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Surface Runoff Harvesting at IUST Campus

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Abstract—*The aim of this study is to utilize the surface runoff for the campus needs. The Islamic University of Sciences and technology (IUST) campus is having fast growth as more students are getting enrolled because of admissions to newly introduced UG and PG programmes and increasing staff recruitments. In order to maintain adequate supplies for the anticipated growth and development in this campus area, additional water sources must be obtained. This study represents an attempt to determine the total amount of surface runoff from the Wasturwan catchment but most importantly deals with the design and orientation of channels along the catchment and thus to design a most efficient system to collect the surface runoff to be used in IUST campus. The infiltration capacity, average infiltration rate and steady-state rate of infiltration has been determined for the Wasturwan area of Pulwama by using the double ring infiltrometer test procedures. The project is also focused on determination of total daily, monthly and average annual water demand of IUST campus and then to compare the total demand of water with the surface runoff which can be collected throughout the year. Watershed maps have also been produced by using softwares like Autocad 3D civil, TX and Golden-Surfer thus providing the best idea for the orientation of channels to collect the surface runoff throughout the year.*

Keywords: *Water stress; Surface runoff harvesting; terrain; Islamic University of Sciences and technology (IUST).*

1. INTRODUCTION

Water is an element that is very important and valuable in human civilization. Water source like lakes, rivers, rain water, or groundwater is one of the chosen places when people first began settling in one place. Lack of water of adequate quality and quantity is a major constraint to develop in many areas of the world. It affects every aspect of human life: health, agricultural yields, food security, technical development, and the economy of states. Water scarcity and water quality problems are of particular concern in the tropical regions of the world where many countries are less developed. In these regions there is often a connection between poor water resources and poverty. Today, world shows us that water shortage could happen at any time. So, regarding to those emergency situations mentioned, having an alternative of rainwater harvesting system would be very useful during the emergency situation.

Rain water harvesting as the name suggests is the harvesting of rainwater in the sense, it is a process involving collection and the storage of rainwater using the help of artificially designed systems that runs off natural or man-made catchment areas like the roof top, compounds rock surface, hilly slopes, artificially repaired impervious or semi pervious land surface. Quite obviously a number of factors play a vital role in the amount of water harvested, some of these factors are the frequency and the quantity of rainfall, catchments characteristics, water demands and the quantum of runoff and above all else the speed and ease with which the rainwater percolates through the subsoil to recharge the ground water. Surface runoff harvesting means reclamation of water from surfaces of hills, and many other open surfaces or catchment. However the surface runoff harvesting from hills can be stored at a higher levels and can be transported by a natural gradient to the points of destination.

The Wasturwan catchment in the backyard of Islamic university of science and technology campus is a hilly catchment area. A huge quantity of runoff from the Wasturwan catchment flows into the adjacent low lying river Jhelum during rainy periods. The runoff can be collected near the backyard of the IUST campus at reasonably higher elevation. The water collected and filtered can be supplied to the IUST campus. It can be further supplied to the identified water stressed area in the same region namely Kumar-mohalla.

Surface runoff is the water that runs off the surface in a rainfall event. This runoff quantity depends upon the infiltration capacity of the underlying soil. The infiltration capacity of the soil depicts the rate with which the water enters the soil. Thus for a dry soil, the infiltration capacity would be maximum as compared to the case when some moisture would be already present in it.

Surface runoff and water treatment represents a procedure used to make water more adequate for a desired end-user. These can finish up utilization as drinking water, industrial processes, restorative and numerous different employments. It of all water treatment procedure is to uproot existing segments in water and enhancing it for subsequent use. It may permit treated water to release into the regular habitat without unfavorable environmental effect. On the other hand, Surface runoff harvesting is one of the systems that could be used as a part of request to achieve a sustainable environment

2. STUDY AREA

The catchment is the stretched face of a continuous mountain range staring from Charsoo area of Awantipora to the victor force camp boundaries along the Wasturwan mountains. The area of catchment is 7.82 Km^2. The catchment in the backyard of IUST is mostly rocky and considerable amount of stones at the base of this mountainous range are seen. The runoff output of such catchments is very high. The hilly terrain has very little to less vegetative cover on it. Natural gullies have formed with time. The mountains are mostly rocky at the top. The base of the wasturwan hilly range supports a considerable number of almond trees and apricot trees and other few agricultural activities, mainly due to the runoff water in rainy periods.

