World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:8, No:6, 2014

Determining the Best Fitting Distributions for Minimum Flows of Streams in Gediz Basin

Naci Büyükkaracığan

***Abstract*—**Today, the need for water sources is swiftly increasing due to population growth. At the same time, it is known that some regions will face with shortage of water and drought because of the global warming and climate change. In this context, evaluation and analysis of hydrological data such as the observed trends, drought and flood prediction of short term flow has great deal of importance. The most accurate selection probability distribution is important to describe the low flow statistics for the studies related to drought analysis. As in many basins In Turkey, Gediz River basin will be affected enough by the drought and will decrease the amount of used water. The aim of this study is to derive appropriate probability distributions for frequency analysis of annual minimum flows at 6 gauging stations of the Gediz Basin. After applying 10 different probability distributions, six different parameter estimation methods and 3 fitness test, the Pearson 3 distribution and general extreme values distributions were found to give optimal results.

***Keywords*—**Gediz Basin, goodness-of-fit tests, Minimum flows, probability distribution.

I. Introduction

TODAY, global climate change and drought are the most important problems that directly affect human life. At the same time, global climate change has already had impacts on the environment. Because of these impacts, glaciers have shrunk, ice on rivers and dams is breaking up earlier, plant and animal ranges have shifted and trees are flowering sooner. Effects of global climate change are now occurring: loss of sea ice, accelerated sea level rise and longer, more intense heat waves. According to many scientists, global temperatures will continue to rise for decades to come, largely due to greenhouse gasses produced by human activities. The degree of climate change impacts on individual regions will vary over time and with the ability of different societal and environmental systems to reduce or adapt to change.

So, climate change is the biggest environmental and humanitarian crisis of current time. The atmosphere of earth is overloaded with heat-trapping carbon dioxide, which threatens large-scale disruptions in climate with disastrous consequences. Clean and enough water supplies the foundation for prosperous populations. Human relies on clean water to survive, yet right now we are heading towards a water crisis. Changing climate patterns are threatening lakes and rivers, and key sources that we tap for drinking water are being overdrawn or tainted with pollution [1].

Naci Büyükkaracığan is Assist. Prof. Dr. with Selcuk University Kadinhani Faik İçil Vocational High school (phone: +90-332-8340306; fax: +90-332-8340306; e-mail: nacibk@ selcuk.edu.tr).

The greenhouse gas increases caused by climate change, compared with the potential to see a change very slowly in geomorphology of the basin. Therefore, the hydrologic regime changes in the basin not being regulated climatic conditions often reflect changes. At the same time, temperature and rainfall are important hydrological parameters which are used in determining climate change Climate changes such as the precipitation, evaporation and temperature are directly related with amount of water during the human activities. Climate includes an average of weather conditions, extreme values and all the statistical difference for many years observed in anywhere in earth. Therefore, knowing the climate changes that may occur in the future is very important for planning for extreme values likely to happen by making the necessary measures and constitutes [2]-[4].

Drought is an expanded period when a region notes a deficiency in its water supply whether surface or underground water. In other words, drought can be defined as a hydrological affecting the natural resources negatively, occurring the precipitation decreased to the normal limits. Effective use of water is one of the measures to reduce the impact of drought. Effective usage of the water is possible not only by taking under control consumption but also by planning to use of current water resources. Therefore, evaluation and analyze of the flows in watery and drought terms shortly hydrologic data, have a great deal of importance in estimation ecology of droughts in flowing waters is not certain known because of much of the available information being gathered opportunistically. Applications on intermittent and arid-zone streams have provided most of the information for determining system of droughts in flows. There can be Drought in streams in which water inflow, stream flow and water availability decrease remarkable low levels for extended periods of time. Droughts can either be periodic, seasonal or supra-seasonal events. The types of disturbance for seasonal droughts are presses and for supra-seasonal droughts, ramps. In droughts, hydrological connectivity is disrupted. Such disruption ranges from flow reduction to complete loss of surface water and connectivity. The longitudinal patterns along streams as to where flow ceases and drying up occurs differ between streams. Three patterns are outlined: ‘downstream drying’, ‘headwater drying’ and ‘mid-reach drying’. Drought affects both direct and indirect stream ecosystems. Marked direct effects include loss of water, loss of habitat for aquatic organisms and loss of stream connectivity. Indirect effects include the deterioration of water quality, alteration of food resources, and changes in the strength and structure of interspecific interactions. Droughts affect on the densities and size- or age-structure of populations, on community composition and diversity, and on ecosystem processes [5], [6].

