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EVALUATION OF SOURCE POTENTIAL BY SIMULATION METHODOLOGY

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SYNOPSIS

A classical approach in evaluating potential of a proposed river basin impoundage mainly consists of a statistical analysis of the precipitation data, leading to a quantum of runoff of the desired reliability. Over the years the role of carryovers in raising the potential was recognised and recent works evolved a method of optimising the quantum of carryovers by using a technique of simulating the operations of the impoundage, on the basis of historical data of rainfall and runoff.

The impoundage that serves as a source for a water supply system is required to ensure a certain daily supply throughout the year and as such evaluation of the potential of such impoundage has to take into account annual variations in the precipitations, durations of dry days, monsoon days and their sequences. "Synthetic Drought Analysis" (SDA) was developed in 1972 as a technique to cater to these peculiar requirements of Water Supply sources. However the author claims that 'SDA' provides for extreme conditions and thus leads to an under utilisation of the source.

Author presents a case study of the proposed Middle Vaitarna Scheme (MVS) wherein he compares the results of 'SDA' and of his own approach based on simulation of operations of the source using historical data of precipitation, duration of dry days, duration of monsoon days and their sequences.

1.0 INTRODUCTION

1.1 River Valley projects generally aim at storing runoff from the catchment to meet the requirements of water for irrigation, power generation or water supply demands of a community. More often these projects are planned as multipurpose projects. Depending upon the needs, the planners either optimise the storage to meet a definite requirement of water or maximise the potential of the available storage to meet various requirements to the maximum possible extent.

1.2 The variations in precipitaion over years enforce considerable variations in the potential of the storage to meet the water demands and hence reliability analyses are invariably carried out to determine various potentials and their respective reliabilities. Since water supply to a community is a high priority item, the potentials for this purpose are determined at 95% reliability level whereas potentials for other uses of comparatively lesser priorities are calculated at 75% reliability levels.

2.0 CARRYOVER ANALYSIS

2.1 95% reliability value of the precipitation and the quantum of runoff determined therefrom indicates that only 5% of the years or one in 20 years, the planned quantum of water will not be available and it also indicates that in the rest of the years the quantum of run-off will be larger than planned. With a view therefore to make use of the extra quantum of water available in good years, to meet the deficiencies in drought year, the storages are provided with carryover capacities. Recently carryover capacities were optimized by simulation of the operations of the proposed storage by using the historical data of precipitation and runoff values.

3.0 PARAMETERS AFFECTING SOURCE POTENTIAL OF WATER SUPPLY SYSTEM

3.1 A water supply system draws a fixed quantity of water every day. In regions where the precipitation is limited to a small portion of the year, the rate of withdrawal is governed by the total available storage at the end of the monsoon period and more importantly on the length of the following dry season. The lengths of dry seasons and monsoon seasons vary considerably and as such reliability analysis of a water supply source is required to take into account variations in precipitation (runoff), variations in durations of dry days and the durations of monsoon days.

3.2 Municipal Corporation of Greater Bombay (MCGB) was faced with a problem in 1970s of evaluating the reliabilities of their existing sources. M/s. Binnie and Partners (B & P), a consulting firm from UK, addressed themselves to this task and came up with a technique titled "Synthetic Drought Analysis" (SDA). [1]

4.0 "SYNTHETIC DROUGHT ANALYSIS"

Bombay's Water Supply Sources

4.1 The city of Bombay draws its water supply from seven sources, of which 5 are impoundages and two are river sources. The three large impoundages-namely lower Vaitarna, Upper Vaitarna and Tansa are clustered on the mainland on North North-East of the city (Refer to Figure 1). Tansa source was developed and commissioned in the year 1892 and has been in continuous use since then. The data such as rain fall and lake levels is recorded there every day since 1892. This data is reliable and is hydrologically representative of the region. This data was used by B & P for "SDA" and by the author for his work.

Durations of Dry Days (D) and Monsoon Days (M)

4.2 The rainfall in this region is restricted to a period of about 4 months viz. June-September every year. The storages generally start receiving the run-offs from 3rd week of June and the lake levels start rising, whereas the lake levels start falling by end of September. However there are considerable variations in these dates.

