Frequency Analysis Of Return Period On Wellington Reservoir In Cuddalore District, Tamilnadu, India.

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Abstract

Frequency analysis is used to bepredicting design of water channel for sites along a watershed and reservoir. The techniqueinvolves using observed annual peak full tank level data to calculate statistical information suchas mean values, standard deviations, skewness, and recurrence intervals. These statistical dataare then used to construct frequency distributions, which are graphs and tables that tell thelikelihood of various full tank level as a function of recurrence interval or exceedence probability.The full tank level, frequency relationship is commonly required for planning anddesigning of various water resource projects. Many sets of relationships have been developed and usedin several parts of the world. The full tank level frequency is a mathematical relationship between the rainfall intensity, the duration and the return period. This relationship is determined through statistical analysisof samples of records at proper meteorological stations. Lekkur in the Northwestern part of the Tittagudi, Cuddalore district, Indiayearly full tank level recordingfrom 1968 since 2012. A total of six different durationsranging from yearly for return periods of 20, 40, 60, 80 and 100 years were analyzed. The water level frequency curves for the region are developed using the available full tank leveldata. The main aim of this paper is to construct full tank level frequency curves for the region using FTL frequencyanalysis techniques. Also, the paper proposes regional water level frequency to estimate FTL intensity forvarious return periods and FTL durations at ungauged sites.

Key Words: Frequency, FTL (full tank level), return period, skewness and standard deviations.

Introduction

The last century has seen unprecedented growth in irrigation projects on a global level. The use of tube well irrigation has decreased the cost of using groundwater and the subsidization of large reservoirs and canals has been used to achieve food security. Worldwide, irrigated land hasincreased from 50 mha (million hectares) in 1900 to 267 mha today (Gleick, 2000). Much of thisincrease has been in developing countries. Between 1962 and 1996, the irrigated area in developing countries increased at about 2 percent a year, leading to a near doubling in irrigated land. For example, in 1950 India had an irrigation potential of 22.6 mha. By 1993-94, this had grown to 86 mha (Saleth, 1996). Between 1949 and 1998, the amount of land in China under irrigation increased from 16 mha to 52.3 mha. This represented a change from 16% to 40% of China's total farmland (Guangzhi et al 1999). Currently 75 percent of all irrigated land is in developing countries including India. Irrigation has increased the amount of land under cultivation, and the yields on existing cropland. It has also allowed double cropping and hasdecreased the uncertainty of water supplied by rainfall and increasing tendency on population and demand of them. Hence the frequency study of return period is so necessary.

This chapter reviews methods for combining historical data into FTL frequency estimates and return period.In civil engineering practice the term ''return period'' has been generally defined as the average number of trials (usuallyyears) to the first occurrence of an event of magnitude greater than a predefined critical event (Benjamin and Cornell 1970). It is wide-ranging and, in parts, idiosyncratic. The serious student will want to study key references. Frequency analysis of hydrologic variables, parameters or data requires that individual observations or data points be independent of each other and that the data be representative of a large and impartial population (of hydrologic data). This representative data is classified as four types of data: 1) complete duration series, 2) annual series, 3) partial duration series, and 4) extreme value series. The FTL frequency analysis, annual and partial duration series are often used. The annual series contains of the largest FTL amount recorded for the given duration in each calendar year. The size of the data set is equal to the number of years of data available. The partial duration series consists of the same size of series but includes the largest independent events recorded regardless of when they occurred. The fractional duration series has higher mean and lower variance than the annual series. In addition, the fractional duration series produces higher rainfall estimates for lower return periods. However, Hershfield (1961) found that rainfall estimates for return periods greater than 10 years were same for both the series. Frequency analysis is the most common statistical methods of analyzing hydrologic data. Frequency analysis is used to predict how often certain values of a variable phenomenonmay occur and to assess the reliability of the prediction. It is a tool for determining design rainfalls and design discharges for drainage works and drainage structures, especially in relation to their required hydraulic capacity.The following ranking methods of frequency analysis are discussed in this chapter - Counting of the number of occurrences in certain intervals of ranking of the data in descending order.The concept of return period is simple and can be used for determining the risk of failure *R* of a hydraulic structure designed to withstand a given *T*-year flood event during a design life of *L* years. Such risk of failure is generally defined as the probability that one or more floods greater than the *T*-year flood occurs during the life of the project. This concept of return period has been used in cases other than floods. For instance, Vogel (1987) considered the return period of the failure of a reservoir system, defined as the expected value of the number of years before the occurrence of the first reservoir system failure. A system failure is considered as a year in which a predefined yield could not be delivered by a water supply system.The main aim of this paper is to construct full tank level frequency curves for the region using FTL frequencyanalysis techniques. Also, the paper proposes regional water level frequency to estimate FTL intensity forvarious return periods and FTL durations at ungauged sites.

