e-ISSN: 2455-5703

Flood Control by Reservoir Operation for Ukai Reservoir

[1]Mr. Kishankumar B. Kalariya [2]Dr. R. B. Khasiya [3]Dr. B. J. Batliwala [4]Dr. J. N. Patel
[1]Assistant Professor [2,3,4]Professor
[1,2,3,4]Department of Civil Engineering
[1]Pacific School of Engineering, Surat, Gujarat, India [2]LDCE, Ahmedabad, Gujarat, India [3,4]SVNIT, Surat, Gujarat, India

Abstract

Floods are common natural disaster occurring in most parts of the world. This results in damage to human life and deterioration of environment. In many parts of the Indian subcontinent, flooding reaches catastrophic proportions during monsoon season. For centuries, floods in the Ganga, the Brahmaputra, the Tapi basin and the Godavari basins have brought number of disasters to the inhabitants in the flood plains apart from inundating large tracts of fertile land. Surat city is one of the major important cities of Gujarat which is settle on Tapi River. It is observed that Surat is highly developed city with full of various activities going on day and night. Any natural calamity which causes loss of lives to property & infrastructure and serious impact on economy of the state. So it becomes highly necessary that past flood events must be studied and analyzed properly in order to propose new flood control systems as well as the storage reallocation and reservoir reoperation of existing ones. In present study "Simulation of the reservoir operation using daily available historical inflow" has been carried out and proposed the revised reservoir operation policy for Ukai dam.
Keyword- Peak Flood, Reservoir Operation, Rule Level, Simulation

I. INTRODUCTION

Floods are recurrent phenomena in India from time immemorial. Every year some or the other parts of the country are affected by floods of varying magnitude. Different regions of the country have different climates and rainfall patterns and as such it is also experienced that when part of the country is experiencing devastating floods, there is another part of the country at the same time which is in grips of severe drought. Out of the total rainfall of India, about 75% of it is received during the four moths (June to September) due to the South-West monsoon which is non-uniformly distributed in space as well. India is traversed by a large number of river systems.

However, the heavy and intense rainfall is not the only factor contributing to floods. The other causes of flood are inadequate capacity within riverbanks to contain high flows and silting of riverbeds, landslides leading to obstruction of flow and change in the river course, retardation of flow due to tidal and backwater effects, poor natural drainage, cyclones, snowmelt and glacial outbursts, and dam break flow. With the flood plains which has resulted in more serious nature of damage over the year.

The National Flood commission (1980) has reported that out of 40 million hectors (ha.) flood prone area, about 15.8 million ha. Areas have been provided with reasonable degree of protection so far. In India, about 40 million ha of land is flood prone, which is about 12% of the total geographical area (328 million ha) of the country the flooding occurs typically during the monsoon season (July-Sept.), caused by the formation of heavy tropical storms, ever decreasing channel capacity due to encroachments on river beds, and sometime due to tidal back water effects from the sea, The Indian sub-continent in general, and the western peninsula in particular, experienced heavy floods during 8th to 11th August 2006 that cause great damage to personal and property.

As mentioned earlier Surat has been blessed by the flow of Tapi however, it has also suffered a lot because of floods in Tapi since historic time. Table.1 shows several flood event which has done great damage to Surat city. The most unforgettable and severe flood event was the flood of the year 2006.

This flood event of 2006 signified concern on flood protection and control as such frequent event causes extensive damage to public property, agriculture, infrastructure, industries, wages etc. along with loss to private properties and business establishments in general. Keep in view that, it is necessary to suggest revised Ukai dam reservoir operation for flood protection & control.

Ukai Dam

Ukai Dam (Tapi River valley 2ndStage) is the largest multipurpose project, next to Narmada Project, undertaken by Government of Gujarat. It was completed in 1973. The Dam is located at village Ukai, Taluka Songadh of District Surat at distance of about 90 Km. from Surat city. It serves multiple purposes like Irrigation, Power generation, Water supply to industries and households, fisheries etc. It is major flood control point coming on Surat city. Ukai is designed to cope with projected floods of 49470 m3/s (17.47 lac cusecs) and probable maximum flood of 59880 m3/s (21.16 lac cusecs). The provided spillway has a capacity of 16.34 lac cusecs. The Ukai Multipurpose project forms the terminal reservoir on the Tapi River harnessing nearly half of the river flow for benefits of irrigation, hydropower generation and other facilities.

Tapi River

River Tapi is the 2nd largest west flowing river of Gujarat State, Central India. It originates from Mulati of Betul District of Madhya Pradesh; which is located 323 Km. from Maharashtra and 189 Km. from Gujarat. Tapi is known for occurrence of large floods due to influence of depressions originating from Bay of Bengal traveling East to West causing rainfall, first in the upper catchment and then in lower catchment resulting of flood along its course.