Figure 1: View of Wasturwan catchment.

3. DATA

The appropriate choice and design of a water harvesting system depend on factors such as climate, soil and land topography (Oweis et al., 1999). It is necessary to collect data on parameters related to these factors.

The parameters relating to climate that must be considered before implementation of a water harvesting system are mainly rainfall amount, intensity and distribution which was obtained from Indian Metrological department, Pune and Rambagh Srinagar.

The relevant parameter in terms of the soil is the texture. Soils that develop a crust on the surface as a result of the impact of raindrops may be more suitable for runoff areas, while fine-textured soils, which can store more water than coarse-textured soils, may be more preferable for basin areas (Boers et al., 1986a; Previati et al., 2010).The data was obtained by conducting infiltration tests in the Wasturwan catchment.

The important parameters to consider in the implementation of a water harvesting system in terms of land topography include the size of the runoff area and the length and gradient of the slope because these determine the runoff water supply to the basin area and also affect the rate of erosion (Oram and de Haan, 1995).This data was made available by using softwares like Autocad 3D civil, Golden Surfer and TX Software.

4. METHODOLOGY

The total amount of runoff which occurs after a rainfall event can be calculated by various methods. The rainfall-runoff relationship is a very complex process because it depends upon many factors. The total amount of Runoff output from the wasturwan catchment was calculated using a simple water budget equation:

Total amount of rainfall – Total Abstractions = Runoff

The rainfall characteristics of Wasturwan Awantipora catchment were studied using the data provided by Indian meterological department Srinagar and the rain-gauge available at Airforce base camp Malangpora Awantipora. The rainfall characteristics were modified into average duration and average intensity of rainfall of Awantipora. The average number of days in a year which produce effective rainfall, which would produce a runoff were also calculated. On the basis of catchment characteristics abstractions like infiltration were taken into account with other minor abstractions like evaporation were taken into consideration as well.

The results were compared with a standard rational method as described below:

Rational Method

Q = A I β ------------------(1)

Where; Q=maximum flood discharge in cubic-meter per second

A = catchment area in sq. kilometer

I = intensity of rainfall in mm per hour

β = A function depending on the characteristics of the catchment in producing the peak runoff

β= 0.56 Pf/ (t_c+1) Where tc is concentration time in hours

And tc = 0.0078(L0.77/S0.385)

L = distance from the critical point to the point of observation in kilometers.

H = difference in elevation between the critical point and the bridge site in meters. P = coefficient of run-off for the catchment characteristics,*for steep bare rock, P= 0.9*

f = a factor to correct for the variation of intensity of rainfall over the area of catchment.

In equation (1), I measures the role of clouds in the region and β represents the role of catchment in producing the peak runoff. The values of A, L and H can be obtained from survey of India topographical maps. I is to be obtained from meteorology department.

Infiltration is the process by which water on the ground surface enters the soil. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration can be measured using an infiltrometer.

4.1 Methods for calculation of Infiltration

4.1.1 Simple Tube Infiltrometer

This is a simple instrument consisting essentially of a metal cylinder, 30 cm diameter and 60 cm long, open at both ends. The cylinder is driven into the ground to a depth of 50 cm. Water is poured into the top part to a depth of 5 cm and a pointer is set to mark the water level. As infiltration proceeds the volume is made up by adding water from a burette to keep the water level at the tip of the pointer. Knowing the volume of water added during different intervals, the plot of infiltration capacity v/s time is obtained. The experiments are continued till a uniform rate of infiltration is obtained and this may take 2-3 hours. The surface of the soil is usually protected by a perforated disc to prevent formation of turbidity and its settling on the soil surface..

4.1.2 Double-ring infiltrometer

This most commonly used infiltrometer is designed to overcome the basic objection of the tube infiltrometer, viz. The tube area is not representative of the infiltrating area. In this two sets of concentrating rings with diameters of 30 and 60 cm and of minimum length of 25 cm are used. The two rings are inserted into the ground and water is applied into both the rings to maintain a constant depth of about 5 cm. The outer ring provides water jacket to the infiltrating water from the inner ring. The water depths in the inner and outer rings are kept the same during the observation period. The measurement of the water volume is done on the inner ring only.

