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DECLINING TREND OF WATER INFLOW IN THE DAMS OF RAJASTHAN STATE

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ABSTRACT
Rajasthan is a semi arid state with the highest of the geographical area (343,000.00 square km) of the Indian subcontinent. Annual rainfall variation is very high over the state ranging from 100 mm to 1000 mm from west to south/east. Matter of water resources planning is of prime importance for the state. There are 237 blocks, out of which 200 blocks are declared as dark zone due to over exploitation of ground water. In these circumstances, it becomes necessary to plan the storage and uses of surface as well as subsurface water (conjunctive use) with maintaining the ecological sustainability. Surface water reservoirs are becoming dry year after year. It was observed from the annual storage data of the dams that water inflow is declining year after year due to various reasons like changes in land use and land pattern, change in hydro geological conditions, changes in environmental factors e.g. temporal and spatial distribution of rainfall, indiscriminate infrastructural development. Due to less water inflow in the dams and increase in the number of dark zone blocks, state is facing the water stress problem. With the increasing population, it will become more severe with the passage of time. Therefore, an effort is being made through this research to test the hypothesis whether there is an appreciable change in water inflow in the dams of Rajasthan state. A total of 115 nos of major & medium dams in the state have been selected by cluster sampling to test the hypothesis. Chi Square test has been conducted for testing the hypothesis and found that there is declining trend of water inflow in the dams and dependabilities of the river basins have been reduced.
Keywords: Chi square test; Dams; Declining trend; Dependability; Inflow

1. INTRODUCTION
Water stress or water scarcity is a burning problem being faced by the present world. It is threat for mankind but a bigger threat for the speechless creatures (biodiversity i.e. animals and vegetations). We have to deal with water storage, minimum d/s water flow, and water demand. All three factors are dependent on precipitation, which is not under our control. We have to manage decreasing water resources & increasing demand along with maintaining the ecological sustainability (Saito et al., 2012; Jain et al., 2008). Assessment of the dependable inflow in existing dams is the first and primary step in the field of water management (Garg, 1984; Shah & Kumar, 2008). To test the actual inflow whether it is dependable or not, a null hypothesis has been generated: "There is no change in the water inflow pattern in the dams of Rajasthan state, i.e. there is no change in design dependability". The hypothesis is tested and found that there is a change in the design dependabilities.

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No scientific research has been undertaken to investigate these issues & to develop strategies particularly in semi-arid areas, and almost no information exists in Rajasthan. On the basis of statistical computations and applying chi square test it has been derived that null hypothesis should be rejected. Further health status of the dams is also tested with respect to desired theoretical inflow. This analysis has been conducted for the dams, selected by area sampling, situated in Tonk district of Rajasthan state.

2. METHODOLOGY

2.1. Study Area

Latitude: 2303’00’’ to 30012’0” N Average altitude: 312m ASL
Longitude: 69030’0” to 78017’0” E Total River Basins: 15