Perturbations in ecosystems consist of two sequential events: (1) The disturbance when the disrupting forces are applied, and (2) The responses by the affected biota to the disturbing forces.

The methodology of a drought can not be certain defined in freshwater ecology. This situation is common, because outside ecology many types of droughts have been recognised: Hydrological, agricultural, meteorological and economic. Droughts in streams disrupt hydrological connectivity. Conversely, floods amplify hydrological connectivity. With the onset of drought, falling water levels reduce the amount of habitat available for most aquatic biota, exposing the marginal areas, breaking surface water contact between the stream and its riparian zone, and reducing the hydraulic heterogeneity of flow. With falling water levels, lentic habitats may increase in extent and new types of habitats may be created, that favour some species, both residents and invaders [7].

The term “minimum flow” can be defined as the lowest continuous flow the pump was permitted to operate, without reference to duration, vibration level or other criteria. Today, minimum flow values are used for continuous operation, for intermittent operation and permissible temperature rise [8].

Flows in a stream are a “zero sum game” – here is a finite amount of water available at any given moment, and if it is being used for one thing; it cannot be used for another. Native streamside vegetation in the riparian zone must have a natural flow in order to survive and reproduce. The plants, fish, and wildlife in any given river have evolved to adapt to that river’s unique rhythms. Altering natural flow can harm these species. By setting different minimum stream flow values for different seasons (e.g., highest in the spring during runoff), we attempt to approximate natural flow cycles [9].

Estimating the future values of flows are necessary for the assessment of design criterion in the planning of the water structures. Successful planning and management of water resources depend on the conditions of the identification of suitable generation models for future stream flows. Especially, missing data filling or extension of available data can be achieved through the synthetic stream flow generation procedures. [10].

Probability distributions are performed to find out a random variable of a certain size for determining the more suitable probability distributions. At the same time, likelihood of future events that may occur during a specific iteration to determines the size of a hydrological event. Probability distribution model is determined by the observed frequency of the data from the analysis of the histogram of the frequency distribution. The most suitable one of the distribution is very significant because of the selected project in constructing hydraulic structure elements like the height of the river terraces that can be improved, getting dimension of some of the parts of highway bridges, making the projects of sluice and the channel has an important effect in the aspect of either cost or life security [11].

The purpose of the study is to determine the best fit probability distribution of annual minimum flows of streams in Gediz basin. Log Normal-2, Gumbel, Pearson 3, Log-Pearson 3, Log-Boughton, Log-Logistic, General Extreme values, Wakeby, Pareto and Weibull distributions were applied to minimum values of streams. Moments, Maximum likelihood, Probability weighted moments, Maximum entropy, Mixed moments, and Individual probability weighted moments methods were used for estimating parameters of the probability distribution. At the end of study, classical khi-square, Kolmogorov-Smirrnov, Anderson and Cramer-von-Misses Appropriateness tests are used as goodness-of-fit tests).

II. Data and Methodology

Gediz Streams is in the Gediz Basin which is located in the part of the Aegean region and the Mediterranean rainfall regimes. Gediz River flows from east to west into the Aegean See just north of Izmir. Gediz River flows from the northeast mountain area to the Aegean See. On the way three more river streams join the Gediz River. From the southeast Alasehir River flows in, from the northern main valley Gordes River is joining and Kumçay River is joining from the Northwest. Water supply from the river network to the irrigation schemes is through cement canals. Gediz Basin has hot dry summers and cool winters. The average annual rainfall amount is some 500 to 530 mm, but extremes of 300 mm and 850 mm also occur. Precipitation is concentrated in the winter period. Precipitation in the basin ranges from over 1 000 mm per year in the mountains to 500 mm per year near the Aegean coast. In the mountains the precipitation mainly falls in forms of snow [12], [13].

In this study, records of 6 gauging stations (509, 510, 514, 515, 518, 523) of the Gediz Basinwere used for analysis.