As the flooding type infiltrometer measures the infiltration characteristics at a spot only, a large number of preplanned experiments are necessary to obtain representative infiltration characteristics for an entire watershed.

4.2. Contouring of Wasturwan Catchment

The Contouring of the wasturwan catchment including the areal extent of the IUST itself was carried out by using softwares like Autocad 3D civil, Golden Surfer and TX Software. The contour map along with three dimensional model of the whole catchment and watershed map of the catchment were produced to have the best of the ideas regarding the catchment characteristics, depression storage, location of ridge lines, steepness of the slopes at different location along the mountain stretch. The contour map with the highest importance made it possible to align the channels for the efficient collection of runoff water coming down the hill after the rainfall events.

5. RESULTS AND DISCUSSIONS

5.1.1. Population of IUST campus

As per the records of Registrar office IUST, the population of IUST (July 2017) is categorized into the following groups:

Table 1: Population of IUST campus

	Category	Number
1.	Teaching staff	194
2.	Students	3626
3.	Non Teaching staff	307
	Total	4127

5.1.2 Water demand of IUST Campus

Water demand represents the average consumption of water for various purposes per person per day. It can be also represented in litres per person per day or litres per capita per day (lpcd).

Water in Islamic university of science and technology (IUST) is mainly used for following purposes:

1. Drinking
2. Toilet

The values of water requirements for drinking and toilet usage as per Indian standard, IS 1172-1993 are 5 lpcd and 45 lpcd respectively in a university. Therefore 50 litres of water are used by a person in IUST in a day as per IS 1172-1993.

As per water supply department of IUST, 20000 gallons of water are pumped to meet the daily water demands of the campus. One gallon of water being equal to 3.785 litres when considering the population of IUST which is 4127. The average water demand of a person as per water supply department of IUST can be calculated as under:

20000 gallons = 3.785 x 20000 liters which is a total of 75700 litres.

Thus the demand per person per day in IUST as per its water supply department is 75700÷4127 = 18.3426 litres per person per day.

Variation in water demand of IUST

The water demand in IUST varies seasonally from summer to winter days as more water is consumed in summer days. The variation in weekly demand is also seen, as more water is required on Fridays for Ablution purposes. The variation is also seen at the weekends as no or little water is consumed during Saturdays and Sundays, as IUST remains off during these days. The peak factor for the maximum weekly demand is taken as 1.48. So the water demand per person per day taking peak factor into the consideration is 27.15 liters.

5.1.3 Average daily water demand at IUST

The average daily water demand at IUST = 27.15 x 4127 = 112.048 cubic meter of water per day.

Average annual water demand of IUST

The average annual working days at IUST are 240 days, so the average annual water demand = 240 x112048.05 = 26891.532 cubic meter of water per year.

5.1.4 Infiltration tests

The data and results from infiltration tests depict that the infiltration property of the wasturwan catchment is low. Such properties are shown by clayey deposits. The tests were carried on flat terrains because it is very difficult to operate infiltration tests using infiltrometer on slopes. However the actual infiltration will be further low because the Wasturwan is a steep terrain. The rain water will have a tendency to run down the hill practically as it will get less time to infiltrate. Thus being on the safer side in the calculations of runoff, we will use the maximum average infiltration rate of three hour durations which was obtained in the tests shown in previous sections. The maximum average infiltration was found out to be 6.43mm for three hours.**Table 2**: Infiltration test of three hours and thirty minute duration.

TIME (minutes)	Δt / hours	Infiltration (cm)	Infiltration rate I / Δt (cm / hr.)
2	0.033	0.20	6.06
5	0.050	0.07	1.4
10	0.083	0.05	0.6
20	0.167	0.05	0.29
30	0.167	0.05	0.29
45	0.250	0.07	0.28
60	0.250	0.05	0.2
90	0.50	0.14	0.28
120	0.50	0.13	0.26
165	0.75	0.23	0.3
180	0.25	0.2	0.8
210	0.75	0.23	0.3

Following points are concluded from the three hour and thirty hour infiltration test carried out at IUST watershed:

1. Initial Infiltration capacity of soili= 6.06 cm/hour
2. Steady state infiltration rate = 3 mm/hour
3. Average infiltration rate= 4.2 mm/hour
4. Average infiltration rate for three hours = 4.13mm/hour.

