ANALYSIS OF RAINFALL SERIES IN THE DESIGN OF URBAN DRAINAGE CONTROL SYSTEMS

Submitted in partial fulfillment of the requirements of the degree of

Master of Technology

In Hydraulics and Flood Control Engineering

by

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CERTIFICATE

This is to certify that the project report entitled "**ANALYSIS OF RAINFALL SERIES IN THE DESIGN OF URBAN DRAINAGE CONTROL SYSTEMS**" being submitted by me is a Bonafide record of my own work carried by me under the guidance of Prof. R. MEHROTRA in the partial fulfillment of the requirement for the award of the degree of Master of Technology in Civil Enginneering with specialization in HYDRAULICS AND FLOOD CONTROL ENGINEERING, DELHI TECHNOLOGICAL UNIVERSITY, DELHI-110042.

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

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

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DECLARATION

I certify that

a) The work contained I the dissertation is original and has been done by myself under the general supervision of my supervisors.

b) The work has not been submitted to any other Institute for any degree or diploma.

c) I have followed the guidelines provided by the Institute in writing the report.

d) I have conformed to the norms and guidelines given in the Ethical Code of Conduct of the Institute.

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Signature of the Student:

Name of the Student: NIKITA JAISWAL

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Finally, I am thankful and grateful to God the Almighty for ushering His blessings on me.

Signature

Name: NIKITA JAISWAL

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CONTENTS

List of symbols

1. PIF = Precipitation-inter-event dry period-frequency
2. P = Precipitation volume
3. F = Frequency
4. I = Inter-event-dry period
5. SUDS = Sustainable Urban Drainage Control Systems
6. C = Runoff coefficient
7. R = Rainfall excess
8. EIA = Equivalent impervious area
9. DEIA = Directly connected impervious area
10. X = no of rainfall events
11. Tr = return period

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Executive summary

Increased urbanization has caused increased flash flooding after sudden rain in Delhi. As the area of vegetation are replaced by concrete, tarmac or roofed areas, the area loses its ability to absorb rainwater. The rain is directed to drainage systems and causes urban flooding. The idea behind urban drainage control systems is to drain away dirty and surface runoff through collection,storage and cleaning before allowing it to released into water courses. Past efforts were mainly directed towards flood control of urban area with the pollution control being largely ignored.

Currently, it is important to develop design methodologies for both flood and pollution control in the city of Delhi because there is heavy pollutional load in River Yamuna. The current criteria used in determining water quantity volumes in urban drainage control systems design neglect predecessor conditions resulting from preceding rainfall. During the dry period between rainfall events,treatment of stormwater proceeds and is considered complete after a specific time period. The inter-event-dry period refers to that time period which occurs between rainfall events.

The minimum inter event dry period used for urban drainage control system design should be consistent with the time required for infiltration,chemical precipitation,residue removal and biological assimilation,the time required for the transport system(pipes, open channels and other structural controls) to return to their design elevations.

Spreadsheet programming was used for calculation using latest 15 years of data from eight rainfall station in state of Delhi. A minimum inter-event-dry period was specified and all rainfall volume was cumulated before the minimum inter-event-dry period. Exceedence probability distributions were calculated for rainfall precipitation volume(p) given inter-event-dry period(I) of 24 , 48, 72, 96, 120 hours. The precipitation volume for each inter event dry period and specified frequency (F) or return period was calculated and results are presented in graphical form are called PIF curves.

Statistical data on rainfall volumes and duration for each minimum inter-even-dry period were also developed. These statistics are useful when probability distribution function are used for hydrologic and storm water designs.

In consideration of the inter event dry period through the use of the design curves developed in the research provide a design where initial conditions are more accurately determined as a result of this type of design.

Chapter 1

Introduction

1.1 GENERAL

Urban flooding is not an unknown event in India. The greater runoff produced after a sudden rainfall encroaching upon and filling up natural drainage channels and urban lakes to use the high-value urban land for buildings are the cause of urban flooding. The illegal filling of urban water bodies in cities like Calcutta,Delhi and Hyderabad etc is a rampant. In Calcutta, for instance, Lake Town, badly situated, has not only suffered heavy floods in 1999 but also in 1970,1978,1984. The number of water bodies in Delhi accounting about 800, now remained 600 and rest are vanished.

1.2 DEFINITION

Urban flooding is the inundation of land or property in a built environment, particularly in more densely popoulated areas, caused by rainfall overwhelming the capacity o drainage systems, such as storm sewers. This is a duration type event. A flood can strike anywhere without warning. It occurs when a large volume of rain falls within a short time.

1.3 CAUSES OF URBAN FLOODING

1.3.1 NATURAL CAUSES:

1. **Heavy rainfall/ flash floods**: Water of heavy rainfall concentrates and flows quickly through urban paved area and impounded in to low lying area raising the water level.

2. **Lack of lakes**: Lakes can store the excess water and regulate the flow of water. When lakes become smaller, their ability to regulate the flow become less and hence flooding.

3. **Silting:** The drains carry large amounts of sediments and deposited in the lower courses making beds shallower thus channel capacity is reduced. When there is

heavy rain, these silted drain cannot carry heavy discharges and results in flooding.

1.3.2 HUMAN CAUSES

1. **Population pressure:** Because of large amount of people, more materials are needed, like wood, land, food etc. this aggravates overgrazing, over cultivation and soil erosion which increases the risk of flooding.

2. **Deforestation :** large areas of forests near the river/ catchment of cities are used to make rooms for settlements, roads and farmlands and is being cleared due to which soil is quickly lost to drains. This raises the drain bed causing overflow and in turn urban flooding.

3. **Urbanization:** leads to paving of surfaces which decreases ground absorption and increases the speed and amount of surface flow. The water rushes down suddenly into the streams from their catchment areas leading to a sudden rise in water level and flash floods. Unplanned urbanization is the key cause of urban flooding. Various kinds of depressions and low lying areas near or around the cities which were act as cushions and flood absorbers are gradually filled up and built upon due to urbanization pressure. This results in inadequate channel capacity causing urban flooding.

4. **Poor water and sewage management:** old drainage and sewerage system has not been overhauled nor is it adequate now. All the drainage and sewer system in many parts of Delhi has collapsed resulting in flooding. This can be seen during rainy seasons every year.

5. Lack of attention to natural hydrological systems.

6. Lack of flood control measures

Figure 1.1 Urban flooding and effects

1.4 SUSTAINABLE URBAN DRAINAGE CONTROL SYSTEMS :

The idea behind SUDS is to try to imitate natural systems that use cost effective solutions with low environmental impact to drain away dirty and surface water run-off through collection, storage, and cleaning before allowing it to be released slowly back into the environment, such as into water courses. This is to counter the effects of conventional drainage systems that often allow for flooding, pollution of the environment – with the resultant harm to wildlife – and contamination of groundwater sources used to provide drinking water. The paradigm of SUDS solutions should be that of a system that is easy to manage, requiring little or no energy input (except from environmental sources such as sunlight, etc.), resilient to use, and being environmentally as well as aesthetically attractive. Examples of this type of system are detention or retention basins, swales, beds and other wetland habitats that collect, store, and filter dirty water along with providing a environment for wildlife.

The SUDS system aims to minimize or eliminate runoff from the site, thus reducing the impact of greater volume and non point pollution loads, the idea being that if all development sites integrated SUDS then urban sewer flooding would be less of a problem. Unlike traditional urban stormwater drainage systems, SUDS provide greater benefits in terms of water quality and biodiversity.

Typically, Urban Drainage Systems composed of:

Input meteorology

Catchment transforming the input to runoff

Engineered elements of the drainage system

Receiving waters.

Figure 1.2 sustainable drainage v/s conventional drainage

1.5 TYPES OF STORM WATER MANAGEMENT SYSTEMS:

The six source controls describe below are commonly submitted by licensed professionals and are expected to be used for compliance with the storm water performance standard. These systems are very adaptable to different site plans, building configurations, and surface and subsurface conditions. Sub surface systems include open-bottom systems to infiltrate storm water . roof top systems allow for maximized building foot prints.

1.5.1 Subsurface Systems:-

Four types of sub surface systems are described below:-

Storage vaults and tanks:

It can be constructed from precast concrete structures, concrete rings ,culverts, pipes, vendor provided products, or cast in place concrete. Tanks and vaults can be built with or without a bottom slab. If built without a bottom slab, a vault system can promote infiltration.

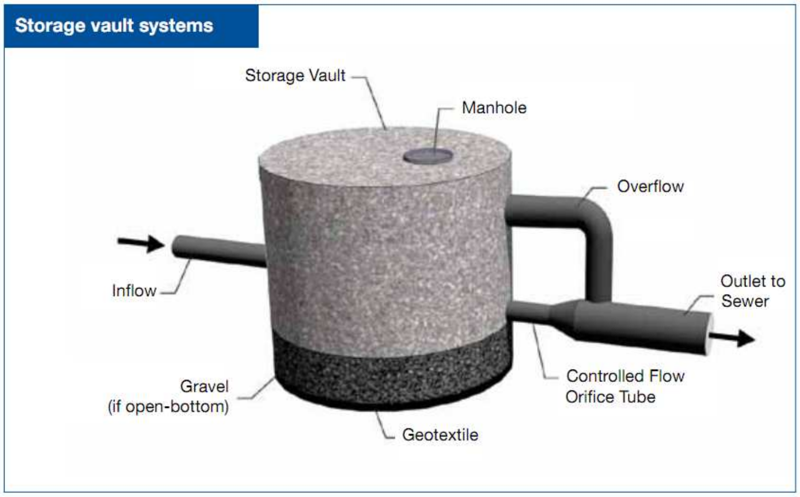

Figure 1.3 storage vaults systems

Gravel beds:

These are excavated areas filled with uniformly graded gravel. The void space between the gravel is used to detain water these systems can also promote infiltration.

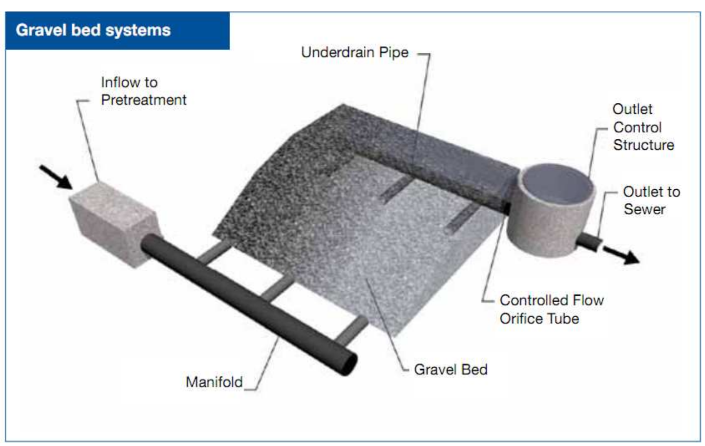

Figure 1.4 gravel bed system

Perforated pipes:

These use a combination a pipe storage and gravel storage to provide detention an improve infiltration.

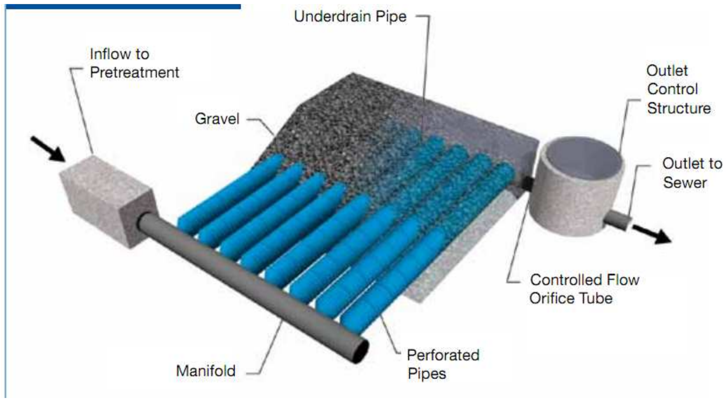

Figure 1.5 Perforated pipes

Storm water chamber:-

These are commercially available in variety of shapes and sizes. These structures detain storm water within the chamber for structural support. These open bottom system also promote infiltration.

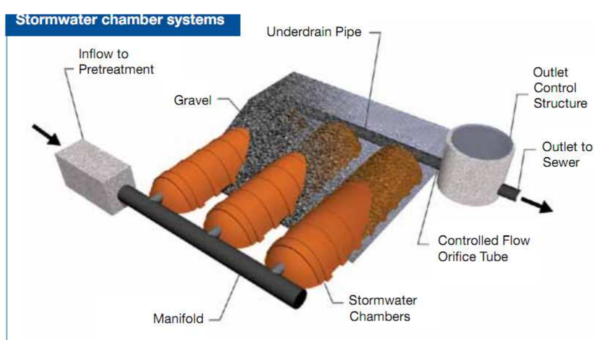

Figure 1.6 **Storm water chamber**

1.5.2 Roof Top Systems:

Two types of roof top systems are briefly described below:

Blue roofs, also known as controlled flow roof drain systems, provide temporary ponding on the roof top surface and slowly release the ponded water through roof drains. Blue roofs have weirs at the roof drain inlets to restrict flow.

Green roofs consist of a vegetative layer that grows in a specially designed soil that may sit above a drainage layer. Green roofs detain stormwater in the void space of the soil media and retain storm water through vegetative uptake and evapotranspiration.

1.6 THE DESIGN STORM

A storm water management facility or urban drainage control system consists of a transport system that collects and transports storm water runoff to a storage area for treatment,typically a detention or retention pond or swales. As we know, there is a complexion in designing these SUDS because of the stochastic nature of rainfall. So there is a need of Design Storm which is consistent with reasonable risk of failure. Runoff rates and volumes are currently calculated using a design storm that is based on rainfall intensities. The risk of failure is related to precipitation volume and a maximum intensity associated with a specified return period, typically 2 year, 3 year, 5 year, 10 year, 25 year, 50 year and 100 year. For example, using a design storm associated with a return period of 25 year, it is expected that the designed transport and storage system will fail on the average once every 25 years, given a long period of record.

Frequency-intensity-duration (FID) curves developed from rainfall data have conventionally been used for selection of the Design Storm Intensity and the determination of the required storage volume for the Drainage system to ease peak discharge. For a specified average rain duration (hours) , an average rainfall intensity which is associated with a given return period is read from FID curves. Design based on the Design Storm concept using FID curves assume an initial condition in which conveyance system are empty and the ponds are at a control elevation at the beginning of the storm event.

1.7 INTER-EVENT-DRY PERIOD

The inter event dry period is a period of time typically measured in hours, beyond which the occurrence of rainfall marks the beginning of another rainfall event. Independent rainfall events results when the inter event dry period is of length sufficiently long so that one event will not affect the probability of the occurrence of the other. When designing stormwater transport and pollution control systems, the inter event dry period between two successive rainfall events should be greater than or equal to the time required for pollution control and be greater than the recovery time of the stormwater transport system and detention/retention pond. An effective drainage system design is that which improve the water eminence by providing storage of the stormwater runoff for a period of time long enough to sufficiently treat the stormwater, thereby reducing the pollutants discharged to receiving waters.

For example, if it is determined that the stormwater should be stored for 72 hours to minimize cumulative effects of pollutants discharged to the receiving waters and to control exposure and recovery time for aquatic organisms, an effective pond design would be one which could recover to its initial conditions in 72 hours with a storage volume based on rainfall with an inter event dry period of 72 hours. Other inter-event time periods are associated with other treatment objectives such as sedimentation in 12 hours and alum treatment in 24 hours. The association of a design storm with a specific inter event dry period will produce a design based on initial conditions which are more accurately defined and allow for a desired treatment level of pollutants based on the detention time of runoff.

1.8 OBJECTIVE

The purpose of this section is to define rainfall volumes based on minimum inter event dry period. These volumes may be used for the design of storm water management facilities. A statistical analysis of selected rainfall stations in Delhi can be developed to relate inter event dry periods (hours) and precipitation volume to specify return periods. These curves are called precipitation-inter event dry period-frequency curve or PIF curves and can be used to determine the runoff volume used for water quality control in detention systems.

The directive of this section is to demonstrate the relevance of the minimum inter-event dry period as it relates to the time required for water quality treatment. To achieve the desired level of treatment, antecedent conditions must be considered when determining storage volume in detention and retention ponds. Integration of inter event dry period concept into design procedures will implement a more rational basis for the design of best management practices.

1.9 LIMITATIONS

The analysis of rainfall is limited to the state of Delhi. The use of the results requires an estimate of time for treatment and in general assumes that no treatment occurs during the storm event. If treatment during that event were possible, the minimum inter event time is calculated as the summation of the time during and between events.

Chapter 2

Literature review

2.1 GENERAL

In the previous chapter, objectives of the study are being discussed along with a detailed introduction. In this chapter, details of literature regarding reason for urban flooding, concept of SUDS, hydrologic design approaches for SUDS, Selection of design storm based on inter-event-dry concept, have been discussed.

2.2 REASON OF URBAN FLOODING AND CONCEPT OF SUDS

In the context of stormwater management, urbanization alters the land surface. Increased areas of impervious surfaces coupled with more compacted soils results in a significant loss of permeability (De Kimpe and Morel 2000). This alters the natural hydrology of catchments and results in river regimes with greater high flows and lower low flows. Higher flows and flood risk results from a greater proportion of incident rainfall on urban catchments appearing as direct runoff and this combined with sewers, gulleys and culverting of natural streams that accompany developments, causes a more rapid conveyance of storm water through the drainage network (Sheeder et al. 2002).

Increases in runoff volumes being conveyed in artificial drainage networks reduce infiltration through the soil column and diminish the capacity of recharge aquifers to provide baseflows (Gardiner 1994).

This approach, as implemented in heavily urbanized areas around Ireland, typically involved detention measures to attenuate runoff and restrict outflows to the green field values that would have occurred prior to development (Doyle et al. 2003). Collected stormwater therefore by passed the natural treatment processes. The main goals of stormwater management were progressively broadened from the 1980s to include natural water cycles and ecosystems of watercources (Niemczynowicz, 1999).

Integrated approaches to stormwater management are also being advocated for the, sustainable management of urban water environments (Rauch et al. 2005). These approaches are based on the promotion of the reuse and recycling the stormwater and while similar, are referred to differently in various countries- integrated stormwater management (IUSM), for example, is a concept that has attracted attention in Australia, New Zealand and the United States, where separate storm and waste water systems are the norm(Brown 2005). Water sensitive urban design (WSUD) is another stormwater management approach that has been implemented in some location in Australia (Coombes et al. 1999).

Approaches of this type that incorporate source (or site) controls in the context of a holistic approach to stormwater management can reduce flood risks and improve the ecological integrity of water sources through improved levels of pollutant and slit removal (Butler and Parkinson 1997; Kerbs and Larsen 1997; Niemezynowicz 1999).

2.3 CONCEPTS USING IN TECHNOLOGIES DEALING WITH STORMWATER RUNOFF

Several practical technologies for dealing with stormwater runoff have been introduced by Urbonas and Roesner (1986), Roesner et al. (1989) and others that include detention and retention basins, infiltration and percolation at the source of runoff, wetlands, sand filters and combinations of these techniques. According to these studies, a balance between storage size and water quality treatment effectiveness is needed. Grizzard et al. (1986) reported results from a field study of basins wit*h* extended detention times in the Washington, D.C area. Based on their observations, they suggested that these basins provided good levels of treatment when they were sized to have an average drain time for all runoff events of 24 hours. This equals to a 40 hour drain time for a brim-full basin.

2.4 HYDROLOGIC DESIGN APPROACHES FOR SUDS

1. DESIGN STORM APPROACH:

The design storm approach was first developed to describe statistical characteristics of rainfall conditions for use in floodplain and flood control analysis and design. In this approach, design storms of various durations are developed through statistical analysis of the rainfall history of a location. These design storms used to represent loading conditions of different severity levels that the facility under design may experience in its lifetime. Numerical hydrologic models are used to transform the input design storms into corresponding output runoff hydrographs from the catchment and from the stormwater detention pond downstream of the catchment.

In spite of critism about the theoretical foundations of the design storm approach (Wenzel 1982. Adams and Howard 1986),the design storm concept has found widespread application in drainage system analysis and design.

Another method for characterization of possible future rainfall conditions and evaluations of their impacts is continous simulation. A historical rainfall record of sufficient length and an adequate simulation model result in reliable statistics of the system performance.

An alternative to the above two approaches for characterization of rainfall conditions and for evaluation of their impacts on the performance of urban flood control detention ponds was proposed by Guo and Adams (1999).

This alternative approach , the analytical probabilistic approach, is based on a different way of statistically analyzing historical rainfall records. A continous rainfall series is first divided into discrete rainfall events. The criterian for distinguishing between events is a minimum time period without rainfall. Now, total volume and duration of these got individual events are subjected to frequency analysis. In addition to event volume and duration, the length of the Interevent dry period separating consecutive rainfall events, referred to as the enter event time, is also subjected to frequency analysis.

A 43 year rainfall record taken between 1936 and 1979 for the city of Odense, Denmark. This record contains full 33 year record which had been utilized for statistical analysis.the range of rainfall varied between 59.4 and 3mm.

Eagleson (1972) pioneered the use of exponential probability distribution to approximate the observed frequency distributions of rainfall event volume, duration and inter-event-time.

2.5 SELECTION OF DESIGN STORM BASED ON INTER-EVENT DRY PERIOD

Many researchers documented the effects of pollutants discharged to receiving waters from the urban stormwater drainage systems (colston, 1974; Huber et al 1979, Larger et al, 1977, Manning et al. 1977, Malmqvisty 1983). Flooding is specifically related to extreme and highly intense storm events but the potential for water pollution is related to more general frequency and temporal distribution effects (Amell ET AL,1983). Storm with a lower return period such as once in 1 year or less can be used for design of detentions basins for quality improvements.

Available rainfall data for a specified location are divided into separate, statistically independent rainfall events based on the time intervals of dry periods between successive events.

Various researchers have used different inter-event-dry periods. Intervals of 4-5 hr were used by Wenzel and Voorhees (1981), Arnell (1982) and Schilling (1983). Others such as Marsalek (1978) used a minimum of 3h and Johansen (1979) used 1 h intervals to separate rainfall events.

The potential impact of stormwater discharges should be an important consideration for control of pollutional loads from urban runoff.

The concept of inter-evnet-dry period is relevant to the engineering design of urban runoff treatment and management systems. Dry periods should be selected on the basis of the time required to minimize cumulative effects of pollutants discharged to receiving streams and to control exposure and recovery time for aquatic organisms.

If the design storm events are based on a minimum of 48 , 72 or 96 hr of dry period , sufficient time may be available for treatment and management of runoff events through infiltration, sedimentation, chemical and physical removal of pollutants.

As an example, the state of Florida administration Code (FAD) and the state of Maryland, Standards and specification for infiltration (1984), specify drainage of runoff water within a period of 72 hour following a storm event. This is particularly applicable in areas with deep sandy soil or in areas with impermeable lenses which protect underlying ground water.

2.6 SUDS in DELHI, INDIA.

Delhi being capital of India is highly urbanized with a population density of approximately 9000 person per Km^2 . It has conventional drainage system. The irrigation and flood control department of Delhi is responsible for planning and execution of main drains having discharge capacity of more than 1000 cusecs (28 cumecs).

The storm water drainage system of Delhi is broadly divided in the 5 drainage basins; namely:

1. Najafgarh
2. Kanjhawala
3. Alipur
4. Shahdra
5. Mehrauli

Major drains receiving runoff from these basins are as under:

1. Najafgarh
2. Supplementary drain
3. Barapullah nala
4. Shahdra outfall drain

Apart from the above major drains,most of the city storm water drains directly outfall into river Yamuna on its right bank catering to the walled Delhi (Old Delhi) and central/New Delhi areas. Most of these drains have been provided with regulators at outfall points to check the back flow of river Yamuna into the city in times of flood. Besides, this the entire sewage of Delhi finds its way into the major storm water drains since there is no independent sewage disposal mechanism in Delhi. The issue of drainage of rainwater and use of stormwater drains for wet waste ie sludge and domestic and commercial sewage to flow and dump itself into river Yamuna has started causing health related issues and other environmental problems, evidenced by the fact that the houses abutting major drains in Delhi such as the Najafgarh drain, as it flows past the colony of Punjabi Bagh in North Delhi, have started facing problem of corrosion of air conditioning equipment evidencing high level of SO_2 gas being emitted from these drains; and the cause for the gas being emitted is the bio waste flowing in these storm water drains.

The river Yamuna provides a natural drainage system since the IT major drains, carrying storm water (as well as sewage of Delhi) outfall into it.

The drainage system of Delhi was conventionally designed to carry storm water, but as a result of an inadequate sewage disposal system a large quantity of untreated sewage finds its way into the storm water drains thereby reducing the existing designed discharge capacity of the storm water drains. Further, direct disposal of sewage, cow dung from dairies, solid and liquid waste from industries, dumping of garbage into storm water drains chocks these drains, thereby reducing the carrying capacity of the drains.

Chapter 3

Rainfall data and selected stations

3.1 HISTORICAL DATA

The findings of this research is directly related to the amount of rainfall data available for state of Delhi. Eight rainfall stations were chosen of this study.

Rainfall data record of latest 15 years in the state of Delhi is collected. The data were obtained from Indian Meteorological Department , Pune for the purpose of this study.

SPSS: STATS PRACTICALLY SHORT AND SIMPLE and MS EXCEL, both spreadsheet programs are used in the management and statistical analysis of rainfall data. The use of computers for the manipulation ,retrieval and ultimate analysis of the very large databases minimized possibility for human error and increased accuracy of this study.

Table. 3.1 Listing of Selected Rainfall Stations used in Analysis

Station name	LATITUDE	DEPARTURE	Months of Data available for analysis
CORONATION PILLAOBSY Distt. : NEW DELHI CATCHMENT No. : 403	28 Degrees N	77 Degrees E	74
KESHOPUR OBSY Distt. : NEW DELHI CATCHMENT No. : 403	28 Degrees N	77 Degrees E	87
NEW DELHI/SAFDAROBSY Distt. : NEW DELHI CATCHMENT No. : 403	28 Degrees N	77 Degrees E	180
CHANDRAWAL OBSY Distt. : CENTRAL DELHI CATCHMENT No. : 403	28 Degrees N	77 Degrees E	49
DELHI UNIVERSITYOBSY Distt. : CENTRAL DELHI CATCHMENT No. : 403	28 Degrees N	77 Degrees E	171
DELHI RIDGE OBSY Distt. : NORTH DELHI CATCHMENT No. : 403	28 Degrees N	77 Degrees E	91
ALIPUR Distt. : NORTH WEST DELHI CATCHMENT No. : 403	28 Degrees N	77 Degrees E	163
CHIRAG DELHI HYDRO Distt. : SOUTH DELHI CATCHMENT No. : 403	28 Degrees N	77 Degrees E	20

Chapter 4

Data analysis and results

4.1 INTRODUCTION

A procedure for estimation of rainfall volumes for given inter-event-dry period and risk of failure is required. A conditional probability distribution is developed and the rainfall volume is obtained, from the distribution, as related to the risk of failure (exceedence probability).

For illustrative purposes, ALIPUR Rainfall Station is selected as a model. The same procedure was used for other Rainfall Data files also. The statistical analysis for this station is based on 163 months of data.

