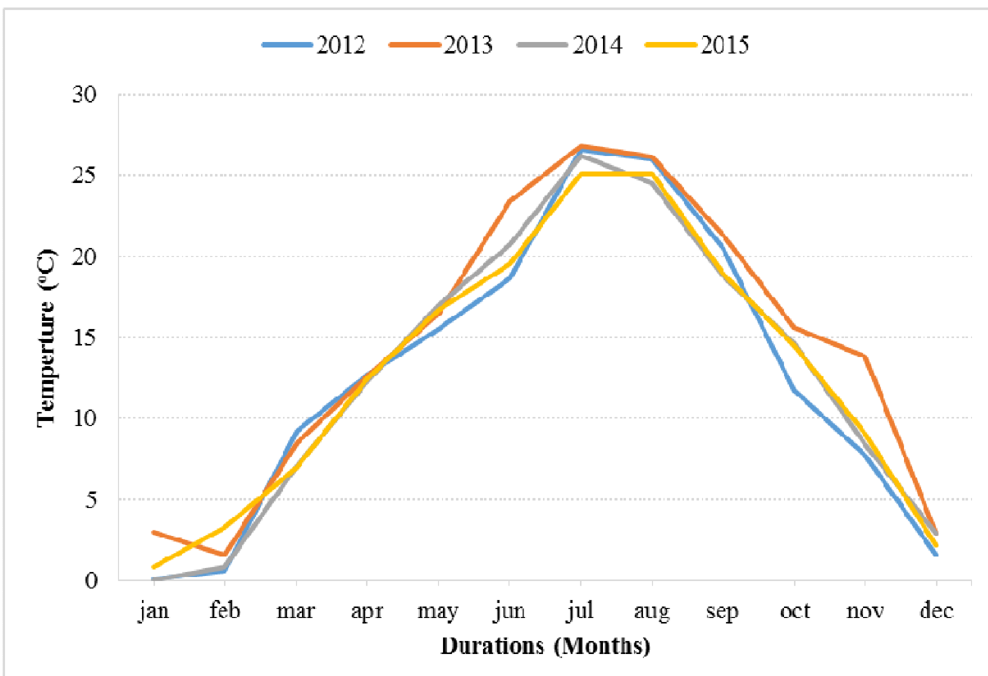

Fig. 4.3: Average monthly temperature for year 2012, 2013, 2014 and 2015

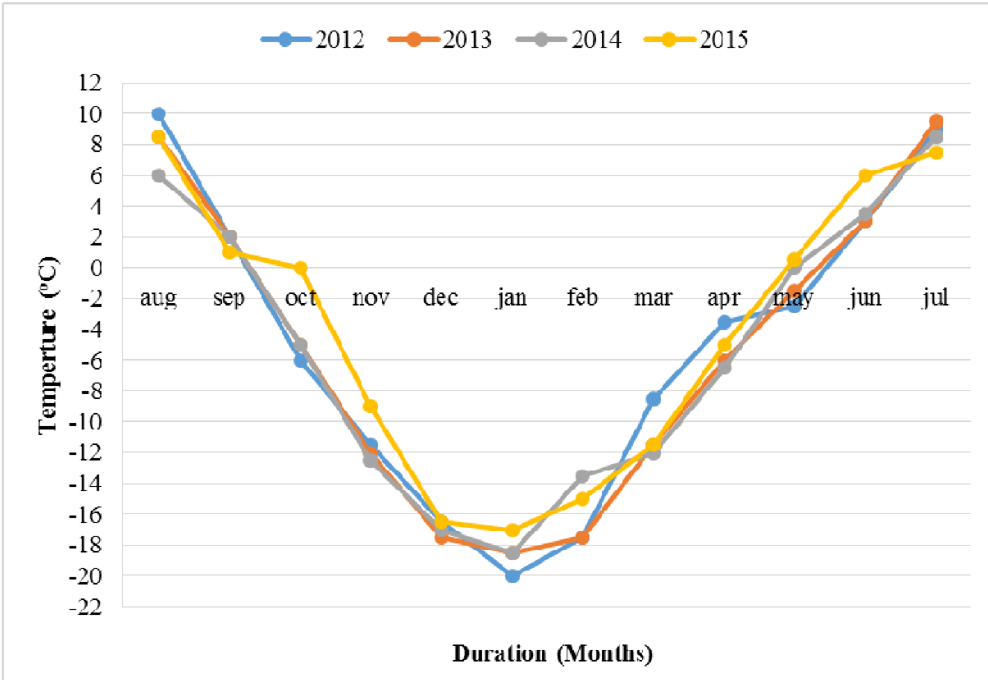

Fig. 4.4: Minimum monthly temperature for year 2012, 2013, 2014 and 2015

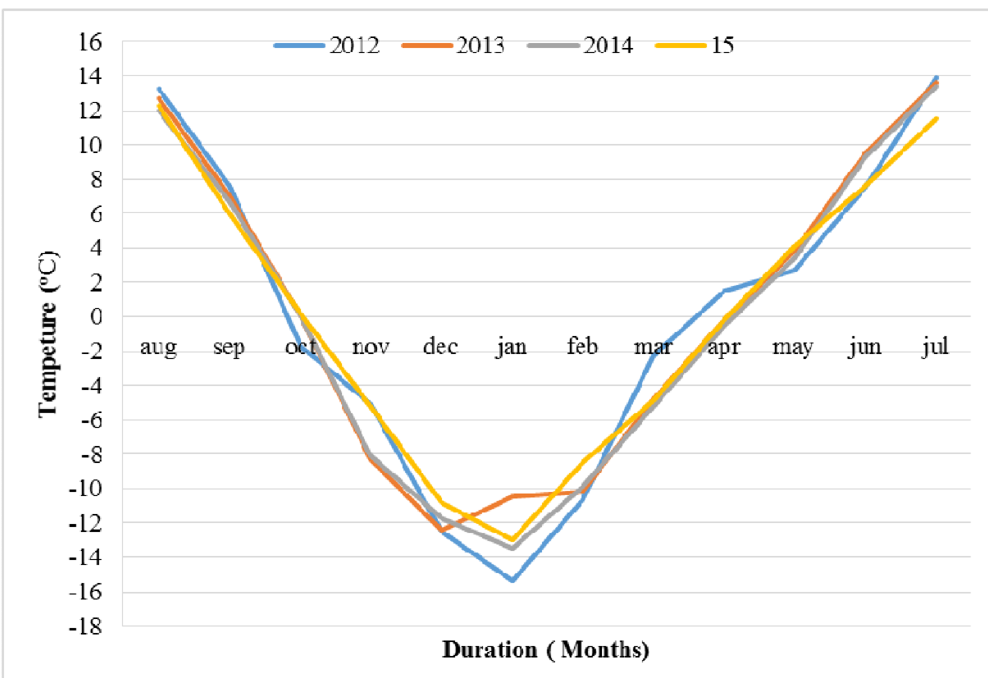

Fig. 4.5: Average monthly night temperature for years 2012-2015

Plate 4.1: Overall view artificial glacier and willow plantation

Table 4.1: Cost for making artificial glacier

S. No.	Item	Quantity	Unit	Rate (INR)	Amount (INR)
1.	Leveling of earth by way of cut and fill by mechanical means	3500	M^2	10	35,000
2	Laying and spreading of earth filling of thickness of 75mm by mechanical/manual means	263	M^3	250	65,750
3.	M.S hallow rectangular section pipes of 2”x1”size	200	M	400	80,000
4.	Transparent white 250 micro poly film	200	M^2	200	40,000
5.	GI pipes of 1.5″ dia and 3M length	15	No	2500	37,500
6.	LLDPE pipes PE 80 75 mm	300	M	80	2,400
7.	Nozzle (modified plumb bob)	2	No	400	800
8.	Stone work 3m × 5m × 2m LS	1	No	50000	50,000
9.	Miscellaneous			20000	20,000
Total					**3,31,450**

4.3.2 Cost analysis comparisons with alternate water storage structure

The details of the pond were collected from the implementing agency who constructed the pond at dairy unit of SKUAST-K at Manasbal. Shape depends on the soil type, which dictates the maximum possible slope that will stay in place without falling in. Normally, the shape is kept as trapezoidal with side slopes of 1:1 to 1:2 and we preferred 1:1 side slope ratio. The pond was constructed in the form of frustum of an inverted pyramid. The size of water harvesting structures is important, but more important is its sustainability, efficiency and appropriateness. The demand dictates the required storage capacity. The water storage capacity of the pond (V, volume) having 1:1 side slopes can be calculated with following formula:

$$V=H/2\ \{(W-2F)\ (L-2F) + (L-2H-2F)\ (W-2H-2F)\} \qquad \text{(Junaid 2010)}$$

Where, L = Top length (m): W = Top width (m);