Calculations of Runoff

1. As per IMD, On an average there are 70 rainfall days in a calendar year in Awantipora, Pulwama.
2. As per IMD, on an average there are only 45 days out of 70 days when a rainfall of 2mm or more occurs.
3. Average intensity of rainfall in Awantipora, Pulwama, as per Indian meteorological department and the data obtained from rain gauge station located at Airbase Camp Malangpora Awantipora is 4mm/hour for 35 days in a calendar year.
4. The average duration of this average intensity is 3 hours. Thus it can be concluded that there are only 35 days or less in a year when an appreciable rainfall occurs in Awantipora. The average intensity for such days and the average duration for such rains will provide us a rainfall of 12mm on our Wasturwan catchment.

4mm/hour x 3 hour = 12 mm rainfall.

5. The area of the catchment was found out to of the order of 7.82 sq. km
6. The projected area of the catchment on which actually rainfall falls will be less than the above quantity mentioned as the Wasturwan catchment is a slope terrain. Thus it is mentioned that the area of catchment is reduced to only 5.5 Sq. kms for the purpose of calculations

Thus the total volume of water in cubic metre for a one day rainfall of 4mm/hour intensity and 3 hour duration will be

$V = 5.5 \times 10^6 m^2 \times 12 \times 10^{-3} m = 66000 m^3$ of water.

The maximum value of average infiltration for three hours was earlier calculated as 6.43mm in the previous sections of infiltration Thus a total of $5.5 \times 10^6 m^2 \times 6.43 \times 10^{-3} m = 35365 m^3$ of water will get infiltrated during the same duration of rainfall.The remaining part of this precipitation will be the runoff output of the Wasturwan catchment, which is:

$66000 – 35365 = 30635 m^3$ of water.

Thus on an average the annual volume of water which flows from the wasturwan Catchment in the form of runoff into the low lying river Jhelum through the naturally formed gullies and channels can be calculated by using the data mentioned above provided by the IMD for 35 days of effective precipitation which can be calculated as under: 30635 x 35 = 107225 m^3

We have, Intensity I = 4mm/hr

Area of catchment A = 5.5 km^2

Using eqn : Discharge Q = 5.5 x .314 x 4 = 6.9 m^3/sec

Therefore ,

Volume = 6.9 x 3 x 3600 = 74520 m^3

The runoff quantity which was calculated from the water budget equation for the one day rainfall of 12mm is 30635 m^3 of water. The runoff quantity calculated for the same rainfall by the standard rational formula has a much higher value than the value calculated by using infiltration characteristics of the whole catchment in the water budget equation. However smaller value of the runoff will be used for the calculation purposes.

The runoff coming down the wasturwan hills will be collected by a collecting drain provided at the base of wasturwan mountains. The collecting drain with a longitudinal slope will carry the water to the reservoir site. The alignment of the collecting drain and the location of reservoir has been shown on the contour map of the catchment for the best suitable contour lines. The reservoir has been kept a volume which will satisfy the water demand of 30 days in IUST. The extra water which could have stored and used for more than 30 days will be lost due to storage problems. However the occurrence of the rains which provide a considerable runoff occur at least twice in every month. The storage could be increased by providing an earthen dam. The provision of earthen dam will facilitate huge collection of water which can be used for a longer time. This stored quantity of water can be provided to the water stressed area known by the name of Kumar Mohalla.

Conclusions

The importance of this project lies in the fact that it would be much more economical to use a gravity based system for circulation of water through the IUST campus and also through the adjoining areas rather than using an energy dependent method. The other important aspect of this project is to minimize the damages caused by the runoff, as it was seen earlier a structure near IUST girls hostel got damaged due to the excessive water pressure on it which was mainly caused due to the excessive runoff. This project will be feasible for the current area of university and also may be designed for future expansions in the area of university taken in accordance with the master plan of the university, such that in future there will be further more reduction in the cost of water lifting.

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