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Impact Of Climate Change On Reservoir Inflowandpeak Inflow-outflow Analysis: A Case Study Of Ukai Reservoir

KEYWORDS: Reservoir Inflow, Climate change,Peak flood, Trend analysis, Ukai Reservoir.

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ABSTRACT Reservoir inflows generates from precipitation occurred in the river basin. Climate change causes variations in the meteorological and hydrological parameters such as rainfall, temperature, humidity etc. leads to the variation in reservoir inflow. Climate change studies aims to better understand the uncertainties involved in the system by analysing trend. The effect of climate change on reservoir inflow for Ukai reservoir has been studied. The paper presents the effect of changing climate using trend analysis on the Ukaireservoir. The study is important from the flooding of Surat city as it is on the downstream side of Ukai dam which is directly affected from the releases of Ukai dam.

1. INTRODUCTION

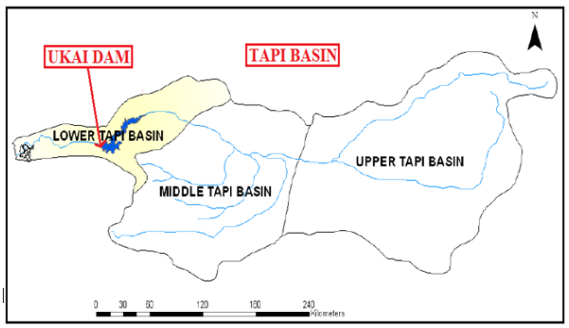
Climate change includes major changes in temperature, precipitation, weather, and reservoir inflow, among other effects, that occur for longer time period fromseveral decades or longer. Reservoir inflow depends precipitation. Stochastic and non-linear variations are well availed and acclaimed in the hydrologic parameters being influenced by climate change. Burn et al (1996) and Labadie (2004) studied studied effect of climate change on reservoir. Impact of climate change on hydrology and water resources for peninsular malaysia was studied by Kavves M. L. et al (2006). McBean et al. (2008) and Xu et al. (2009) carried out a long term trend analysis. Lund (1996) derived the optimised operating rules by analysing patterns of changes in inflow to facilitate the decision making for redefined strategies.
Zealand C. M. et al (1999),ASCE task committee (2000) and Lischeid (2001)used Artificial neural networkfor investigating trends. Guiller (2005) and Jain et al. (2009) applied ANN in analysing stream flow prediction. Mann-Kendall (MK) test is popularly used to identify the trends (Zhang et al. 2001) though earlier statical methods were used. Kumar et al. (2009), Douglas et al. (2000), Sawami (2011) and Song et al. (2012) have applied Mann-Kendall's method.In the present study effect of climate change due on reservoir inflow is done statistically using trend analysis methods and Reservoir Inflow-outflow analysis is dealt later.

2. STUDY AREA

Ukai dam situated on Tapiriver, Tapi (Vyara), Gujarat is selected as study area. Ukai Dam is.Fig.1 shows the Ukai dam and and Fig.2 shows Tapi basin.



Fig. 1.Ukai dam



3. METHODOLOGY AND DATA ANALYSIS

3.1 DATA COLLECTION

14 years (2000 to 2013) data were obtained from the Ukai Civil (Circle), Ukai dam authority.

3.2 ANALYSIS OF DATA

Regression statistics, Mann-Kendall method and Sen's-slope estimator have been used for trend analysis.

3.2.1Regression statistics

The regression equation is obtained as in eqn. (1).

$$Y = aX + C$$

Where, X =time (year), a =slope coefficient, b = least square estimates of the intercept.

.a and b can be obtained from eqns. (2) and (3).

$$a = \frac{n\,\Sigma(x*y) - \Sigma x * \Sigma y}{n\,\Sigma(x*x) - (\Sigma x)*(\Sigma x)} \qquad 2.$$

$$b = \frac{\Sigma y - b * \Sigma x}{n} \qquad 3.$$

The sample correlation, r, is obtained from eqn.

Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X

$$\frac{n\,\Sigma(x*y) - \Sigma x * \Sigma y}{\sqrt{[n\,\Sigma(x*x) - (\Sigma x)*(\Sigma x)]*[n\Sigma(y*y) - (\Sigma y)*(\Sigma y)]}} \quad 4.$$

r ranges from -1 to 1. R-square 2), (R2) or the square of the correlation coefficient, is a fraction between 0.0 and 1.0. Results of regression and inflow variations are shown in Table 1 and Fig.2 respectively.

Table 1: Results of Regression statistics

Variable	Regression Equation	Sample correlation	R-square	Whether Statistical significance
Reservoir Inflow	y = 350.14x - 693410	0.19233	R^2 = 0.0443	NO

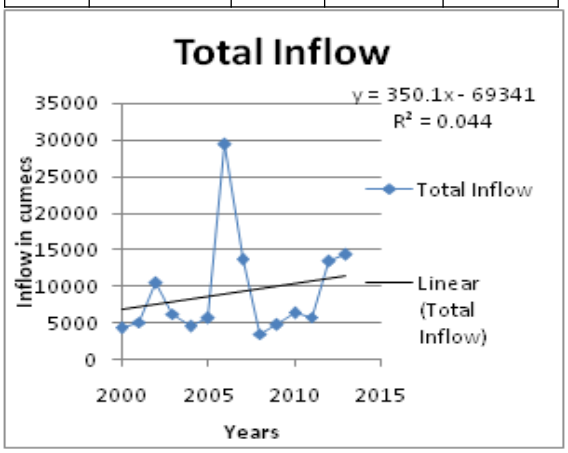


Fig. 3.Reservoir Inflow variation with time

The statistical analysis of regression values shows that R-square, sample correlation and P-values are statistical in significant. However the formed trend line shows increasing trend.

3.2.2 Mann-Kendall statistics

Mann-Kendall trend test is widely used method in trend analysis. Mann originally derived the test and Kendall (1975) subsequently derived the test statistic commonly known as the Kendall's Tau statistic (Paulin and Xiaogang, 2005). The Mann-Kendall (MK) test is popularly used to identify the trends in climatological time series (Zhang et al. 2001). Kendall (1965) gave multivariate analysis for trend recognition.The Mann-Kendall statistic (S) is given by

$$S = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sign\,(Tj - Ti) \quad 5.$$

$$sign\,(T) = \begin{cases} 1\ for\ Tj > Ti \\ 0\ for\ Tj = Ti \\ -1\ for\ Tj < Ti \end{cases} \quad 6.$$

The time series consist of n data points and and are two sub-sets of data where $i = 1, 2, 3, \ldots, n-1$ and $j = i+1, i+2, i+3, \ldots, n$. Each data point Ti is used as a reference point and is compared with all the Ti data points as given in eqns. (5) and (6). A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. Prashanth (2005) estimated the variance of S as in eqn. 7.

$$\sigma^2 = \frac{1}{18}[n(n-1)(2n+5) - \sum_{p=1}^{g}(tp-1)(2tp+5)] \quad 7.$$

In the above equation, n stands for number of data points, g is the number of tied groups (a tied group is a set of sample data having the same value), and tp is the number of data points in the pth group. The normalized test statistic Zs can be estimated using eqn. 8 as follows:

$$Zs = \begin{cases} \frac{S-1}{\sigma} & for\ S > 0 \\ 0 & for\ S = 0 \\ \frac{S+1}{\sigma} & for\ S < 0 \end{cases} \quad 8.$$

The test statistic Zs is used as a measure of significance of trend. McBean and Motiee (2008) also indicated that the existence of positive autocorrelation in the data. A tau test is a non-parametric hypothesis test for statistical dependence based on the tau coefficient. Kandall's tau correlation coefficient (τ) is given by,

$$\tau = \frac{S}{n(n+1)/2} \quad 9.$$

Equations 5, 6, 7, 8 and 9were adopted for analysis and results of the test are summarized in the Table 2.