4.2 DEFINING STORM EVENTS

Spreadsheet programming was used to combine Rainfall Data Readings and define Storm Events on the basis of inter-event-dry period. This technique generates an individual fifteen year Rainfall Record for each specific inter-event-dry period. The rainfall volume in a particular time is assigned to an event in progress if it is less than the inter- event-dry period from the previous reading, else it is recognized as a start of a subsequent independent event.

4.3 PROCEDURE FOR DEVELOPING FREQUENCY DISTRIBUTIONS

Certain years of data were analyzed for each station and rainfall events were defined for inter-event dry periods of 24 hr, 48 hr, 72 hr, 96 hr and 120 hr. The rainfall producing runoff will be variable from one location to another location. The mean, maximum, minimum rainfall for each inter event dry period, as well as, the standard deviation , variance, coefficient of variation and no of events are found in appendix-.?

For the design exceedence level, the precipitation volume for a specific return period is determined from the exceedence probability distributions:

$Pr(P>P_T)=1-F(P_T/\Delta)= 1-\Sigma pr(P/\Delta)$

where:

P= precipitation volume, depth

P_T= design precipitation volume, depth

Δ= inter event dry period

Using the exceedence probability distribution allow the direct calculation of the return period for which a specific precipitation volume can be expected to exceed. The recurrence interval, or return period, is the inverse of the exceedence probability:

$$T_r = \frac{M}{N}/(1-\Pr(X \le x))$$

Where:

Tr = return period (months)

pr(X$\le x$)=probability of occurence

M= number of months in the record

N= number of rainfall events

For the purpose of generating the PIF curves, precipitation volumes for the return periods of 2 month, 3 month, 4 month, 6 month were determined from the exceedence probability analysis using linear interpolation when required. Precipitations volumes can be read directly from the PIF curves for a desired inter event dry period and return period.

It is reasonable to use these graphs to calculate the rainfall volume to be used in the design of storm water management systems. A 6 month or 1 year return period may be sufficient for designing detention or retention basins for pollution control. In addition selection of 72h as a minimum inter event dry period would seem to allow sufficient time for a primary treatment.

The exceedence probability distribution for 24 hour inter-event-dry period and the associated return periods for the Alipur Rainfall station is shown in table 4.1. for the purpose of generating PIF curves , precipitation volumes for return periods of 2-month, 3-month, 4-month and 6-month were determined from exceedence probability analysis using linear interpolation when required (refer to table no 4.1). The PIF Curves found in Appendix B were created for each of the eight rainfall stations using previously described procedure. The PIF curve for Alipur is shown in figure 4.1. precipitation volumes can be read directly from the PIF curves for a desired inter-event dry period and return period.

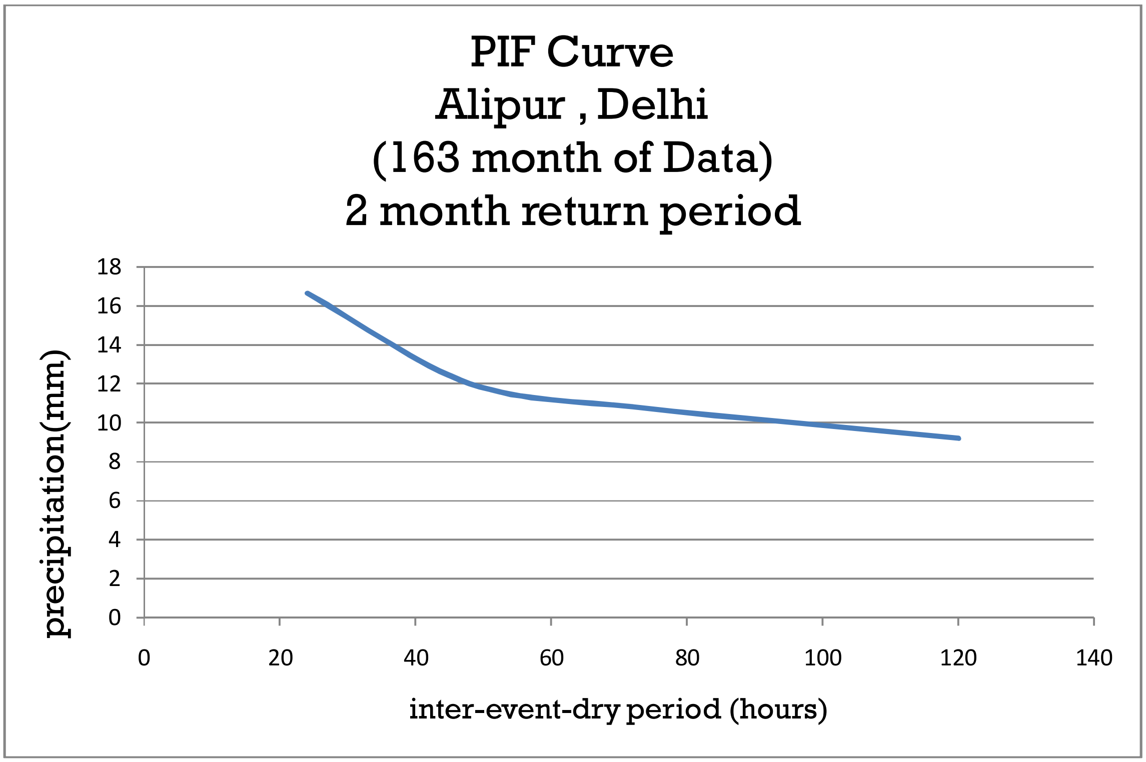

Figure 4.1 P-I-F curve for Alipur,DELHI (2 month Return Period)

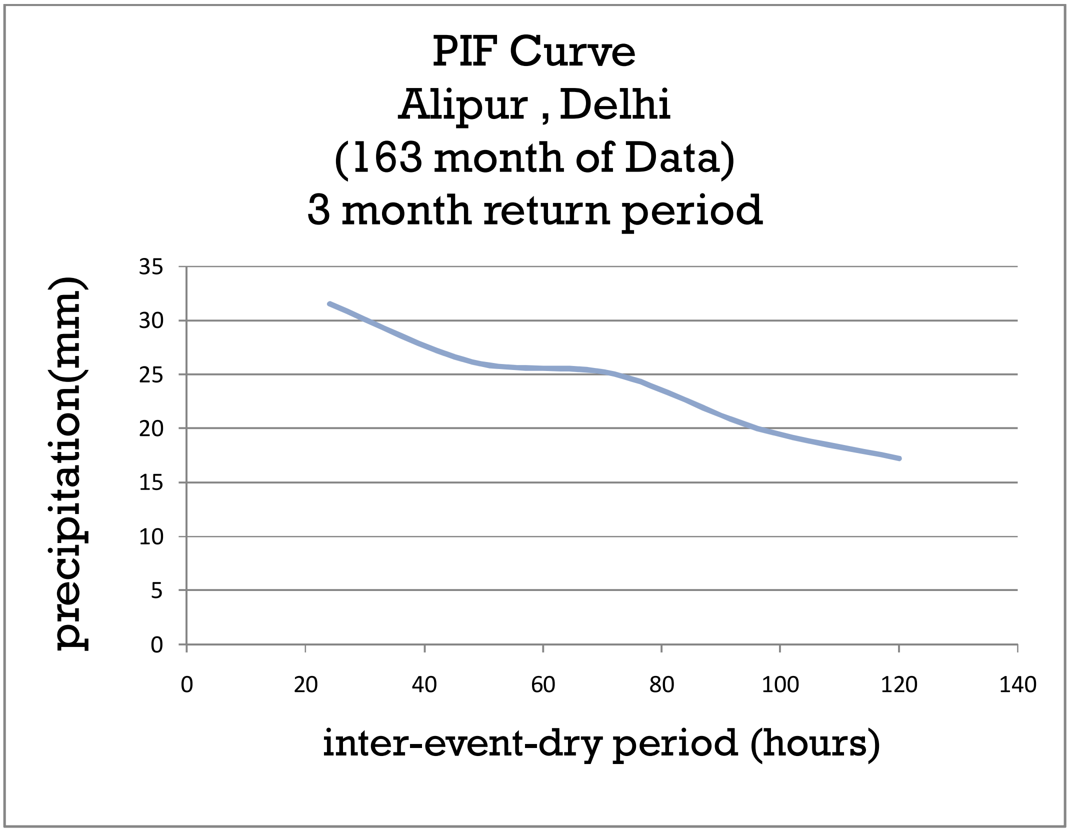

Figure 4.2 P-I-F curve for Alipur,DELHI (3 month Return Period)

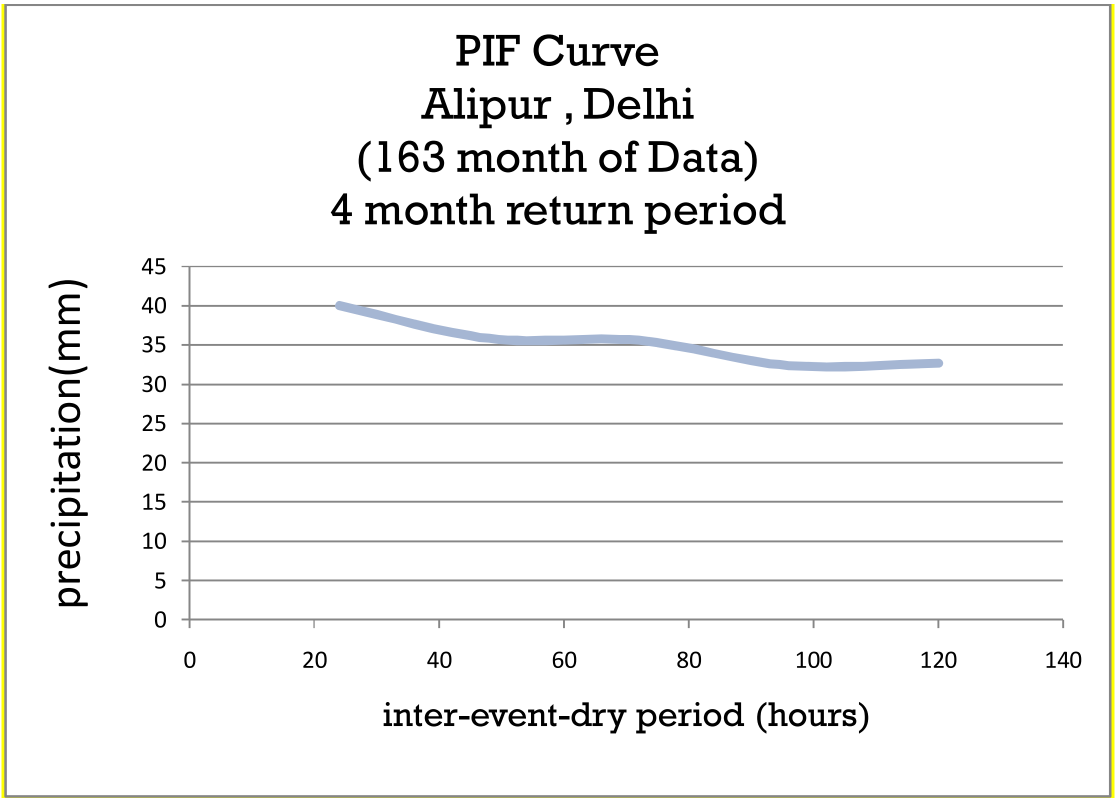

Figure 4.3 P-I-F curve for Alipur,DELHI (4 month Return Period)

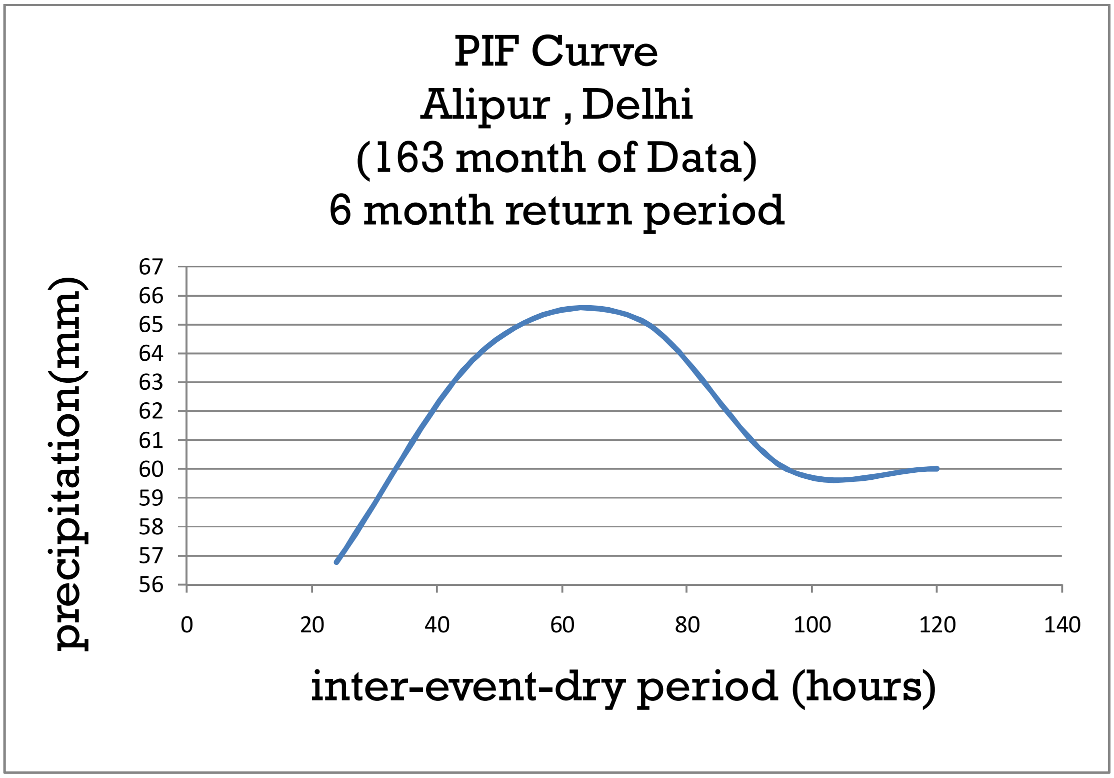

Figure 4.4 P-I-F curve for Alipur,DELHI (6 month Return Period)

P(MM)	X	X/N	SUM X/N	(1-P_r)	T_r(mo.)
0	0	0	0	1	***
10	32	0.231884	0.231884	0.768116	1.537736
20	33	0.23913	0.471014	0.528986	2.232877
30	15	0.108696	0.57971	0.42029	2.810345
40	18	0.130435	0.710145	0.289855	4.075
50	10	0.072464	0.782609	0.217391	5.433333
60	4	0.028986	0.811594	0.188406	6.269231
70	5	0.036232	0.847826	0.152174	7.761905
80	2	0.014493	0.862319	0.137681	8.578947
90	3	0.021739	0.884058	0.115942	10.1875
100	2	0.014493	0.898551	0.101449	11.64286
110	3	0.021739	0.92029	0.07971	14.81818
120	3	0.021739	0.942029	0.057971	20.375
130	2	0.014493	0.956522	0.043478	27.16667
140	1	0.007246	0.963768	0.036232	32.6
150	1	0.007246	0.971014	0.028986	40.75
160	1	0.007246	0.978261	0.021739	54.33333
170	1	0.007246	0.985507	0.014493	81.5
180	0	0	0.985507	0.014493	81.5
190	0	0	0.985507	0.014493	81.5
200	0	0	0.985507	0.014493	81.5
210	1	0.007246	0.992754	0.007246	163
220	0	0	0.992754	0.007246	163
>220	1	0.007246	1	0	#DIV/0!
N=	138				

return period	rainfall
2 month	16.64634
3 month	31.49965
4 month	40
6 month	56.7804

X=NUMBER OF RAINALL EVENTS IN THE INTERVAL 0 TO 4 MM

(1-Pr)=1-SUM(X/N)

Tr=(163 months/138 storms)/(1-Pr)

Table:4.1 Exceedence probability and return period calculations for Alipur, Delhi ; using 163 month of Rainfall Data And Inter-Event-Dry Period of 24 hour.

4.4 USING PIF CURVES IN DESIGN

4.4.1 Runoff-rainfall relation

A watershed area will produce an amount of runoff or rainfall excess after occurrence of a storm event. This amount of rainfall depends upon:

The precipitation volume and intensity

The percent of impervious area

The percent of directly connected impervious area, or that area transported directly to the detention or retention pond

The underlying soil types for the pervious areas, and their degree of saturation resulting from previous rainfall

The initial condition of the conveyance system and detention pond resulting from antecedent rainfall.

In the design of a stormwater management facility, the watershed characteristics producing runoff must be determined.

The runoff coefficient, designated C, as defined by , the ratio of rainfall excess to precipitation.

$$C=R/P$$

Where:

C= runoff coefficient

R= rainfall excess

P= Precipitation volume

The runoff coefficient C ranges in values from 0 to 1.

Typically in design, a watershed area will be composed of many different surfaces and underlying soil types, resulting in several distinct runoff coefficients.

4.4.2 Equivalent impervious area

The product of the total watershed area and the calculated effective runoff coefficient is equal to the equivalent impervious area (A) for watershed.

$$EIA = C \times A$$

The equivalent impervious area calculation equates a watershed area of mixed land uses to analyze equivalent watershed area comprised of only one completely impervious surface with no initial abstraction. The resulting EIA will be used in conjunction with the PIF curves for the design of detention ponds.

If a watershed area consists of only directly connected impervious area (DCIA) that has no initial abstraction and there is no runoff contribution from off-site or adjacent basins, then the resulting equivalent impervious area is equal to the total watershed area.

$$EIA = DCIA$$

When a watershed is comprised of both impervious and pervious surfaces,a runoff coefficient for the pervious areas based on the underlying soil types and their hydrologic characteristics must be determined.

Utilizing the procedure to establish the equivalent impervious area (EIA), these PIF curves can be employed to determine the volume of storage required for water superiority improvement, treatment volume. The precipitation volume for the desired inter event dry period and return period is read from the PIF curves multiply by the EIA to calculate the volume required for treatment.

$$\text{Treatment volume} = \frac{EIA \times P}{1000} \ \text{m}^3$$

Where:

Treatment volume= storage volume, cubic meters

EIA= Equivalent impervious area

P= precipitation volume, mm

1000= conversion factor, millimeter/meter

Chapter 5

Conclusion and Recommendations

5.1 OVERVIEW

This work is based on the concept of inter-event-dry period which forms the basis of rainfall analysis and finding of return periods by use of exceedence probability distribution functions. It is proposed to use a minimum inter-event-dry period as a design of urban drainage control systems which act as storm water control as well as pollution control source. The specified inter-event-dry period with specific return period should be consistent with the length of time needed for the consideration of potential impacts on receiving waters such that cumulative effects are minimized or desired purification time is achieved. Designer get flexibility to get the varying water quality improvement level based on different system detention times by the use of Inter-event-dry period in designs.

Conditional frequency distributions on rainfall volumes given a minimum inter-event-dry period was developed for eight regions of Delhi. For specified exceedence frequencies PIF (precipitation-inter-event-dry period-frequency) curves were developed that relate precipitation volume to minimum inter-event-dry periods.

Rainfall volume with a recurrence interval or return period of 6 months and a 72 hour inter-event-dry period is recommended for design of urban drainage control systems.

5.2 RECOMMENDATIONS

It is very difficult to establish SuDs in an urbanized city like Delhi, India. There is no space available in the city to develop a new drainage pattern.Therefore it is mandatory to follow an integrated approach where engineers and planers must develop SuDs along with the existing drainage patterns in the city. From the GIS study it was also found out that another option is to develop filter strips, ponds, basins, swales etc. near the bank of the river Yamuna since wastewater from the agricultural land pollutes the river directly.For Delhi city the EMC's of different physico-chemical stormwater pollutants have been estimated for different stations. Landuse classification using GIS and remote sensing has been done.The next step is to study in detail the existing drainage pattern of the city and to locate the hot-spots for establishment of SuDs. In NCT, India for different scale, diffuse pollution problem can be tackled using following methods:

• Source Control: Constructing the filter drains, strips, infiltration trenches,PPS, soakaways and swales are required.

• Site Controls: Detention basins, filter drains, infiltration basins, soakaways And swales can be established.

• Regional Controls: The treatment facility under this type of control incorporates retention ponds, stormwater wetlands and enhanced extended detention basins.

APPENDIX A

EXCEEDENCE PROBABILITY AND RETURN PERIOD CALCULATIONS;USING AVAILABLE MONTH OF DATA AND REPECTIVE INTER EVENT DRY PERIODS

RAINGUAGE STATION : ALIPUR

		24 HR	IEDP		
P(MM)	X	X/N	SUM X/N	$(1-P_r)$	T_r(mo.)
0	0	0	0	1	***
10	32	0.231884	0.231884	0.768116	1.537736
20	33	0.23913	0.471014	0.528986	2.232877
30	15	0.108696	0.57971	0.42029	2.810345
40	18	0.130435	0.710145	0.289855	4.075
50	10	0.072464	0.782609	0.217391	5.433333
60	4	0.028986	0.811594	0.188406	6.269231
70	5	0.036232	0.847826	0.152174	7.761905
80	2	0.014493	0.862319	0.137681	8.578947
90	3	0.021739	0.884058	0.115942	10.1875
100	2	0.014493	0.898551	0.101449	11.64286
110	3	0.021739	0.92029	0.07971	14.81818
120	3	0.021739	0.942029	0.057971	20.375
130	2	0.014493	0.956522	0.043478	27.16667
140	1	0.007246	0.963768	0.036232	32.6
150	1	0.007246	0.971014	0.028986	40.75
160	1	0.007246	0.978261	0.021739	54.33333
170	1	0.007246	0.985507	0.014493	81.5
180	0	0	0.985507	0.014493	81.5
190	0	0	0.985507	0.014493	81.5
200	0	0	0.985507	0.014493	81.5
210	1	0.007246	0.992754	0.007246	163
220	0	0	0.992754	0.007246	163
>220	1	0.007246	1	0	#DIV/0!
N=	138				

return period	rainfall
2 month	16.64634
3 month	31.49965
4 month	40
6 month	56.7804

\Table A.1 Exceedence probability and return period calculations for Alipur, Delhi ; using 163 month of Rainfall Data And Inter-Event-Dry Period(IEDP) of 24 hour.

		48HR	IEDP		
P(mm)	X	X/N	SUM X/N	(1-Pr)	Tr(mo)
0	0	0	0	1	***
10	20	0.185185	0.185185	0.814815	1.852273
20	25	0.231481	0.416667	0.583333	2.587302
30	13	0.12037	0.537037	0.462963	3.26
40	14	0.12963	0.666667	0.333333	4.527778
50	5	0.046296	0.712963	0.287037	5.258065
60	2	0.018519	0.731481	0.268519	5.62069
70	4	0.037037	0.768519	0.231481	6.52
80	2	0.018519	0.787037	0.212963	7.086957
90	2	0.018519	0.805556	0.194444	7.761905
100	3	0.027778	0.833333	0.166667	9.055556
110	3	0.027778	0.861111	0.138889	10.86667
120	3	0.027778	0.888889	0.111111	13.58333
130	3	0.027778	0.916667	0.083333	18.11111
140	1	0.009259	0.925926	0.074074	20.375
150	0	0	0.925926	0.074074	20.375
160	0	0	0.925926	0.074074	20.375
170	2	0.018519	0.944444	0.055556	27.16667
180	0	0	0.944444	0.055556	27.16667
190	0	0	0.944444	0.055556	27.16667
200	0	0	0.944444	0.055556	27.16667
210	1	0.009259	0.953704	0.046296	32.6
220	1	0.009259	0.962963	0.037037	40.75
>220	4	0.037037	1	0	#DIV/0!
N=	108				

return period	rainfall
2month	12.011
3month	26.13497
4month	35.83697
6month	64.21779

TABLE A.2 Exceedence probability and return period calculations for Alipur, Delhi ; using 163 month of Rainfall Data And Inter-Event-Dry Period of 48 hour.

		72HR	IEDP		
P(mm)	X	X/N	SUMX/N	1-Pr	Tr(mo)
0	0	0	0	1	***
10	17	0.168317	0.168317	0.831683	1.940477
20	23	0.227723	0.39604	0.603960228	2.672132
30	12	0.118812	0.514852	0.485148347	3.326532
40	13	0.128713	0.643565	0.356435475	4.52778
50	3	0.029703	0.673267	0.326732505	4.939396
60	3	0.029703	0.70297	0.297029535	5.433336
70	5	0.049505	0.752475	0.247524584	6.520004
80	2	0.019802	0.772277	0.227722604	7.086962
90	2	0.019802	0.792079	0.207920624	7.761911
100	2	0.019802	0.811881	0.188118644	8.578955
110	2	0.019802	0.831683	0.168316663	9.588245
120	4	0.039604	0.871287	0.128712703	12.53848
130	2	0.019802	0.891089	0.108910723	14.8182
140	2	0.019802	0.910891	0.089108743	18.11115
150	1	0.009901	0.920792	0.079207752	20.37504
160	0	0	0.920792	0.079207752	20.37504
170	1	0.009901	0.930693	0.069306762	23.28577
180	0	0	0.930693	0.069306762	23.28577
190	0	0	0.930693	0.069306762	23.28577
200	0	0	0.930693	0.069306762	23.28577
210	1	0.009901	0.940594	0.059405772	27.16674
220	1	0.009901	0.950495	0.049504782	32.60011
>220	5	0.049505	1	-1.68317E-07	
N=	101				
		return period		rainfall	
		2 month		10.8135	
		3 month		25.0102	
		4 month		35.6064	
		6 month		65.21469	

TABLE A.3 Exceedence probability and return period calculations for Alipur, Delhi ; using 163 month of Rainfall Data And Inter-Event-Dry Period of 72 hour

		96HR	IEDP		
P(mm)	X	X/N	SUM X/N	1-Pr	Tr(mo)
0	0	0	0	1	***
10	15	0.164835	0.164835	0.835165	2.144736
20	22	0.241758	0.406593	0.593407	3.018518
30	10	0.10989	0.516483	0.483517	3.704544
40	11	0.120879	0.637362	0.362638	4.939392
50	3	0.032967	0.67033	0.32967	5.433331
60	3	0.032967	0.703297	0.296703	6.037034
70	1	0.010989	0.714286	0.285714	6.269227
80	3	0.032967	0.747253	0.252747	7.086952
90	1	0.010989	0.758242	0.241758	7.409086
100	2	0.021978	0.78022	0.21978	8.149994
110	2	0.021978	0.802198	0.197802	9.055548
120	3	0.032967	0.835165	0.164835	10.86666
130	1	0.010989	0.846154	0.153846	11.64284
140	3	0.032967	0.879121	0.120879	14.81816
150	1	0.010989	0.89011	0.10989	16.29998
160	2	0.021978	0.912088	0.087912	20.37496
170	1	0.010989	0.923077	0.076923	23.28566
180	0	0	0.923077	0.076923	23.28566
190	0	0	0.923077	0.076923	23.28566
200	0	0	0.923077	0.076923	23.28566
210	1	0.010989	0.934066	0.065934	27.1666
220	1	0.010989	0.945055	0.054945	32.5999
>220	5	0.054945	1	1.65E-07	10866667
N=	91				

return period	rainfall
2 month	10
3 month	20
4 month	32.39265
6 month	60

TABLE A.4 Exceedence probability and return period calculations for Alipur, Delhi ; using 163 month of Rainfall Data And Inter-Event-Dry Period of 96 hour.