A. *Probability Distribution Model*

A probability distribution assigns a probability to each measurable sub set of the possible outcomes of a random experiment, survey, or procedure of statistical inference. Examples are found in experiments whose sample space is non-numerical, where the distribution would be a categorical distribution; experiments whose sample space is encoded by discrete random variables, where the distribution can be specified by a probability mass function; and experiments with sample spaces encoded by continuous random variables, where the distribution can be specified by a probability density function. More complex experiments, such as those involving stochastic processes defined in continuous time, may demand the use of more general probability measures.

The flow value that a random variable x gets in an observation is a random hydrological event. An estimation can be done about what frequency the event can be seen even the value of the variable. This is possible by showing theoretical equation model of the random variable.

This model of flow peak series is stated with the equation below [14].

$$P\ (Q \leq Qt\ ) = F(Q = Q +) = SQ + F\ (Q)dQ \quad (1)$$

T is the annual overflow peak flow in Q+ above. Return period T(year) is used more than exceed probability and expressed as:

$$T = 1/Prob(Q < Q_{+})\ ve\ Prob\ (Q \leq Q_{+}) = 1 - 1/T \quad (2)$$

It is needed to distinguish between discrete and continuous random variables to define probability distributions for the simplest cases. In the discrete case, one can easily assign a probability to each possible value: If the random variable is real-valued (or more generally, if a total order is defined for its possible values), the cumulative distribution function (CDF) gives the probability that the random variable is no larger than a given value; in the real-valued case, the CDF is the integral of the probability density function (pdf) provided that this function exists.

Frequency analysis is based on Probability Distribution Model. This analysis involves using observed annual flow discharge data to estimate statistical information such as mean values, standard deviations, skewness, and recurrence intervals. These statistical data are then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various discharges as a function of recurrence interval or exceedance probability. Frequency distributions can take on many forms according to the equations used to carry out the statistical analyses [11].

B. Log-Normal 2 Distribution

N, a log-normal distribution X, the parameters denoted μ and σ are, respectively, the mean and standard deviation of the variable's natural logarithm (by definition, the variable's logarithm is normally distributed), which means:

$$X = e^{\mu+\sigma Z} \quad (3)$$

with Z a standard normal variable.

In contrast, the mean, standard deviation, and variance of the non-logarithmized sample values are respectively denoted m, s.d., and v in this article. The two sets of parameters can be related as (see also arithmetic moments below)[3].

$$\mu = \ln \frac{m^2}{\sqrt{v+m^2}}\ ,\ \ \sigma = \sqrt{ln\ (1 + \frac{v}{m^2})} \quad (4)$$

The probability density function of a log-normal distribution is:

$$f_x = (x; \mu, \sigma) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{(lnx-\mu)^2}{2\sigma^2}}\ ,\ \ x > 0 \quad (5)$$

This follows by applying the change-of-variables rule on the density function of a normal distribution. The cumulative distribution function is:

$$f_x = (x; \mu, \sigma) = \frac{1}{2}\left[1 + erf\ (\frac{\ln x - \mu}{\sigma\sqrt{2}})\right] = \varphi(\frac{\ln x - \mu}{\sigma}) \quad (6)$$

where erfc is the complementary error function, and Φ is the cumulative distribution function of the standard normal distribution [15].

C. Gumbel Distribution

This distribution is used for modelling the distribution of the maximum (or the minimum) of a number of samples of various distributions. Such a distribution might be used to represent the distribution of the maximum level of a river in a particular year if there was a list of maximum values for the past ten years. It is useful in predicting the chance that an extreme earthquake, flood or other natural disaster will occur. The potential applicability of the Gumbel distribution to represent the distribution of maxima relates to extreme value theory which indicates that it is likely to be useful if the distribution of the underlying sample data is of the normal or exponential type [16].