Table 2. Mann-Kendall Trend Analysis Results for Annual Inflows

Parameter	Kendall's S	Kendall's τ	Mann-Kendall test Zs value	Nature of trend	Identified trend (95% confidence level)	Statistically significant
Reservoir Inflow	16	0.2051	0.915	Positive	No trend	No

3.2.1 Sen's Slope estimator

Sen's estimator has been widely used for determining the magnitude of trend in hydro-meteorological time series. In this method, the slopes (Ti) of all data pairs are first calculated by

$$T_i = (X_j - X_k)/(j-k)\ i=1,2,3\ldots.\ N \quad 10.$$

Where Xjand Xk are data values at time j and k (j > k) respectively. The median of N values of Ti is Sen's estimator of slope which is calculated as

$$\beta = \begin{cases} T\frac{N+1}{2} & N\ is\ odd \\ \frac{1}{2}\left(T\frac{N}{2} + \frac{N+2}{2}\right) & N\ is\ even \end{cases} \quad 11.$$

A positive value of β indicates an upward (increasing) trend and a negative value indicates a downward (decreasing) trend in the time series.

At first C∝is computed by following equation

$$C\propto = Zs - \propto/2*((VAR\ (S))1/2 \quad 12.$$

Where VAR (S) has been defined above in Man-Kendall's test

Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X

and Zs - /2is obtained from the standard normal distribution. Next M1= (N- C)/2 and M2 = (N+ C)/2 are computed. Lower and Upper limits of the confidence intervals Tmax.andTmin. are the Mth largest and M2 +1)thlargest of the N ordered slope estimate Ti. Sen's method is not affected greatly by gross data errors or outliers and it can becomputed when data are missing.

Table 3 summarises the analysis carried out for Estimated Sen's slope test.
Table 3: Estimated Sen's Slope value

Sr. No.	Parameters Name Sen's slope/ statistic	Value Number	Value
1	Minimum	1st	3568.363
2	Maximum	14th	23091.052
3	Mean	-	8921.04
4	Standard Deviation	-	5389.39
5	Sen' slope (Median)	39.5th	291.78
6	Lower limit (Sen's slope estimator)	26.95th	-192.293
7	Upper Limit (Sen's slope estimator)	53.475th	1019.532
8	Kendall's Tau	-	0.2051

4. Inflow-Outflow Analysis during occurrence of peak flood

4.1 Peak Inflow and Outflow at Ukai dam

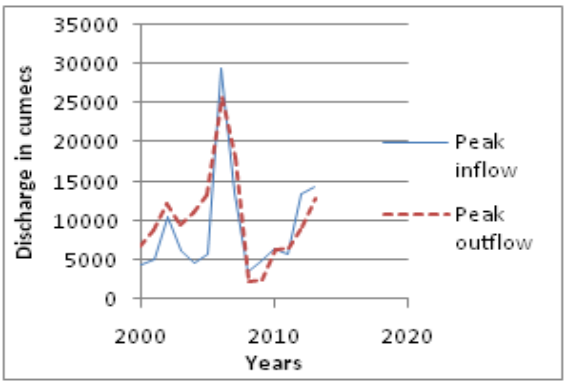
Ukai dam experiences high inflow results in high release of runoff downstream which further results in flooding conditions. The carrying capacity of Tapi river, downstream to Ukai dam is 8490 cumecs (3,00,000 cusecs) as per CWC survey. The scenario of Inflows and outflows occurred during past 14 years at Ukai dam is as given below in Table 4.