H=Depth of tank (m); F= Free-board (m)

$$V=3/2\ \{(21-2\times0.1)\ (21-2\times0.1) + (21-2\times3-2\times0.1)\ (21-2\times3-2\times0.1)\}$$

$$V= 977\ m^3$$

Note: L and H can be decided depending upon site conditions. However, H should not be less than 1.5 m and more that 5 m. normally free board (F) for the small ponds may be kept between 0.1 to 0.3m. Units of measurement can be taken in feet or meters.

Computation of requirement of material: The material for trapezoidal shaped farm pond with side slopes of 1:1 can be calculated as under:

Area of the lining sheet

$$= \{2\sqrt{2}\ (H+F) + 1.0 + (W-2H-2F)\} \times \{(2\sqrt{2}\ (H+F) + 1.0 + (L-2H-2F)\}$$

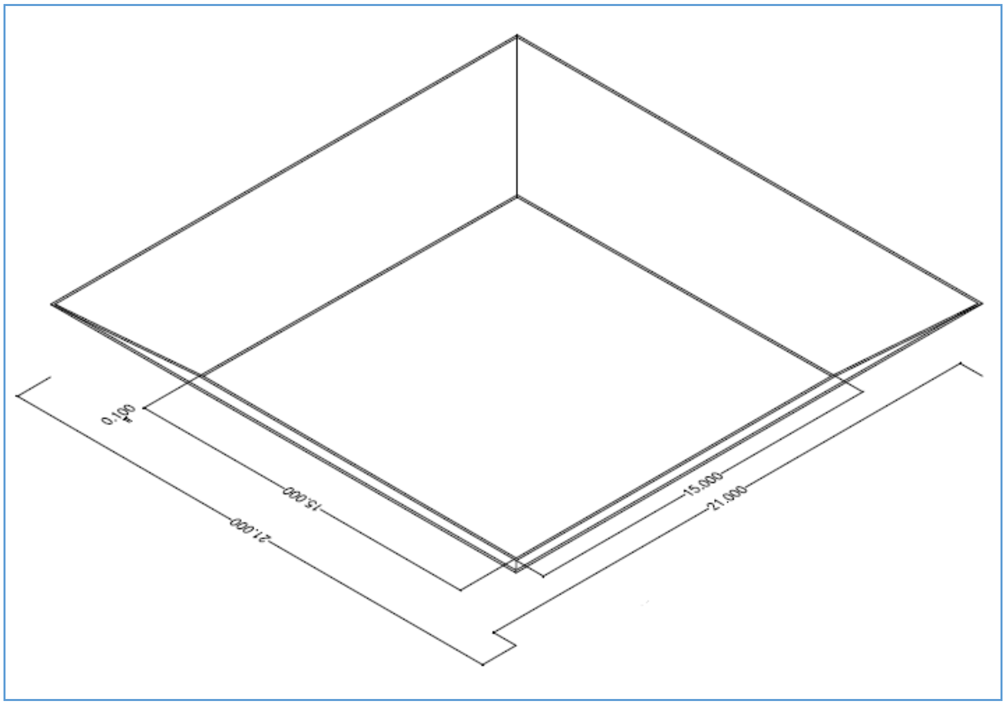

Fig 4.6: Isometric view of RCC Tank

(Excluding peripheral path)

$= \{2\sqrt{2}\ (3+0.1) + 1.0 + (21\text{-}2\times3\text{-}2\times.01)\} \times \{(2\sqrt{2}\ (3+0.1) + 1.0 + (21\text{-}2\times3\text{-}2\times.01)\}$

Area of the lining sheet = 602 m^2

Area for periphery = 2(L+W) × 0.50

= 2(21+21) × 0.50

= 42 m^2

Total Area of the lining sheet = 602+42

=644 say 650 m^2

Excavation

First of all, the pond dimensions L, W, D and side slope were marked the top level (outer rectangle/trapezium) as well as the bottom level (inner rectangle/trapezium) length and width clearly on the ground (Plate 4.2). Pegs were inserted at the corners of both the rectangles and a rope was tied to demarcate pond dimensions.