		120HR	IEDP		
P(mm)	X	X/N	SUM X/N	1-Pr	Tr(mo)
0	0	0	0	1	***
10	15	0.176471	0.176471	0.823529	2.328573
20	20	0.235294	0.411765	0.588234882	3.260002
30	6	0.070588	0.482353	0.517646647	3.704548
40	10	0.117647	0.6	0.399999588	4.794123
50	2	0.023529	0.62353	0.376470176	5.093756
60	5	0.058824	0.682353	0.317646647	6.037045
70	1	0.011765	0.694118	0.305881941	6.269239
80	3	0.035294	0.729412	0.270587824	7.086967
90	0	0	0.729412	0.270587824	7.086967
100	3	0.035294	0.764706	0.235293706	8.150014
110	2	0.023529	0.788236	0.211764294	9.055573
120	3	0.035294	0.82353	0.176470176	10.86669
130	0	0	0.82353	0.176470176	10.86669
140	3	0.035294	0.858824	0.141176059	13.58337
150	1	0.011765	0.870589	0.129411353	14.81823
160	2	0.023529	0.894118	0.105881941	18.11118
170	1	0.011765	0.905883	0.094117235	20.37509
180	0	0	0.905883	0.094117235	20.37509
190	0	0	0.905883	0.094117235	20.37509
200	0	0	0.905883	0.094117235	20.37509
210	1	0.011765	0.917647	0.082352529	23.28583
220	1	0.011765	0.929412	0.070587824	27.16683
>220	6	0.070588	1	-4.11765E-07	-4657143
N=	85				

return period	rainfall
2 month	9.2
3 month	17.2085
4 month	32.7116
6 month	60.01

TABLE A.5 Exceedence probability and return period calculations for Alipur, Delhi ; using 163 month of Rainfall Data And Inter-Event-Dry Period of 120 hour.

RAINGUAGE STATION: CHANDWAL

	24 hour	IEDP			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	52	0.379562	0.379562	0.620438	0.576471
20	29	0.211679	0.591241	0.408759	0.875
30	10	0.072993	0.664234	0.335766	1.065217
40	10	0.072993	0.737226	0.262774	1.361111
50	13	0.094891	0.832117	0.167883	2.130434
60	6	0.043796	0.875912	0.124088	2.882352
70	4	0.029197	0.905109	0.094891	3.769229
80	1	0.007299	0.912409	0.087591	4.083331
90	5	0.036496	0.948905	0.051095	6.999994
100	1	0.007299	0.956204	0.043796	8.166659
110	1	0.007299	0.963504	0.036496	9.799988
120	1	0.007299	0.970803	0.029197	12.24998
130	0	0	0.970803	0.029197	12.24998
140	1	0.007299	0.978102	0.021898	16.3333
150	0	0	0.978102	0.021898	16.3333
160	1	0.007299	0.985401	0.014599	24.49993
170	1	0.007299	0.992701	0.007299	48.99971
180	0	0	0.992701	0.007299	48.99971
190	0	0	0.992701	0.007299	48.99971
200	0	0	0.992701	0.007299	48.99971
210	1	0.007299	1	4.38E-08	8166667
220	0	0	1	4.38E-08	8166667
>220	0	0	1	4.38E-08	8166667
N=	137				

Returnperiod	rainfall(mm)
2 month	48.30456
3month	61.32654
4month	80
6month	86.57144

TABLE A.6 Exceedence probability and return period calculations for Chandwal, Delhi ; using 49 month of Rainfall Data And Inter-Event-Dry Period of 24 hour.

		48 hour	IEDP		
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	43	0.380531	0.380531	0.619469	0.7
20	21	0.185841	0.566372	0.433628292	1.0000001
30	8	0.070796	0.637168	0.362831832	1.195122
40	7	0.061947	0.699115	0.300884929	1.4411766
50	7	0.061947	0.761062	0.238938027	1.814815
60	4	0.035398	0.79646	0.203539796	2.1304351
70	3	0.026549	0.823009	0.176991124	2.4500004
80	2	0.017699	0.840708	0.159292009	2.7222227
90	7	0.061947	0.902655	0.097345106	4.4545467
100	2	0.017699	0.920354	0.079645991	5.4444463
110	2	0.017699	0.938053	0.061946876	7.000003
120	2	0.017699	0.955752	0.044247761	9.8000059
130	0	0	0.955752	0.044247761	9.8000059
140	1	0.00885	0.964602	0.035398204	12.250009
150	0	0	0.964602	0.035398204	12.250009
160	1	0.00885	0.973451	0.026548646	16.33335
170	1	0.00885	0.982301	0.017699088	24.500037
180	0	0	0.982301	0.017699088	24.500037
190	0	0	0.982301	0.017699088	24.500037
200	0	0	0.982301	0.017699088	24.500037
210	2	0.017699	1	-2.65487E-08	-16333333
220	0	0	1	-2.65487E-08	-16333333
>220	0	0	1	-2.65487E-08	-16333333
N=	113				
			return period		rainfall(mm)
			2 month		55.86733
			3month		71.52427
			4month		77.01179
			6month		103.57142

TABLE A.7 Exceedence probability and return period calculations for Chandwal, Delhi ; using 49 month of Rainfall Data And Inter-Event-Dry Period of 48 hour.

	72 hour	IEDP			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	26	0.295455	0.295455	0.704545	0.790323
20	16	0.181818	0.477273	0.522726818	1.065218
30	6	0.068182	0.545455	0.454545	1.225001
40	7	0.079545	0.625	0.374999545	1.48485
50	5	0.056818	0.681819	0.318181364	1.750003
60	3	0.034091	0.71591	0.284090455	1.960003
70	1	0.011364	0.727273	0.272726818	2.04167
80	4	0.045455	0.772728	0.227272273	2.450005
90	9	0.102273	0.875	0.124999545	4.454562
100	2	0.022727	0.897728	0.102272273	5.444469
110	2	0.022727	0.920455	0.079545	7.00004
120	1	0.011364	0.931819	0.068181364	8.166721
130	1	0.011364	0.943182	0.056817727	9.800078
140	0	0	0.943182	0.056817727	9.800078
150	0	0	0.943182	0.056817727	9.800078
160	2	0.022727	0.96591	0.034090455	16.33355
170	1	0.011364	0.977273	0.022726818	24.50049
180	0	0	0.977273	0.022726818	24.50049
190	0	0	0.977273	0.022726818	24.50049
200	0	0	0.977273	0.022726818	24.50049
210	1	0.011364	0.988637	0.011363182	49.00196
220	1	0.011364	1	-4.54545E-07	-1225000
>220	0	0	1	-4.54545E-07	-1225000
N=	88				
			return period		rainfall(mm)
			2 month		64.89776
			3month		82.74372
			4month		87.73235
			6month		103.5713

TABLE A.8 Exceedence probability and return period calculations for Chandwal, Delhi ; using 49 month of Rainfall Data And Inter-Event-Dry Period of 72 hour

96 hour	IEDP				
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	23	0.310811	0.310811	0.689189	0.960785
20	14	0.189189	0.5	0.499999811	1.324325
30	6	0.081081	0.581081	0.41891873	1.580646
40	6	0.081081	0.662162	0.337837649	1.960001
50	4	0.054054	0.716216	0.283783595	2.333335
60	2	0.027027	0.743243	0.256756568	2.578949
70	1	0.013514	0.756757	0.243243054	2.722224
80	3	0.040541	0.797297	0.202702514	3.26667
90	6	0.081081	0.878379	0.121621432	5.444453
100	0	0	0.878379	0.121621432	5.444453
110	3	0.040541	0.918919	0.081080892	8.166686
120	1	0.013514	0.932433	0.067567378	9.800027
130	1	0.013514	0.945946	0.054053865	12.25004
140	0	0	0.945946	0.054053865	12.25004
150	0	0	0.945946	0.054053865	12.25004
160	1	0.013514	0.95946	0.040540351	16.33341
170	1	0.013514	0.972973	0.027026838	24.50017
180	0	0	0.972973	0.027026838	24.50017
190	0	0	0.972973	0.027026838	24.50017
200	0	0	0.972973	0.027026838	24.50017
210	1	0.013514	0.986487	0.013513324	49.00069
220	1	0.013514	1	-1.89189E-07	-3500000
>220	0	0	1	-1.89189E-07	-3500000
N=	74				

return period	rainfall(mm)
2 month	41.071423
3month	75.101993
4month	83.36732
6month	102.0407768

TABLE A.9 Exceedence probability and return period calculations for Chandwal, Delhi ; using 49 month of Rainfall Data And Inter-Event-Dry Period of 96 hour

RAINGUAGE STATION :CHIRAG

	24 hour	IEDP			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
5	8	0.195122	0.195122	0.804878	0.6060606
10	12	0.292683	0.487805	0.512195073	0.952381
15	9	0.219512	0.707317	0.292682878	1.6666669
20	1	0.02439	0.731707	0.268292634	1.8181821
25	3	0.073171	0.804878	0.195121902	2.5000006
30	0	0	0.804878	0.195121902	2.5000006
35	2	0.04878	0.853659	0.146341415	3.3333344
40	0	0	0.853659	0.146341415	3.3333344
45	1	0.02439	0.878049	0.121951171	4.0000016
50	1	0.02439	0.902439	0.097560927	5.0000025
55	1	0.02439	0.926829	0.073170683	6.6666711
60	1	0.02439	0.95122	0.048780439	10.00001
65	0	0	0.95122	0.048780439	10.00001
70	0	0	0.95122	0.048780439	10.00001
75	0	0	0.95122	0.048780439	10.00001
80	1	0.02439	0.97561	0.024390195	20.00004
85	0	0	0.97561	0.024390195	20.00004
90	1	0.02439	1	-4.87805E-08	-10000000
>**90**	0	0	1	-4.87805E-08	-10000000
N=	41				

return period	rainfall(mm)
2 month	21.3669
3 month	33.012
4 month	45
6 month	52.994

TABLE A.10 Exceedence probability and return period calculations for Chirag, Delhi ; using 20 month of Rainfall Data And Inter-Event-Dry Period of 24 hour

		48 hour	IEDP		
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
5	2	0.090909	0.090909	0.909091	1
10	4	0.181818	0.272727	0.727273	1.25
15	3	0.136364	0.409091	0.590909	1.538461
20	4	0.181818	0.590909	0.409091	2.222222
25	3	0.136364	0.727273	0.272727	3.333332
30	0	0	0.727273	0.272727	3.333332
35	0	0	0.727273	0.272727	3.333332
40	0	0	0.727273	0.272727	3.333332
45	0	0	0.727273	0.272727	3.333332
50	0	0	0.727273	0.272727	3.333332
55	0	0	0.727273	0.272727	3.333332
60	1	0.045455	0.772727	0.227273	3.999998
65	0	0	0.772727	0.227273	3.999998
70	0	0	0.772727	0.227273	3.999998
75	0	0	0.772727	0.227273	3.999998
80	0	0	0.772727	0.227273	3.999998
85	1	0.045455	0.818182	0.181818	4.999998
90	1	0.045455	0.863636	0.136364	6.666662
>90	3	0.136364	1	9.09E-08	10000000
N=	22				

return period	rainfall(mm)
2 month	18.3371
3 month	23.4684
4 month	80
6 month	87.994

TABLE A.11 Exceedence probability and return period calculations for Chirag, Delhi ; using 20 month of Rainfall Data And Inter-Event-Dry Period of 48 hour

72 hour					
P(mm)	X	X/N	SUMX/N	1-Pr	Tr
0	0	0	0	1	***
5	2	0.125	0.125	0.875	1.428571
10	2	0.125	0.25	0.75	1.666667
15	1	0.0625	0.3125	0.6875	1.818182
20	3	0.1875	0.5	0.5	2.5
25	2	0.125	0.625	0.375	3.333333
30	0	0	0.625	0.375	3.333333
35	0	0	0.625	0.375	3.333333
40	1	0.0625	0.6875	0.3125	4
45	0	0	0.6875	0.3125	4
50	0	0	0.6875	0.3125	4
55	0	0	0.6875	0.3125	4
60	1	0.0625	0.75	0.25	5
65	0	0	0.75	0.25	5
70	0	0	0.75	0.25	5
75	0	0	0.75	0.25	5
80	0	0	0.75	0.25	5
85	0	0	0.75	0.25	5
90	1	0.0625	0.8125	0.1875	6.666667
>90	3	0.1875	1	0	#DIV/0!
N=	16				
		return period		rainfall(mm)	
		2month		16.33377	
		3month		22.976	
		4month		55	
		6month		87.994	

TABLE A.12 Exceedence probability and return period calculations for Chirag, Delhi ; using 20 month of Rainfall Data And Inter-Event-Dry Period of 72 hour

		96 hour			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
5	2	0.133333	0.133333	0.866667	1.538461
10	2	0.133333	0.266666	0.733334	1.818181
15	1	0.066667	0.333333	0.666667	1.999999
20	3	0.2	0.533333	0.466667	2.857141
25	2	0.133333	0.666666	0.333334	3.999996
30	0	0	0.666666	0.333334	3.999996
35	0	0	0.666666	0.333334	3.999996
40	0	0	0.666666	0.333334	3.999996
45	0	0	0.666666	0.333334	3.999996
50	0	0	0.666666	0.333334	3.999996
55	0	0	0.666666	0.333334	3.999996
60	1	0.066667	0.733333	0.266667	4.999994
65	0	0	0.733333	0.266667	4.999994
70	0	0	0.733333	0.266667	4.999994
75	0	0	0.733333	0.266667	4.999994
80	0	0	0.733333	0.266667	4.999994
85	0	0	0.733333	0.266667	4.999994
90	1	0.066667	0.8	0.2	6.666656
>90	3	0.2	1	3.33E-07	4000000
N=	15				
		return period		rainfall(mm)	
		2 month		15.058	
		3 month		20.685	
		4 month		55.4587	
		6 month		88.125	

TABLE A.13 Exceedence probability and return period calculations for Chirag, Delhi ; using 20 month of Rainfall Data And Inter-Event-Dry Period of 96 hour

		120 hour			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
5	1	0.076923	0.076923	0.923077	1.666667
10	2	0.153846	0.230769	0.769231	2
15	0	0	0.230769	0.769231	2
20	3	0.230769	0.461538	0.538462	2.857142
25	2	0.153846	0.615385	0.384615	3.999999
30	0	0	0.615385	0.384615	3.999999
35	0	0	0.615385	0.384615	3.999999
40	0	0	0.615385	0.384615	3.999999
45	0	0	0.615385	0.384615	3.999999
50	0	0	0.615385	0.384615	3.999999
55	0	0	0.615385	0.384615	3.999999
60	1	0.076923	0.692308	0.307692	4.999999
65	0	0	0.692308	0.307692	4.999999
70	0	0	0.692308	0.307692	4.999999
75	0	0	0.692308	0.307692	4.999999
80	0	0	0.692308	0.307692	4.999999
85	0	0	0.692308	0.307692	4.999999
90	1	0.076923	0.769231	0.230769	6.666664
>90	3	0.230769	1	7.69E-08	20000000
N=	13				
		return period		rainfall(mm)	
		2 month		10	
		3 month		20.657	
		4 month		55.5	
		6 month		88.1366	

TABLE A.14 Exceedence probability and return period calculations for Chirag, Delhi ; using 20 month of Rainfall Data And Inter-Event-Dry Period of 120 hour

RAINFALL STATION :CORONATION NEW DELHI

			24 hour		
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	172	0.605634	0.605634	0.394366	0.660715
20	65	0.228873	0.834507	0.165492761	1.57447
30	14	0.049296	0.883803	0.116196986	2.242428
40	12	0.042254	0.926057	0.073943465	3.523819
50	6	0.021127	0.947183	0.052816704	4.933352
60	1	0.003521	0.950704	0.049295577	5.285735
70	6	0.021127	0.971831	0.028168817	9.250065
80	1	0.003521	0.975352	0.02464769	10.57151
90	2	0.007042	0.982395	0.017605437	14.80017
100	2	0.007042	0.989437	0.010563183	24.66713
110	1	0.003521	0.992958	0.007042056	37.00104
120	0	0	0.992958	0.007042056	37.00104
130	0	0	0.992958	0.007042056	37.00104
140	0	0	0.992958	0.007042056	37.00104
150	1	0.003521	0.996479	0.00352093	74.00414
160	0	0	0.996479	0.00352093	74.00414
170	0	0	0.996479	0.00352093	74.00414
180	0	0	0.996479	0.00352093	74.00414
190	0	0	0.996479	0.00352093	74.00414
200	0	0	0.996479	0.00352093	74.00414
210	1	0.003521	1	-1.97183E-07	-1321429
220	0	0	1	-1.97183E-07	-1321429
>220	0	0	1	-1.97183E-07	-1321429
N=	284				
	return period		rainfall(mm)		
	2month		26.417		
	3month		30.5913		
	4month		43.378		
	6month		61.80183		

TABLE A. 15 Exceedence probability and return period calculations for Coronation,New Delhi ; using 74 month of Rainfall Data And Inter-Event-Dry Period of 24 hour

48 hour					
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	54	0.425197	0.425197	0.574803	1.013699
20	26	0.204724	0.629921	0.370078591	1.574469
30	9	0.070866	0.700788	0.299212449	1.947369
40	7	0.055118	0.755906	0.244094339	2.387098
50	7	0.055118	0.811024	0.188976228	3.083336
60	2	0.015748	0.826772	0.173228197	3.363639
70	6	0.047244	0.874016	0.125984102	4.625005
80	2	0.015748	0.889764	0.110236071	5.285721
90	4	0.031496	0.92126	0.078740008	7.400014
100	3	0.023622	0.944882	0.055117961	10.57146
110	1	0.007874	0.952756	0.047243945	12.33337
120	0	0	0.952756	0.047243945	12.33337
130	0	0	0.952756	0.047243945	12.33337
140	1	0.007874	0.96063	0.039369929	14.80006
150	1	0.007874	0.968504	0.031495913	18.50009
160	3	0.023622	0.992126	0.007873866	74.00141
170	0	0	0.992126	0.007873866	74.00141
180	0	0	0.992126	0.007873866	74.00141
190	0	0	0.992126	0.007873866	74.00141
200	1	0.007874	1	-1.49606E-07	-3894737
210	0	0	1	-1.49606E-07	-3894737
220	0	0	1	-1.49606E-07	-3894737
>220	0	0	1	-1.49606E-07	-3894737
N=	127				

	return period	rainfall(mm)
	2 month	32.0833
	3 month	50
	4 month	65.161
	6 month	83.3806

TABLE A. 16 Exceedence probability and return period calculations for Coronation, Delhi ; using 74 month of Rainfall Data And Inter-Event-Dry Period of 48 hour

72 hour					
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	39	0.345133	0.345133	0.654867	1
20	27	0.238938	0.584071	0.415928947	1.574469
30	8	0.070796	0.654868	0.345132487	1.897437
40	6	0.053097	0.707965	0.292035142	2.242426
50	7	0.061947	0.769912	0.230088239	2.846157
60	3	0.026549	0.79646	0.203539566	3.217395
70	4	0.035398	0.831859	0.168141336	3.894743
80	3	0.026549	0.858407	0.141592664	4.625008
90	3	0.026549	0.884956	0.115043991	5.69232
100	5	0.044248	0.929204	0.070796204	9.250034
110	1	0.00885	0.938053	0.061946646	10.57147
120	0	0	0.938053	0.061946646	10.57147
130	1	0.00885	0.946903	0.053097088	12.33339
140	1	0.00885	0.955752	0.044247531	14.80009
150	1	0.00885	0.964602	0.035397973	18.50013
160	3	0.026549	0.991151	0.008849301	74.00215
170	0	0	0.991151	0.008849301	74.00215
180	0	0	0.991151	0.008849301	74.00215
190	0	0	0.991151	0.008849301	74.00215
200	1	0.00885	1	-2.56637E-07	-2551724
210	0	0	1	-2.56637E-07	-2551724
220	0	0	1	-2.56637E-07	-2551724
>220	0	0	1	-2.56637E-07	-2551724
N=	113				

return period	rainfall(mm)
2 month	32.9736
3 month	54.244
4 month	70.1441
6 month	90.8648

TABLE A. 17 Exceedence probability and return period calculations for Coronation, Delhi ; using 74 month of Rainfall Data And Inter-Event-Dry Period of 72 hour

96 hour					
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	37	0.355769	0.355769	0.644231	1.104477
20	26	0.25	0.605769	0.394231	1.804877
30	7	0.067308	0.673077	0.326923	2.176469
40	5	0.048077	0.721154	0.278846	2.551722
50	4	0.038462	0.759615	0.240385	2.959997
60	4	0.038462	0.798077	0.201923	3.523805
70	3	0.028846	0.826923	0.173077	4.111106
80	3	0.028846	0.855769	0.144231	4.933325
90	2	0.019231	0.875	0.125	5.692297
100	3	0.028846	0.903846	0.096154	7.399982
110	0	0	0.903846	0.096154	7.399982
120	0	0	0.903846	0.096154	7.399982
130	1	0.009615	0.913461	0.086539	8.2222
140	0	0	0.913461	0.086539	8.2222
150	2	0.019231	0.932692	0.067308	10.57139
160	5	0.048077	0.980769	0.019231	36.99956
170	1	0.009615	0.990384	0.009616	73.99822
180	0	0	0.990384	0.009616	73.99822
190	0	0	0.990384	0.009616	73.99822
200	1	0.009615	1	2.31E-07	3083333
210	0	0	1	2.31E-07	3083333
220	0	0	1	2.31E-07	3083333
>220	0	0	1	2.31E-07	3083333
N=	104				

return period	rainfall(mm)
2 month	25.2688
3 month	40.701
4 month	68.135
6 month	91.8033

TABLE A. 18 Exceedence probability and return period calculations for Coronation, Delhi ; using 74 month of Rainfall Data And Inter-Event-Dry Period of 96 hour

120 hour					
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	34	0.357895	0.357895	0.642105	1.213115
20	20	0.210526	0.568421	0.431578684	1.804879
30	7	0.073684	0.642106	0.357894474	2.176472
40	5	0.052632	0.694737	0.305262895	2.551726
50	3	0.031579	0.726316	0.273683947	2.846157
60	4	0.042105	0.768421	0.231578684	3.36364
70	5	0.052632	0.821053	0.178947105	4.352948
80	3	0.031579	0.852632	0.147368158	5.285724
90	2	0.021053	0.873684	0.126315526	6.16668
100	2	0.021053	0.894737	0.105262895	7.400019
110	0	0	0.894737	0.105262895	7.400019
120	0	0	0.894737	0.105262895	7.400019
130	1	0.010526	0.905263	0.094736579	8.222245
140	0	0	0.905263	0.094736579	8.222245
150	2	0.021053	0.926316	0.073683947	10.57147
160	4	0.042105	0.968421	0.031578684	24.66687
170	1	0.010526	0.978948	0.021052368	37.00046
180	0	0	0.978948	0.021052368	37.00046
190	1	0.010526	0.989474	0.010526053	74.00185
200	0	0	0.989474	0.010526053	74.00185
210	0	0	0.989474	0.010526053	74.00185
220	1	0.010526	1	-2.63158E-07	-2960000
>220	0	0	1	-2.63158E-07	-2960000
N=	95				

return period	rainfall(mm)
2 month	25.263
3 month	52.9787
4 month	66.43309
6 month	88.1084

TABLE A.19 Exceedence probability and return period calculations for Coronation, Delhi ; using 74 month of Rainfall Data And Inter-Event-Dry Period of 120 hour

RAINGUAGE STATION:DELHI RIDGE

	24 hour				
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	109	0.529126	0.529126	0.470874	0.938144
20	28	0.135922	0.665048	0.334952	1.31884
30	14	0.067961	0.733009	0.266991	1.654544
40	8	0.038835	0.771844	0.228156	1.936168
50	13	0.063107	0.834951	0.165049	2.676467
60	5	0.024272	0.859223	0.140777	3.137926
70	6	0.029126	0.888349	0.111651	3.956514
80	4	0.019417	0.907767	0.092233	4.789463
90	4	0.019417	0.927184	0.072816	6.066649
100	0	0	0.927184	0.072816	6.066649
110	2	0.009709	0.936893	0.063107	6.999976
120	1	0.004854	0.941747	0.058253	7.583306
130	1	0.004854	0.946602	0.053398	8.272694
140	1	0.004854	0.951456	0.048544	9.09996
150	6	0.029126	0.980582	0.019418	22.74975
160	2	0.009709	0.990291	0.009709	45.499
170	0	0	0.990291	0.009709	45.499
180	0	0	0.990291	0.009709	45.499
190	1	0.004854	0.995145	0.004855	90.996
200	0	0	0.995145	0.004855	90.996
210	1	0.004854	1	2.14E-07	2068182
220	0	0	1	2.14E-07	2068182
>220	0	0	1	2.14E-07	2068182
N=	206				

	return period	rainfall(mm)
	2month	40.94594
	3month	57.54716
	4month	70.5959
	6month	89.4787

TABLE A. 20 Exceedence probability and return period calculations for Delhi Ridge, Delhi ; using 91 month of Rainfall Data And Inter-Event-Dry Period of 24 hour

		48 hour			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	73	0.470968	0.470968	0.529032	1.109757
20	19	0.122581	0.593549	0.406451355	1.444445
30	14	0.090323	0.683871	0.316128774	1.857144
40	8	0.051613	0.735484	0.264515871	2.219514
50	8	0.051613	0.787097	0.212902968	2.757579
60	6	0.03871	0.825807	0.17419329	3.370375
70	3	0.019355	0.845162	0.154838452	3.791673
80	1	0.006452	0.851613	0.148386839	3.956529
90	5	0.032258	0.883871	0.116128774	5.055567
100	1	0.006452	0.890323	0.109677161	5.352954
110	3	0.019355	0.909678	0.090322323	6.500019
120	2	0.012903	0.922581	0.077419097	7.583359
130	0	0	0.922581	0.077419097	7.583359
140	2	0.012903	0.935484	0.064515871	9.100036
150	4	0.025806	0.961291	0.038709419	15.16677
160	2	0.012903	0.974194	0.025806194	22.75023
170	0	0	0.974194	0.025806194	22.75023
180	0	0	0.974194	0.025806194	22.75023
190	2	0.012903	0.987097	0.012902968	45.50091
200	0	0	0.987097	0.012902968	45.50091
210	0	0	0.987097	0.012902968	45.50091
220	0	0	0.987097	0.012902968	45.50091
>220	2	0.012903	1	-2.58065E-07	-2275000
N=	155				
		return period		rainfall(mm)	
		2 month		33.95027	
		3 month		54.0322	
		4 month		80.4	
		6 month		105.652	

TABLE A.21 20 Exceedence probability and return period calculations for Delhi Ridge, Delhi ; using 91 month of Rainfall Data And Inter-Event-Dry Period of 48 hour