4.3 The start of the dry days period was defined as that day from which the lake level starts falling continuously and the end of the dry period was defined as the day from which the lake level starts rising continuously. These definitions automatically define the start of the monsoon days as the end of the dry days and vice versa. The Tansa data was used to determine the durations of dry periods (D) in days and the durations of monsoon periods (M) in days for each year since 1892. This basic data was statistically analysed to establish the following values:

(a)	Value of a single dry period which is not likely to be exceeded in 95% of the years (D)	287 days
(b)	Value of a single monsoon period which is likely to be the least in 95% of the years (M)	75 days
(c)	Value of the total of two consecutive monsoon periods which is likely to be the least in 95% of such combinations (MM)	170 days
(d)	Value of the combination of consecutive Dry-Monsoon-Dry Period which is not likely to be exceeded in 95% of the years (DMD)	658 days
(e)	Value of the combination of consecutive Dry-Monsoon-Dry-Monsoon-Dry periods which is not likely to be exceeded in 95% of the years (DMDMD)	1040 days

The values of precipitation (runoff) of 95% reliability were calculated for single M and the combinations of two consecutive Ms and these values were assumed to be representative of precipitation and runoffs during the above mentioned 'M' and 'MM' values.

4.4 Subsequently 'DMD' value was used to determine the value of second 'D' by assuming the first 'D' to be single 'D' and the following 'M' to be single 'M'. Similarly 'MM' value was used to determine the value of second 'M' by assuming the first 'M' to be single 'M'. The value of the third `D' in `DMDMD' was determined by assuming `DMD' to be same as `DMD' calculated earlier and the second `M' in `DMDMD' to be second `M' value as determined from `MM' value. Thus individual values of `D's & `M's in DMD and `DMDMD' were established. These values are presented in the table below.

Table-1
Individual Season Lengths

Dry Season (days)	Monsoon Season (days)	Length in days at the required reliability (days)	Combined drought periods at required reliability Combinations	Periods (days)
D1		287		
	M1	75		
D2		296	DMD	658
	M2	95		
D3		287	DMDMD	1040
.	.	.		
.	.	.		
.	.	.		

Hypothetical Drought Conditions

4.5 Assuming the impoundage to be full at the start of the first dry period, mass curve of inputs was developed to represent D, DMD & DMDMD situations and the uniform rates of withdrawals over the periods were worked out after accounting for the losses due to seepage and evaporation. This exercise was run for `D', `DMD' and `DMDMD' values. The least of the uniform permissible withdrawal values during hypothetical consecutive one, two & three drought years sandwiching one & two consecutive years of scanty rainfall was recommended as the 95% reliable value of the daily withdrawal from the impoundage.

Validation of SDA' findings.

4.6 These exercises indicated the 95% reliable value of average daily withdrawal, for the then existing impoundages in Vaitarna River Basin. However, ever increasing demand of the city had necessitated MCGB to overdraw all the lakes and even then the experience of the last 15 years has shown that there was no crisis. As a matter of fact no conditions anywhere near the synthesised droughts were experienced in the last 15 years.

5.0 MIDDLE VAITARNA SCHEME (MVS) - A CASE STUDY

5.1 Bombay City's ever increasing water demand has kept the Water Supply Project Department continuously busy in executing augmentation schemes and simultaneously in planning for the new sources. Currently a project named "Bombay-III" is under execution and it will be completed and commissioned by 1994. However even then the demands will not be met and as such work is underway to prepare a scheme that will have to be taken up even before 1994.

5.2 Vaitarna River has already been harnessed by providing two impoundages namely Lower Vaitarna commissioned in 1957 and Upper Vaitarna commissioned in 1972. Upper Vaitarna impoundage has a considerable carry over capacity which was required to be drawn upon on some occasions to maintain the designed daily releases. However, the observations at the Lower Vaitarna showed that even after 1972 considerable water overflowed every year, thus leading to the conclusion that the river has still some spare potential and therefore our present efforts are aimed at evaluating the maximum spare potential, with a view to take up this source for development of the next scheme.

