# **RAINFALL RUNOFF CALCULATOR WITH MATLAB**

Yogesh N Saraf<sup>1</sup>, Shruti N Pawar<sup>2</sup>, Alok P Jadhav<sup>3</sup>

<sup>1,2</sup>Civil Engineering Department, V.J.T.I., Mumbai (India) <sup>3</sup>Civil Engineering Department, D.Y. Patil College of Engg., Akurdi, Pune (India)

## ABSTRACT

Rainfall-runoff analysis is very important and challenging area of research. The issue becomes more crucial and difficult as population grows in particular city. The semiarid area of western Maharashtra province is an important grain production base in India, in the area the nature characteristics is small quantity and concentrate distribution in rainfall, and agriculture development was restricted by drought and soil and water loss seriously. Surface runoff not only leads to rainfall use efficiency decrease, it is also the important factor which causes soil erosion. The objective of this paper is to review the different forecasting algorithm algorithms of rainfall- runoff modelling. This paper find out pros and cons of these algorithms and suggest framework of new algorithm for Rainfall-runoff modelling which gives better water consumption.

Keywords: ANN, MATLAB, Neural Networks, Rainfall Runoff Modelling, Water Harvesting, Computation of Runoff.

### I. INTRODUCTION

The rainfall-runoff relationship is one the most complex hydrological phenomenon due to the tremendous spatial and temporal variability of watershed characteristics and rainfall patterns as well as a number of variables involved in the physical processes. Also, this process is non-linear in nature and thus difficult to arrive at explicit solutions. The runoff needs to be estimated for efficient utilization of water resources.

Hydrological Model is a simplified representation of natural system. We can say that "A model is a collection of symbols, which represents the system in a concise form that works as a representation of natural system or some aspect of it". The rainfall-runoff calculator is one of the most frequently used events in hydrology. It determines the runoff signal which leaves the watershed from the rainfall signal received by the basin. Numerous methods have been developed by different researchers to simulate the rainfall-runoff process. Although a variety of rainfall- runoff models are available, selection of a suitable rainfall-runoff model for a given watershed is essential to ensure efficient planning and management of watersheds. In order to estimate runoff from rainfall events, loss rate or infiltration parameters for the basin have to be calculated. The infiltration capacity of the basin depends on the land use and soil property.

The rainfall-runoff plays a significant role in water resource management planning and hydraulic design. Several attempts have been made to model the non-linearity of the rainfall–runoff process, arising from intrinsic non-linearity of the rainfall–runoff process and from seasonality.

These rainfall-runoff models generally fall into these broad categories; namely, black box or system theoretical models, conceptual models and physically-based models. Black box models normally contain no physically based input and output transfer functions and therefore, are considered to be purely empirical models.

Conceptual rainfall-runoff models usually incorporate interconnected physical elements with simplified forms, and each element is used to represent a significant or dominant constituent hydrologic process of the rain- fall-runoff transformation. A dimensional analysis technique has also been developed and used to obtain mean annual flood estimation in several Indian catchments.

In recent year, applications of Artificial Neural Network (ANN) has become increasing popular in water resources and have been used in various fields for the prediction and forecasting of complex nonlinear processes, including the rainfall-runoff phenomenon. Many studies have demonstrated that the ANNs are excellent tools to model the complex rainfall–runoff process and can perform better than the conventional techniques. However, many a times, less attention is given to simplify the ANN structure.

#### **1.1 Nature of the problem:**

The runoff mainly occurs in the hilly regions. The soil type also affects the runoff i.e. if the soil is laterite, it doesn't allow the water to percolate inside & allows to flow. So the rainwater is not absorbed or percolated under the ground surface. As the rainwater is not stored, the runoff occurs in a large quantity & the ground water table decreases. As the ground water table decreases, the people staying in such a region don't get water in the period of March to half of the June is known as the Dry Season.