		72 hour			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	62	0.469697	0.469697	0.530303	1.3000001
20	15	0.113636	0.583333	0.416666636	1.6545456
30	12	0.090909	0.674242	0.325757545	2.1162793
40	4	0.030303	0.704545	0.295454515	2.3333336
50	6	0.045455	0.75	0.24999997	2.7575761
60	5	0.037879	0.787879	0.212121182	3.2500005
70	5	0.037879	0.825758	0.174242394	3.9565224
80	2	0.015152	0.840909	0.159090879	4.3333342
90	5	0.037879	0.878788	0.121212091	5.6875014
100	1	0.007576	0.886364	0.113636333	6.0666683
110	3	0.022727	0.909091	0.090909061	7.5833359
120	1	0.007576	0.916667	0.083333303	8.2727303
130	0	0	0.916667	0.083333303	8.2727303
140	1	0.007576	0.924242	0.075757545	9.1000036
150	5	0.037879	0.962121	0.037878758	18.200015
160	0	0	0.962121	0.037878758	18.200015
170	3	0.022727	0.984849	0.015151485	45.500091
180	0	0	0.984849	0.015151485	45.500091
190	1	0.007576	0.992424	0.007575727	91.000364
200	0	0	0.992424	0.007575727	91.000364
210	1	0.007576	1	-3.0303E-08	-22750000
220	0	0	1	-3.0303E-08	-22750000
>220	0	0	1	-3.0303E-08	-22750000
N=	132				
			return period		rainfall(mm)
			2 month		27.608
			3 month		55
			4 month		71.315
			6 month		100

TABLE A.22 Exceedence probability and return period calculations for Delhi Ridge, Delhi ; using 91 month of Rainfall Data And Inter-Event-Dry Period of 72 hour

		96 hour			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	44	0.423077	0.423077	0.576923	1.516667
20	12	0.115385	0.538462	0.461538385	1.895834
30	10	0.096154	0.634615	0.365384538	2.394737
40	3	0.028846	0.663462	0.336538385	2.600001
50	4	0.038462	0.701923	0.298076846	2.935485
60	3	0.028846	0.730769	0.269230692	3.250001
70	4	0.038462	0.769231	0.230769154	3.791668
80	1	0.009615	0.778846	0.221153769	3.956523
90	2	0.019231	0.798077	0.201923	4.333335
100	1	0.009615	0.807692	0.192307615	4.550002
110	3	0.028846	0.836539	0.163461462	5.352944
120	2	0.019231	0.855769	0.144230692	6.06667
130	1	0.009615	0.865385	0.134615308	6.500004
140	0	0	0.865385	0.134615308	6.500004
150	3	0.028846	0.894231	0.105769154	8.272733
160	2	0.019231	0.913462	0.086538385	10.11112
170	3	0.028846	0.942308	0.057692231	15.16669
180	0	0	0.942308	0.057692231	15.16669
190	1	0.009615	0.951923	0.048076846	18.20003
200	0	0	0.951923	0.048076846	18.20003
210	0	0	0.951923	0.048076846	18.20003
220	0	0	0.951923	0.048076846	18.20003
>220	5	0.048077	1	-7.69231E-08	
N=	104				
			return period		rainfall(mm)
			2 month		22.2
			3 month		50.20513
			4 month		81.16465
			6 month		120

TABLE A.23 Exceedence probability and return period calculations for Delhi Ridge, Delhi ; using 91 month of Rainfall Data And Inter-Event-Dry Period of 96 hour

120 hour					
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	39	0.438202	0.438202	0.561798	1.819999
20	11	0.123596	0.561798	0.438202	2.333332
30	10	0.11236	0.674157	0.325843	3.137929
40	3	0.033708	0.707865	0.292135	3.499997
50	3	0.033708	0.741573	0.258427	3.956518
60	1	0.011236	0.752809	0.247191	4.13636
70	3	0.033708	0.786517	0.213483	4.789468
80	1	0.011236	0.797753	0.202247	5.055549
90	0	0	0.797753	0.202247	5.055549
100	1	0.011236	0.808989	0.191011	5.352934
110	1	0.011236	0.820224	0.179776	5.687492
120	2	0.022472	0.842696	0.157304	6.49999
130	2	0.022472	0.865168	0.134832	7.583319
140	0	0	0.865168	0.134832	7.583319
150	2	0.022472	0.88764	0.11236	9.09998
160	1	0.011236	0.898876	0.101124	10.11109
170	1	0.011236	0.910112	0.089888	11.37497
180	0	0	0.910112	0.089888	11.37497
190	2	0.022472	0.932584	0.067416	15.16661
200	0	0	0.932584	0.067416	15.16661
210	1	0.011236	0.94382	0.05618	18.19992
220	0	0	0.94382	0.05618	18.19992
>220	5	0.05618	1	2.47E-07	4136364
N=	89				
		return period		rainfall(mm)	
		2 month		10.3507	
		3 month		28.375	
		4 month		52.4403	
		6 month		113.8517	

TABLE A.24 Exceedence probability and return period calculations for Delhi Ridge, Delhi ; using 91 month of Rainfall Data And Inter-Event-Dry Period of 120 hour

RAINGUAGE STATION: DELHI UNIVERSITY

		24 hour			
P(mm)	X	X/N	SUMX/N	1-Pr	Tr(mo)
0	0	0	0	1	***
10	182	0.487936	0.487936	0.512064	0.895289
20	70	0.187668	0.675604	0.32439644	1.413225
30	28	0.075067	0.750671	0.249329416	1.838712
40	16	0.042895	0.793566	0.206433973	2.220783
50	16	0.042895	0.836461	0.163538531	2.803285
60	19	0.050938	0.8874	0.112600193	4.071441
70	5	0.013405	0.900805	0.099195367	4.621638
80	6	0.016086	0.91689	0.083109576	5.516152
90	10	0.02681	0.9437	0.056299925	8.142907
100	3	0.008043	0.951743	0.048257029	9.500068
110	2	0.005362	0.957105	0.042895099	10.68759
120	2	0.005362	0.962467	0.037533169	12.2144
130	3	0.008043	0.97051	0.029490273	15.54564
140	2	0.005362	0.975872	0.024128343	19.00027
150	4	0.010724	0.986596	0.013404483	34.20088
160	0	0	0.986596	0.013404483	34.20088
170	0	0	0.986596	0.013404483	34.20088
180	0	0	0.986596	0.013404483	34.20088
190	0	0	0.986596	0.013404483	34.20088
200	0	0	0.986596	0.013404483	34.20088
210	1	0.002681	0.989276	0.010723517	42.75137
220	3	0.008043	0.997319	0.002680622	171.0219
>220	1	0.002681	1	-3.43164E-07	-1335937
N=	373				

return period	rainfall(mm)
2month	34.22172
3month	51.55313
4month	50.9437
6month	81.84217

TABLE A.25 Exceedence probability and return period calculations for Delhi university, Delhi ; using 171 month of Rainfall Data And Inter-Event-Dry Period of 24 hour

	48 hour				
P(mm)	X	X/N	SUM X/N	1-Pr	Tr(mo.)
0	0	0	0	1	***
10	115	0.40636	0.40636	0.59364	1.017856
20	48	0.169611	0.575971	0.424029	1.424999
30	27	0.095406	0.671378	0.328622	1.838707
40	16	0.056537	0.727915	0.272085	2.220776
50	13	0.045936	0.773851	0.226149	2.67187
60	16	0.056537	0.830388	0.169612	3.562491
70	7	0.024735	0.855123	0.144877	4.17072
80	4	0.014134	0.869258	0.130742	4.621607
90	8	0.028269	0.897526	0.102474	5.896527
100	3	0.010601	0.908127	0.091873	6.576893
110	3	0.010601	0.918727	0.081273	7.434744
120	2	0.007067	0.925795	0.074205	8.142811
130	2	0.007067	0.932862	0.067138	8.999943
140	2	0.007067	0.939929	0.060071	10.05875
150	3	0.010601	0.95053	0.04947	12.21418
160	1	0.003534	0.954063	0.045937	13.15372
170	1	0.003534	0.957597	0.042403	14.24986
180	1	0.003534	0.96113	0.03887	15.54528
190	1	0.003534	0.964664	0.035336	17.09979
200	2	0.007067	0.971731	0.028269	21.37468
210	3	0.010601	0.982332	0.017668	34.19918
220	3	0.010601	0.992932	0.007068	85.49487
>220	2	0.007067	1	4.24E-07	1425000
N=	283				

return period	rainfall(mm)
2 month	30.42216
3 month	53.68428
4 month	67.1945
6 month	91.523

TABLE A.26 Exceedence probability and return period calculations for Delhi university, Delhi ; using 171 month of Rainfall Data And Inter-Event-Dry Period of 48 hour

	72 hour				
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	98	0.395161	0.395161	0.604839	1.139999
20	42	0.169355	0.564516	0.435484	1.583332
30	22	0.08871	0.653226	0.346774	1.98837
40	15	0.060484	0.713709	0.286291	2.408448
50	14	0.056452	0.770161	0.229839	2.999996
60	12	0.048387	0.818548	0.181452	3.799994
70	5	0.020161	0.838709	0.161291	4.274992
80	6	0.024194	0.862903	0.137097	5.029401
90	4	0.016129	0.879032	0.120968	5.699986
100	3	0.012097	0.891129	0.108871	6.333316
110	3	0.012097	0.903226	0.096774	7.124979
120	3	0.012097	0.915322	0.084678	8.142829
130	0	0	0.915322	0.084678	8.142829
140	3	0.012097	0.927419	0.072581	9.499962
150	3	0.012097	0.939516	0.060484	11.39995
160	1	0.004032	0.943548	0.056452	12.21422
170	0	0	0.943548	0.056452	12.21422
180	2	0.008065	0.951613	0.048387	14.24991
190	0	0	0.951613	0.048387	14.24991
200	2	0.008065	0.959677	0.040323	17.09988
210	1	0.004032	0.963709	0.036291	18.99985
220	3	0.012097	0.975806	0.024194	28.49966
>220	6	0.024194	1	2.9E-07	2375000
N=	248				
		return period		rainfall(mm)	
		2 month		30.27685	
		3 month		50.0125	
		4 month		64.2227	
		6 month		94.7476	

TABLE A.27 Exceedence probability and return period calculations for Delhi university, Delhi ; using 171 month of Rainfall Data And Inter-Event-Dry Period of 72 hour

	96 hour				
P(mm)	X	X/N	SUMX/N	1-Pr	Tr
0	0	0	0	1	***
10	78	0.395939	0.395939	0.604061	1.436975
20	36	0.182741	0.57868	0.42132	2.060241
30	10	0.050761	0.629442	0.370558	2.342465
40	10	0.050761	0.680203	0.319797	2.714285
50	10	0.050761	0.730964	0.269036	3.226414
60	11	0.055838	0.786802	0.213198	4.071427
70	5	0.025381	0.812183	0.187817	4.621619
80	4	0.020305	0.832487	0.167513	5.181816
90	0	0	0.832487	0.167513	5.181816
100	4	0.020305	0.852792	0.147208	5.896548
110	2	0.010152	0.862944	0.137056	6.333329
120	3	0.015228	0.878173	0.121827	7.124995
130	0	0	0.878173	0.121827	7.124995
140	4	0.020305	0.898477	0.101523	8.549993
150	2	0.010152	0.908629	0.091371	9.499991
160	1	0.005076	0.913705	0.086295	10.05881
170	1	0.005076	0.918782	0.081218	10.68749
180	2	0.010152	0.928934	0.071066	12.21427
190	0	0	0.928934	0.071066	12.21427
200	3	0.015228	0.944162	0.055838	15.54543
210	1	0.005076	0.949238	0.050762	17.09997
220	1	0.005076	0.954315	0.045685	18.99996
>220	9	0.045685	1	8.63E-08	10058824
N=	197				
		return period		rainfall(mm)	
		2 month		19.03417	
		3 month		45.5789	
		4 month		59.1554	
		6 month		102.3711	

TABLE A.28 Exceedence probability and return period calculations for Delhi university, Delhi ; using 171 month of Rainfall Data And Inter-Event-Dry Period of 96 hour

	120 hour				
P(mm)	X	X/N	SUMX/N	1-Pr	Tr
0	0	0	0	1	***
10	66	0.354839	0.354839	0.645161	1.425001
20	34	0.182796	0.537635	0.462365301	1.988373
30	18	0.096774	0.634409	0.365591108	2.514708
40	8	0.043011	0.67742	0.322580355	2.850003
50	10	0.053763	0.731183	0.268816914	3.420004
60	8	0.043011	0.774194	0.225806161	4.071434
70	4	0.021505	0.795699	0.204300785	4.500006
80	4	0.021505	0.817205	0.182795409	5.02942
90	0	0	0.817205	0.182795409	5.02942
100	5	0.026882	0.844086	0.155913688	5.896563
110	2	0.010753	0.854839	0.145161	6.333346
120	4	0.021505	0.876344	0.123655624	7.4348
130	0	0	0.876344	0.123655624	7.4348
140	4	0.021505	0.89785	0.102150247	9.000026
150	2	0.010753	0.908602	0.091397559	10.05886
160	1	0.005376	0.913979	0.086021215	10.68754
170	1	0.005376	0.919355	0.080644871	11.40004
180	2	0.010753	0.930108	0.069892183	13.1539
190	0	0	0.930108	0.069892183	13.1539
200	1	0.005376	0.935484	0.064515839	14.25006
210	1	0.005376	0.940861	0.059139495	15.54553
220	2	0.010753	0.951613	0.048386806	19.00011
>220	9	0.048387	1	-2.90323E-07	-3166667
N=	186				
		return period		rainfall(mm)	
		2 month		20.227	
		3 month		42.6315	
		4 month		60	
		6 month		102.367	

TABLE A.29 Exceedence probability and return period calculations for Delhi university, Delhi ; using 171 month of Rainfall Data And Inter-Event-Dry Period of 120 hour

RAINGUAGE STATION :KESHOPUR NEW DELHI

		24 hour			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	77	0.469512	0.469512	0.530488	1
20	26	0.158537	0.628049	0.371951	1.426229
30	19	0.115854	0.743902	0.256098	2.071427
40	15	0.091463	0.835366	0.164634	3.222218
50	4	0.02439	0.859756	0.140244	3.782603
60	2	0.012195	0.871951	0.128049	4.142851
70	4	0.02439	0.896341	0.103659	5.117637
80	3	0.018293	0.914634	0.085366	6.214272
90	3	0.018293	0.932927	0.067073	7.909068
100	1	0.006098	0.939024	0.060976	8.699972
110	2	0.012195	0.951219	0.048781	10.87496
120	0	0	0.951219	0.048781	10.87496
130	2	0.012195	0.963414	0.036586	14.49992
140	1	0.006098	0.969512	0.030488	17.39989
150	1	0.006098	0.97561	0.02439	21.74983
160	0	0	0.97561	0.02439	21.74983
170	1	0.006098	0.981707	0.018293	28.99969
180	1	0.006098	0.987805	0.012195	43.4993
190	1	0.006098	0.993902	0.006098	86.99722
200	0	0	0.993902	0.006098	86.99722
210	1	0.006098	1	1.95E-07	2718750
220	0	0	1	1.95E-07	2718750
>220	0	0	1	1.95E-07	2718750
N=	164				
	return period		rainfall(mm)		
	2 month		28.8937		
	3 month		38.06926		
	4 month		50.6034		
	6 month		78.04643		

TABLE A. 30 Exceedence probability and return period calculations for Keshopur, Delhi ; using 87 month of Rainfall Data And Inter-Event-Dry Period of 24 hour

		48 hour			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	53	0.395522	0.395522	0.604478	1.074073
20	23	0.171642	0.567164	0.432836	1.499999
30	13	0.097015	0.664179	0.335821	1.933331
40	15	0.11194	0.776119	0.223881	2.899995
50	6	0.044776	0.820895	0.179105	3.624992
60	4	0.029851	0.850746	0.149254	4.349989
70	4	0.029851	0.880597	0.119403	5.437482
80	4	0.029851	0.910447	0.089553	7.249969
90	3	0.022388	0.932835	0.067165	9.666611
100	1	0.007463	0.940298	0.059702	10.87493
110	1	0.007463	0.947761	0.052239	12.42848
120	0	0	0.947761	0.052239	12.42848
130	1	0.007463	0.955223	0.044777	14.49987
140	0	0	0.955223	0.044777	14.49987
150	0	0	0.955223	0.044777	14.49987
160	0	0	0.955223	0.044777	14.49987
170	0	0	0.955223	0.044777	14.49987
180	2	0.014925	0.970149	0.029851	21.74972
190	0	0	0.970149	0.029851	21.74972
200	0	0	0.970149	0.029851	21.74972
210	0	0	0.970149	0.029851	21.74972
220	1	0.007463	0.977612	0.022388	28.9995
>220	3	0.022388	1	3.88E-07	1673077
N=	134				
		return period		rainfall(mm)	
		2 month		30.69358	
		3 month		41.3912	
		4 month		50.5172	
		6 month		70.31035	

TABLE A.31 Exceedence probability and return period calculations for Keshopur, Delhi ; using 87 month of Rainfall Data And Inter-Event-Dry Period of 48 hour

72 hour					
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	41	0.372727	0.372727	0.627273	1.260869
20	20	0.181818	0.554545	0.445455	1.775509
30	10	0.090909	0.645454	0.354546	2.230768
40	13	0.118182	0.763636	0.236364	3.34615
50	3	0.027273	0.790909	0.209091	3.782604
60	3	0.027273	0.818182	0.181818	4.349993
70	3	0.027273	0.845454	0.154546	5.117638
80	3	0.027273	0.872727	0.127273	6.214272
90	2	0.018182	0.890909	0.109091	7.249982
100	0	0	0.890909	0.109091	7.249982
110	1	0.009091	0.9	0.1	7.909069
120	0	0	0.9	0.1	7.909069
130	2	0.018182	0.918182	0.081818	9.666634
140	0	0	0.918182	0.081818	9.666634
150	0	0	0.918182	0.081818	9.666634
160	1	0.009091	0.927272	0.072728	10.87496
170	0	0	0.927272	0.072728	10.87496
180	3	0.027273	0.954545	0.045455	17.3999
190	1	0.009091	0.963636	0.036364	21.74984
200	0	0	0.963636	0.036364	21.74984
210	0	0	0.963636	0.036364	21.74984
220	1	0.009091	0.972727	0.027273	28.99971
>220	3	0.027273	1	2.73E-07	2900000
N=	110				
		return period		rainfall(mm)	
		2 month		24.93116	
		3 month		36.89657	
		4 month		53.83194	
		6 month		78.04616	

TABLE A.32 Exceedence probability and return period calculations for Keshopur, Delhi ; using 87 month of Rainfall Data And Inter-Event-Dry Period of 72 hour

96 hour					
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	36	0.349515	0.349515	0.650485	1.298508
20	19	0.184466	0.533981	0.466019	1.812502
30	10	0.097087	0.631068	0.368932	2.289476
40	14	0.135922	0.766991	0.233009	3.625007
50	2	0.019417	0.786408	0.213592	3.954554
60	2	0.019417	0.805826	0.194174	4.35001
70	3	0.029126	0.834952	0.165048	5.117661
80	2	0.019417	0.854369	0.145631	5.800017
90	2	0.019417	0.873787	0.126213	6.692331
100	1	0.009709	0.883496	0.116504	7.250027
110	1	0.009709	0.893204	0.106796	7.909123
120	0	0	0.893204	0.106796	7.909123
130	1	0.009709	0.902913	0.097087	8.700039
140	2	0.019417	0.922331	0.077669	10.87506
150	0	0	0.922331	0.077669	10.87506
160	1	0.009709	0.932039	0.067961	12.42865
170	0	0	0.932039	0.067961	12.42865
180	2	0.019417	0.951457	0.048543	17.40016
190	1	0.009709	0.961165	0.038835	21.75024
200	0	0	0.961165	0.038835	21.75024
210	0	0	0.961165	0.038835	21.75024
220	1	0.009709	0.970874	0.029126	29.00044
>220	3	0.029126		1	0.84466
N=	103				
		return period		rainfall(mm)	
		2 month		23.9309	
		3 month		35.32016	
		4 month		52.23	
		6 month		82.242	

TABLE A.33 Exceedence probability and return period calculations for Keshopur, Delhi ; using 87 month of Rainfall Data And Inter-Event-Dry Period of 96 hour

			120 hour		
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	35	0.37234	0.37234	0.62766	1.474575
20	16	0.170213	0.542553	0.457447	2.023254
30	8	0.085106	0.627659	0.372341	2.485711
40	11	0.117021	0.74468	0.25532	3.624994
50	2	0.021277	0.765957	0.234043	3.954538
60	3	0.031915	0.797872	0.202128	4.578938
70	3	0.031915	0.829787	0.170213	5.437486
80	3	0.031915	0.861702	0.138298	6.692287
90	2	0.021277	0.882978	0.117022	7.909062
100	0	0	0.882978	0.117022	7.909062
110	1	0.010638	0.893617	0.106383	8.699965
120	0	0	0.893617	0.106383	8.699965
130	1	0.010638	0.904255	0.095745	9.666624
140	1	0.010638	0.914893	0.085107	10.87495
150	0	0	0.914893	0.085107	10.87495
160	0	0	0.914893	0.085107	10.87495
170	1	0.010638	0.925531	0.074469	12.4285
180	1	0.010638	0.93617	0.06383	14.4999
190	1	0.010638	0.946808	0.053192	17.39986
200	0	0	0.946808	0.053192	17.39986
210	0	0	0.946808	0.053192	17.39986
220	0	0	0.946808	0.053192	17.39986
>220	5	0.053191	1		#DIV/0!
N=	94				
	return period		rainfall(mm)		
	2month		19.57618		
	3month		34.51414		
	4month		50.72779		
	6month		74.5238		

TABLE A.34 Exceedence probability and return period calculations for Keshopur, Delhi ; using 87 month of Rainfall Data And Inter-Event-Dry Period of 120 hour

RANGUAGE STATION :NEW DELHI SAFDARBSY

		24 hour			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	205	0.504926	0.504926	0.495074	0.895522
20	61	0.150246	0.655172	0.344828	1.285714
30	39	0.096059	0.751231	0.248769	1.782177
40	22	0.054187	0.805419	0.194581	2.27848
50	13	0.03202	0.837438	0.162562	2.727271
60	15	0.036946	0.874384	0.125616	3.529409
70	6	0.014778	0.889162	0.110838	3.999996
80	8	0.019704	0.908867	0.091133	4.864859
90	4	0.009852	0.918719	0.081281	5.454538
100	5	0.012315	0.931034	0.068966	6.428561
110	4	0.009852	0.940887	0.059113	7.499986
120	2	0.004926	0.945813	0.054187	8.181802
130	3	0.007389	0.953202	0.046798	9.473662
140	2	0.004926	0.958128	0.041872	10.58821
150	2	0.004926	0.963054	0.036946	11.99996
160	1	0.002463	0.965517	0.034483	12.8571
170	5	0.012315	0.977832	0.022168	19.9999
180	4	0.009852	0.987685	0.012315	35.99968
190	1	0.002463	0.990148	0.009852	44.99951
200	0	0	0.990148	0.009852	44.99951
210	1	0.002463	0.992611	0.007389	59.99912
220	1	0.002463	0.995074	0.004926	89.99802
>220	2	0.004926	1	1.08E-07	4090909
N=	406				
	return period		rainfall(mm)		
	2month		34.3889		
	3month		53.4		
	4month		70.1234		
	6month		95.6		

TABLE A.35 Exceedence probability and return period calculations for New delhi, Delhi ; using 180 month of Rainfall Data And Inter-Event-Dry Period of 24 hour

		48 hour			
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	154	0.487342	0.487342	0.512658	1.111112
20	38	0.120253	0.607595	0.392404835	1.451614
30	27	0.085443	0.693038	0.306961797	1.855671
40	22	0.06962	0.762658	0.237341544	2.400002
50	13	0.041139	0.803798	0.196202304	2.903229
60	11	0.03481	0.838608	0.161392177	3.529417
70	5	0.015823	0.854431	0.145569392	3.91305
80	8	0.025316	0.879747	0.120252937	4.736851
90	2	0.006329	0.886076	0.113923823	5.00001
100	5	0.015823	0.901899	0.098101038	5.806465
110	2	0.006329	0.908228	0.091771924	6.206912
120	4	0.012658	0.920886	0.079113696	7.200021
130	6	0.018987	0.939874	0.060126354	9.47372
140	0	0	0.939874	0.060126354	9.47372
150	3	0.009494	0.949367	0.050632684	11.25005
160	2	0.006329	0.955696	0.04430357	12.85721
170	1	0.003165	0.958861	0.041139013	13.84623
180	5	0.015823	0.974684	0.025316228	22.5002
190	0	0	0.974684	0.025316228	22.5002
200	3	0.009494	0.984177	0.015822557	36.00052
210	1	0.003165	0.987342	0.012658	45.00081
220	1	0.003165	0.990507	0.009493443	60.00144
>220	3	0.009494	1	-2.27848E-07	-2500000
N=	316				
		return period		rainfall(mm)	
		2 month		32.7272	
		3 month		51.5484	
		4 month		71.0554	
		6 month		104.833	

TABLE A.36 Exceedence probability and return period calculations for New delhi, Delhi ; using 180 month of Rainfall Data And Inter-Event-Dry Period of 48 hour

72 hour					
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	124	0.457565	0.457565	0.542435	1.224491
20	33	0.121771	0.579336	0.420663782	1.578949
30	20	0.073801	0.653137	0.346863044	1.914896
40	18	0.066421	0.719558	0.28044238	2.368425
50	17	0.062731	0.782288	0.217711753	3.050853
60	8	0.02952	0.811809	0.188191458	3.52942
70	5	0.01845	0.830259	0.169741273	3.913053
80	6	0.02214	0.852399	0.147601052	4.500013
90	2	0.00738	0.859779	0.140220978	4.736856
100	4	0.01476	0.874539	0.12546083	5.294136
110	5	0.01845	0.892989	0.107010646	6.206921
120	1	0.00369	0.896679	0.103320609	6.428598
130	4	0.01476	0.91144	0.088560461	7.500036
140	1	0.00369	0.91513	0.084870424	7.826126
150	3	0.01107	0.9262	0.073800314	9.000052
160	2	0.00738	0.93358	0.06642024	10.00006
170	2	0.00738	0.94096	0.059040166	11.25008
180	4	0.01476	0.95572	0.044280018	15.00014
190	1	0.00369	0.95941	0.040589982	16.36381
200	4	0.01476	0.97417	0.025829834	25.71471
210	1	0.00369	0.97786	0.022139797	30.00058
220	1	0.00369	0.98155	0.01844976	36.00083
>220	5	0.01845	1	-4.24354E-07	-1565217
N=	271				
		return period		rainfall(mm)	
		2 month		31.928	
		3 month		71.48134	
		4 month		50	
		6 month		107.73334	

TABLE A.37 Exceedence probability and return period calculations for New delhi, Delhi ; using 180 month of Rainfall Data And Inter-Event-Dry Period of 72 hour

				96 hour	
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	98	0.431718	0.431718	0.568282	1.395349
20	32	0.140969	0.572687	0.427313	1.85567
30	16	0.070485	0.643172	0.356828	2.222222
40	12	0.052863	0.696035	0.303965	2.608695
50	15	0.066079	0.762114	0.237886	3.333332
60	8	0.035242	0.797357	0.202643	3.913042
70	4	0.017621	0.814978	0.185022	4.285713
80	4	0.017621	0.832599	0.167401	4.73684
90	3	0.013216	0.845815	0.154185	5.142855
100	1	0.004405	0.85022	0.14978	5.294115
110	3	0.013216	0.863436	0.136564	5.806449
120	2	0.008811	0.872247	0.127753	6.206894
130	2	0.008811	0.881057	0.118943	6.666663
140	1	0.004405	0.885462	0.114538	6.923073
150	3	0.013216	0.898678	0.101322	7.826082
160	2	0.008811	0.907489	0.092511	8.571423
170	4	0.017621	0.92511	0.07489	10.58823
180	2	0.008811	0.933921	0.066079	11.99999
190	0	0	0.933921	0.066079	11.99999
200	3	0.013216	0.947137	0.052863	14.99998
210	2	0.008811	0.955947	0.044053	17.99997
220	1	0.004405	0.960352	0.039648	19.99997
>220	9	0.039648	1	6.17E-08	12857143
N=	227				

	return period	rainfall(mm)
	2 month	23.8556
	3 month	45.479
	4 month	62.333
	6 month	114.85