5.3 Figure 1 referred earlier shows the locations of the existing impoundages and the proposed impoundage for Middle Vaitarna Scheme (MVS). The topographical survey has been completed and the geotechnical survey is underway at the proposed site. The lake spread of the lower Vaitarna, topographical survey of the area, the location and the elevation of the tail race water channel of the power house at Upper Vaitarna and feasibility of using the proposed impoundage for power generation in future, have determined the site of the new dam, the Full Reservoir Level (FRL) and the maximum quantum of storage. The maximum storage capacity of the impoundage is 192.5 Mm3 at the FRL. Anticipated operation of the three impoundages is shown in Figure 2.

6.0 OBJECTIVE OF THE STUDY

6.1 Given the data of precipitation & runoff values based on rainfall records and similar runoff evaluations made in the region and also given the data concerning various durations of dry days & monsoon days for each year since 1892 and their sequences as generated from Tansa Lake records, the objective of the study is to evaluate the value of daily withdrawal which is likely to be the least in 95% of the years, from the proposed Middle Vaitarna storage designed to store 192.5 Mm3 at the FRL.

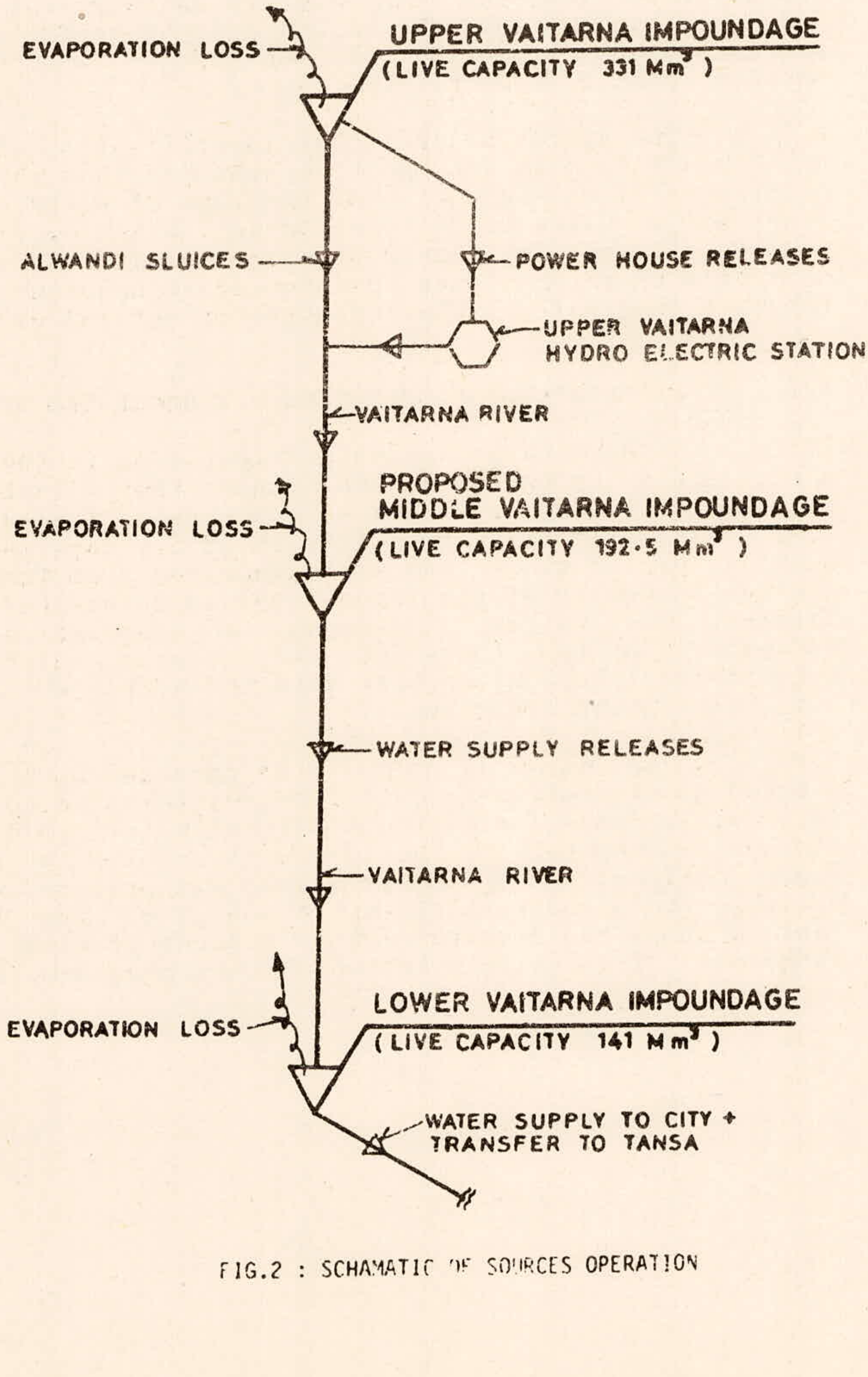

FIG.2 : SCHAMATIC OF SOURCES OPERATION

7.0 CRITICAL EXAMINATION OF SDA APPROACH

7.1 The D' and 'M' values have been derived from single values of dry days & monsoon day periods and though their individual occurrence is acceptable, their occurrence in succession & their use in working out values of second 'D' in 'DMD' is not acceptable. Similarly evaluation of second 'M' from 'MM' is also ambiguous for the same reason. There is no reason to believe that 95% reliable 'M' and 'MM' values will necessarily represent 95% precipitations (runoffs) of one monsoon and two consecutive monsoon seasons respectively.

7.2 The author believe that identification of extreme values of 'D' & 'M' and an attempt to synthesise them into a sequence of occurrence for evaluation of the rate of withdrawal will give rise to a value of daily withdrawal which will have a much smaller probability than 0.05 which is aimed at . This approach obviously therefore leads to unnecessary under-utilisation of the source & thus defeats the objective of optimal use of source.

8.0 SIMULATION OF OPERATION - A SUGGESTED APPROACH