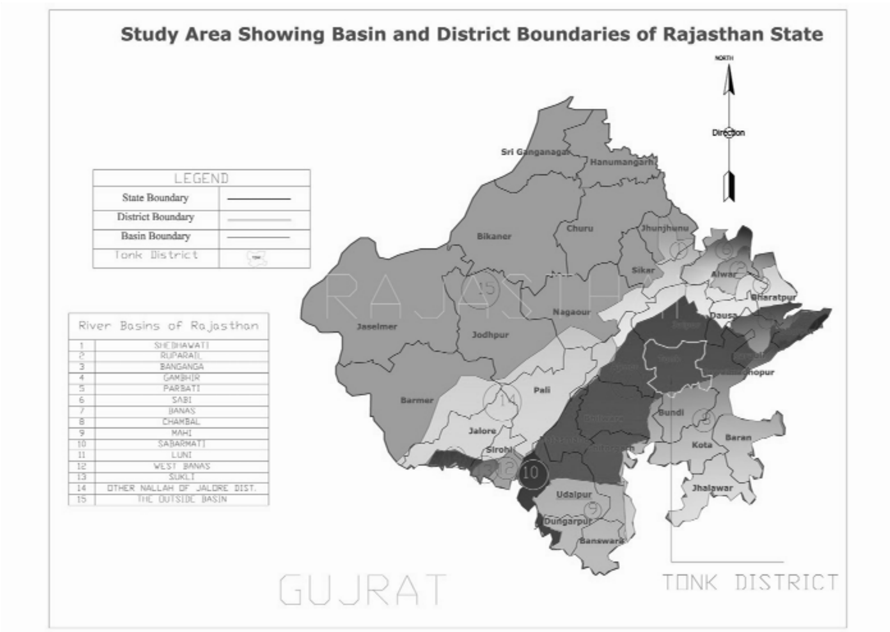

Figure 1 Study area

Whole of the state is covered in this research for cluster sampling (Major-Medium dams of the state) and further Tonk District is selected for area sampling. The research methodology is a scientific step by step procedure to conduct the study and arrive at a conclusion to accept or reject the hypothesis. Following research methodology has been adopted to conduct the proposed research (Figure 2).

2.2. Size of Datasets

Precise and correct data collection and its sampling are of utmost importance in any study because the inference is drawn on the basis of results obtained from the available data. For a correct and precise analysis, data should be correct, precise, coherent and consistent. Following procedure is adopted to collect the desired and relevant data:

Primary Data: Primary data has been collected through personal interview & questionnaire about the causes of decreasing inflow of water in the dams.

Secondary Data: Rainfall-Runoff-Water inflow data have been collected from the Water Resources Department. Maximum available water inflow data of last 30 years for 115 nos. selected dams (Major and Medium dams i.e. cluster sampling) of the state has been collected