Table 4. Peak Inflow-Outflow at Ukai dam

year	Peak inflow (cumecs)	Peak outflow (cumecs)	year	Peak inflow (cumecs)	Peak outflow (cumecs)
2000	4361.11	6739.35	2007	13722.11	18023.59
2001	5121.25	8749.82	2008	3560.21	2292.30
2002	10486.51	12232.76	2009	4748.39	2433.80
2003	6245.12	9405.10	2010	6345.51	6238.37
2004	4561.89	11015.15	2011	5777.25	6547.86
2005	5747.38	13252.16	2012	13476.58	9194.95
2006	29397.59	25724.70	2013	14391.00	12920.05

4.2 Analysis of Inflow and Outflow and variation in Released water

There should be a strong co-relation between inflow and outflow, analysis shows the co-efficient of correction about 0.7311. It means that the correlation is weaker but not bad during peak inflow or release



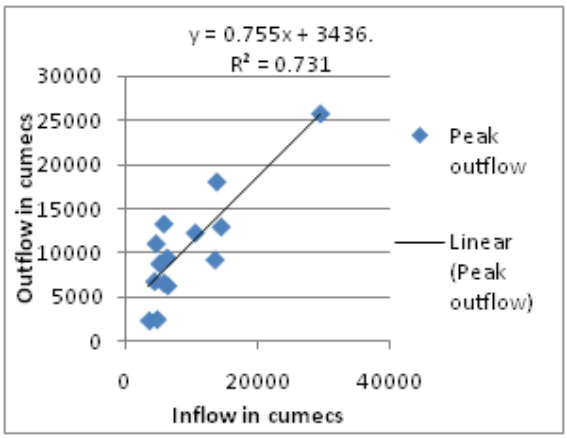


Fig. 4. Peak Inflow and Peak Outflow Comparison for Ukai reservoir

4.3 Probability of occurrence and Return period analysis

Gumbul's distribution method using Weibull's method were adopted for analysis of 14 years Ukai reservoir's peak for finding out the high flood return periods. The probability of occurrence of the peak flood, 3560 cumecs (year 2008) is 93.33 %. Whereas the probability of occurrence of flood, 14391 cumecs (year 2013) is 13.33 %. The highest observed magnitude during the 14 year study period was 29397 cumecs (year 2006) which has a probability of occurrence is 6.67 %. After Gumbel's distribution analysis, the magnitude of 25-year return period as peak flood observed was 38432 cumecs and analysed peak magnitude of flood having a 40-year return period was calculated as 43582 cumecs.

5. Discussion of Results

5.1 Regression Analysis

Regression statistics analysis is unable to give information about trend to be increasing or decreasing. The correlation coefficient equal to 0.18933 indicates a weak relationship between the variables and period as presented in Table 1.

5.2 Mann-Kendall

The value of S evaluated as positive which demonstrates an existence of a positive trend. Also the value of Zs is 0.915(less than Z0.05) which make it statistically insignificant as presented in Table 1.

5.3 Sen's Slope estimator

Interpretation has been enhanced by using Sen's slope estimator. The positive values of Kandal's Tau (τ) equal to 0.2051 shows an increasing trend of inflow in Ukai reservoir. The estimated Sen's slope value,Kandal's Tau and statistical values in the Sen's slope estimator is shown in Table 5.

5.4 Peak Inflow Outflow Assessment

The analysis carried out on the peak inflow-peak outflow shows that the magnitude of flood to be saturated or stored in the Ukai reservoir depends upon the rule level and storage availability. The Inflows occurring in late monsoon season

Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X

results in high releases. The analysis shows that that there is 35 % probability that inflow at any time during monsoon having magnitude 8490 cumecs (3,00,000 cusecs) have possibility to cross the downstream carrying capacity of the river. Releases greater than this magnitude may cause downstream flooding situations.

5. CONCLUSION

An attempt has been made to study effect of climate change on reservoir inflow using trend analysis for Ukai reservoir. The trend analysis is done using regression statistics method, Man-Kandall's test and Sen's slope estimator. The study indicates an increasing trend in the inflows to theUkaireservoir. There were some notable changes in the hydro meteorological variables at Ukai dam/reservoir.

The analysis of peak Inflow-peak outflow shows that the reservoir inflow's magnitude is itself responsible for the downstream flooding at Surat city during late monsoon month (September). The inflow greater than 8490 cumecs at a reservoir level higher than rule level may result in corresponding high discharge (outflow) which may also be more than the normal carrying capacity of Tapi river at downstream.

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