Digging was initiated at the area of the inner rectangle until desired depth was achieved. Excavated soil was kept near the pond periphery and later was used following the principle of cut and fill ratio. The process gave 1:1 slope by digging the side walls of outer rectangle for better stability of walls and application of LLDPE pond lining. This was readily ascertained by joining the top corners of the outer rectangle with the adjacent and nearest bottom corners of inner rectangle with a wooden frame. Excavation was done by mechanical means and by deploying JCB and two dumper.

Finishing of pond bed and side walls

After excavation, the side slopes of pond are made smooth and compacted by removing angular projections, protruding stones, pebbles, roots etc. Before laying the sheet, a spray of water is applied in order to smoothen the surface and to avoid damage by sharp protruding objects. A simple pipe of 4 inch diameter spillway was provided to regulate the outflow.

Jointing of LDPE sheet

Plastic sheets were available up to 30 m length with 8 m width and 300 micron. Joining points between sheets were reduced as much as possible, so that in this manner seepage lose is reduced as well. Otherwise this can become an an issue.

Jointing required, a heated press with a temperature ranging from 100-120 ^{o}C 30 cm wide strip on one sheet is overlapped on the other sheet, and is put over the counterpart. Then the heater is pressed, and allowed to cool. Heat resistant sheets that are not malleable by heat, were placed between the heater and the other sheets in order to avoid the sticking of LLDPE sheet with heater.

Laying of LDPE sheet and fixing outlet pipe

The plastic sheet was spread over the dugout area after ensuring that there are no sharp stones, pebbles, etc. on the side slopes. Anchored the lining sheet edges in a small trench (0.25×0.25 m) dug around the external periphery of the pond was made to ensure that the sheet lies smoothly on the side walls of the pond and firmly held. The trench was approximately 0.5 m away from the external periphery of the pond. The lining sheet fit in the pond area were kept loosely so that it would not break when it is anchored. For fixing the outlet pipe through the sheet, a hole of 5 cm diameter were made.

Plate 4.2: Under construction earthen pond

Table 4.2: Cost for making earthen pond with LLDPE film

S. No.	Item	Quantity	Unit	Rate (INR)	Amount (INR)
1.	Earth work in excavation, of soil up to 3 meters of depth including disposal of excavated materials by Mechanical Transport including all leads, lifts, loading, unloading.	977	M^3	120	117240
2.	Dressing, watering, ramming & removing of roots, hand picking of stones and including leads, lifts and clearing the floor and side walls of the pond	530	M^2	50	26500
3	Laying of 2 inch sand cushion of LDPE sheet including leveling	225	M^2	112	25200
4	Purchased and installed 300 micron LDPE sheet including jointing, spreading and anchoring of the sheet at the top	650	M^2	83	53950
Total					**2,22,890**

Plate 4.3: Earthen pond with LLDPE

Features of the farm pond are listed below:

- 16 ha of land, which rain gun irrigation system, which was otherwise under flood irrigation.
- Area 440 square meters with addition 2 meter for path on the periphery of tank which bring total area under pond to 530 m^2
- Source of water is Manasbal Lake
- Capacity of pond -9.77 lakh litters
- The pond is well equipped with two 4 inch PVC inlet pipe lines, output is feed t.

The details of the pond were collected from the implementing agency who construct the tank at research station of SKUAST-K at Satakna Leh. The shape is kept as trapezoidal with side slopes of 1:1 and. The pond was constructed in the form of frustum of an inverted pyramid. The size of water harvesting structures is important, but more important is its sustainability, efficiency and appropriateness. The demand dictates the required storage capacity. The water storage capacity of the pond (V, volume) having 1:1 side slopes can be calculated with following formula:

$$V=H/2 \{(B-2F) (L-2F) + (L-2H-2F) (B-2H-2F)\}$$

Where, L = Top length (m): B = Top width (m);

H=Depth of tank (m); F= Free-board (m)

$$V=2/2 \{(17-2\times0.1) (19-2\times0.1) + (19-2\times2-2\times0.1) (17-2\times2-2\times0.1)\}$$

$$V= 505.28 \ m^3$$

Computation of material requirement: The material for trapezoidal shaped R.C.C with side slopes of 1:1 can be calculated as under:

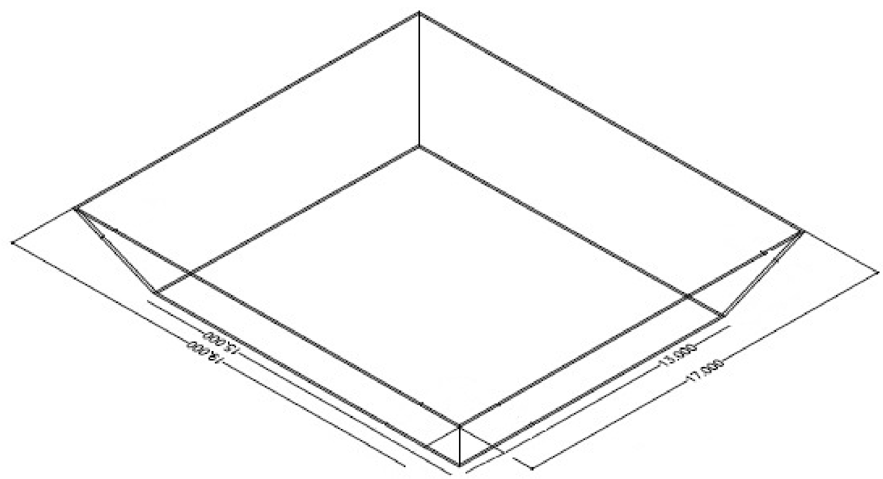

Fig 4.7: Isometric view of RCC Tank

Concrete quantity for base = $\{l \times b \times t\}$

Concrete quantity for sides = $\{2(\frac{L+l}{2})\ S_h \text{ x } t\} + \{2(\frac{B+b}{2})\ S_h \text{ x } t\}$

Where, l = bottom length (m): b = bottom width (m): t = concrete thickness (m): S_h= side slant height

Concrete quantity for base = $\{15 \times 13 \times 0.1016\}$

$= 19.81\ M^3$

Concrete quantity for sides = $\left\{2\left(\frac{19+15}{2}\right)2.828 \times 0.101\right\} + \left\{2\left(\frac{17+13}{2}\right)2.828 \times 0.101\right\}$

$= 18.38\ M^3$

Total concrete quantity for tank = 19.81 + 18.38

$= 38.19$ say 40 m^3

Steel quantity was taken 2 per cent of the total concrete quantity which came to be

Total steel required = 40×0.2

$= 0.8\ M^3$

$= 0.8\ m^3 \times 7850\ kg/m^3$ (density of steel)

Total steel required = 6280 kg

Earth excavation

First of all, the tank dimensions (L, W, H) and side slope and were marred the top level (outer rectangle/trapezium) as well as the bottom level (inner rectangle/trapezium) length and width clearly on the ground. Pegs were inserted at the corners of both the rectangles and a rope was tied to demarcate pond dimensions. Digging was started at the area of the inner rectangle until the desired depth was achieved. Excavated soil was kept near the tank periphery and later were used to following the principle of cut and fill ratio. The process gave a 1:1

Plate 4.4: Construction of R.C.C Tank

slope by digging the side walls of outer rectangle for better stability of walls and application of reinforcement cement concrete. This was readily ascertained by joining the top corners of the outer rectangle with the adjacent and nearest bottom corners of inner rectangle with a wooden frame. Excavation was done by mechanical means by deploying JCB and two dumper.

Clearing of bed and side walls

After excavation, the side slopes of tank are made smooth and compacted by removing angular projections, protruding stones, pebbles, roots etc. Before laying the sheet, a spray of water is applied in order to smoothen the surface and to avoid damage to the sheets by sharp protruding objects. This process also clean the surfaces for concreting. A pipe of 3 inch was provided to as suction pipe to solar pump to feed the micro-irrigation system.

Concreting

After clearing the bed, a stone soiling of 100mm was done which was followed by a manual compaction. In addition the surfaces were levelled to have no slope in any direction. Then, cement concrete of specified (1:4:8) 1 cement 4 course sand 8 graded stone agg was laid in position. 40mm nominal bore and on top of which reinforced cement concrete, of 100mm 1:1.5:3 mix (1cement: 1.5 course sand 3 graded stone agg. 20mm nominal size were laid.