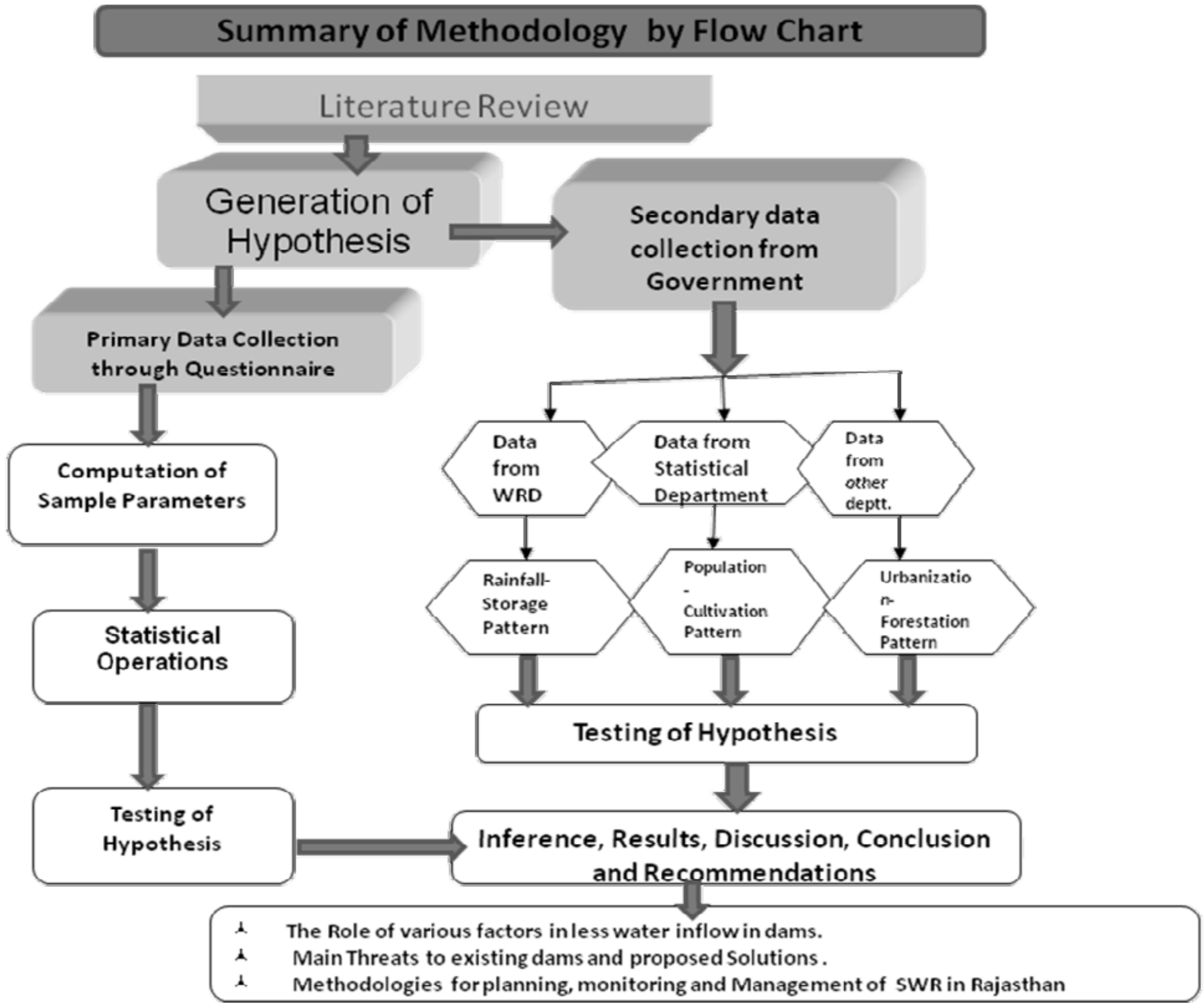

Figure 2 Research methodology

Sampling: Since water resources planning is mainly dependent on Medium and Major Dams. Therefore cluster sampling technique has been adopted. However to incorporate the effect on Minor dams a second analysis on the basis of area sampling has also been done.

Scaling: For presenting actual dependabilities of the basins, Ordinal and Interval scaling has been done. Health status of the dams of Tonk district has been awarded on the basis of Interval scale.

There are fifteen river basins in the state. There are numerous water bodies in the state. Basin wise total inventory of dams of the state is shown in (Table 1).

Total nos. of water bodies in the Rajasthan State:	72569
Small+ Minor+ Medium+ Major Dams:	3302
Minor+ Medium+ Major Dams:	693
Medium+ Major Dams	115
Major Dams:	22

Table 1 Details of Basing wise Dams in Rajasthan

S.N.	Name of Basin	Total No. of Dams	Live Storage in MCM	CCA in Ha
1.	Shekhawati	63	89.72	16228.04
2.	Ruparail	54	101.64	35097.40
3.	Banganga	196	412.26	67186.63
4.	Gambhir	98	231.56	40587.40
5.	Parwati	17	157.28	31463.10
6.	Sabi	67	107.65	19821.35
7.	Banas	1314	3639.74	742656.01
8.	Chambal	250	2906.77	1053413.64
9.	Mahi	244	2726.58	241692.42
10.	Sabarmati	54	200.085	13979.00
11.	Luni	904	1136.65	210200.24
12.	West Banas	19	79.00	14937.00
13.	Sukli	8	44.29	11194.00
14.	Other Nala	0	0.00	0.00
15.	Out side	14	9.00	1902.71
	Total	3302	11842.24	2500358.94

Water resources planning is mainly dependent on Minor, Medium and Major Dams, Therefore threats of less water inflow for these dams is being studied in this research. For the purpose of this study we are considering 3302 notified dams. Accordingly basin wise analysis, as basin being a hydraulic boundary, is undertaken in the study.

2.3. Computation Methodology

Theoretical inflow: Thiessen Polygon (Figure 3) method can be adopted to arrive at weighted rainfall (Punmia & Jain, 2010). Theoretical inflow has been computed using 30 years rainfall data affecting the inflow in the respective dam. Computation of actual inflow has been done on the basis of Strange's Table.

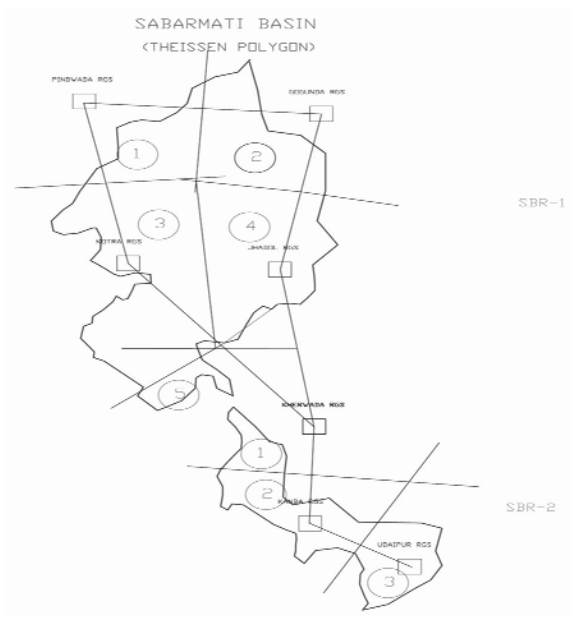

Figure 3 Thiessen polygon

Actual Inflow: Data of actual inflow in the dams has been collected form Water Resources Department of Government of Rajasthan. On this basis of these actual inflow values, Observed Dependabilities have been computed.