Hence, in order to avoid or prevent such effective runoff, it becomes necessary to calculate the estimated runoff value first. In conventional methods it is tedious to perform peak runoff calculations. Therefore the thought comes in mind to have an alternative method to calculate the runoff value in an easier way, which will perform all calculations within a fraction of second.

#### 1.2 Objectives:

- i. To develop a rainfall-runoff calculator with MATLAB.
- ii. To study MATLAB software and it's coding/programming.
- iii. To study rainfall-runoff relationship in brief.

#### 1.3 Present Study:

We are designing 'Rainfall-runoff calculator with MATLAB' and its coding. We are studying software which is much more useful for calculation of runoff values from the given data of rainfall. On the basis of the runoff results, proposed remedies can be adopted to reduce the runoff in urban as well as in forest areas.

#### **II. COMPUTATION OF RUNOFF**<sup>[1]</sup>

As pointed out earlier, the entire rain water falling over the surface of the earth does not reach the surface streams and river channels. A certain part of this water is lost to the atmosphere through evaporation or transpiration, and certain part which infiltrates into the soil into the soil is lost to the ground water reservoir. The remaining water, called the surface runoff, flows and joins the surface streams. However, the total flow or runoff in a surface stream is the combination of surface runoff and the runoff derived from the underground water, called base flow. This total flow in the stream called runoff or stream flow or discharge is very important, and has to be evaluated, because it directly tells us the amount of water available in the surface source, and hence their yields.

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### 1.1 Fundamental equation for Computation of Runoff (Volume or Depth on a Given Area):<sup>[2]</sup>

The process of runoff has already been discussed in a previous article. It was stated there: that the rain is, first of all, intercepted as interception ( $P_i$ ), then sorted in depressions as depression storage ( $P_i$ ), and then used in removing the soil-moisture deficiency. All this has to be accomplished before any stream flow or ground water accretion can start. The amount of precipitation required to fulfil these needs generally termed as initial basin recharge and may be denoted by L. It includes  $P_i$ ,  $S_d$  and rain absorbed by the soil moisture deficiency, which depends upon the prevailing soil moisture conditions at the time of rain, Initial basin recharge is, therefore, the water withheld within the basin before the precipitation starts contributing to the steam flow or the ground as ground water accretion the basin (L) us filled up, the water will infiltrate into the ground as ground water accretion (G), and excess water will flow as direct runoff (Q).

The total precipitation (P) on a basin can, therefore, be easily represented by the equation

$$\mathbf{P} = \mathbf{L} + \mathbf{G} + \mathbf{Q}$$

$$Or \qquad Q = P - L - G$$

i.e. Runoff = Precipitation – Initial Basin recharge – Ground water accretion.

#### 1.2 Methods Used for Computing Runoff:

a) Runoff Coefficient Method<sup>[2]</sup>:

Q = KP

Where, Q = Runoff

P = Precipitation

K =A constant having a value less than 1 or at most equal to 1. The value of K depends upon the imperviousness of the drainage area. Its value increases with the increase in, imperviousness of the catchment area, and may approach unity (1.0) as the area becomes fully impervious.

#### b) Infiltration Curve (IC) Method<sup>[2]</sup>:



Fig no. 1: Infiltration Curve (Fig No. 7.85. IE & HS- Santosh K Garg)<sup>[2]</sup>

The infiltration capacity curve is a plot of the infiltration capacity against time, if the I.C. curve is superimposed on the rainfall hyetograph, the resultant amount will represent nothing but the runoff, as show in figure. The above method can be used very easily, if the rainfall rate never falls below the infiltration capacity rate. But

natural rains of varying intensities, sometimes below and sometimes above the prevailing infiltration capacity, results in a distortion of the capacity time curve. It is generally assumed that the occurred up to that time. Thus,

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if a rain begins at low rates, and the rainfall during the first hour is two-third of the infiltration in one hour, the capacity rate at the end of the hour will be taken as the capacity that would have prevailed at t=2/3 hr and not at t=1 hr.

c) Using Infiltration Indices<sup>[2]</sup>:

 $W_{index}$  and  $\phi_{index}$  are the two indices which are commonly used.