Table 4.3: Cost of construction RCC water storage tank

S. No.	Item	Quantity	Unit	Rate (INR)	Amount (INR)
1.	Earth work in excavation, of soil up to 2.2 meters of depth including disposal of excavated materials by Mechanical Transport including all leads, lifts, loading, unloading.	510	M^3	320	1,63,160
2.	Dressing, watering, ramming & removing of roots, hand picking of stones and including leads, lifts and clearing the floor and side walls of the pond	380	M^2	65	24,700
3	Lying stone soling dry hand packed on horizontal level including cartage	40	M^3	220	8800
4	Providing and laying in position cement concrete of specified grade including the cost of centering and shuttering level. (1:4:8) 1 cement 4 course sand 8 graded stone agg. 40 mm nominal bore, including curing	20	M^3	7000	1,40,000
5	Reinforced cement concrete, of 100mm included. Cost of centering and shuttering finishing & excluding reinforcement 1:1.5:3 mix (1cement: 1.5 course sand 3 graded stone agg. 20mm nominal size. Including	40	M^3	6700	2,68,000
6	Reinforcement for RCC work including straightening, cutting, bending placing in position and binding all complete. (Thermo-mechanical treated bars(TMT)	6300	KG	58	365400
7	12mm cement plaster finishing with a floating coat of neat cement of mix 1:3 mix (1 cement 3 fine sand).	40	M^2	880	35200
Total					**10,05,260**

The cost comparison of the three structures is reflected in Fig. 4.8

As shown in the cost of RCC water store tank is extremely high as compared to the LLDPE earthen pond and artificial glacier which is least expensive, however, it is still in research and development, hence it is plausible to assume that the costs of constructing an artificial glacier can be further reduced with experience and the development of advanced methods.