Study Area

The study area considered is Wellington reservoir watershed which is located in the Tittakuditaluk (Fig1). It lies between the longitudes of 11◦21’ to 11◦31’ E and latitudes of 78◦57’ to 79◦28’N. The present study area occupies an aerial extent of 100 sq.km and the relief ranges from 62 m to 121 m above MSL. As of 2001 India Census, Tittagudi had a population of 20,734. In this taluk, agriculture area is 823.74 km2. The study area receives an average rainfall of 1100 mm with more than 80% of the rainfall received during the NE monsoon. The minimum and maximum temperature ranges between 20°C and 34°C in the month of January and May respectively. River Vellar flows in the southern part of the study area. Geomorphologically the area consists of old flood plains, pediments, duricrust and pediments covered by forest land senthilkumar 2006. Black soil is predominant soil type in this area and main occupation of the area is agriculture. The groundwater level of the study area ranges from 2m to 8m bgl (below ground level). The Wellington Reservoir is located in Vellar Basin across a tributary stream PeriyaOdai of Vellar River. The Reservoir was constructed during 1913-1923 and irrigatesVellar River at Tholudur regulator and an additional catchment area of 129 $(Km)^2$ of its own during North East Monsoon. Paddy, Sugarcane is the major crops grown in and around wellington ayacut.