Fig no 2: Infiltration Indices

(Fig No. 7.86. IE & HS- Santosh K Garg)<sup>[2]</sup>

$$W_{index} = \frac{F}{t_r} = \frac{P-Q}{t_r}$$

Where, F = Total infiltration including initial basin recharge, called *potential infiltration*.

- P = Total precipitation.
- Q = Total runoff.
- $t_r$  = Duration of rainfall in hr.

It can be from this figure that Index would be equal to:

$$\Phi_{index} = \frac{Total infiltration during period of rainfall excess}{Period of rainfall excess (t_e)} = \frac{A_2 + A_4 + A_6}{t_e}$$
Whereas,  $W_{index} = \frac{A_1 + A_2 + A_3 + A_4 + A_5 + A_6}{t_r}$ 

 $\Phi_{index}$  and  $W_{index}$  will evidently be equal for a uniform rain of the type shown in Fig., but they would not be equal for a non-uniform rain of the type shown in Fig.



Fig.3. Uniform Rainfall.

(Fig No. 7.87. IE & HS- Santosh K Garg)<sup>[2]</sup>

However, for rains which are reasonably uniform or for heavy rains, these indices are found to be nearly equal. But in a usual case of moderate rain of non-uniformed intensity, the Index will be somewhat higher than Windex. These indices will change with a change in interception, depression storage, and initial soil moisture. They will also change with the amount of precipitation. These indices are not the actual infiltration rates, but

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merely measure of *potential basin recharge*, which is sometimes, called *potential infiltration*, and includes infiltration as well as initial basin recharge.

The runoff coefficient K can be determined, if the value of Windex is known, by using the equation,

$$K = \frac{P - W_{index}}{P}$$

### d) Inglis Formula<sup>[2]</sup>:

This formula is generally used for southern parts of India, for estimating runoff. It is expressed as,

Q = 0.85P - 30.4 .....For Hilly Catchments.  $Q = P\left[\frac{P-17.8}{254}\right]$  .....For Plain Areas.

#### e) Khosla's Formula<sup>[2]</sup>:

This general formula can be used for any catchment, and is applicable to both India and U.S.A., where the rainfall is fairly uniformly distributed throughout the year, this formula is very useful, and states that,

 $Q = P - 0.4813T_m$  ......When,  $T_m > 4.5$  deg. C.

Where, Q = yearly or monthly runoff in cm

P = yearly or monthly rainfall in cm

 $T_m$  = mean yearly or monthly temperature in degree centigrade.

#### **III. ANN MODELLING**

This could be treated as the core of this research. Artificial neural network compiled with the hypothesis of irrigation engineering using Matlab sums up the entire research. The modelling took place in following seven steps:

#### 3.1 Collection of Data:

The data collection for the purpose of estimating runoff happens outside the neural network toolbox manually. The real time data was collected from MERI, Nashik. The data was sorted in two parts of each 30% and 70% respectively. The 30% data was neatly left beside for future testing. And 70% data was used to train the ANN Model. The data collected was actually the data of different rain gauge stations, few were recording type and few were non-recording type. The data was purely the depth of rainfall occurred in the respective catchment areas of Maharashtra State.

#### 3.2 Create a Network:

Designing the architecture of any neural network is considered as the assessment point in order to evaluate the scale of integration of the research application. The input consists of the rainfall in mm for each particular day and place. The number of inputs are then sorted by their respective place (different formulae are used for different site conditions viz. urban, hilly or forest areas. It is divided based on different ground infiltration conditions). The hidden layer system consists of five different formulae and their computation. Furthermore, the analysis tab is solely dedicated to the sorting and representation of data in graphical and tabular format. It is also dedicated to choose the best results from available five resources.