Expected Dependability: According to the decision taken by the State Government, expected dependabilities have been adopted as 50% for the hydrological design of the dams. Accordingly storage of the dams has been fixed.

Actual Dependability: Actual dependability of each dam has been computed using actual inflow data. Number of years in which actual inflows exceeds the design inflow shows the actual dependability, which has been computed by following formula.

$$\text{Actual Dependability} = \frac{m}{n+1} \times 100\% \quad (1)$$

Null Hypothesis H_0: There is no change in the expected dependability.

2.4. Analyzing and Processing Data

A performance test has been conducted on the dams of Tonk district considering the year wise inflow in the dams (Table 2).

Criteria to award health status to the dams:

When actual inflow as % of design capacity ≥ 100%	Safe:	2 dams
When actual inflow as % of design capacity = 75%–100%	Semi Critical:	14 dams
When actual inflow as % of design capacity = 50%–75%	Critical:	6 dams
When actual inflow as % of design capacity < 50%	Hyper Critical:	9 dams

Above analysis shows that only 2 dams are getting equal or more inflow then design capacity and remaining dams are in declining trend as far as water inflow is concerned.

For 31 numbers of major, medium & minor dams, we have observed (actual) values and expected (theoretical/design) values of water inflow, therefore Chi-Square test has been applied to draw the inference about the null hypothesis (Table 3).

Table 3 Chi Square test

S.N.	Name of Basin	Capacity of the Basin (MCM)	E_i %	O_i % (A)	O_i % (B)	Chi^2 (A)	Chi^2 (B)
1.	Banas	2243	11.94	6.25	4.16	2.71	5.08
2.	Shekhawati	9	0.05	0.00	0.00	0.04	0.05
3.	Ruparail	27	0.14	0.01	0.00	0.12	0.14
4.	Banganga	148	0.79	0.12	0.00	0.57	0.79
5.	Gambhir	147	0.78	0.21	0.05	0.42	0.69
6.	Parbati	16	0.08	0.02	0.00	0.05	0.08
7.	Sabi	24	0.13	0.00	0.00	0.13	0.13
8.	Chambal	3414	18.17	10.91	9.77	2.91	3.89
9.	Mahi	2791	14.86	14.42	9.30	0.01	2.08
10.	Luni	533	2.84	1.27	0.67	0.86	1.65
11.	West Banas	39	0.21	0.14	0.08	0.02	0.08
	Total	9391	50.00	33.36	24.02	7.84	14.66