8.1 The data regarding precipitation in the catchment of the proposed impoundage and the runoff that will be generated by various precipitation values were generated for every year since 1892. Similarly the dates of start of dry days period & end of dry days period since 1892 were generated from Tansa records. The storage capacity of the impoundage was determined as mentioned earlier. The values of seepage & evaporation losses were estimated on the basis of the records maintained at the neighboring lakes. Given this data the author was armed to carry out a simulation exercise.

8.2 The lake will normally be operated upon by withdrawing a fixed quantum of water daily for transmission to the City. The lake will loose certain quantity of water per day by way of seepage & evaporation. The lake will receive the run off during every monsoon. A computer programme was prepared wherein it was possible to simulate these operations right from 1892 to 1987. Table 2 shows the excerpt of the computer printout. Various daily withdrawal figures were tested on this programme & the maximum withdrawal rate that brought about failures in 5% of the years was accepted as the 95% reliable value of the daily withdrawal from the lake.

8.3 Author, amongst other cases, examined the cases specifically mentioned in Table 3.

Table-3
Yields Under Different Conditions

Sr. No.	Description	Value of acceptable daily withdrawal rate at 95% reliability (in Mm3/day)
1.	Single dry season of 270 days with 95% reliable run off value for the catchment (classical approach). 95% reliable runoff = 132 Mm3	0.36
2.	Use of 'SDA' (B&P approach) (see Fig.3)	0.46
3.	Historical series of precipitations (runoffs) and lengths of dry & monsoon days seasons (Simulation Technique)	0.48
4.	Historical series of precipitation (runoffs) and lengths of dry & monsoon days seasons and by using the carry over capacity of Upper Vaitarna impoundage, if available in that particular year (Simulation Technique)	0.54

(Above cases take into account estimated annual evaporation losses etc.,)

9.0 CONCLUSIONS

(1) Impact of variations and lengths of dry seasons and monsoon seasons requires special consideration while evaluating the reliability of a source for water supply system.

(2) Use of 'SDA' leads to under-utilisation of the source.

(3) When comparatively long term data is available the simulation of the operation of the source ensures maximum utilisation of the source at the desired reliability level. This can be appreciated by a study of Figure 4.