TABLE A.38 Exceedence probability and return period calculations for New delhi, Delhi ; using 180 month of Rainfall Data And Inter-Event-Dry Period of 96 hour

			120 hour		
P(mm)	X	X/N	SUM X/N	1-Pr	Tr
0	0	0	0	1	***
10	78	0.397959	0.397959	0.602041	1.525423
20	31	0.158163	0.556122	0.443878	2.068965
30	15	0.076531	0.632653	0.367347	2.499999
40	11	0.056122	0.688775	0.311225	2.950818
50	9	0.045918	0.734694	0.265306	3.461536
60	8	0.040816	0.77551	0.22449	4.090906
70	4	0.020408	0.795918	0.204082	4.499996
80	5	0.02551	0.821428	0.178572	5.142852
90	3	0.015306	0.836735	0.163265	5.624994
100	1	0.005102	0.841837	0.158163	5.806445
110	2	0.010204	0.852041	0.147959	6.206889
120	0	0	0.852041	0.147959	6.206889
130	2	0.010204	0.862245	0.137755	6.666658
140	0	0	0.862245	0.137755	6.666658
150	3	0.015306	0.877551	0.122449	7.499989
160	2	0.010204	0.887755	0.112245	8.181805
170	3	0.015306	0.903061	0.096939	9.473666
180	1	0.005102	0.908163	0.091837	9.99998
190	0	0	0.908163	0.091837	9.99998
200	2	0.010204	0.918367	0.081633	11.24997
210	1	0.005102	0.923469	0.076531	11.99997
220	0	0	0.923469	0.076531	11.99997
>220	15	0.076531	1	1.84E-07	5000000
N=	196				
	return period		rainfall(mm)		
	2month		18.7311		
	3month		40.9633		
	4month		60		
	6month		104.833		

TABLE A.39 Exceedence probability and return period calculations for New delhi, Delhi ; using 180 month of Rainfall Data And Inter-Event-Dry Period of 120 hour

APPENDIX B

PRECIPITATION VOLUME STATISTICS

Table B.1. PRECIPITATION VOLUME STATISTICAL INFORMATION AS A FUCTION OF MINIMUM INTER-EVENT-DRY PERIOD FOR ALIPUR

Minimum Dry Period (hours)	24	48	72	96	120
Count (N)	139	108	101	91	85
Mean(mm)	39.109	49.782	54.248	59.359	63.593
Std. error of mean	3.8310	5.6784	6.4298	7.7710	8.4254
Median	25	25.4	27	27	30.5
Mode	2.0a	16.5a	10.1a	10.1a	10.1a
Std. deviation	45.1665	59.0116	64.6188	74.1302	77.6787
Variance	2040.009	3482.374	4175.593	5495.280	6033.976
Range	230.3	278.4	291.2	394.7	394.7
Minimum	1.2	1.2	1.2	1.2	1.2
Maximum	231.5	279.6	292.4	395.9	395.9

Table B.2. PRECIPITATION VOLUME STATISTICAL INFORMATION AS A FUCTION OF MINIMUM INTER - EVENT DRY PERIOD FOR KESHOPUR

Minimum Dry Period (hours)	24	48	72	96	120
Count (N)	164	132	109	103	94
Mean(mm)	26.574	32.969	39.642	41.846	46.660
Std. error of mean	2.9348	4.4754	5.7688	6.4223	8.3309
Median	12.7	15.5	15.8	18.1	18.050
Mode	6	6	4a	4a	6
Std. deviation	37.5844	51.4179	60.2283	65.1789	80.7714
Variance	1412.588	2643.804	3627.450	4248.288	6524.024
Range	207.5	306.6	306.6	398.1	498.5
Minimum	0.6	0.6	0.6	0.6	0.6
Maximum	208.1	307.2	307.2	398.7	499.1

Table B.3. PRECIPITATION VOLUME STATISTICAL INFORMATION AS A FUCTION OF MINIMUM INTER- EVENT DRY PERIOD FOR DELHI UNIVERSITY

Minimum Dry Period (hours)	24	48	72	96	120
Count (N)	375	283	245	205	186
Mean(mm)	26.062	34.959	40.268	47.886	52.778
Std. error of mean	2.0134	2.8971	4.3190	5.5915	6.8929
Median	10.6	15.7	16.4	16.9	18.050
Mode	1.2	1.2	1.2	2.3	2.3
Std. deviation	38.99	48.7367	67.6031	80.0578	94.0069
Variance	1520.216	2375.263	4570.173	6409.258	8837.301
Range	275.4	247.3	535	542.2	800.3
Minimum	1.1	1.1	1.1	1.1	1.1
Maximum	276.5	248.4	536.1	543.3	801.4

Table B.4. PRECIPITATION VOLUME STATISTICAL INFORMATION AS A FUCTION OF MINIMUM INTER EVENT DRY PERIOD FOR DELHI RIDGE

Minimum Dry Period (hours)	24	48	72	96	120
Count (N)	206	155	134	104	89
Mean(mm)	26.60	35.42	39.63	51.67	59.63
Std. error of mean	2.742	4.625	5.302	8.202	12.429
Median	8.50	11.60	12.15	15.65	15.10
Mode	1	1	1	1a	1
Std. deviation	39.348	57.581	61.370	83.641	117.253
Variance	1548.283	3315.517	3766.318	6995.760	13748.310
Range	205	458	458	607	688
Minimum	1	1	1	1	1
Maximum	206	459	459	608	689

Table B.5. PRECIPITATION VOLUME STATISTICAL INFORMATION AS A FUCTION OF MINIMUM INTER EVENT DRY PERIOD FOR CORONATION, DELHI

Minimum Dry Period (hours)	24	48	72	96	120
Count (N)	156	136	121	113	104
Mean(mm)	23.96	41.39	47.90	55.78	63.16
Std. error of mean	2.520	11.283	13.927	19.318	23.794
Median	10.50	13.01	14.90	14.50	14.45
Mode	1	1a	6a	6a	1a
Std. deviation	31.473	131.578	153.195	205.349	242.655
Variance	990.526	17312.639	23468.774	42168.359	58881.562
Range	157	1488	1652	2159	2458
Minimum	1	1	1	1	1
Maximum	157	1489	1653	2160	2459

Table B.6. PRECIPITATION VOLUME STATISTICAL INFORMATION AS A FUCTION OF MINIMUM INTER EVENT DRY PERIOD FOR CHIRAG DELHI

Minimum Dry Period (hours)	24	48	72	96	120
Count (N)	41	22	16	15	13
Mean(mm)	18.180	34.318	47.188	50.333	58.077
Std. error of mean	3.1749	7.7363	14.3834	17.3446	20.3589
Median	10.8	19	20.1	19.8	20.4
Mode	3.6	9.6	3.6a	3.6a	19.2
Std. deviation	20.3296	36.2864	57.5335	67.1755	73.4052
Variance	413.292	1316.7	3310.104	4512.547	5388.317
Range	86.6	110.2	205.6	243.6	258
Minimum	1	3.6	3.6	3.6	3.8
Maximum	87.6	113.8	209.2	247.2	261.8

Table B.7. PRECIPITATION VOLUME STATISTICAL INFORMATION AS A FUCTION OF MINIMUM INTER EVENT DRY PERIOD FOR SAFAGDARBSY,DELHI

Minimum Dry Period (hours)	24	48	72	96	120
Count (N)	406	316	272	227	196
Mean(mm)	26.916	33.806	41.542	46.497	61.151
Std. error of mean	2.0745	3.0977	4.5179	5.4197	8.9938
Median	9.5	10.6	13.450	13.70	15.70
Mode	1	1	1	1a	3.4
Std. deviation	41.8	55.0656	74.5109	81.6557	125.9134
Variance	1747.301	3032.224	5551.871	6667.660	15854.196
Range	272.8	435.6	775.4	775.4	1041.0
Minimum	0.6	0.7	0.7	0.7	0.7
Maximum	273.4	436.3	776.1	776.1	1041.7

Table B.8. PRECIPITATION VOLUME STATISTICAL INFORMATION AS A FUCTION OF MINIMUM INTER EVENT DRY PERIOD FOR CHANDRAWAL, DELHI

Minimum Dry Period (hours)	24	48	72	96	120
Count (N)	137	113	89	77	67
Mean(mm)	28.897	35.061	44.179	50.418	59.137
Std. error of mean	2.9652	3.9923	5.0632	7.4498	9.8311
Median	15.5	15.6	22.2	21.7	27.7
Mode	2.2	3.2a	18	2.2a	9.0a
Std. deviation	34.7067	42.4382	47.7661	65.3715	80.4709
Variance	1204.555	1801.004	2281.602	4273.439	6475.573
Range	204.7	204.3	213.6	296.5	430.9
Minimum	0.2	0.6	0.6	0.6	0.6
Maximum	204.9	204.9	213.8	297.1	431.5

APPENDIX C

PIF CURVES

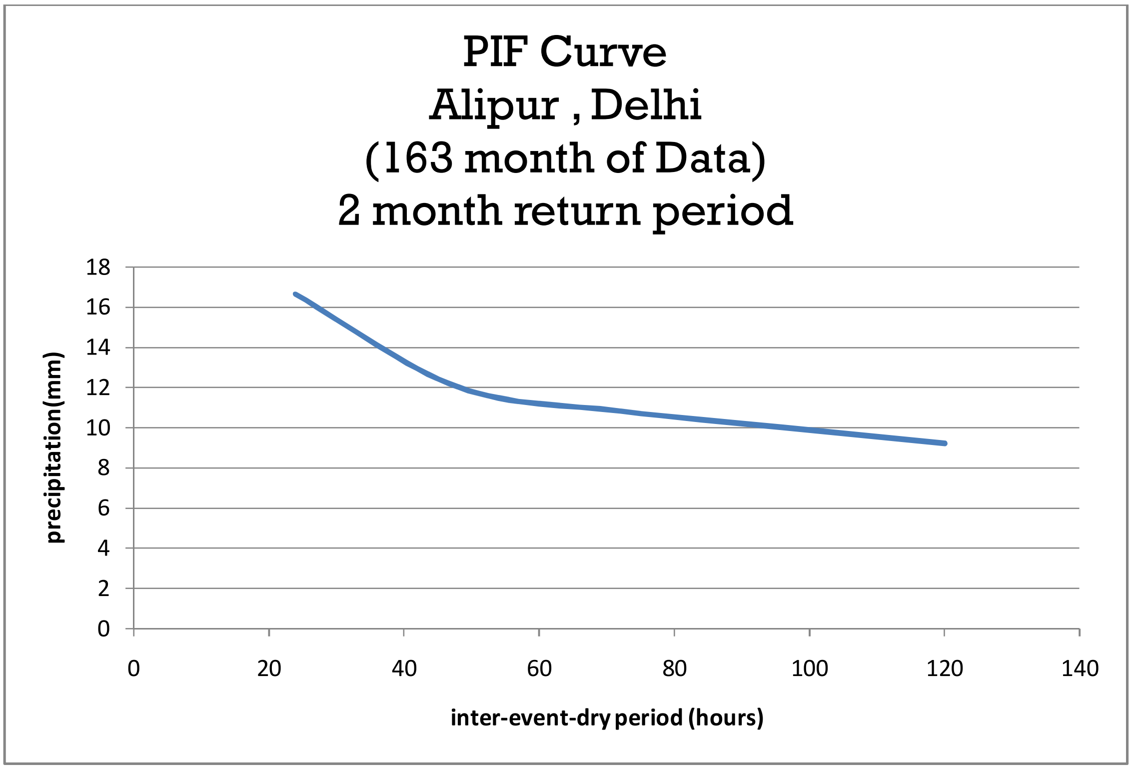

Fig. C.1 PIF Curve Alipur, Delhi (163 month of Data) 2 month return period

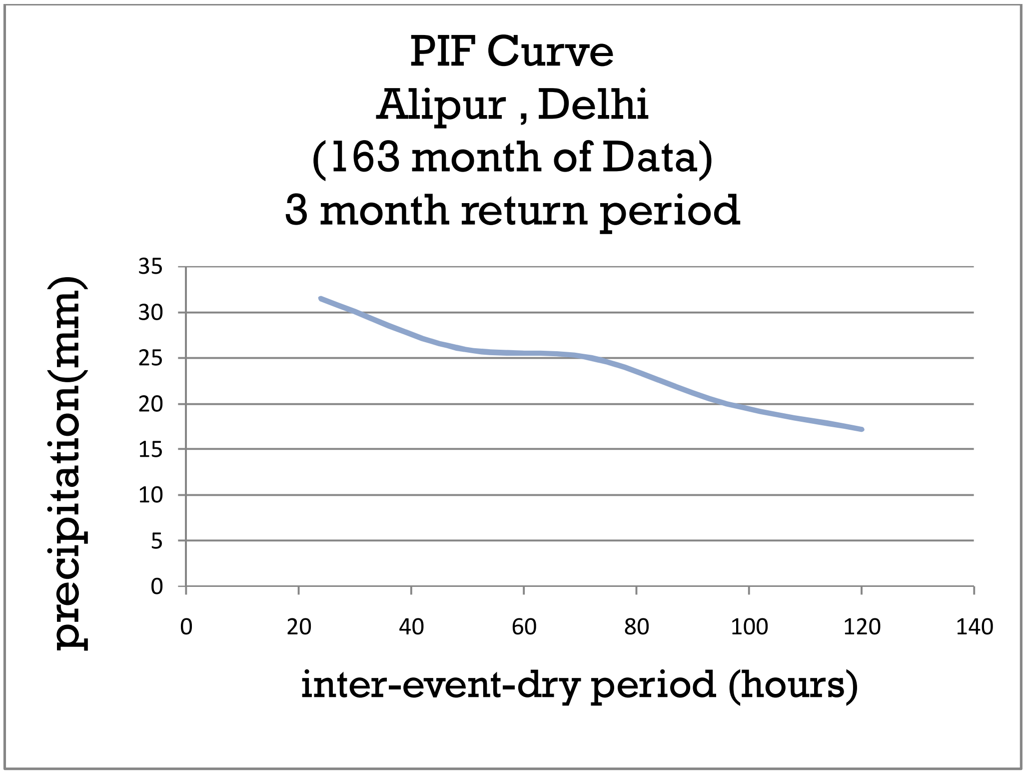

Fig. C.2 PIF Curve Alipur, Delhi (163 month of Data) 3 month return period

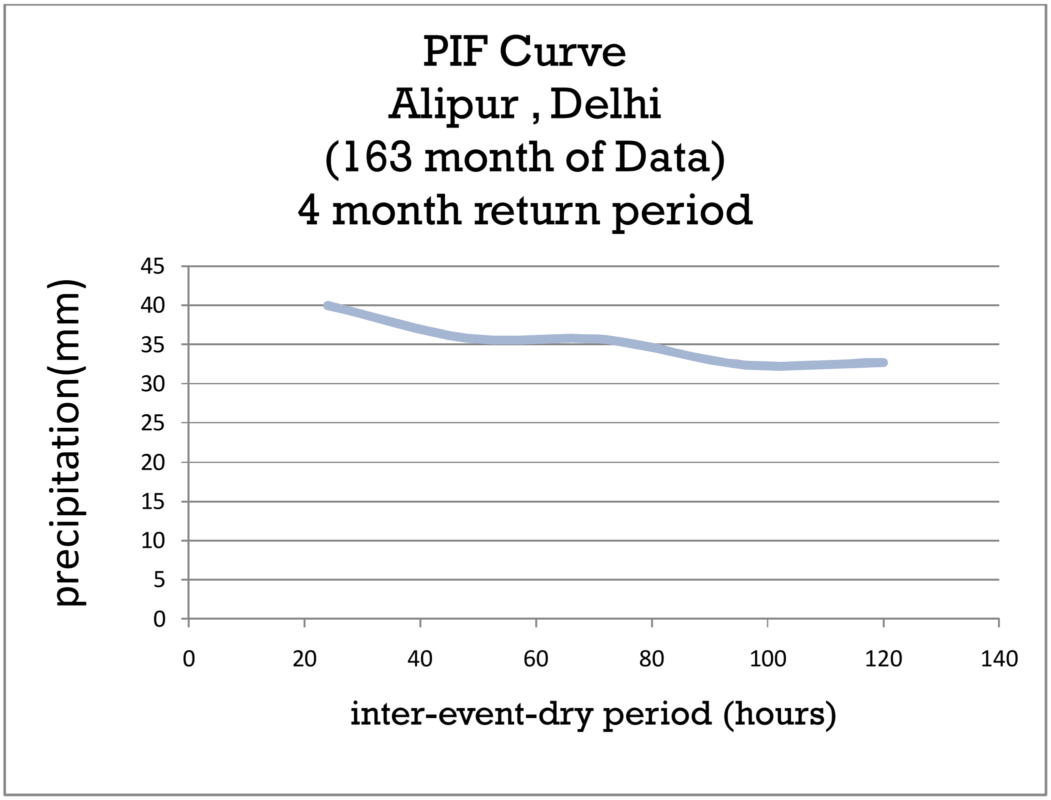

FIGURE C.3 PIF Curve Alipur, Delhi (163 month of Data) 4 month return period

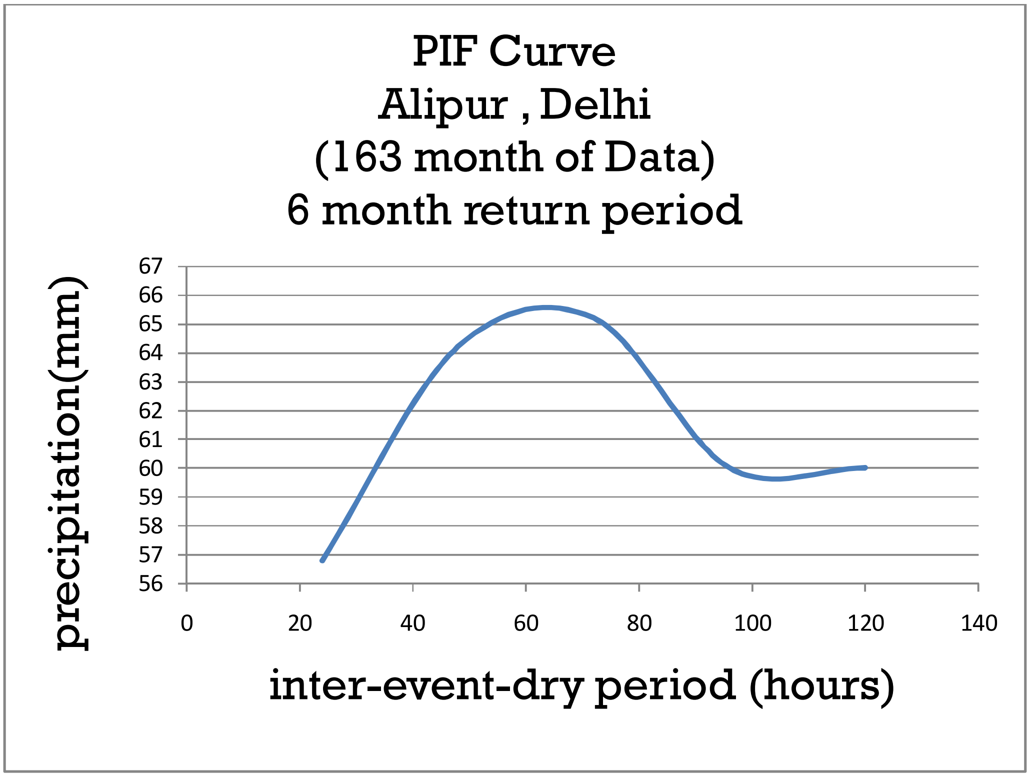

FIGURE C.4 PIF Curve Alipur, Delhi (163 month of Data) 6 month return period

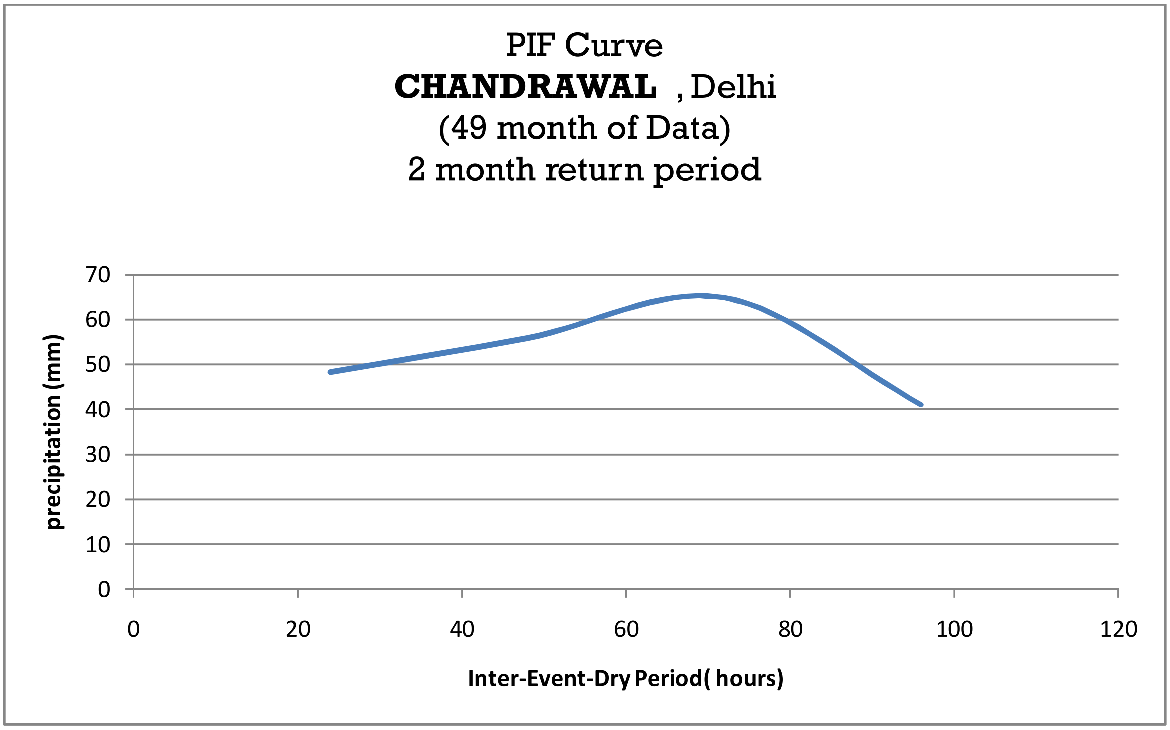

FIGURE C.4 PIF curve for Chandwal, delhi(2 month return period)