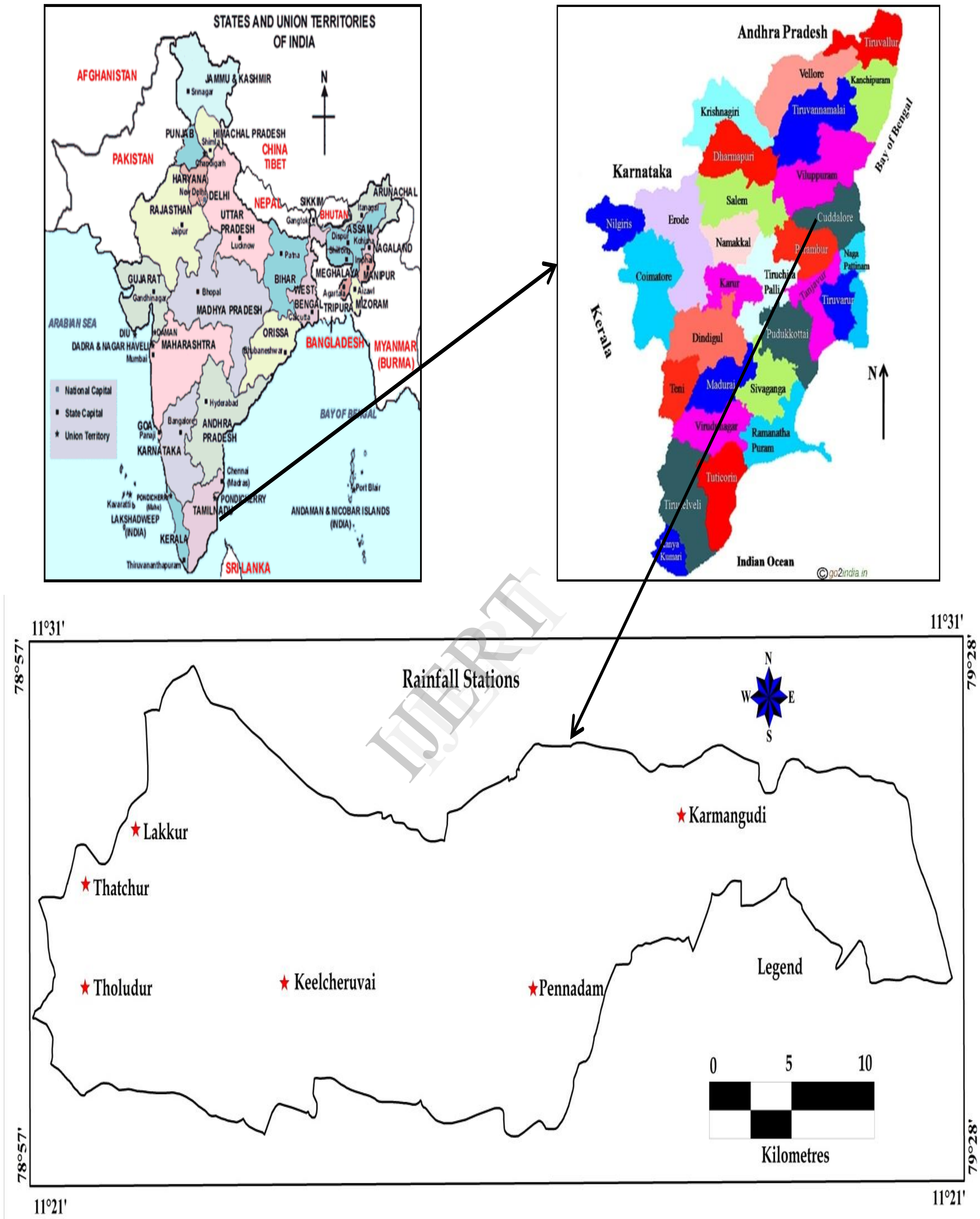

Fig: 1 Locations of Rainguage stations

Methodology

Only onegauge stations were selected for frequency analysis of annualpeak FTL utmost. The FTL annual series data for the four stations were fitted with several standardelevation versus annual average rainfall probability distributions. To determine the best-fitted probability distribution, a set of criteria was established. The results of the analysis provided the full tank level depths for various return periods of station. These processes were repeated for annual full tank level (45 Years).The return period is a useful statistic for characterizing extreme hydrologic events, such asdroughts. Its assignment to severe droughts can provide useful information aboutimprovements in water systems management under dry conditions (Bonaccorso et al. 2003). The return period of an event (T) can be defined in several ways depending on the application and user. Some (e.g. Lloyd 1970; Loaiciga and Marino 1991; Shiau and Shen 2001) have defined the return period as the average elapsed time between the occurrencesof critical events (floods or droughts). Bonaccorso et al. (2003) developed a return period concept that extends the method proposed by Shiau and Shen (2001), as it expresses the return period of drought severity as a function of the statistical characteristics of historical long records of precipitation and of a threshold parameter.The study site was Kilcheruvai, Pennadam, Tholudur and Thatchur, Indian Country and Cuddalore City. It was further described below about its geological environment and climatic and hydrological conditions.

Geological Environment

All the geological formations ranging in age from Archaean to Recent. The hard consolidated and crystalline rocks ofArchaean age represent the fissured and fractured formations and occur in the westernpart of the district covering major part of Tittagudi and western part ofVirudhachalam taluks and consists mainly Charnockite and associated rocks ofArchaean age. The unconsolidated quaternary sediments consisting of laterite, fluvial and coastal alluvium and the semi consolidated formations comprisingthe Cuddalore sandstone and Gopurapuram formations of Tertiary era, Calcareoussandstone moral of Upper cretaceous, and unconsolidated quaternary alluvium andthe Cuddalore sandstone. In the area underlain by cretaceous formations, calcareous Sandstone. In the semi consolidated Gopurapuram formations areessentially argillaceous, comprising silts, clay stones, calcareous sandstones, siliceouslimestones and algal limestones, tube wells tapping cretaceousformation and Cuddalore sandstone. It is generally used for drinking/irrigationpurposes.It includes various types of soil, fine to coarse-grained sands, silts,clays laterite and lateritic gravels.Laterite and lateritic gravels occur in major part of the district covering the Cuddaloresandstones. The Laterites are generally ferruginous and sometimes extensive inoccurrence as near Vadalur and Maduraipakkam, Laterites are dark brown.