REFERENCE

1. Middleton, R.N.; (1969), 'Bombay Water Supply - Estimation of Reservoir Yields by "Synthetic Drought" Techniques', Journal of Indian Water Works Association , Vol 1, No 1, pp 18 - 28

Table - 2

Excerpt of the Computer Print Out for withdrawal rate of 0.5 Mm^3/Day

S No.	YEAR	INITIAL STOR.	INFLOW	NO.OF MONSOON DAYS	MONSOON RELEASE	BALANCE STOR.	SPILL	NO. OF DRY DAYS	DRY REL	RES. STATUS	INDICATOR
1	1896	.0	314.9	75	37.4	192.5	85.0	292	145.7	39.4	S
2	1897	39.4	286.0	111	55.4	192.5	77.5	247	123.3	61.8	S
3	1898	61.8	203.8	117	58.4	192.5	14.7	247	123.3	61.8	S
4	1899	61.8	62.6	63	31.4	93.1	.0	324	161.7	.0	F
5	1900	.0	279.0	93	46.4	192.5	40.1	253	126.2	58.9	S
6	1901	58.9	98.4	94	46.9	110.4	.0	295	147.2	.0	F
7	1902	.0	218.0	82	40.9	175.1	.0	269	134.2	33.5	S
8	1903	33.5	217.8	107	53.4	192.5	5.4	248	123.8	61.3	S
9	1904	61.3	127.0	101	50.4	137.9	.0	284	141.7	.0	F
10	1905	.0	166.0	78	38.9	127.1	.0	270	134.7	.0	F
11	1906	.0	175.2	94	46.9	128.3	.0	274	136.7	.0	F
12	1907	.0	227.7	76	37.9	189.8	.0	290	144.7	37.6	S
13	1908	37.6	224.7	103	51.4	192.5	18.5	253	126.2	58.9	S
14	1909	58.9	255.1	112	55.9	192.5	65.6	261	130.2	54.9	S
15	1910	54.9	171.6	113	56.4	170.0	.0	244	121.8	40.9	S
16	1911	40.9	212.8	95	47.4	192.5	13.7	282	140.7	44.4	S
17	1912	44.4	307.7	83	41.4	192.5	118.2	271	135.2	49.9	S
18	1913	49.9	207.2	129	64.4	192.5	80.2	239	119.3	65.8	S
19	1914	65.8	318.1	111	55.4	192.5	136.0	269	134.2	58.9	S
20	1915	58.9	251.7	120	59.9	192.5	58.2	221	110.3	74.8	S
21	1916	74.8	325.9	156	77.8	192.5	130.4	219	109.3	75.8	S
22	1917	75.8	240.0	147	73.4	192.5	49.9	240	119.8	65.3	S
23	1918	65.3	125.5	72	35.9	154.9	.0	268	133.7	13.8	S
24	1919	13.8	283.2	128	63.9	192.5	40.6	244	121.8	63.3	S
25	1920	63.3	158.9	117	58.4	163.9	.0	267	133.2	23.2	S
26	1921	23.2	234.8	107	53.4	192.5	11.7	240	119.8	65.3	S
27	1922	65.3	218.8	115	57.4	192.5	34.2	265	132.2	52.9	S
28	1923	52.9	208.2	98	48.9	192.5	19.7	256	127.7	57.4	S
29	1924	57.4	185.5	117	58.4	184.4	.0	226	112.8	64.3	S
30	1925	64.3	163.2	108	53.9	173.5	.0	208	103.7	22.4	S
31	1926	22.4	237.7	101	50.4	192.5	17.2	251	125.2	59.9	S
32	1927	59.9	246.9	122	60.9	192.5	53.3	272	135.7	49.4	S
33	1928	49.4	234.3	72	35.9	192.5	55.2	282	140.7	44.4	S
34	1929	44.4	167.4	98	48.9	162.9	.0	255	127.2	26.2	S
35	1930	26.2	267.1	91	45.4	192.5	57.4	287	'43.2	41.9	S
36	1931	41.9	207.7	114	56.9	192.5	80.2	255	127.2	57.9	S
37	1932	57.9	251.7	73	36.4	192.5	80.7	279	139.2	45.9	S
38	1933	45.9	277.5	98	48.9	192.5	81.9	261	130.2	54.9	S
39	1934	54.9	218.7	95	47.4	192.5	33.7	270	134.7	50.4	S
40	1935	50.4	197.6	98	48.9	192.5	6.6	274	136.7	48.4	S
41	1936	48.4	195.1	100	49.9	192.5	1.1	260	129.7	55.4	S
42	1937	55.4	258.3	114	56.9	192.5	64.3	241	120.3	64.8	S
43	1938	64.8	262.9	130	64.9	192.5	70.4	258	128.7	56.4	S
44	1939	56.4	266.9	79	39.4	192.5	31.4	277	138.2	46.9	S
45	1940	46.9	275.3	127	63.4	192.5	66.3	245	122.3	62.8	S
46	1941	62.8	234.1	86	42.9	192.5	61.6	278	138.7	46.4	S
47	1942	46.4	286.9	78	38.9	192.5	101.9	274	136.7	48.4	S
48	1943	48.4	285.0	129	64.4	192.5	36.5	232	115.8	69.3	S
49	1944	69.3	302.1	89	44.4	192.5	134.5	283	141.2	43.9	S
50	1945	43.9	269.8	110	54.9	192.5	65.5	258	128.7	56.4	S
51	1946	56.4	280.6	98	48.9	192.5	95.5	281	140.2	44.9	S
52	1947	44.9	280.9	100	49.9	192.5	83.4	247	123.3	61.8	S
53	1948	61.8	189.7	111	55.4	192.5	3.6	274	136.7	48.4	S
54	1949	48.4	213.3	108	53.9	192.5	14.3	261	130.2	54.9	S
55	1950	54.9	281.4	89	44.4	192.5	99.3	281	140.2	44.9	S