The standard Gumbel distribution is the case where μ=0and β=1 with cumulative distribution function:

$$F(x) = e^{-e^{(-x)}} \quad (7)$$

and probability density function

$$F(x) = e^{-\ x-e^{-x}} \quad (8)$$

In this case the mode is 0, the median is ln(ln(2)) ≈ 0.3665 the mean is, γ and the standard deviation is ∏√6≈ 1.2825 is quantile function and generating Gumbel variates since the quantile function (inverse cumulative distribution unction), Q(p) of a Gumbel distribution is given by

$$Q(p) = \mu - \beta \ln(-\ln(p)) \quad (9)$$

The variate Q(u) has a Gumbel distribution with parameters μand β when the random variate *U* is drawn from the uniform distribution on the interval (0,1)

D. Pearson 3 Distribution

The Pearson system is originally devised in an effort to model visibly skewed observations. It is well known at the time how to adjust a theoretical model to fit the first two cumulant so moments of observed data: Any probability distribution can be extended straightforwardly to form a location-scale family. However, it is not known how to construct probability distributions in which the skewness (standardized third cumulant) and kurtosis (standardized fourth cumulant) could be adjusted equally freely. This need become apparent when trying to fit known theoretical models to observed data that exhibited skewness. Pearson's examples include survival data, which are usually asymmetric [17].

Functions of distributions are:

$$= \mu_1 + \frac{b_0}{b_1} - (m+1)b_1 \quad (10)$$

$$Gamma(m+1, b_1^2) \quad (11)$$

$$b_0 + b_1(x -) \quad (12)$$

E. Log-Pearson 3 Distribution

The Pearson Type III, or Gamma, distribution is used to calculate the frequency of maxima events when the distribution of all events (both big and small) is log-normally distributed. Events will be log-normally distributed when they are the product of a large number of independent random variables. In hydrologic applications, the log-normal distribution has been found to reasonably describe such variables as the depth of precipitation of individual storms and annual peak discharges [18].

The probability density function using the shape-scale parametrization is,

$$f(x;k;\theta) = \frac{x^{k-1}e^{-\frac{x}{\theta}}}{\theta^k\Gamma(k)} \text{ for } x > 0 \text{ and } k,\theta > 0 \quad (13)$$

The cumulative distribution function is the regularized gamma function:

$$f(x;k;\theta) = \int_0^x f(u;k;\theta)du = \frac{\gamma(k, \frac{x}{\theta})}{\Gamma(k)} \quad (14)$$

F. Log-Boughton Distribution

If ln{ln[r/(r - 1)]} is symbolized by B, the log-Boughton (LB) distribution is based on the relationship:

$$(Kb - A)(B - A) = C\ (40) \quad (15)$$

where Kb is the frequency factor of the LB distribution; and A and C are its parameters. Those parameters are computed by an empirical method "to minimize the mean square error of C". This distribution does not have a clear-cut analytical probability density function. It was alleged to be at least as good as the popular flood frequency analysis models. The methods of ML and PWM are not so far applicable to this distribution [19].

G. Log-Logistic Distribution

The log-logistic distribution is the probability distribution of a random variable whose logarithm has a logistic distribution. It is similar in shape to the log-normal distribution but has heavier tails. Its cumulative distribution function can be written in closed form, unlike that of the log-normal [20].The cumulative distribution function,

$$F(x;\alpha;\beta) = \frac{1}{1+\left(\frac{x}{\alpha}\right)^{-\beta}} \quad (16)$$

The probability density function is,

$$F(x;\alpha;\beta) = \frac{\left(\frac{\beta}{\alpha}\right)\left(\frac{x}{\alpha}\right)^{\beta-1}}{1+\left(\frac{x}{\alpha}\right)^{-\beta}} \quad (17)$$

H. General Extreme Value Distribution (GEV)

This distribution is a family of continuous probability distributions developed within theory to combine the Gumbel, Fréchet and Weibull families also known as type I, II and III extreme value distributions. By the extreme value theorem the GEV distribution is the only possible limit distribution of properly normalized maxima of a sequence of independent and identically distributed random variables. Note that a limit distribution need not exist: this requires regularity conditions on the tail of the distribution. Despite this, the GEV distribution is often used as an approximation to model the maxima of long (finite) sequences of random variables [21].

I. Wakeby Distribution

The Wakeby distribution is defined by the transformation,

$$x = \varepsilon + \left(\frac{\alpha}{\beta}\right)\left(1-(1-U)^{\beta}\right) - \left(\frac{\gamma}{\delta}\right)\left(1-(1-U)^{-\delta}\right) \quad (18)$$

where U is a standard uniform random variable. That is, the above equation defines the percent point function for the Wakeby distribution.

The parameters β, γ and δ are shape parameters. The parameter β is a location parameter and the parameter α is a scale parameter [22].