Results and Discussion

Frequency Analysis by Ranking of Data

Data for frequency analysis can be ranked in either ascending or descending order. For a ranking in descending order, the suggested procedure is as follows:

- Rank the total number of data (n) in descending order according to their value (x), the highest value first and the lowest value last;
- Assign a serial number (r) to each value x (xr, r = 1,2,3,...,n), the highest value being x1 and the lowest being xn;
- Divide the rank (r) by the total number of observations plus 1 to obtain the frequency of exceedance:

$$F(x > xr) = r/(n-1) \qquad (1)$$

Calculate the frequency of non-exceedance

$$F(x \leq xr) = 1 - F(x > xr) = 1 - r/(n-1) \qquad (2)$$

If the ranking order is ascending instead of descending, we can obtain similar relations by interchanging $F(x > xr)$ and $F(x \leq xr)$.

Table 1 shows how the ranking procedure was applied to the annual rainfallsto illustrate the application of theoretical frequency distributions. The estimates of the frequencies obtained from Equations 1 and 2 are not unbiased. But then, neither are the other estimators found in literature. For values of x close to the average value (), it makes little difference which estimator is used, and the bias is small.In Figure 2 the full tank level have been plotted against their respectivereturn periods. Smooth curves have been drawn to fit the respective points as well as possible and the 100 years full tank level is 30 ft.These curves can be considered representative of average future frequencies. The advantages ofthe smoothing procedure used are that it enables interpolation and that to a certain extent itlevels off random variation. Its disadvantage is that it may suggest an accuracy of prediction thatdoes not exist. It is therefore useful to add confidence intervals for each of the curves in orderto judge the extent of the curves reliability.The frequency analysis discussed here is usually adequate to solve problems related to agriculture. If there are approximately 45 years of information available, predictions for 100 year return periods, made with the methods described in this section, will be reasonably reliable, but predictions for return periods of 100 years or more will be less reliable.

Previous Related Studies

1. Hershfield (1961) published the results of a comprehensive rainfall frequency analysis and mapping for the entire United States.
2. Miller (1964) published the results of a similar analysis and mapping for rainfall durations from two to 10 days for the contiguous United States in the Technical Paper No. 49.
3. MacVicar (1981) performed a frequency analysis of rainfall for the South and Central Florida area for the District.
4. Sculley (1986) conducted a frequency analysis of wet season, dry season and annual rainfall for the District.
5. Trimble (1990) performed a frequency analysis of one and three-day rainfall maxima for the District.
6. Abtew et al. (1993) compared six methods used in the spatial analysis of monthly rainfall in South Florida.
7. Van Lent and Tracy (1994) performed an assessment of the rain gage network in the District using the geo-statistical analysis.

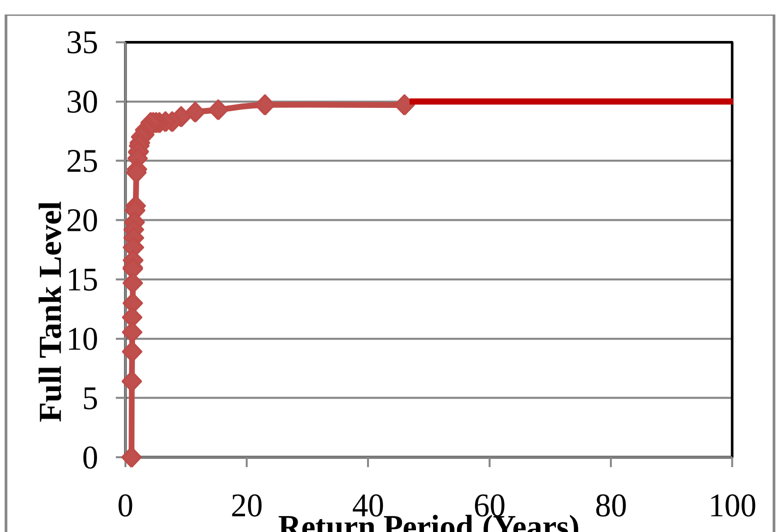

Fig 2: FTL – Return period relations derived from Table 1.