Note:- Seepage and evaporation losses considered with inflow.

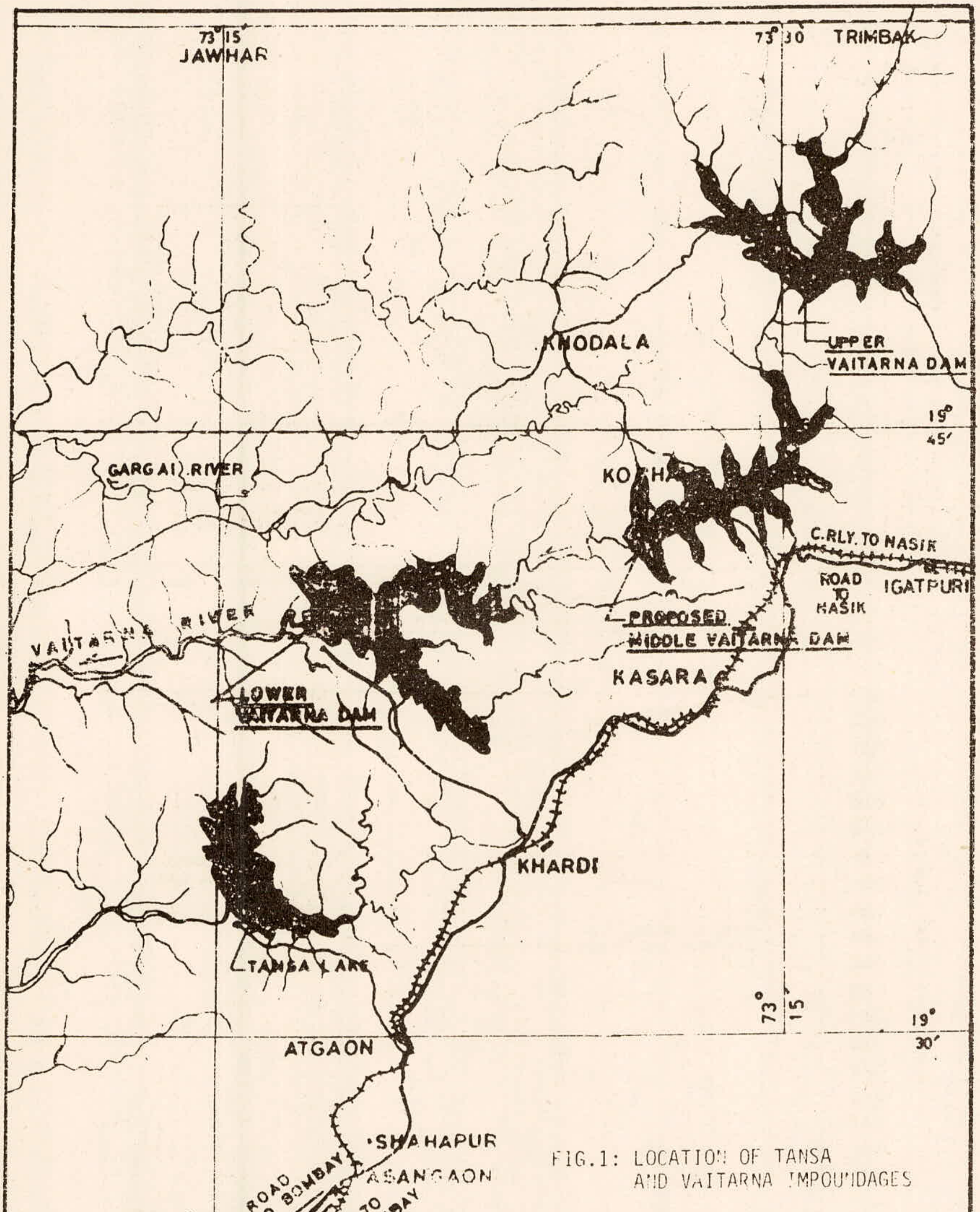