Table 2 Abstract of Dam Wise Performance of Tonk District of Rajasthan state

S.N.	Name of Dam	Type of Dam	Design Parameters Capacity (MCM)	Mean Rain fall (mm)	Actual Inflow	Actual Mean Rain fall (mm)	Actual inflow as % of design capacity col 10/4	Health Status of Dam
1	2	3	4	5	10	14	16	17
1.	Bisalpur	Major	938.8	588	726	520	77.34%	Semi Critical
2.	Galwa	Major	48.7	724	33	507	67.40%	Critical
3.	Tordi Sagar	Major	47.1	686	10	403	21.45%	Hyper Critical
4.	Mashi	Medium	48.1	483	23	461	46.91%	Hyper Critical
5.	Chandsen	Medium	14.7	569	4	371	24.57%	Hyper Critical
6.	Moti Sagar	Medium	12.9	635	11	453	85.60%	Semi Critical
7.	Dakhiya	Minor	8.6	584	4	453	40.92%	Hyper Critical
8.	Kirawal S.	Minor	6.5	569	2	371	32.43%	Hyper Critical
9.	Shahodra	Minor	6.5	569	5	460	83.04%	Semi Critical
10.	Shyodan P.	Minor	6.3	864	5	466	77.48%	Semi Critical
11.	Chandlai	Minor	4.5	610	3	594	56.25%	Critical
12.	Doulat Sagar	Minor	4.5	559	2	499	47.80%	Hyper Critical
13.	Bidoli	Minor	4.1	635	4	565	89.62%	Semi Critical
14.	Panwad Sagar	Minor	4.1	584	3	368	62.76%	Critical
15.	Thanwla	Minor	3.4	584	2	367	56.55%	Critical
16.	Ghareda Sagar	Minor	2.9	508	2	641	82.51%	Semi Critical
17.	Ramsagar L.H.	Minor	2.9	569	2	331	72.28%	Critical
18.	Soonthra	Minor	2.8	711	2	514	81.63%	Semi Critical
19.	Kumhariya	Minor	2.7	304*	3	304	93.68%	Semi Critical
20.	Ramsagar G.	Minor	2.5	508	1	331	20.69%	Hyper Critical
21.	Halolaw K.	Minor	2.1	508	2	403	100.00%	**Safe**
22.	Matholao	Minor	2.0	719	0	565	16.05%	Hyper Critical
23.	Mohamad garh	Minor	2.0	940	2	514	95.65%	Semi Critical
24.	Dhibru Sagar	Minor	1.8	660	2	403	85.47%	Semi Critical
25.	Bhanpura	Minor	1.8	514*	2	514	87.90%	Semi Critical
26.	Bhavalpur K.	Minor	1.7	402.8*	2	403	88.53%	Semi Critical
27.	Mansagar A.	Minor	1.6	584	2	367	100.00%	**Safe**
28.	Nasirda	Minor	1.6	584	1	367	84.57%	Semi Critical
29.	Duni Sagar	Minor	1.4	584	1	576	46.00%	Hyper Critical
30.	Sangrampur a N.	Minor	1.4	584	1	368	56.46%	Critical
31.	Dudi Sagar	Minor	0.4	711	0	514	78.00%	Semi Critical

3. RESULTS AND DISCUSSION

From the Table 2, it can be inferred that only 2 dams are in a safe state while most of the dams are in a critical state. Dependability for design capacity has been reduced or we can say that water inflow for the design dependability has been reduced.

Chi Square value for 11 numbers of basin i.e. n=10 (11-1) Degree of Freedom at the 5% level of significance is 3.94. Computed values 7.84 and 14.66 are more than the specified value, therefore the hypothesis is rejected i.e. Expected dependability has been reduced.

Observed weighted dependability of the state is showing a declining trend during last 10 years (A=last 10 years of data range).

The dams in the Rajasthan state are receiving less water than their theoretical yield/designed capacity (Figures 4&5). The probable reasons are to be explored and their effect is to be quantified, that have changed the hydrological characteristics like less water inflow.

Figure 4 Bisalpur Dam: life line of Jaipur (Capital of the State), Ajmer and Tonk District is suffering from less water inflow

Figure 5 Bhakhra Dam water level dangerously low; worry for three states

Water inflow in the dams is declining year after year (Rajasthan High Court, 2004). The reason of which may be change in rainfall pattern or change in catchment characteristics (Hassanzadeh et al., 2012; Iglesias et al., 2007; Yıldırım et al., 2011; Risbey et al., 2007). The outcome of this study shows that water inflow in the dams of Rajasthan state is not as per expected inflow. Results of this study shows that there is an urgent need of proper planning and management of available but reducing quantum of water.

4. CONCLUSION

From the study, it is tested hypothesis that dams in the Rajasthan state are not getting water as per their designed dependabilities. Conditions aggravate more when we observe that dams are even not receiving water as per their theoretical yield. The regular phenomenon of decreased water inflow in the dams has resulted in disruption of water resources planning of the state. Non-receipt of computed water, results in failure of water management plan of the state leading to formation & execution of contingency plan on war footing every year.

Probable factors responsible are may be: Regular increase in population has resulted in an increase in agricultural activities, more interception through increased local Water Harvesting Structures, industrial & residential expansion, surface and subsurface exploitation, and above all climate change & spatial-temporal distribution of rainfall. All these reasons are more or less related to the bursting population in the country, which compel to change the land use pattern. A suitable relationship may be established to assess the impact of these factors

5. ACKNOWLEDGEMENT

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6. NOTATION

ASL : Above Sea Level
MCM : Million Cubic Meters
m : Number of years when water inflow is more than the design/required capacity.
n : Total number of observation.
D_n : Dependability
A : 20 years data range (1990-2009)
B : 10 years data range (2000-2009)
O_i : Observed weighted dependability
E_i : Expected weighted dependability
$Chi^2 = (O_i-E_i)^2/E_i$

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