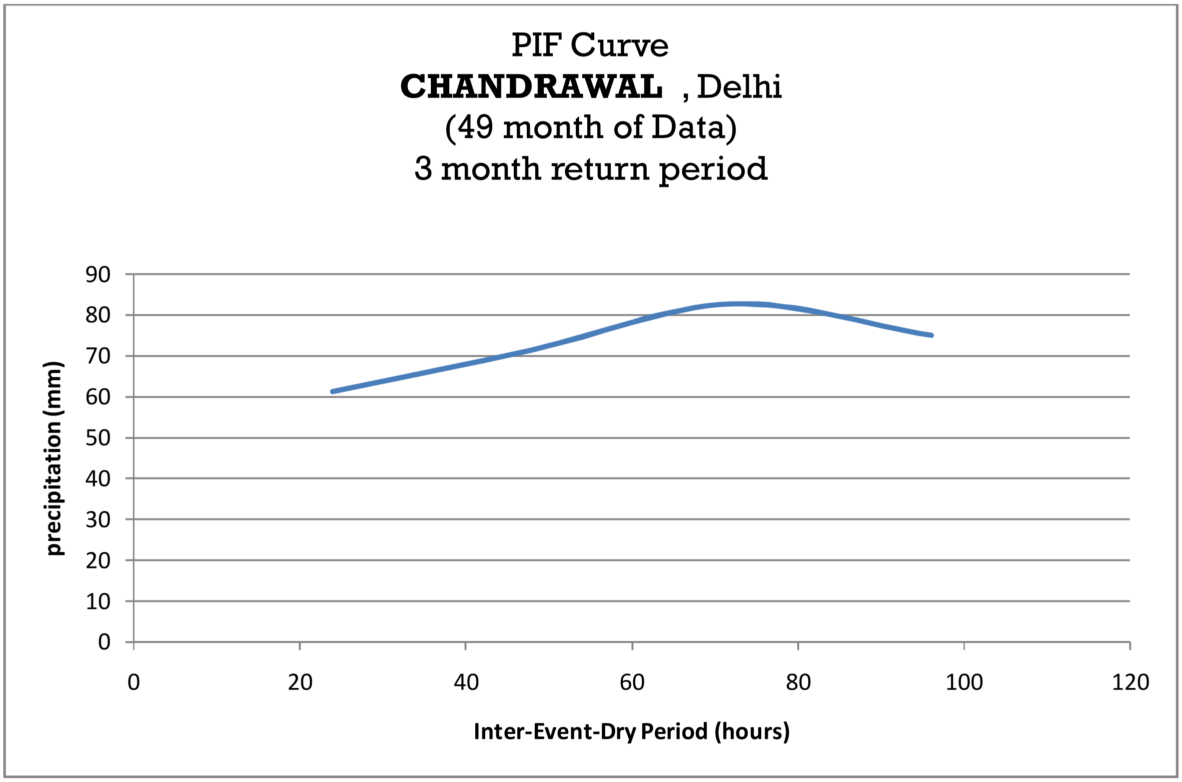

FIGURE C.5 PIF Curve Chandwal, Delhi (49 month of Data) 3 month return period

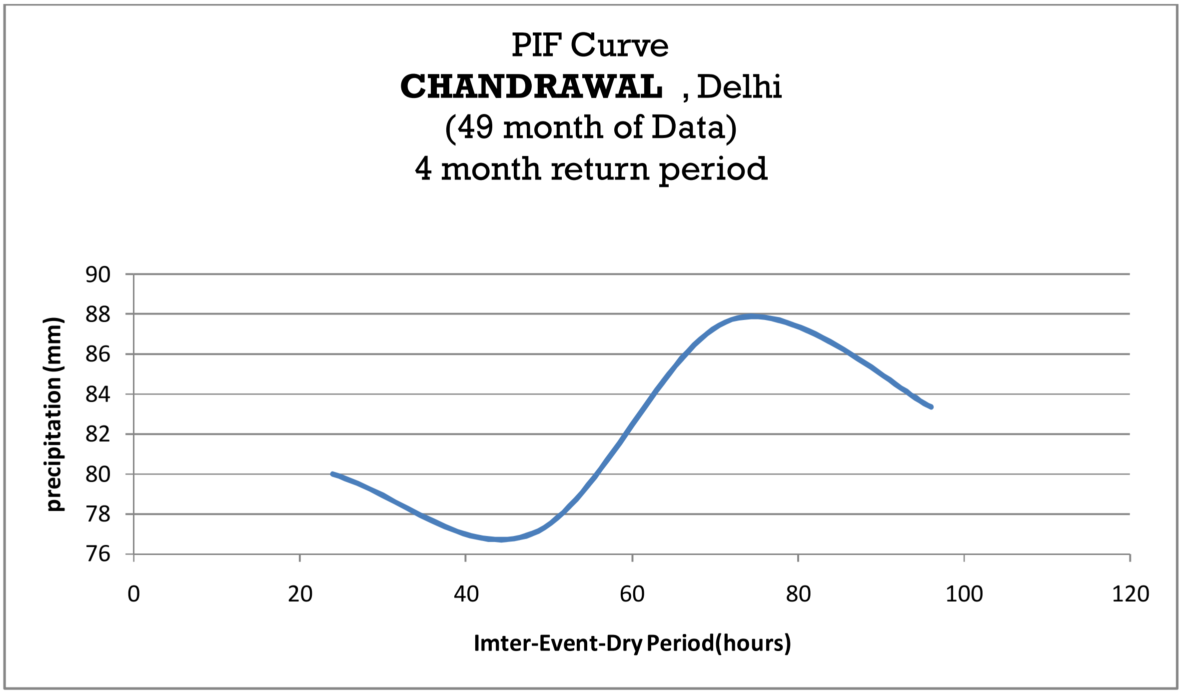

FIGURE C.6 PIF Curve Chandwal, Delhi (49 month of Data) 4 month return period

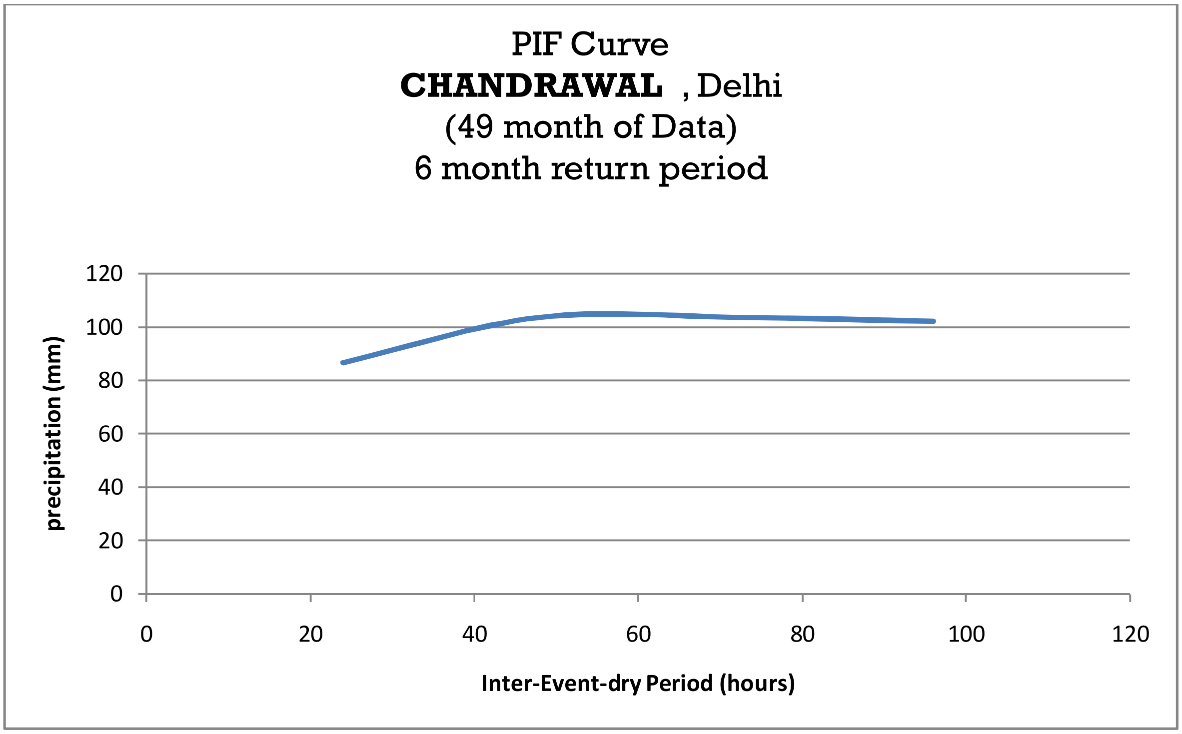

FIGURE C.7 PIF Curve Chandwal, Delhi (49 month of Data) 6 month return period

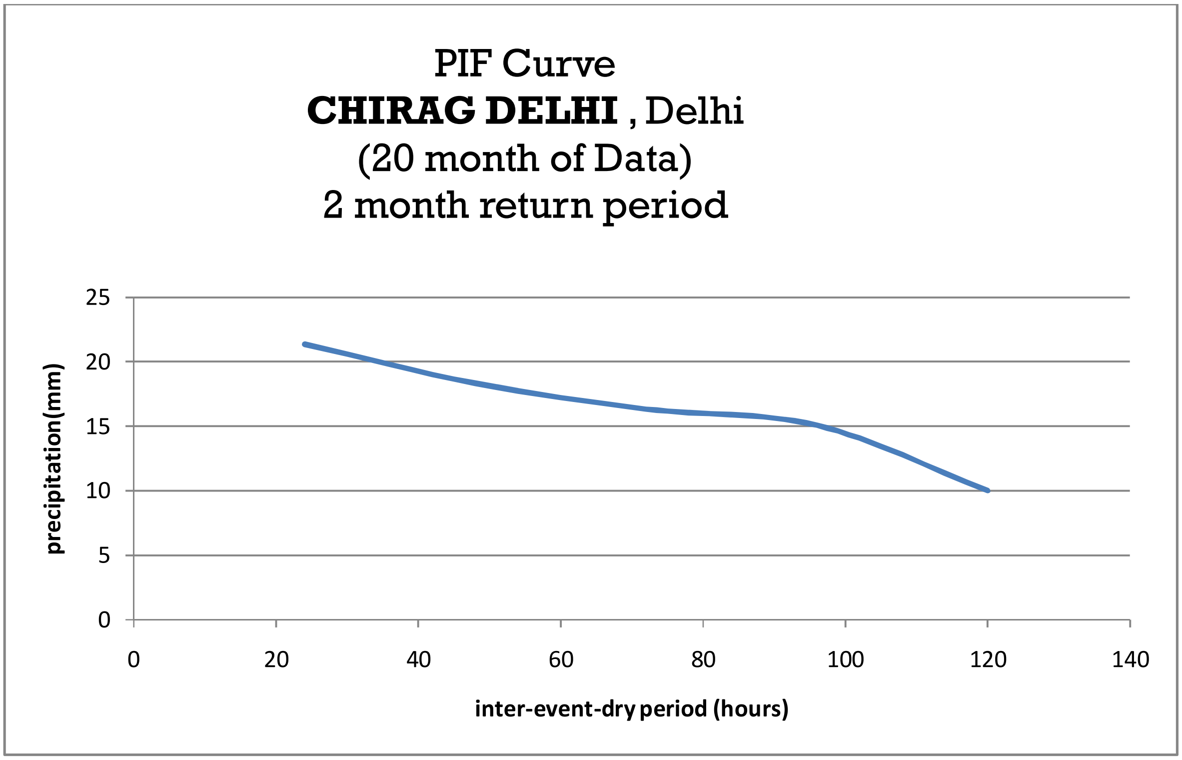

FIGURE C.8 PIF Curve chirag, Delhi (20 month of Data) 2 month return period

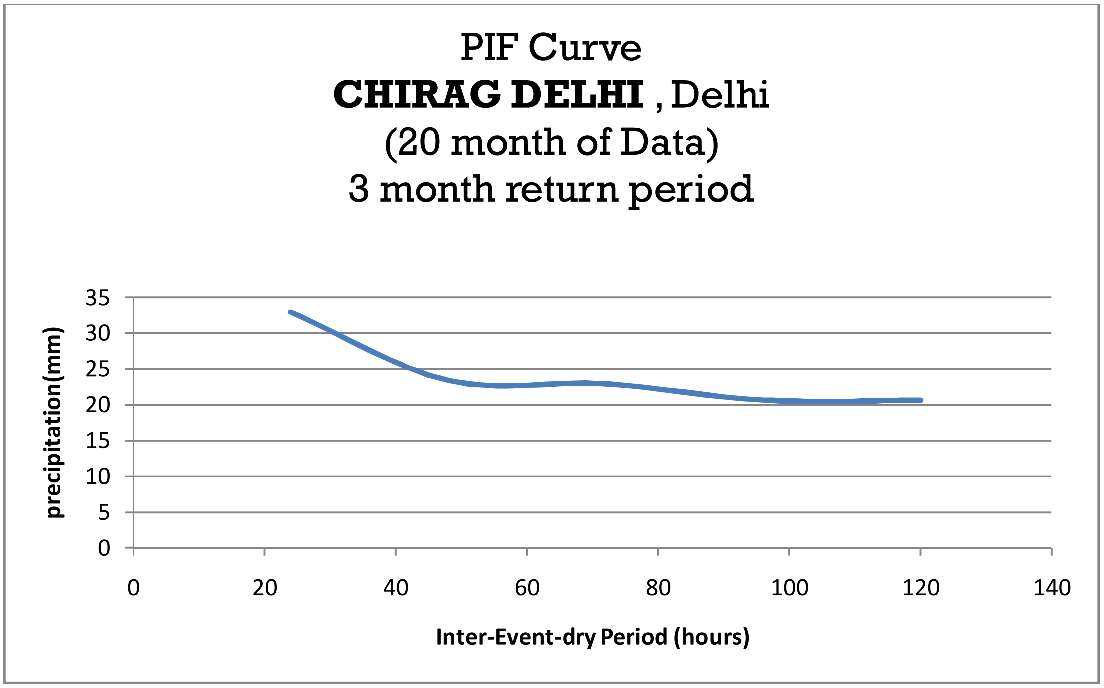

FIGURE C.9 PIF Curve chirag, Delhi (20 month of Data) 3 month return period

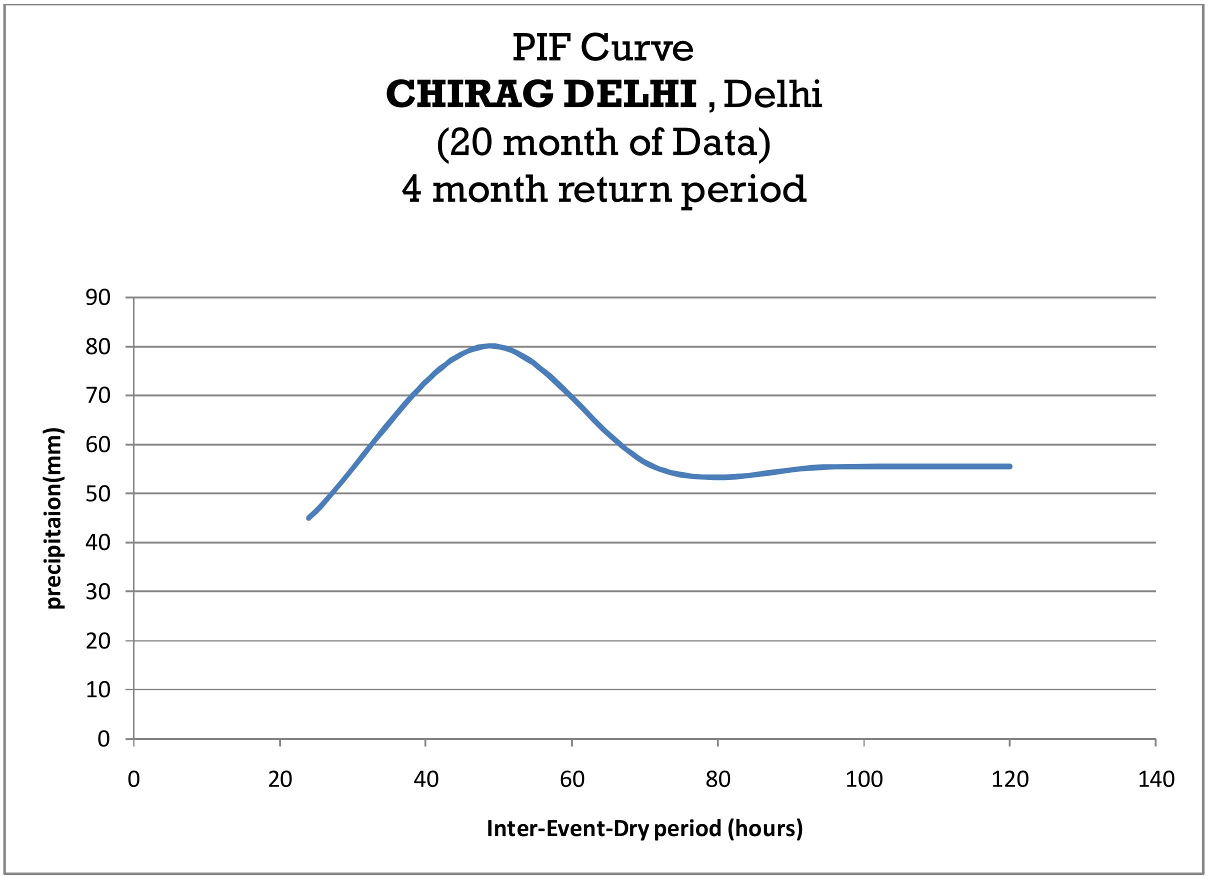

FIGURE C.10 PIF Curve Chirag, Delhi (20 month of Data) 4 month return period

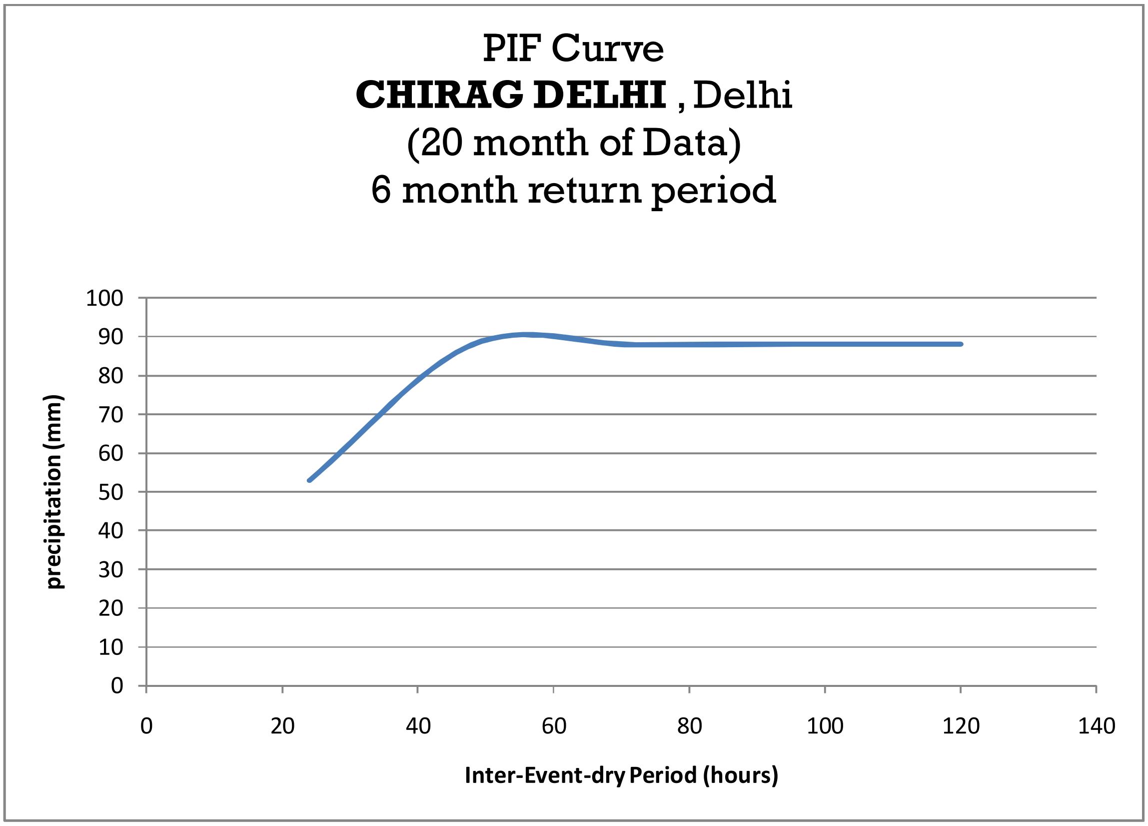

FIGURE C.11 PIF Curve Chirag, Delhi (20 month of Data) 6 month return period

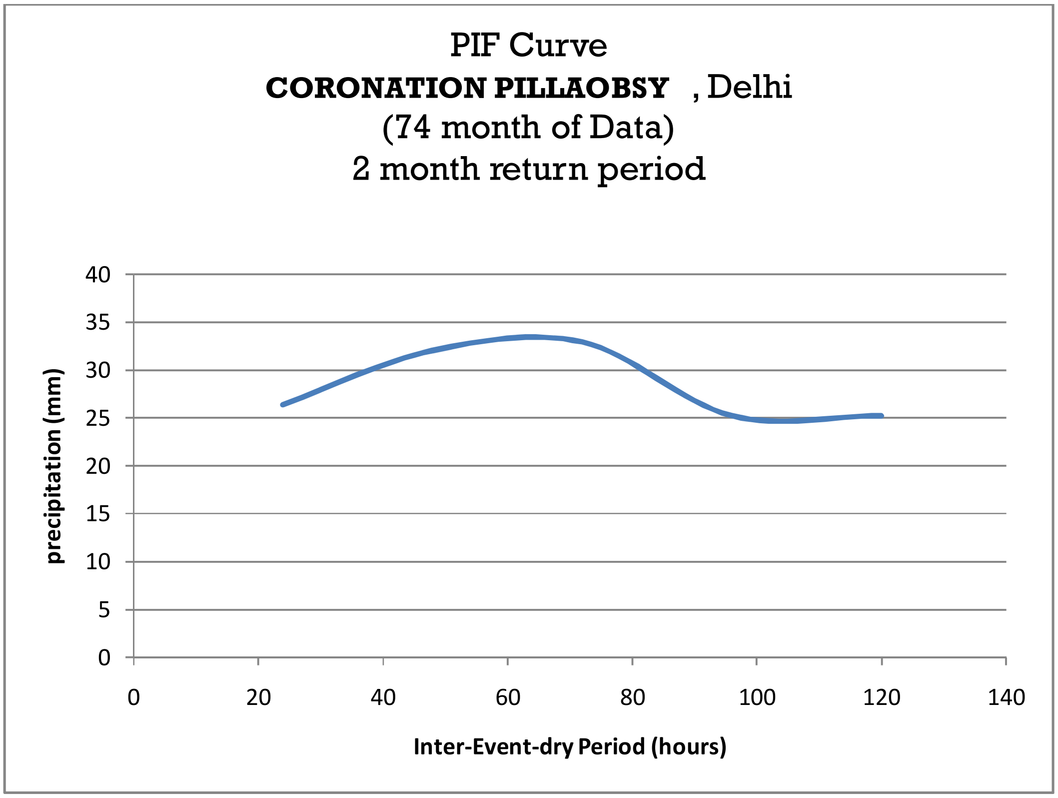

FIGURE C.12 PIF Curve Coronation, Delhi (74 month of Data) 2 month return period

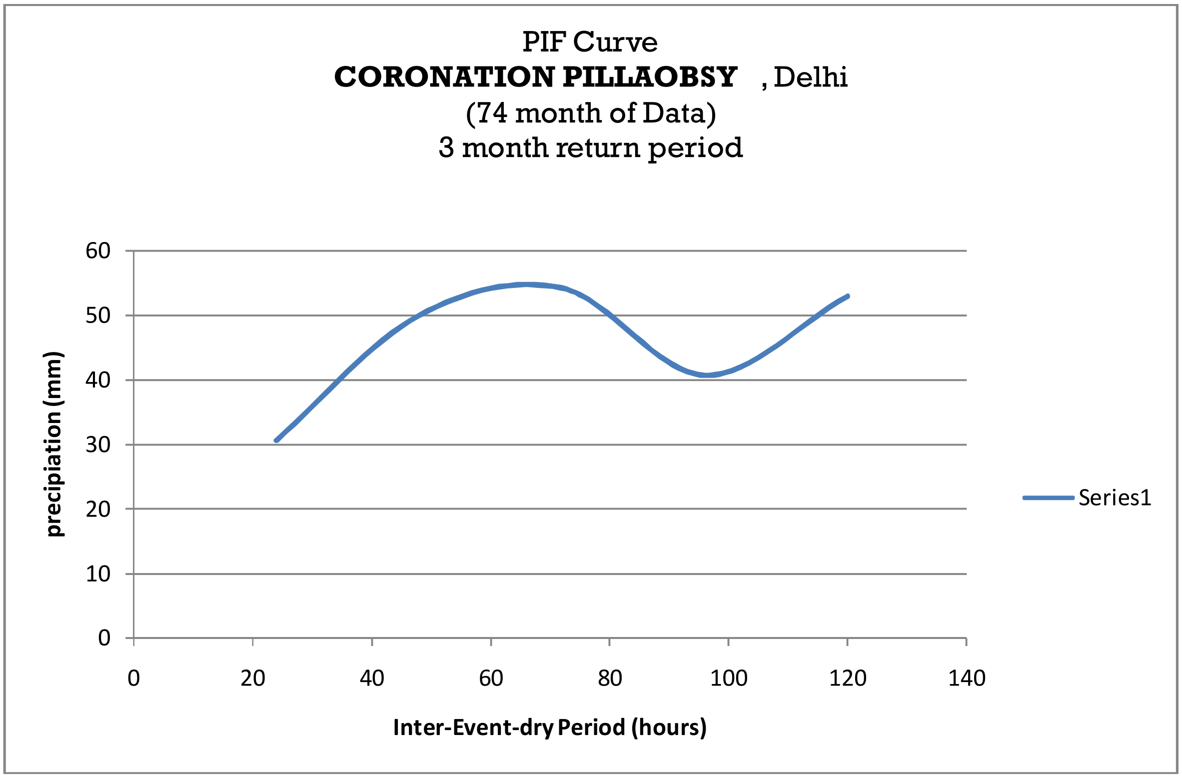

FIGURE C.13 PIF Curve Coronation, Delhi (74 month of Data) 3 month return period

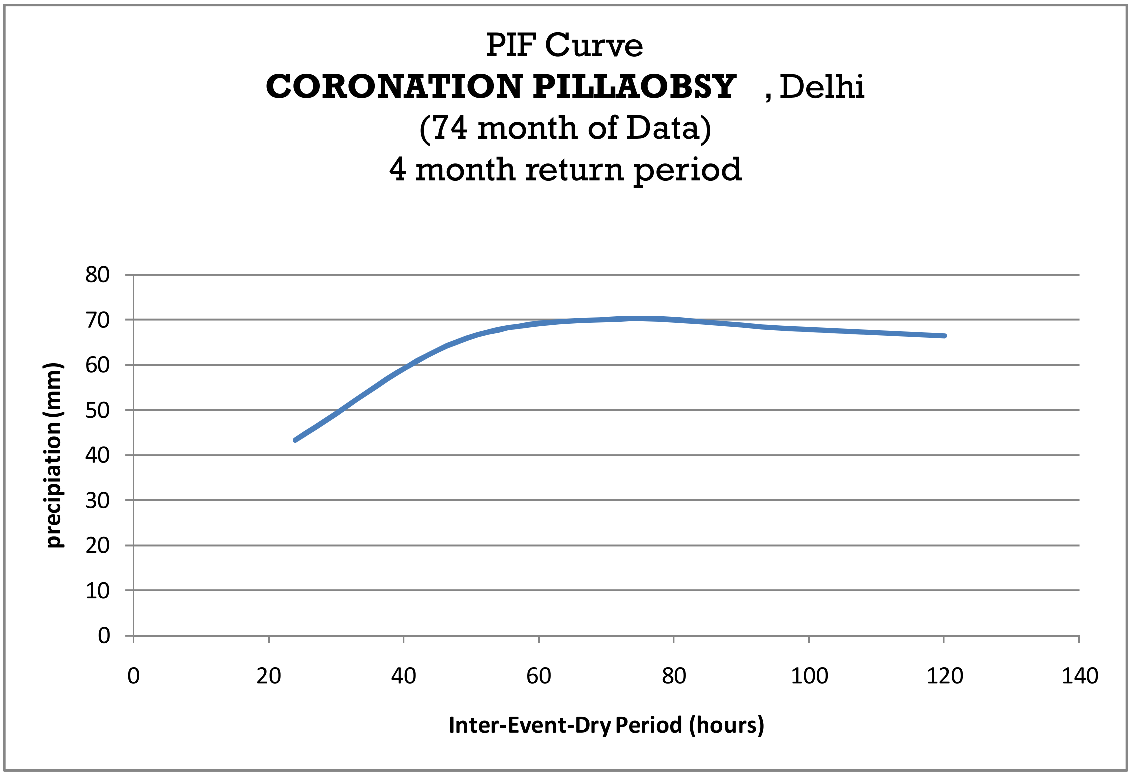

FIGURE C.14 PIF Curve Coronation, Delhi (74 month of Data) 4 month return period

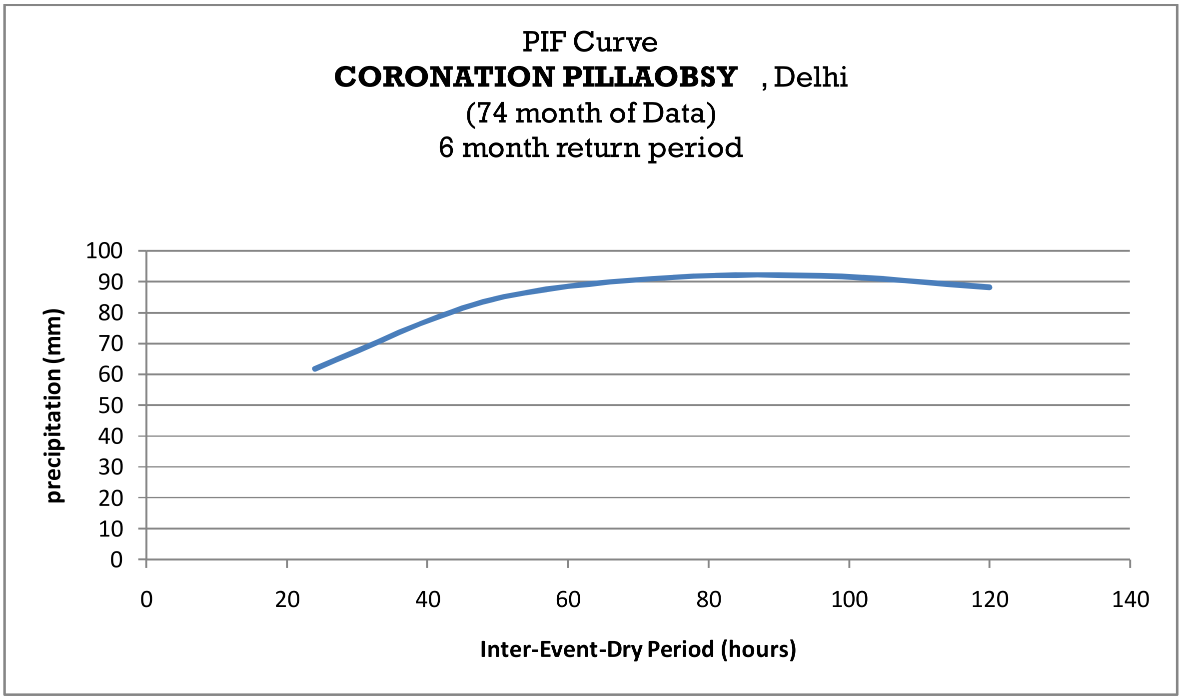