FIG.1: LOCATION OF TANSA AND VAITARNA IMPOUNDAGES

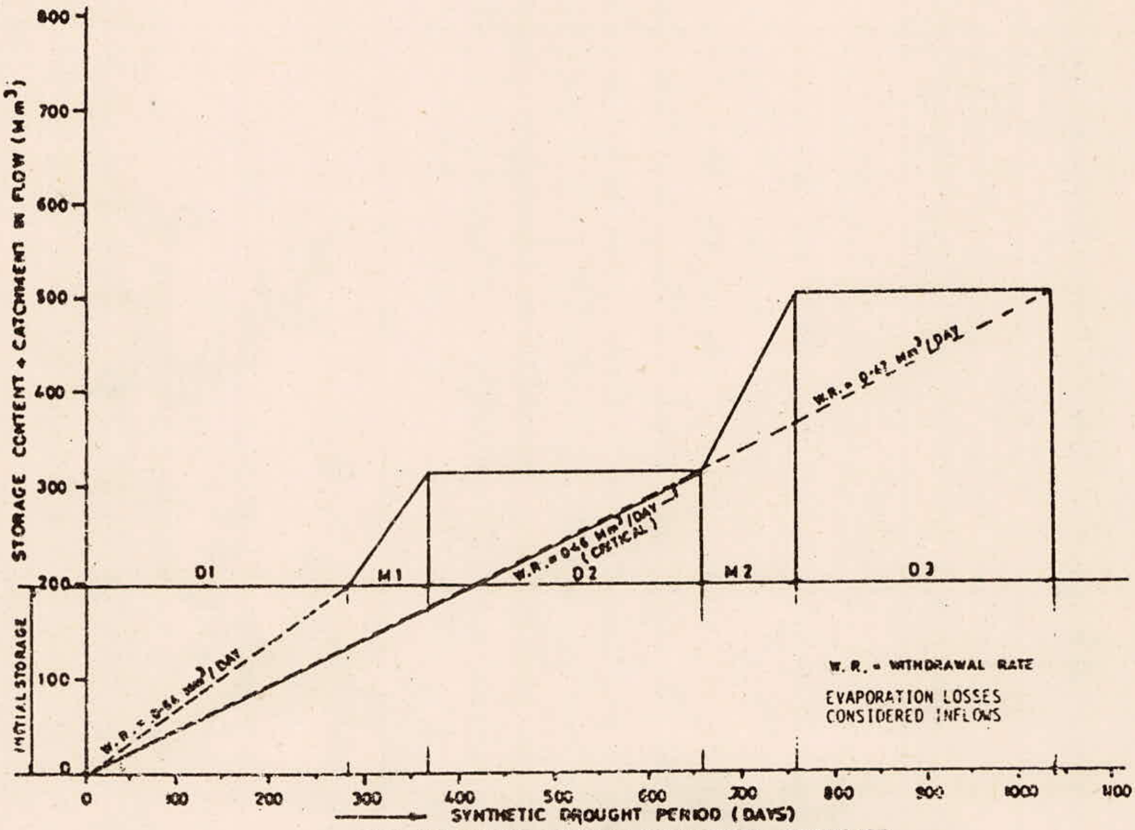