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Fig no: 4: ANN Architecture (Source: Self)

### 3.3 Configure the Network<sup>[3]</sup>:

The configuration of inputs and ultimate outputs must be done in order to maintain accuracy of the analysis. After a neural network has been created, it must be configured. The configuration step consists of examining input and target data, setting the network's input and output sizes to match the data, and choosing settings for processing inputs and outputs that will enable best network performance. The configuration step is normally done automatically, when the training function is called. However, it can be done manually, by using the configuration function. For example, to configure the network you created previously to approximate a sine function, issue the following commands<sup>[4]</sup>:

#### 3.4 Initializing the Weights and Balances:

This step consists of assigning the weights and balances in the five equations according to their importance and adaption in India. In this project, Khosla's formula has given the highest weightage since it is cited as the most reliable method of determining runoff in Indian terrain conditions. In this project, the weight of the each formula does nothing but only set preference of begin and representing the analysis. Furthermore, the weighted average has been computed in order to draw the hyetograph from the given rainfall and runoff values. The complexity involves in taking the runoff values with their weighted averages whereas rainfall values are straight away taken from input.

#### 3.5 Training Network:

This step involves operating the MATLAB model with the 70% data as discussed in *collection of data* part. This develops and set neurons of artificial neural network in such a fashion that they behave exactly as the human brain could have assessed the data. The main advantage of using ANN network is saving the time taken to scrutinize the huge amount of data with more than three parameters at single source. This topic describes two different styles of training. In incremental training the weights and biases of the network are updated each time an input is presented to the network. In batch training the weights and biases are only updated after all the inputs

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are presented. The batch training methods are generally more efficient in the MATLAB environment, and they are emphasized in the Neural Network Toolbox software<sup>[5]</sup>, but there some applications where incremental training can be useful, so that paradigm is implemented as well.

#### 3.6 Validating Network:

This is the step where we test the remaining 30% real time data at once to judge the reliability of the project. The data is brought in such a way that the ultimate output of the data was already known. Then this output is cross checked with the MATLAB output. In this project, the network was validated by the experienced professors in V.J.T.I. The model was unexceptionally useful in order to get the real time data analysis which is further used to analyse the runoff occurring in particular area. The software model has been validated using the graphs and tables in output as results. The screenshots below could help explain the working of actual software: **Input:** 



Fig no: 5: Input of MATLAB Program

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## **Output:**



Fig no: 6: Output of MATLAB ProgramUsing Network:

The ready model is now open for all to use it over the real time or arbitrary data. The network is based on the principles of neural computing. The results shown are purely analytical.

## **IV. REMEDIAL MEASURES:**

Most of researchers often miss the crucial section of the research i.e. to suggest the parameters to overcome the statement of problem discussed in the paper. It assures the full-fledged implementation of the research work. Few remedial measure as collectively referred from internet and few references are divided according to land type as follows:

- a) Forest Areas<sup>[6]</sup>: Continuous Contour Trenches, Vegetative Contour and Graded Bunding, Bench Terracing, Live Check Dams, Brush Wood Dams, Earthen Structure, Loose Boulder Structure, Gabion Structures.
- b) Cultivated Areas<sup>[6]</sup>: Replace lawn areas with native plants, Add Organic Matter to your Soil, Create a Rain-Garden, Reduce the slope of your yard, Install Berms and Vegetated Swales.
- c) Urban Areas<sup>[7]</sup>: Bio-retention, Detention Pond, Grass Lined, Infiltration Trenches, Permeable Pavements, Sand Filter.
- d) Single Family Residence in Urban Areas<sup>[7]</sup>: Cisterns, Green Roofs, Rain Barrels, Rain Garden.

## **V. CONCLUSION**

India has a very wide range of non-uniform rainfall. And to calculate runoff from these non-uniform values become tedious and time consuming. By using this module or calculator, a person or any institute can easily

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calculate runoff within a flash of second and results will be more accurate as compared to other conventional methods.

Thus, after knowing the actual runoff value, the question arises about remedial measures to control or simply prevent runoff and let it being used for other psurposes. After studying books, nature of terrain and other available resources we have chosen some effective remedial measures to control runoff which are given in the chapter-Remedial Measures.

### VI. ACKNOWLEDGEMENT

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