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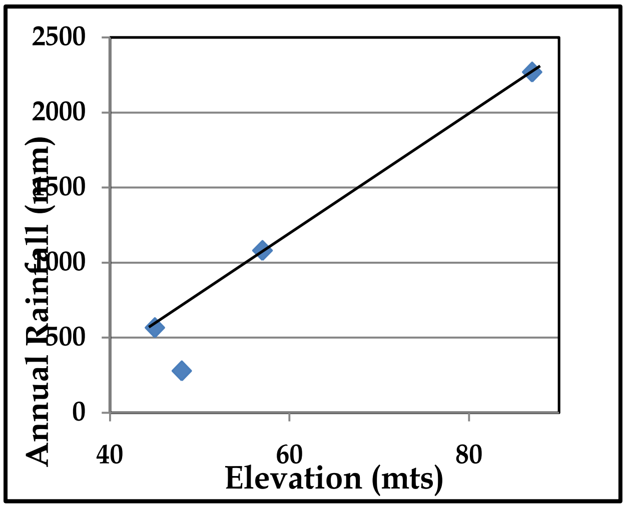
Table1. Frequency distributions based on ranking of the maximum rainfall

Rank	FTL descending order (ft)	Year	F(x > xr), r/(n+1)	F(x ≤ xr), 1-r/(n+1)	Tr (years), (n=1)/r
1	29.7	1968	0.02	0	46
2	29.7	1969	0.04	-0.02	23
3	29.3	1970	0.07	-0.04	15.3
4	29.1	1971	0.09	-0.07	11.5
5	28.7	1972	0.11	-0.0.09	9.2
6	28.3	1973	0.13	-0.11	7.8
7	28.3	1974	0.15	-0.13	6.6
8	28.2	1975	0.17	-0.15	5.8
9	28.2	1976	0.20	-0.17	5.1
10	28.2	1977	0.22	-0.20	4.6
11	28.2	1978	0.24	-0.22	4.2
12	27.8	1979	0.26	-0.24	3.8
13	27.65	1980	0.28	-0.26	3.5
14	27.6	1981	0.31	-0.28	3.3
15	27.2	1982	0.33	-0.30	3.1
16	27.1	1983	0.35	-0.33	2.9
17	27	1984	0.37	-0.35	2.7
18	27	1985	0.39	-0.37	2.6
19	26.5	1986	0.41	-0.39	2.4
20	26.25	1987	0.43	-0.41	2.3
21	25.8	1988	0.46	-0.43	2.2
22	25.7	1989	0.48	-0.46	2.1
23	25.2	1990	0.50	-0.48	2
24	24.3	1991	0.52	-0.50	1.9
25	24	1992	0.54	-0.52	1.8
26	24	1993	0.57	-0.54	1.8
27	21.2	1994	0.59	-0.57	1.7
28	20.85	1995	0.61	-0.59	1.6
29	20.8	1996	0.63	-0.61	1.59
30	19.85	1997	0.65	-0.63	1.5
31	19.8	1998	0.67	-0.65	1.5
32	19.2	1999	0.70	-0.67	1.4
33	18.5	2000	0.72	-0.70	1.4
34	17.7	2001	0.74	-0.72	1.4
35	17.7	2002	0.76	-0.74	1.3
36	16.6	2003	0.78	-0.76	1.3
37	16	2004	0.80	-0.78	1.2
38	15.9	2005	0.83	-0.80	1.2
39	14.7	2006	0.85	-0.83	1.2
40	13	2007	0.87	-0.85	1.2
41	11.8	2008	0.90	-0.87	1.1
42	10.55	2009	0.91	-0.89	1.1
43	8.9	2010	0.93	-0.91	1.1
44	6.4	2011	0.96	-0.93	1.0
45	0	2012	0.98	-0.96	1.0