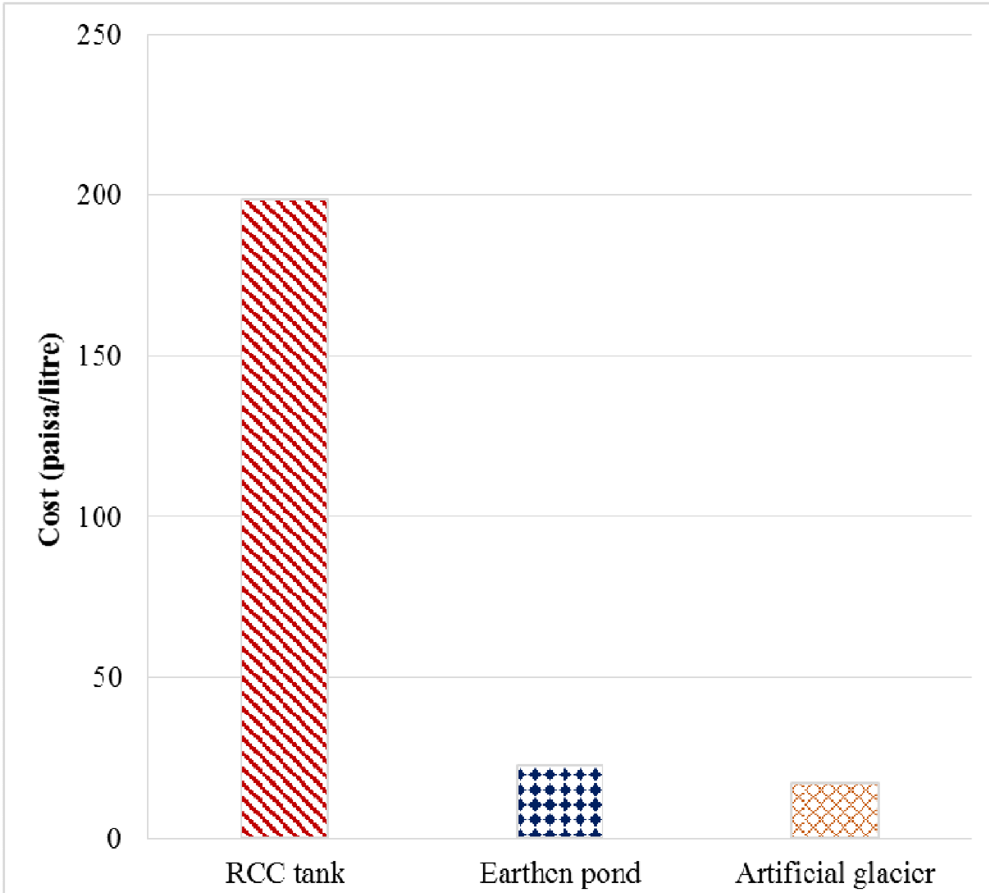

Fig. 4.8: Comparison per liter cost

Chapter – 5

SUMMARY AND CONCLUSION

Water is a limiting factor for profitable agriculture, in terms both of overall amount and intermittence and/or irregularity of rainfall events throughout the growing season of the crop. In this context, irrigation (full or supplementary) of the crops is needed for providing best level of production. However, water is becoming a scarce natural resource and agriculture represents the major water consumption, thus, proper irrigation storing has to be employed by the producers for exploring water saving measures. Crop-water requirement is crucial for water resources management and planning in order to improve water-use efficiency (Hamdy and Lacirignola, 1999; Katerji and Rana, 2008).

Artificial glaciers are a unique form of water conservation in regions affected by climate change and shrinking glaciers. The artificial glacier system strives to collect all the water that flows wastefully in Ladakhi village streams during the winter and freezes them in the form of huge ice cones, for use during the period of acute water scarcity in spring season particularly April to mid-June.

In the case of Phyang village roughly 150 liters per second flow down into the Indus river during the winter months. If all of this water could be piped to feed the desert, an astounding amount of nearly two billion liters over five winter months from November to March could be used.

Of this roughly one billion liters can be frozen and the rest can be soaked in the desert as moisture, to be re-absorbed by the tree roots later. This means there is a total potential for building roughly 100 ice stupas, each roughly 100 feet (30 m) tall and storing roughly 10 million liters of water. This figure in simple terms means that 1,000 water tanker trucks.

As for the cost of building ice stupas, in the case of Phyang village, the infrastructural cost comes to less than 18 paisa per liter, which is less as compared to the cheapest government built reservoirs in Leh.

The amount of water which is 3,62,880 liters at the rate of 4.2 liter per second (lps) a day reaching the site of glacier completely free of cost, using no machines or energy except gravity. With increase in temperature glacier start melting, water at the ice stupa freezes only around eight hours a day. Rest of the time the water is fed into the swale (a long earthen absorption tank) or into the serpentine canals in which the 5,000 trees have been planted.

Although the tree saplings are dormant and do not need watering, during these months, the system allows addition moisture to the entire field with the excess water from the glacier so that this moisture is available to the saplings later in spring when the entire village will be struggling for each drop of water.

Once even this moisture dries up the ice stupa will start feeding its melting waters to the saplings through an elaborate system of drip irrigation. The ice stupa is expected to have fully melted by early June. Then, the natural glacial melt water in the Phyang stream would start flowing once again, and this water can be used to irrigate newly planted trees adjacent to the glacier. Therefore, from June to September the same pipes that feed the ice stupas during the winter, become the pipeline for bringing the excess stream of water to the desert, rather than making it flow into the river Indus. By the end of October the artificial glacier cycle would start again, covering irrigation needs for the whole year.

5.1 Scope for future research

The present work has focused only on raising artificial glacier, drip irrigation and cost analysis. There are certain issues which are worth mentioning for future investigations. The available data was scarce as the study was confined to a limited time period. Based on the findings of the present study, it is suggested to concentrate future investigations on the following aspects:

This study did not use data from the site of glacier, however it was collected from the Defense Institute of High Altitude Research (DIHAR), hence there is scope of working in this direction to collect real time weather data from the actual site of the glacier.

Evapotranspiration needs to be studied and investigated so that an accurate calculation of peak water requirement for the trees is available specifically for the plantations irrigated by this artificial glacier

Freezing of water inside the source pipeline was an issue which can be further studied, and may be solved by using bigger diameter pipes.

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner – Dr. M.A. Lone during thesis Viva-Voce examination held on 02-05-2017 have been incorporated in the final manuscript entitled **"Design of Micro-Irrigation System for Artificial Glacier"** submitted by **Master of Technology in Agricultural Engineering (Soil and Water Engineering) bearing Regd. No. 2014-AE-16-M.**

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