FIG-3 : YIELDS DURING SYNTHETIC DROUGHTS

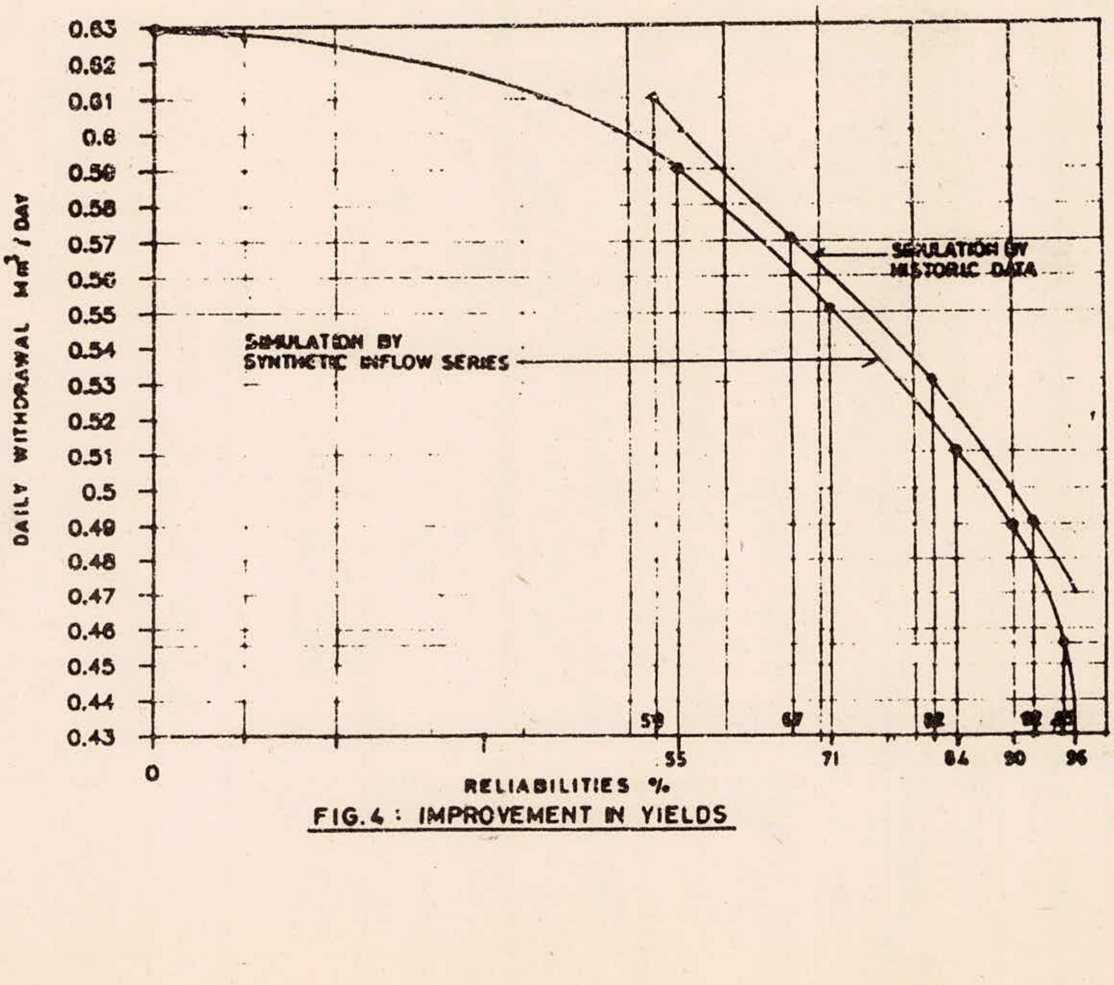

FIG.4 : IMPROVEMENT IN YIELDS