Rainfall Distribution Characteristics



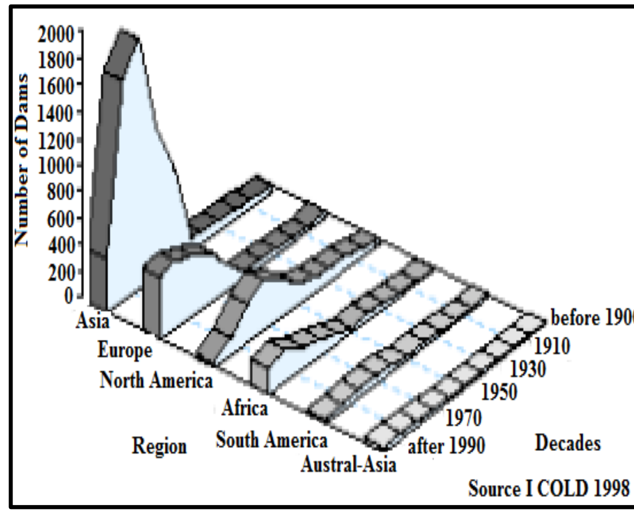


Fig 3. Elevation versus annual average rainfallFig 4. Development countries on Irrigation

With regard to the rainfall of Wellington reservoir area, it can be found that rainfall concentrations and its distribution are shown in the rainfall and elevation (Fig 3). The rainfall of Wellington reservoirarea is mainly concentrated in the northwest and southwest area, that is, the area within Wellington Reservoir watershed is the highest MSL (mean sea level) point of ayacut area. Therefore, this study is focusing on the further investigation on the effects of altitude on rainfall. From the relation of elevation versus annual average rainfall (as shown in Fig. 3), there is a tendency that the rainfall increases as the elevation increases. From a further investigation on flats (elevation 36 to 109 m) defined in the soil and waterconservation technical standards, it is found that thereis a similar tendency, but comparing to the whole, the effect of altitude on rainfall within this area is not significant.In addition to topography and climate, what other factors affecting the rainfall distribution are significantly related to rainfall.The techniqueinvolves using observed annual peak flow discharge data to calculate statistical information suchas mean values, standard deviations, skewness, and recurrence intervals. These statistical dataare then used to construct frequency distributions (Table 2).

Table 2: Statistics of return period and Rainfall

		Return Period	Rainfall
N	Valid	45	45
	Missing	0	0
Mean		4.4904	22.1878
Median		2.0000	25.2000
Mode		1.20	28.20
Std. Deviation		7.57532	7.11812
Variance		57.385	50.668
Skewness		4.315	-1.164
Std. Error of		.354	.354
Kurtosis		21.348	.926
Std. Error of Kurtosis		.695	.695
Range		44.98	29.70
Percentiles	25	1.3500	17.7000
	50	2.0000	25.2000
	75	4.0000	28.0000

Demand of Frequency in Return period

Globally there is a lot of heterogeneity among land qualities and populations. Not every location is well suited to water development, and the potential benefits of irrigation have not been spread evenly throughout the world (Fig 4). The following chart shows the distribution of irrigation dams built throughout the world. There have been many irrigation projects developed in Asia, which have been mostly successful. South America and Africa have had relatively few irrigation projects developed, and the benefits have been minimal. An important concern for the future is the limited supply of fresh water. Recent years have seen a decline in the number of water projects build worldwide, because of environmental and cost concerns. Most of the areas that are good locations for water projects have already been developed, and there are growing concerns about the quality of available water as well as thequantity. In addition, more is known about the potential negative environmental effects of the construction of large dams and poorly managed irrigation systems. Evidence of this change can be seen in the projects funded by the World Bank. Existing water systems, along with the use of more efficient irrigation technologies will be essential in upcoming decades. Thus, this chapter both assesses the performance of irrigation systems in the past and introduces the direction of reforming water systems as we prepare towards the future.