J. Pareto Distribution

The Pareto distribution is a skewed, heavy-tailed distribution that is sometimes used to model the distribution of incomes. From the definition, the cumulative distribution function of a Pareto random variable with parameters α and x_m is:

$$F_x(x) = \begin{cases} 1 - (x_m)/x^{\alpha}, & x \geq x_m \\ 0 \quad , & x < x_m \end{cases} \quad (19)$$

$$Q(p) = \mu - \beta \ln\left(ln \quad (p)\right) \quad (20)$$

When plotted on linear axes, the distribution assumes the familiar J-shaped curve which approaches each of the orthogonal axes asymptotically. All segments of the curve are self-similar (subject to appropriate scaling factors). When plotted in a log-log plot, the distribution is represented by a straight line.

It follows (by differentiation) that the probability density function is [23]:

$$F_x(x) = \begin{cases} \frac{\alpha\, x_m^{\alpha}}{x^{\alpha+1}} & x \geq x_m \\ 0 & x < x_m \end{cases} \quad (21)$$

K. Weibull Distribution

The Weibull distribution is a continuous probability distribution. The probability density function of a Weibull random variabilities:

$$f(x;;\mathrm{k}) = \begin{cases} \frac{k}{-} - \left(\frac{x}{-}\right)^{k-1} e^{-\left(\frac{x}{-}\right)^{\mathrm{k}}}, & x \geq 0 \\ 0 & , x < x_m \end{cases} \quad (22)$$

where k > 0 is the shape parameter and λ > 0 is the scale parameter of the distribution. Its complementary cumulative distribution function is a stretched exponential function. The Weibull distribution is related to a number of other probability distributions; in particular, it interpolates between the exponential distribution, (k = 1) and the Rayleigh distribution (k = 2). The cumulative distribution function for the Weibull distribution is [24]:

$$f(x;;k) = 1 - e^{-\left(\frac{x}{}\right)^{k}} \quad (23)$$

L. Parameter Estimation Methods

The most important characteristic needed in parameter estimations is neutrality. However it is recommended to use the least variance sample. In this study moments, maximum likelihood, probability weighted moments, probability weighted moments, maximum entropy, mixed moments, maximum entropy, and individual probability weighted moments methods are applied respectively. For more information about methodology of method, it can be looked: [8], [9], [25]-[30].

M. Goodness of Fit Tests

Measures of goodness of fit typically summarize the discrepancy between observed values and the values expected under the model in question. Measures can be used in statistical hypothesis testing to test for normality of residuals, to test whether two samples are drawn from identical distributions. There are of a lot of goodness of fit tests in literature. It is a quick and reliable way of controlling the situation whether an original data set is suitable to a given theoretical probability distribution or not. Also it is a simple way to graphic comparison of cumulative observation based distribution to cumulative intensity function of proposed theoretical distribution. If the distributions were fitted according to at least two tests, that distribution was accepted. In this study, Kolmognov – Simirrnov, Chi-square and Cramer-von-Misses test were used to find out the best fitting distribution to data. Methodology of this test can be looked: [2], [12], [29], [30].

III. Results and Discussion

Probability distribution models, according to a selected period that may repeat itself in order to calculate probability distribution of each model requires certain statistical parameters. In the study of distributions of 2, 5, 10, 25, 50,100 and 1000 years were estimated by using a packed software program (made by Haktanır) [19].

Each year the total currents measured at a station Csx values was greater than zero (between 0.12 to 1.33). That was skewed to the right shows a distribution function. Skewness and coefficients of variation were different from each other. This situation is explained as differences of the physical characteristics of watersheds, stream bed characteristics and climate factors.

As a result of the analysis, the probability distribution of the different models, different current values were calculated for the same duration of relapse and recurrence times higher than for these differences. In general, less than 50 years while the small differences between replicates flows, these differences increased as the duration of relapse. This is less than 100 years in obtaining replications currents into account of the distributions are used. The highest current values of more than 100 years often Pearson 3 and General Extreme Value while the lowest values of the log logistic distribution. It can be said that this situation is due to Probability distribution models having different forms of distribution (Table I).