FIGURE C.15 PIF Curve Coronation, Delhi (74 month of Data) 6month return period

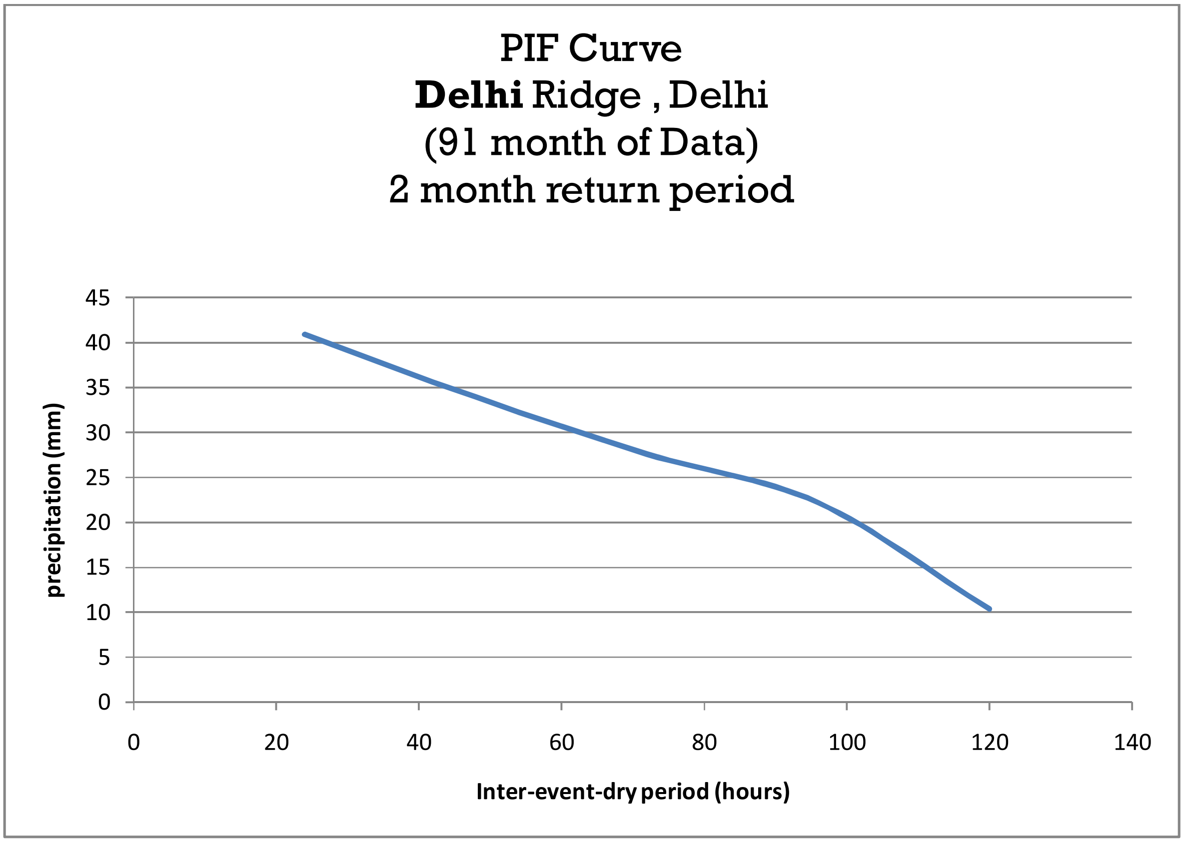

FIGURE C.16 PIF CURVE for Delhi ridge(91 month of data) 2month return period

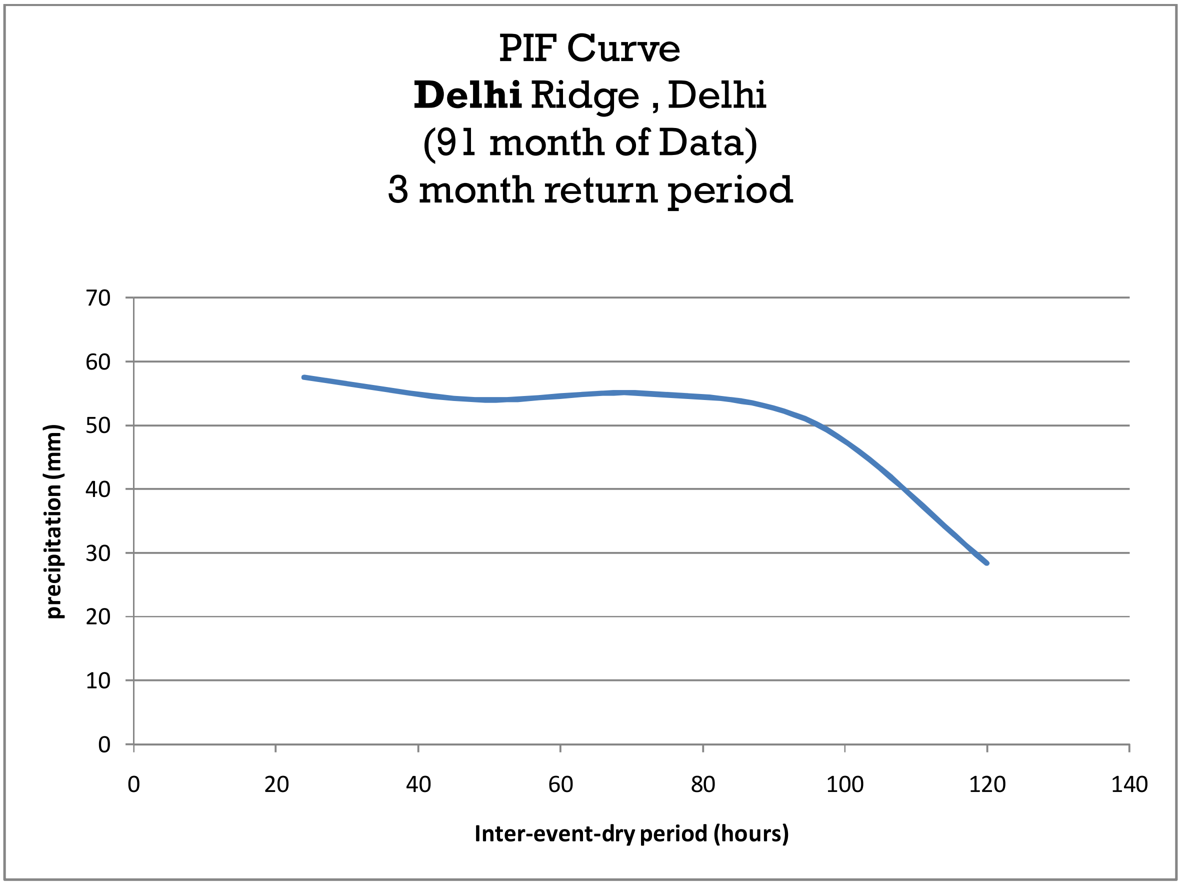

FIGURE C.17 PIF CURVE for Delhi ridge(91 month of data) 3month return period

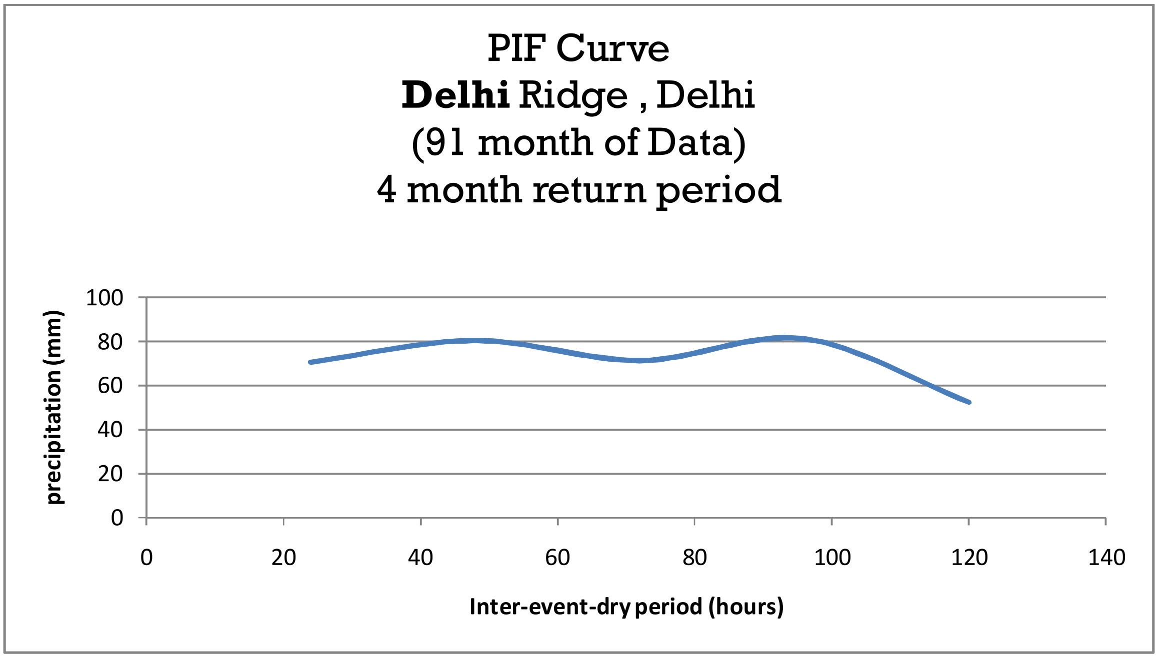

FIGURE C.18 PIF CURVE for Delhi ridge(91 month of data) 4month return period

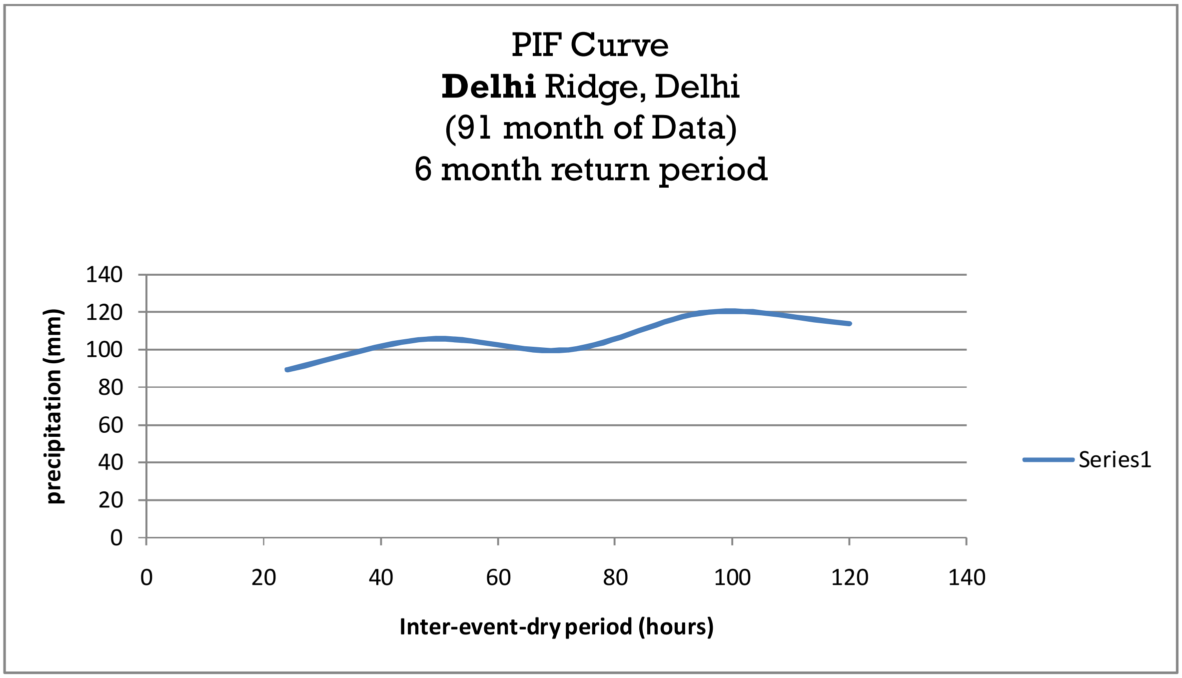

FIGURE C.19 PIF CURVE for Delhi ridge(91 month of data) **6**month return period

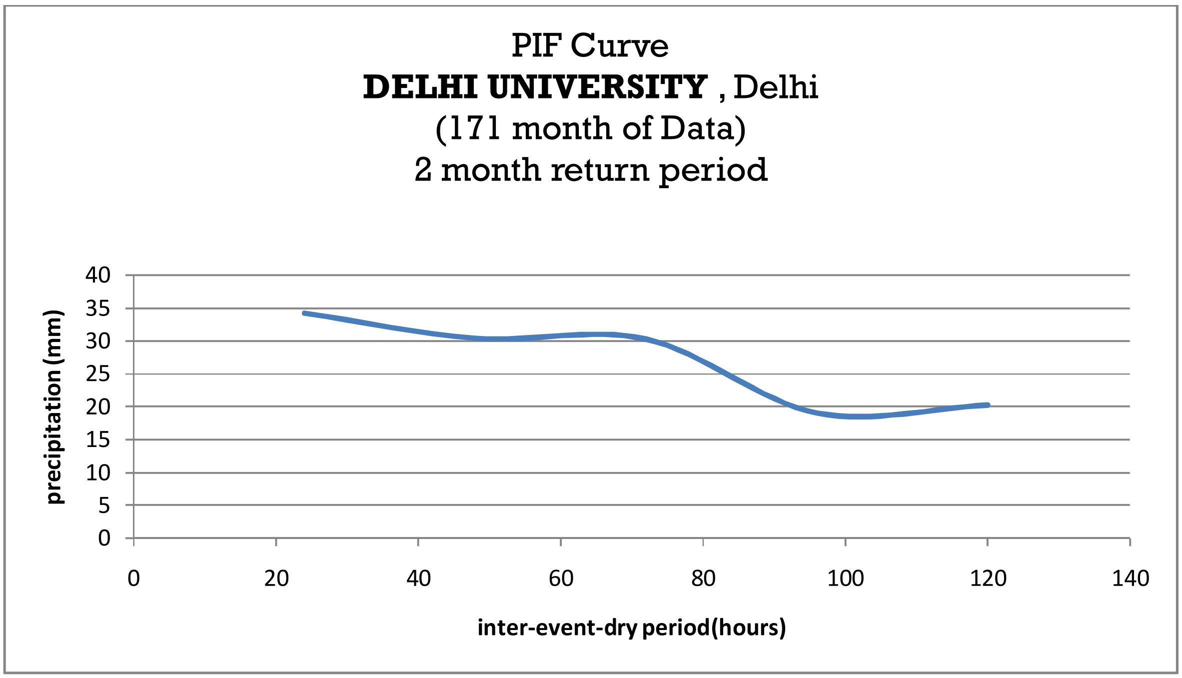

FIGURE C.20 PIF Curve Delhi university, Delhi (171 month of Data) 2 month return period

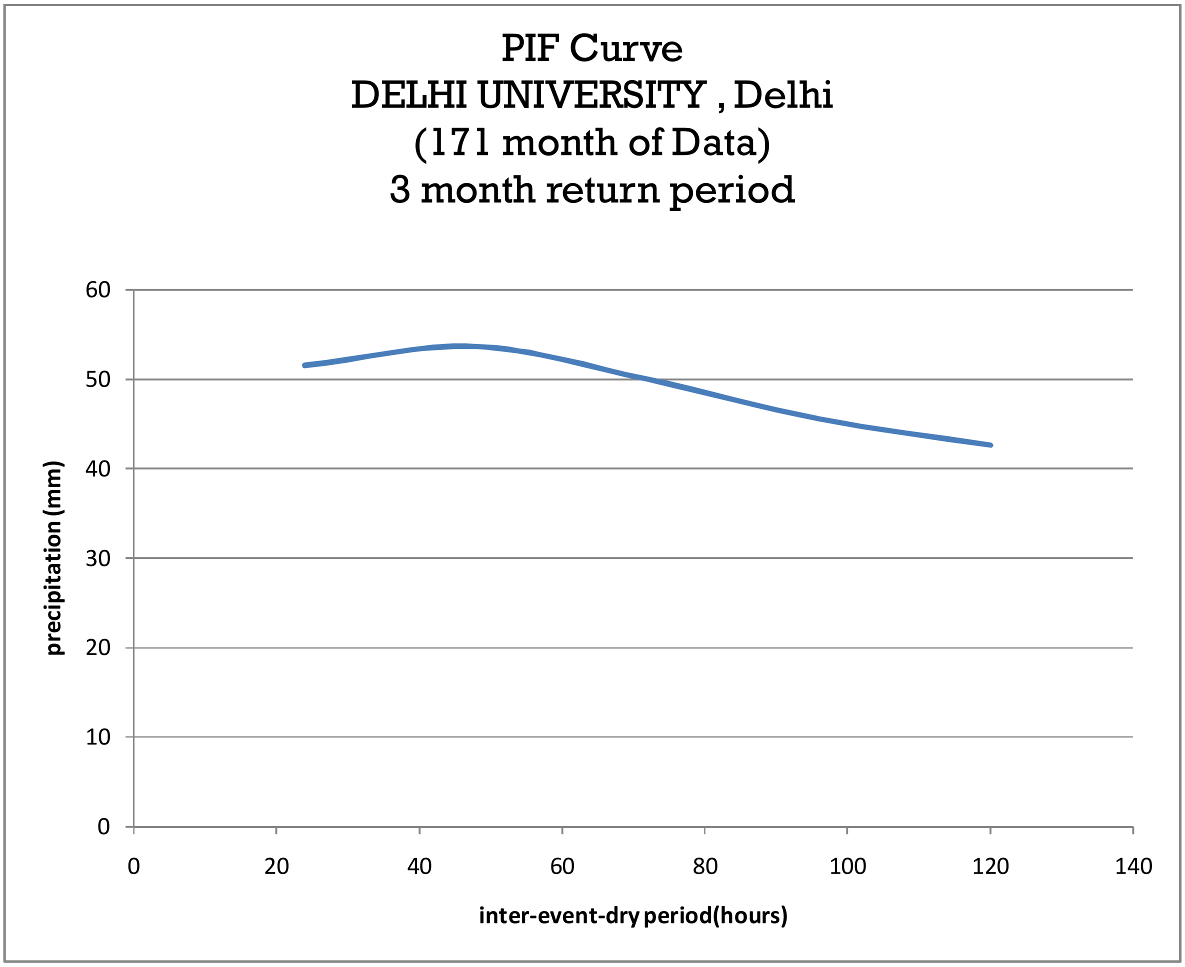

FIGURE C.21 PIF Curve Delhi university, Delhi (171 month of Data) 3 month return period

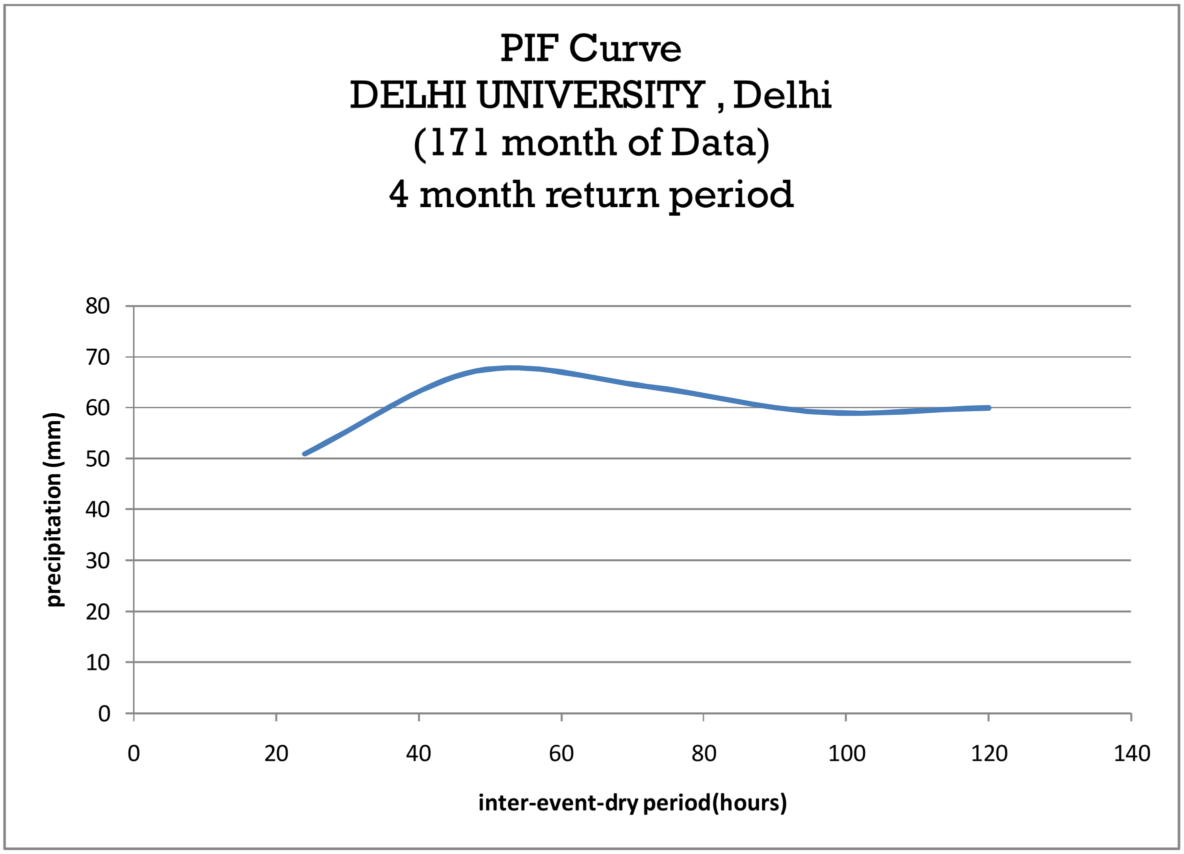

FIGURE C.23 PIF Curve Delhi university, Delhi (171 month of Data) 4 month return period

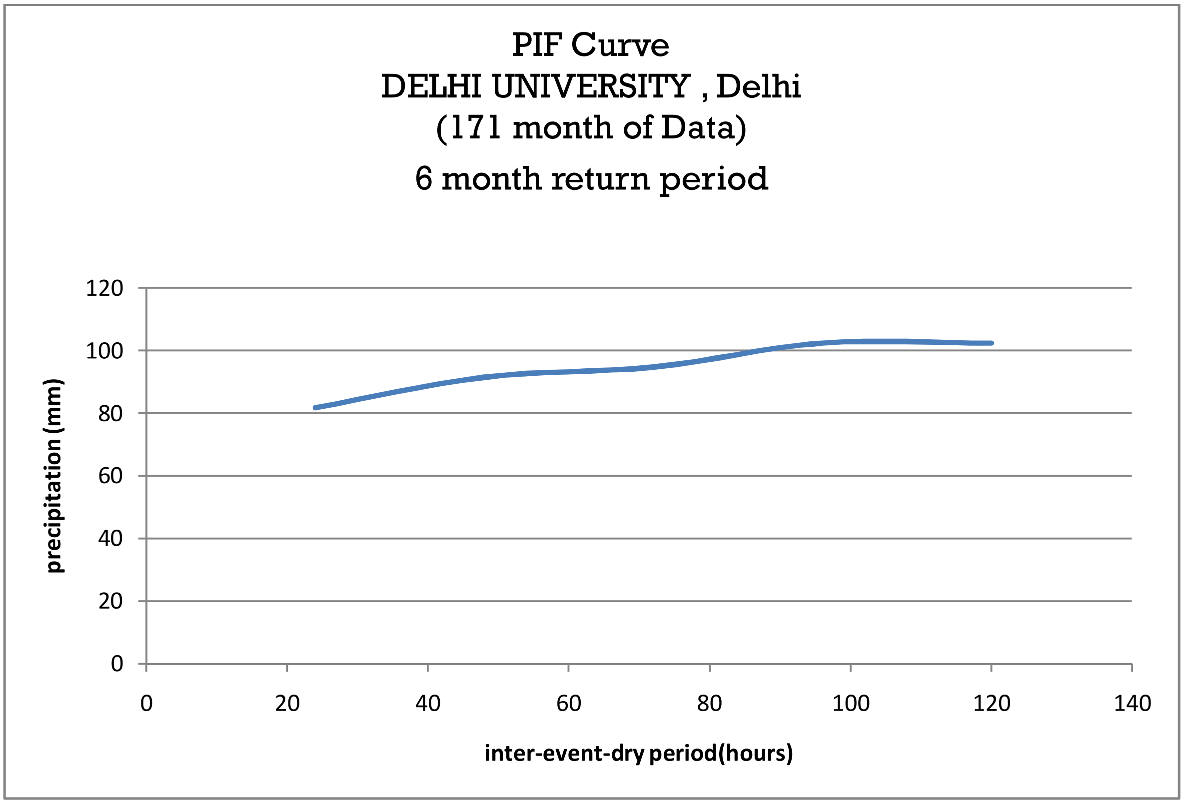

FIGURE C.24 PIF Curve Delhi university, Delhi (171 month of Data) 6 month return period

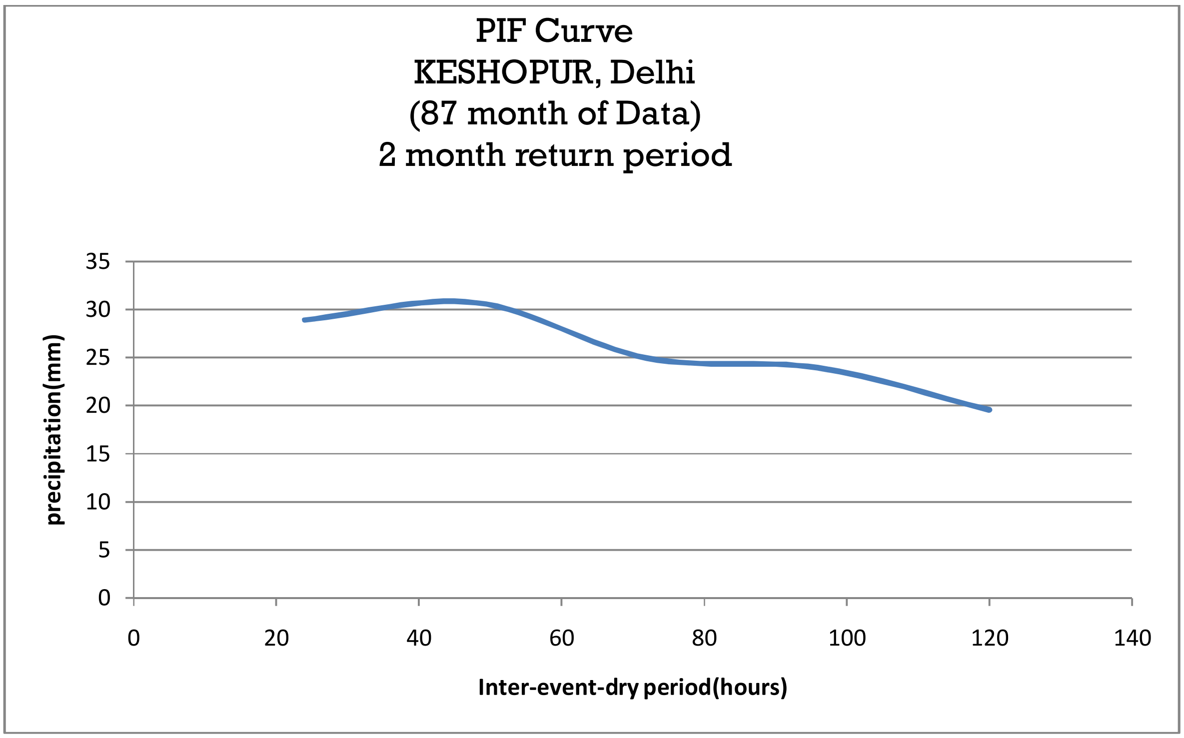

FIGURE C.25 PIF curves for Keshopur,Delhi(87 month of data), 2 month return period