Table 3: Frequency of Return Period

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2.2	2.2	2.2
1.05	1	2.2	2.2	4.4
1.10	3	6.7	6.7	11.1
1.20	4	8.9	8.9	20.0
1.30	2	4.4	4.4	24.4
1.40	3	6.7	6.7	31.1
1.50	2	4.4	4.4	35.6
1.60	2	4.4	4.4	40.0
1.70	1	2.2	2.2	42.2
1.80	2	4.4	4.4	46.7
1.90	1	2.2	2.2	48.9
2.00	1	2.2	2.2	51.1
2.10	1	2.2	2.2	53.3
2.20	1	2.2	2.2	55.6
2.30	1	2.2	2.2	57.8
2.40	1	2.2	2.2	60.0
2.60	1	2.2	2.2	62.2
2.70	1	2.2	2.2	64.4
2.90	1	2.2	2.2	66.7
3.10	1	2.2	2.2	68.9
3.30	1	2.2	2.2	71.1
3.50	1	2.2	2.2	73.3
3.80	1	2.2	2.2	75.6
4.20	1	2.2	2.2	77.8
4.60	1	2.2	2.2	80.0
5.10	1	2.2	2.2	82.2
5.60	1	2.2	2.2	84.4
6.60	1	2.2	2.2	86.7
7.70	1	2.2	2.2	88.9
9.20	1	2.2	2.2	91.1
11.50	1	2.2	2.2	93.3
15.30	1	2.2	2.2	95.6
23.00	1	2.2	2.2	97.8
46.00	1	2.2	2.2	100.0
Total	45	100.0	100.0	

Table: 4. Frequency of Rainfall

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2.2	2.2	2.2
6.40	1	2.2	2.2	4.4
8.90	1	2.2	2.2	6.7
10.55	1	2.2	2.2	8.9
11.80	1	2.2	2.2	11.1
13.00	1	2.2	2.2	13.3
14.70	1	2.2	2.2	15.6
15.90	1	2.2	2.2	17.8
16.00	1	2.2	2.2	20.0
16.60	1	2.2	2.2	22.2
17.70	2	4.4	4.4	26.7
18.50	1	2.2	2.2	28.9
19.20	1	2.2	2.2	31.1
19.80	1	2.2	2.2	33.3
19.85	1	2.2	2.2	35.6
20.80	1	2.2	2.2	37.8
20.85	1	2.2	2.2	40.0
21.20	1	2.2	2.2	42.2
24.00	2	4.4	4.4	46.7
24.30	1	2.2	2.2	48.9
25.20	1	2.2	2.2	51.1
25.70	1	2.2	2.2	53.3
25.80	1	2.2	2.2	55.6
26.25	1	2.2	2.2	57.8
26.50	1	2.2	2.2	60.0
27.00	2	4.4	4.4	64.4
27.10	1	2.2	2.2	66.7
27.20	1	2.2	2.2	68.9
27.60	1	2.2	2.2	71.1
27.65	1	2.2	2.2	73.3
27.80	1	2.2	2.2	75.6
28.20	4	8.9	8.9	84.4
28.30	2	4.4	4.4	88.9
28.70	1	2.2	2.2	91.1
29.10	1	2.2	2.2	93.3
29.30	1	2.2	2.2	95.6
29.70	2	4.4	4.4	100.0
Total	45	100.0	100.0	

Conclusion

The research carried out has demonstrated that surface water FTL appears to occur at higher rainfall intensitiesand return periods than those used as thresholds in the service. However, significant questions remain regarding themagnitude and duration of surface water FTL represented by the FTL event data which were available. These questions are vital to any development or updating of thresholds based on a similar approach. This in turn highlightsthe need to introduce a national standard for recording of FTL event data, which would facilitate a more accurate analysis based on the methodology described in this paper.Without improved data, it will not be possible to make effective decisions regarding how best to warn of potential.From the results of the frequency analysisdistribution is the primary distribution pattern for this study site. But, the FTLdata used in this study are sufficient, i.e., the data arecompletely 45 consecutive years. Besides, for the common frequency analysis methods used in this study, it shows that the proportion of frequency distribution is the highest. By increasing the number of years of data and employing different methods for theanalysis, it is believed that more accurate results could be obtained.

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