TABLE I
Fittest Distributions as to Goodness of Fit Tests

Station Number	χ^2	K-S	CvM
509	GEV V	Pearson 3	GEV
510	Pearson 3	Pearson 3	Pearson 3
514	GEV	Log-Pearson 3	Pearson 3
515	Pearson 3	GEV	Pearson 3
518	Pearson 3	GEV	Pearson3
523	Pearson 3	Pearson3	Log-Pearson 3

Pearson 3and GEV were suitable for all stations, Weilbull and Wakeby distributions were less successful than other distributions. Pareto distribution was all bad fit for all basin. Moments method gave the suitable results for all series. Maximum likelihood method has given the most suitable result especially for the Log Normal, Pearson, 3 and Gumbel distributions have superiorite on Log-Logistic and Log-Pearson 3. Probability weighted moments method was good at Pearson 3 and GEV. Maximum entropy method, Mixed moments method and Individual probability weighted moments method ere more powerless than the others (Table II).

TABLE II
Evaluation of Distributions as to Goodness of Fits

Distrubiton	χ^2 test	K-S test	CvM
Log-Normal 2	1	2	2
Gumbel	-	2	1
Pareto	-	-	-
Log-Logistic	3	1	2
Pearson 3	6	6	6
Log-Pearson 3	2	3	3
Log-Boughton	-	2	2
Wakeby	-	2	1
GEV	6	6	6
Weilbull	1	2	1

IV. Conclusion

The best selection probability distribution is important to describe the low flow statistics for the studies related to drought analysis. In this study, the most suitable probability distribution model for the minimum annual flows of Gediz basin was determined by using the observations, a range of repeats itself with the amount of current. Pearson 3 distribution distribution became first 74% and second 16% among all distributions. GEV was first 40% and second 55%. At the same time, normal distribution, except instead of two parameters, standard deviation and mean, it also has skew. When the skew is small, Pearson III distribution approximates normal values. Maximum Likelihood parameter estimating method gave the most suitable results among other.

The Pearson 3 and GEV distributions show us, the likely values of discharges to expect in the stream at various recurrence intervals based on the available record. This point is important for designing structures in or near the stream that can be affected by floods or drought and also to protect against the largest expected event. For this reason, it is customary to perform the frequency analysis using the instantaneous minimum flow data. Thus, these results Pearson 3and GEV can be suggested for the project and planning of hydraulic structures will be built in this basin.

ACKNOWLEDGMENT

This study is supported by the Scientific Research Projects Unit of Selcuk University, Konya/Turkey (Project no: 14701143.