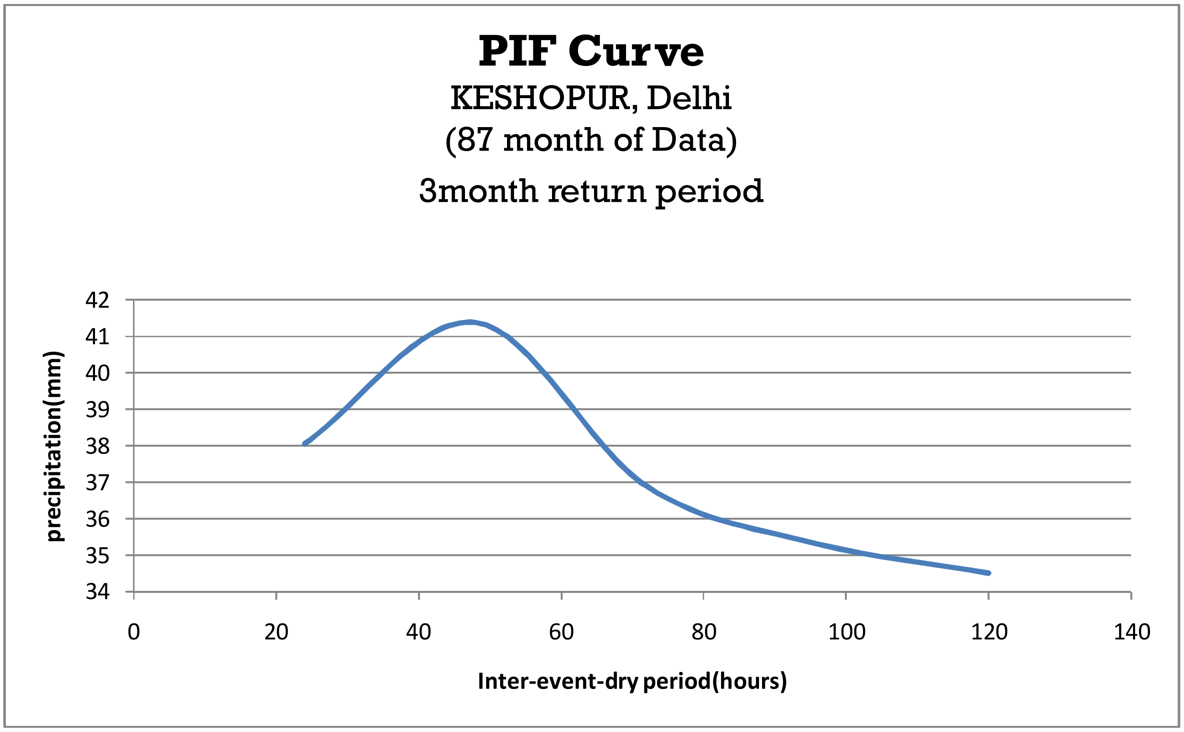

FIGURE C.26 PIF curves for Keshopur,Delhi(87 month of data), 3 month return period

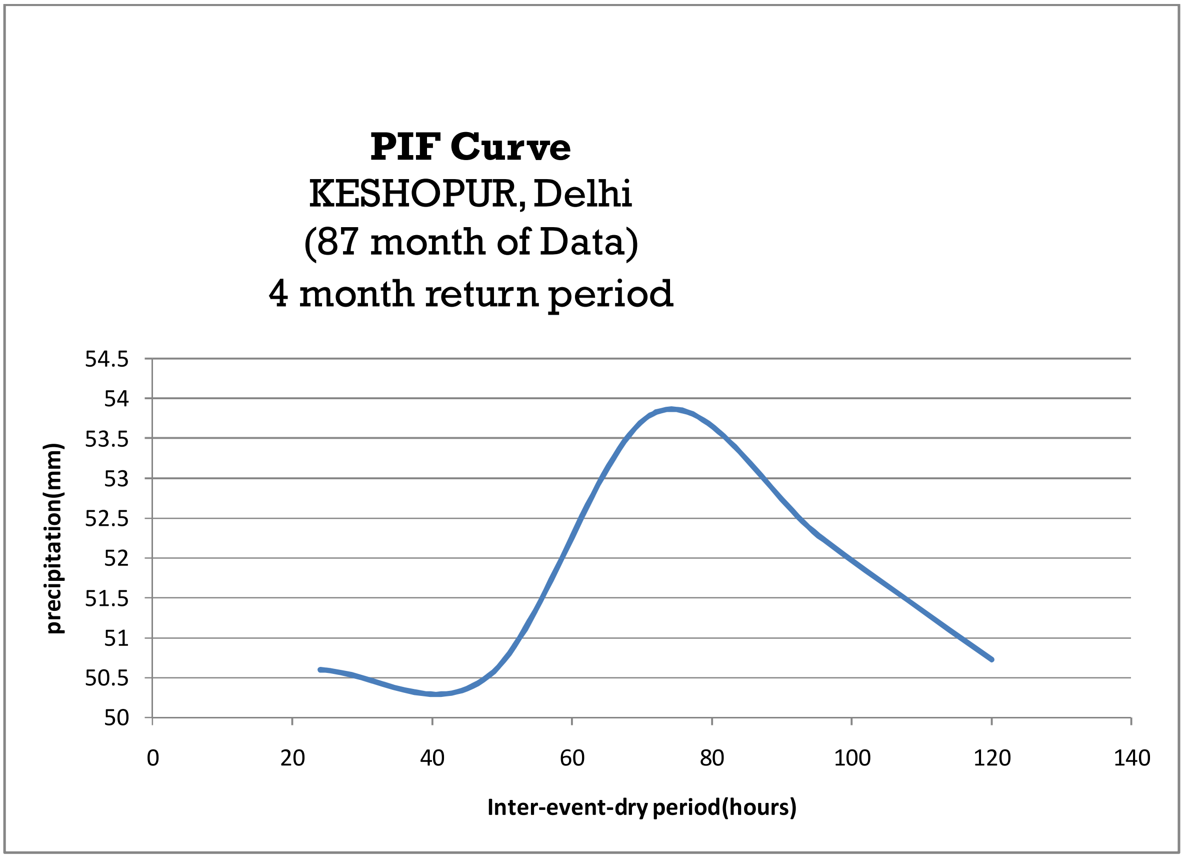

FIGURE C.27 F PIF curves for Keshopur,Delhi(87 month of data), 4 month return period

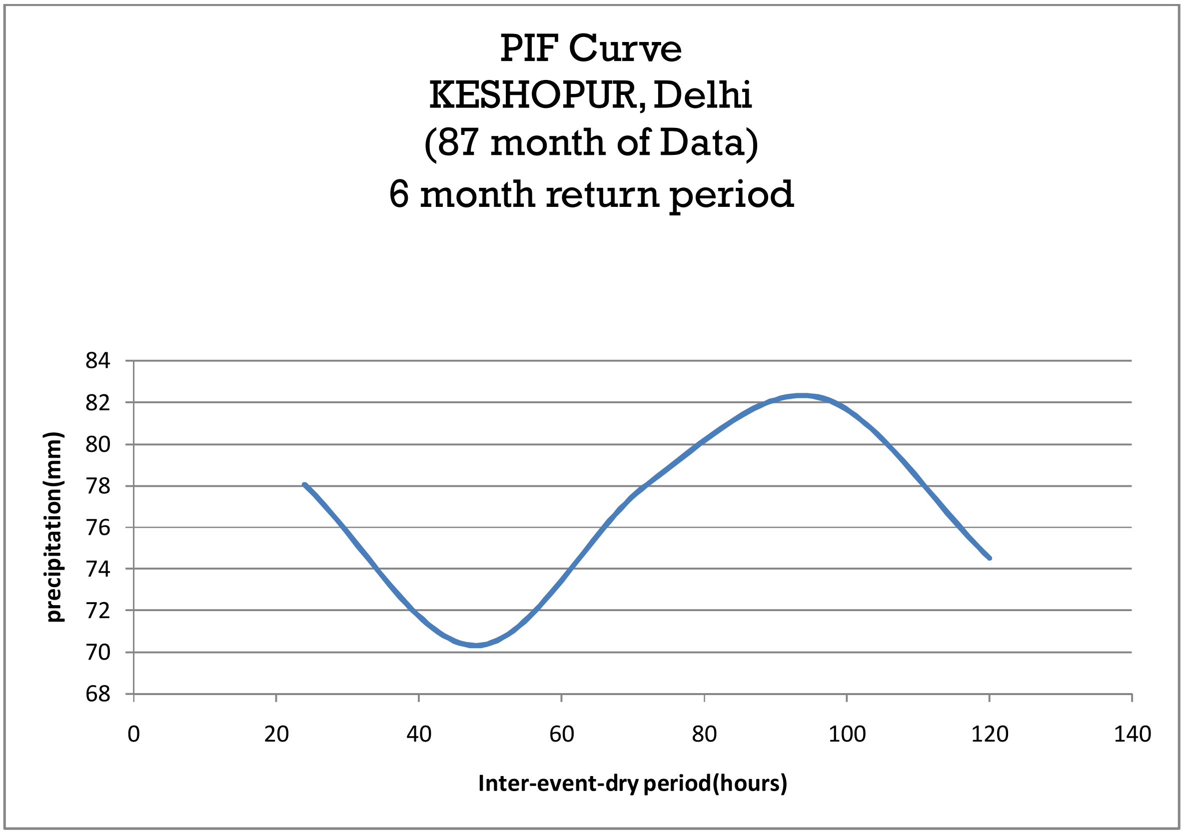

FIGURE C.28 PIF curves for Keshopur,Delhi(87 month of data), 6 month return period

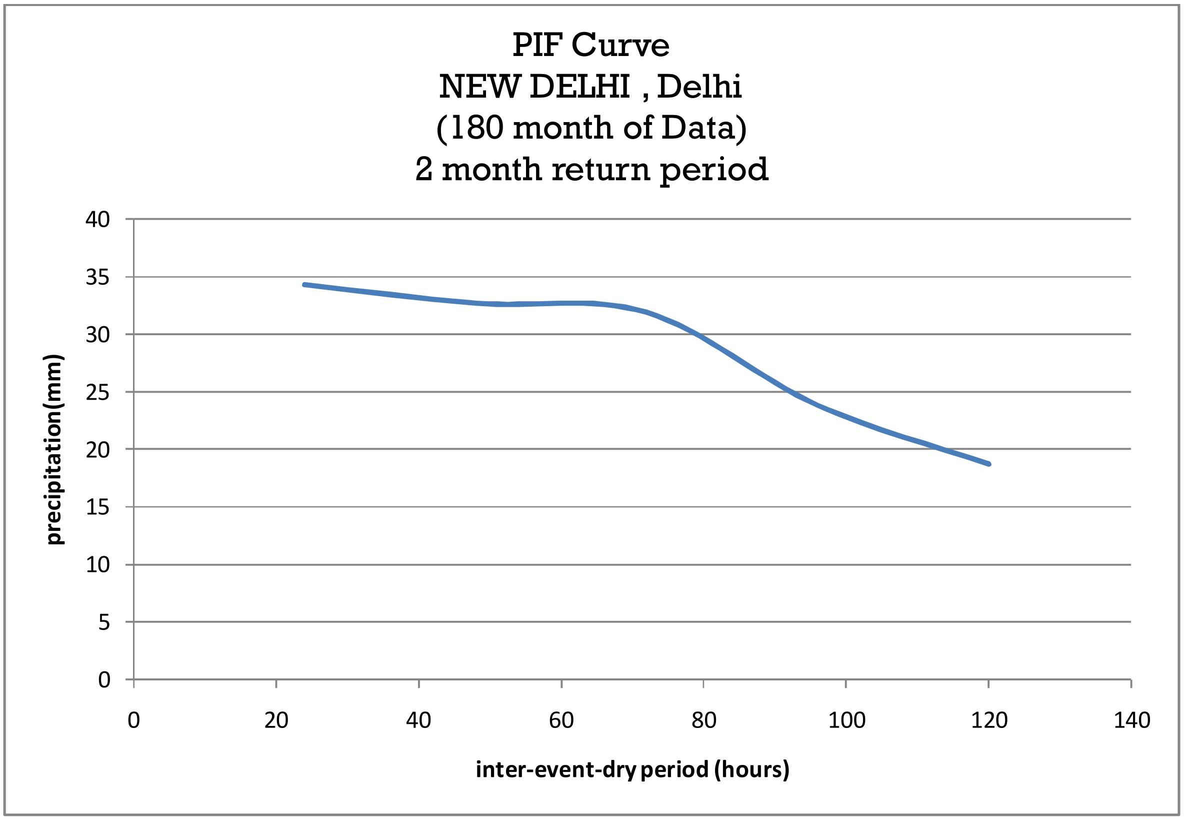

FIGURE C.29 PIF curve NEW DELHI (180 month of data), 2 month return period

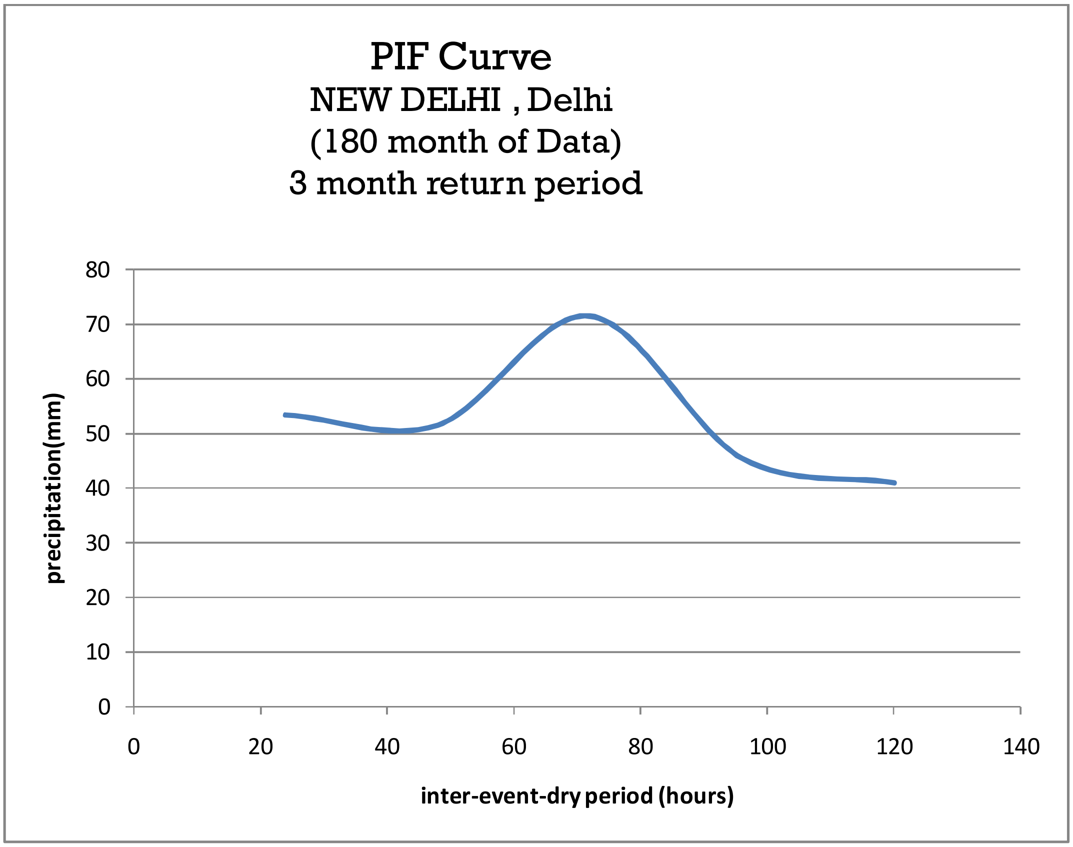

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FIGURE C.30 PIF curve NEW DELHI (180 month of data), 3 month return period

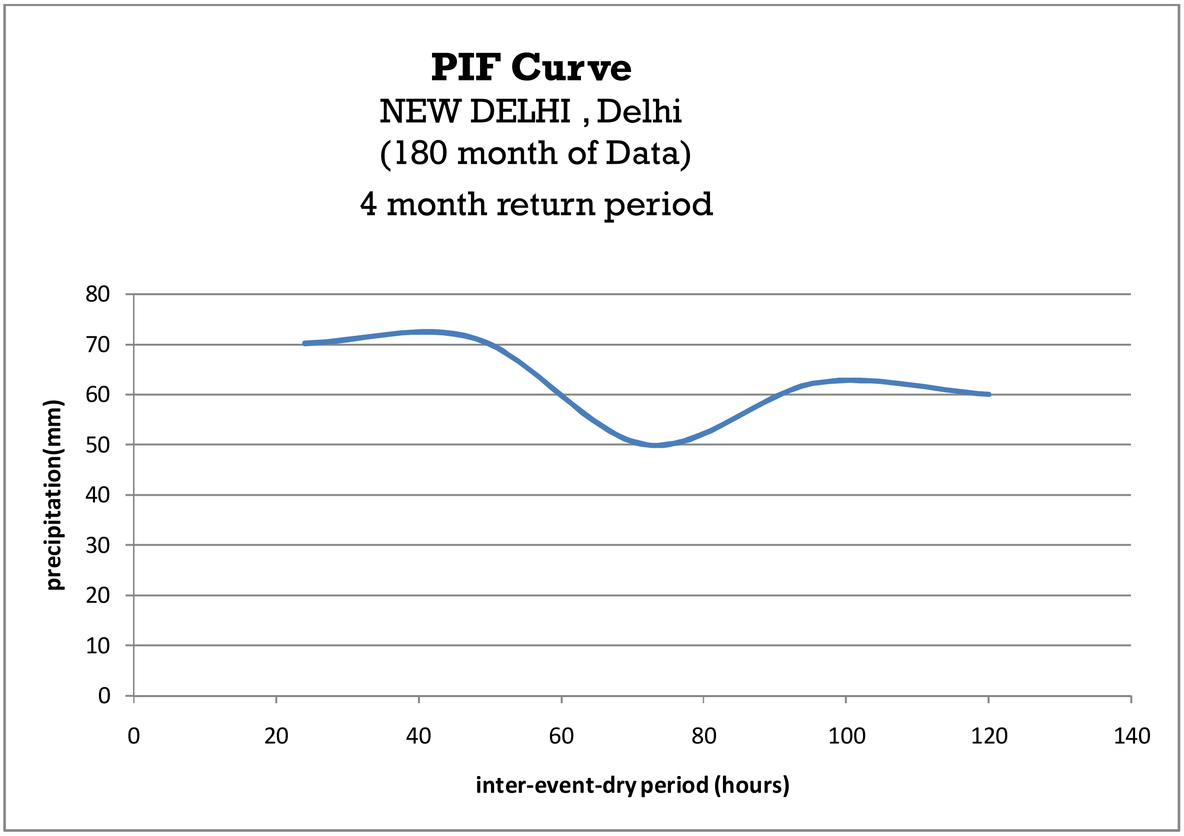

FIGURE C.31 PIF curve NEW DELHI (180 month of data), 4 month return period

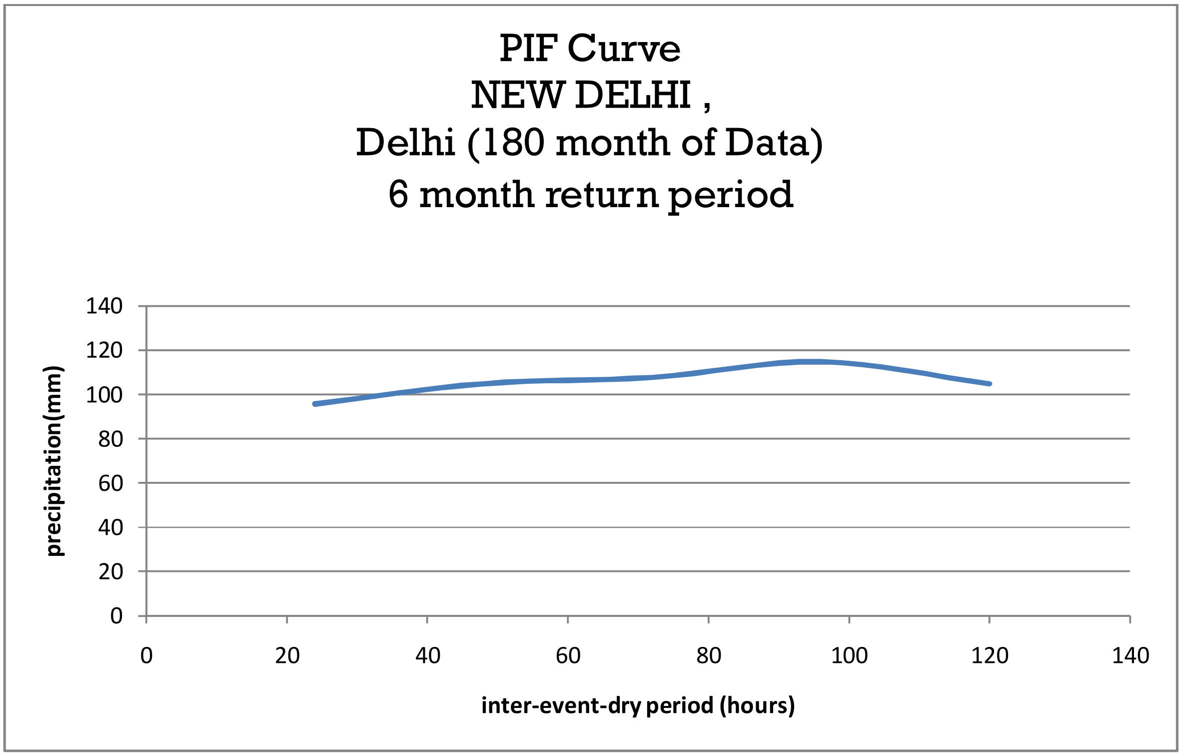

FIGURE C.32 PIF curve NEW DELHI (180 month of data), 6 month return period

REFERENCES

1. Adams, B.J. and J.B. Bontje, "Microcomputer application of analytical models for urban stormwater management, in Emerging Computer Techniques in Stormwater and flood amangement", edited by W.James ,pp.138-162, Am.soc.civ.eng, New York, 1984.
2. By Barry J. Adams, Hugh G. Fraser, Charles D.D. Howard, M.Sami Hanafy, " Meteorological data analysis for drainage system design," Journal of Environmental Engineering, vol. 112, no.5,1986.
3. Brown, R.R. (2005)," Impediments to integrated urban stormwater management : the need for institutional reform. Environ.manage.,36(3),455-468.
4. Butler,D. and Parkinson, J. (1997) ," towards sustainable urban drainage, water sci. technology, 35(9),53-63.
5. Coombes, P.J, Arguue, J.R and kuzera, G.(1999) figtree place: A case study in water sensitive urban development (WSWD), urban water, I, 335-342.
6. De Kimpe, C.D. and Morel, J. (2000)," Urban soil management: a growing concern, soil sci.,165,31-40.
7. Eagleson, P.S; climate ,soil and vegetation, 2, the distribution of annual precipitation derived from observed storm sequences, water.res, Res.14(5),713-721,1978.
8. Guo and Adams, Hydrologic analysis of urban catchments with event based probabilistic model,2, peak discharge rate, water,resource.
9. Grizzard, T.J, C.W. Randall, B.L. weand and K.L. ellis, 1986 ," effectiveness of extended detention based, urban runoff quality enhancement technology, ASCE, new York, new York.
10. Gardiner, J.L. (1994) ," Sustainable development for river catchments, water environ. J.,8(3),308-319.
11. Huber W.C. and Dickinson, R.E. (1988). Stormwater management model, version 4: user manual. Environmental research laboratory. Office of research and development, U.S. environmental protection agency, Athens, ga.
12. Howard, C.D., Theory of storage and treatment plant overflows, J. Environment. Eng.,102(EE4),709-722,1976.

13. Johansen L.(1979)," Design rainfall for sewer systems. phD. Thesis," department of sanitary engineering, technical university of Denmark, Report 79-2, Lyngby, Denmark.
14. Kerbs, K and Larsen, T.A. (1997)," guiding the devepolment of urban draianage systems by sustainability criteria, water sci. technology;35(9),89-98.
15. Manning M.J.; Sullivan R.H. and Kipp T.M. (1977)," Nationwide evaluation of combined sewer overflows and urban stormwater discharges, vol III, Characterization of discharged, USEPA-600/2-77-064c,Washington.D.C.
16. Marsalek J.(1978) Research on the design storm concept, ASCE urban water resources research program, technical memorandam no.33.
17. Niemczynowicz, J.(1999), urban hydrology and water management present and future challenges, urban water I,1-14.
18. Rauch,W.,Seddelke,Brown,R. And Krebs, P. (2005)," Integrated approaches in urban storm drainage: where do we stand? Environ. Manage,35(4). 396-409.
19. Roesner, L.A., B.Urbonas and M.A. Soneen, 1989. Current practices in design of urban runoff quality facilities. Proceedings of an engineering foundation conference held in july 1988 at Potosi, Missouri Published by ASCE, NEW YORK.
20. Thorkild Hvitved-Jacobsen and Yousef A. Yousef," Analysis of rainfall series in design of urban drainage control systems," international journal of water resources, vol.22, no.4, pp.491-496,1988.
21. Sheeder, S.A.., Ross, I.D and Carlson, T.N.(2002), Dual Urban and Rural Hydrograph signals in three small watersheds,. J.Am.Water res. Assoc, 38(4),1027-1039.
22. Schilling W. (1983) Univariate Versus multivariate rainfall statistics – problems and potential. In proceedings of a specified seminar on rainfall- the basis for urban runoff design and analysis., Copenhagen, Denmark.ppt.129-137.
23. Urbanas, B and L.A Roesner,1986(editors). Urban runoff quality. Impacts and quality enhancement technology, proceedings of an engineering foundation conference in June 1986 in Herniker, New Hampshire. ASCE, new York, new York.

24. Wenzel H.G. and Voorchers M.L (1981) An evaluation of the urban design storm concept, water resources centre, university of Illinois at Urbana-Champaign. Research report UILU-WRC-81-0164,III.
25. Wenzal H.G. Jr (1982)," Rainfall for urban stormwater design: urban stormwater hydrology water resources monograph T, D.F. kibler, (ed). American geophysical union, Washington D.C.