REFERENCES

[1] http://www.nrdc.org/water/default.asp
[2] U.C. Kothyari, V.P. Singh, and V. Aravamuthan, “An investigation of changes in rainfall and temperature regimes of the Ganga basin in India”, *Water Resources Management*, 1997, vol. 11, pp: 17-34.
[3] D.R. Cayan, and D.H. Peterson , “The influence of north Pacific atmospheric circulation on streamflow in the West”, *Geophysical Monogram Series*, 1989, vol. 55, pp. 375-397.
[4] N.Büyükkaracığan and M.F. Sevimli, “Homogenityand Trend Analyses of FloodSeries inTurkey: EnvironmentalAssessments”, *ICEEE*, 2010.
[5] A.Ülke, and T.Baran, “KöprüçayYıllık Akım Verilerine Uygun Olasılık Dağılım Fonksiyonu ve Kuraklık Analizi”, *Antalya Yöresinin İnşaat Mühendisliği Sorunları Kongresi*, 2005, pp. 142-154.
[6] P.S.Lake, “Ecological effects of perturbation by drought in flowing waters”,*Freshwater Biology,*2003, vol. 48, , pp. 1161–1172.
[7] S. Gopalakrishnan, “A New Method for Computing Minimum Flow,” *Proceedings of the Fifth International Pump Users Symposium*; Texas A&M University, May 1988, pp. 41-47.
[8] C. Bathurst, “At-a-Site variationand minimum flowres istancefor Mountainrivers”, *Journal of Hydrology*, 2002, vol.269, pp. 11–26.
[9] N. Büyükkaracığan and H. Uzun, “Frequency Analysis of Minimum Flows in Susurluk Rivers”, *ICFM FA*2013.
[10] N. Büyükkaracığan and Y. Akyol, Application of Probability distributions to Annual Total Flows in Sakarya Streams, *ICECE* 2012.
[11] OSU, Techical Report, Analysis Techniques: Flood Frequency Analysis, http://streamflow.engr.oregonstate.edu/analysis/floodfreq/, 2013
[12] N. Büyükkaracığan, and E. Kahya, “A Comparison of Various distributions Used in Frequency Analysis Applying to Annual Peak Series of Konya Basin”, *ICGCC EI (UKIDEK),* 2007, pp. 279-287
[13] J. R. Benjamin, and C. A. Cornell, “Probability, Statistics, and Desicion for Civil Engineers”, *McGraw-Hill Bode Company*, 1970, New York.
[14] R. Rao, and K. Hamed, “Frequency Analysis of Upper Flood Data by L Moments”, *Water Resources Management,* 1994, vol. 8, pp. 183-201.
[15] B.P. Sangal, and A.K. Biswas, *“The 3-Parameter Lognormal Distribution and Its Applications in Hydrology”,* Water Resources Research*, 1970*, vol. 6, pp. 505–515.
[16] E.J. Gumbel, "Les valeursextrêmes des distributions statistiques", *Ann. Inst. Henri Poincaré* , 1935, vol. 5, pp. 115–158.
[17] W.PElderton, and N.L. Johnson, “Systems of Frequency Curves”, *Cambridge University Press*, 1969.
[18] U.S. Interagency Advisory Committee on Water Data "Guidelines for Determining Flood Flow Frequency", *Bulletin 17 B of the Hydrology Committee*, U.S. Geological Survey, Reston, VA.
[19] T. Haktanır,”Statistical Modelling of Annual Maximumflows in Turkish rivers”, *Hydrological Sciences - Journal - des Sciences Hydrologiques*, giques, 1991, vol. 36, pp. 367-389.
[20] M.M. Shoukri, I.U.M. Mian,and D.S. Tracy, "Sampling Properties of Estimators of the Log-Logistic Distribution with Application to Canadian Precipitation Data", *The Canadian Journal of Statistics*, 1988, vol. 16 (3), pp. 223–236.
[21] S. Coles, “An Introduction to Statistical Modeling of Extreme Values*”, Springer-Verlag*. 2001, pp. 459-465.
[22] http://www.itl.nist.gov/div898/software/dataplot /refman2/ auxillar
[23] M. O. Lorenz. "Methods of measuring the concentration of wealth". *Publications of the American Statistical Association*, vol. 70, pp. 209–219.
[24] P.Pillai, and A.Papoulis, "Probability, Random Variables, and Stochastic Processes”, *McGraw Hill,* 2002.
[25] M. Vogel, and N. Fennessey, “L Moment Diagrams Should Replace Product Moment Diagrams”, *Water Resources Research*, 1993, vol. 29, pp. 1745-1752.
[26] B. Önöz, “A new parameter estimator method: probability weighted moments”, *DSİ Technique Bulletin*, 1994, vol. 81, pp. 49-54.
[27] Rasmussen, j., et al., “Christensen, and K. Hinsby, Climatechange effects on irrigationdemandsand minimum streamdischarge”, *Hydrol. Earth Syst. Sci. Discuss*.,2012, vol. 9, pp. 4989–5037.
[28] Rasmussen, j.,et all, “Christensen, and K. Hinsby, Climatechangeeffects on irrigation demand sand minimum streamdischarge”,*Hydrol. Earth Syst. Sci. Discuss*.,2012, vol. 9,pp. 4989–5037.
[29] U.C. Kothyari, V.P. Singh, and V. Aravamuthan, “An investigation of changes in rainfall and temperature regimes of the Ganga basin in India”, *Water Resources Management*, 1997, vol. 11, pp. 17-34.
[30] WMO, “Statistical Distributions for Flood Frequency Analysis”, *World Meteorology Organization*, 1989, Report no: 33.

Assist. Prof. Dr. Naci Büyükkaracığan is currently member of academic staff at Selcuk University. His main research interests are statistics and computer programmes in civil engineering. At the same time, he is studying at fuzzy logic systems, modelling and simulator systems in water resources. He is also member of editor committe of Journal of Social and Technical researches. Phone: +90 332 8340306, e-mail: nacibk@selcuk.edu.tr