II. DATA COLLECTION

Data has been collected to fulfill the objectives of the study. Collection of data from various agencies, offices are compiled and enlisted. The large data scrutinize for different analysis in this research study. Among some of the data like Ukai Dam technical features, irrigation demand, hydropower generation, inflow, outflow, daily reservoir water level, existing gate operation policy rule levels, historical flood data are used for modification of rule level for Ukai reservoir. Tapi river cross section data are used for determination of flood carrying capacity in Surat City.

III. METHODOLOGY

A. Simulation

A simulation model is usually characterized as a representation of a physical system used to predict the response of the system under a given set of conditions. A multiple reservoir system is such a physical system, which can be analyzed by simulation models. Simulation models may not be able to generate an 'optimal' solution to a reservoir problem directly. However, with numerous simulations using alternative decision policies, these models can detect an 'optimal' solution or a near-optimal solution.

Typical simulation models associated with reservoir operation include a mass-balance computation of reservoir inflows, outflows and changes in storage. They may also include economic evaluation of flood damages, hydroelectric power benefits, irrigation benefits and other similar characteristics. Simulation models often use historical data.

In the present study reservoir simulation model is developed to simulate reservoir operation for 24 years (1990-2013) using daily available historical inflows. Day's end storage and canal releases are obtained from simulation. Day's end storage overlaid over a simulation period. Ultimately calculation of rule level for revised Ukai reservoir operation.

B. Constraints for Simulation

The reservoir operation program is simulated based on the following constraints.

1) Storage Constraint

The reservoir storage in any day should not be more than the capacity of the reservoir and should not be less than the dead storage. The constraint is:

$$S_{min} \leq S_t \leq S_{max} \qquad t = 1, 2, 3 \ldots 30$$

S_t = Initial storage during the day't'.

S_{min} = Minimum storage capacity of the reservoir in MCM (1142 MCM)

S_{max} = Maximum capacity of the reservoir in MCM.

2) Overflow Constraint

When the final storage exceeds the maximum capacity of the reservoir, the constraint is given by:

$$O_t = S_{t+1} - S_{max} \text{ and } \qquad t = 1, 2, 3,..30$$

$$O_t \geq 0$$

O_t = Surplus from the reservoir during time period t

S_{t+1} = Final storage in the day t in MCM

3) Releases Constraint

Total release during any day should not exceed the demand (Irrigation, Industrial, Domestic) and the constraint is given by:

$$R_t \leq D_t \qquad t = 1, 2, 3 \ldots 30$$

R_t = Releases for various demand during time period t

D_t = Demands for the day t in MCM

4) Mass Balance Constraint

The relationship between the day to day storage is given by the continuity equation stated by:

$$S_{t+1} = S_t + I_t - D_t - R_t - E_t - O_t \quad t = 1,2,3,..30$$

I_t = Daily inflow during time period t in MCM

E_t = Evaporation loss in the reservoir during time period t in MCM

R_t =Releases for the demand in the river downstream during time period t in MCM
O_t = Surplus from the reservoir if any during time period t in MCM
S_{t+1} = Final storage in the day t in MCM
S_t = Storage in the reservoir at the beginning of time period t.
D_t = Demand of water to be satisfied during time period t.

IV. DATA ANALYSIS

Year	Date	Initial Storage in starting of Day	Inflow	ULBC Requirement	D/S irri. Requirement	Drinking Requirement	Industrial Requirment	Actual Release Through Hydro	Computed Release Through Hydro	Final Storage at day's end	Spill	Final Storage after spill at Day's end	Average Storage	R.L. with respect to average storage	R.L. with respect to average storage	Evaporation loss	Demand Deficit	Final Storage after Evaporation losses at Day's
		Mm3	Mm3	Mm3	Mm3	Mm3	Mm3	Mm^3	Mm3	Mm3	Mm3	Mm3	Mm3	Ft	m	Mm3	Mm3	Mm3
1990	1-Jun	1142	41.07	1.97	8.51	0.21	0.65	20.97	20.97	1160.13	0	1160.13	1151.06	86.21	282.86	0.61	0	1159.51
	2-Jun	1159.51	12.81	1.97	8.51	0.21	0.65	34.18	34.18	1136.17	0	1142	1150.76	86.21	282.85	0.61	1.36	1141.39
	3-Jun	1141.39	8.99	1.97	8.51	0.21	0.65	16.55	16.55	1131.86	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	4-Jun	1141.39	8.73	1.97	8.51	0.21	0.65	29.49	29.49	1118.66	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	5-Jun	1141.39	0	1.97	8.51	0.21	0.65	21.79	21.79	1117.63	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	6-Jun	1141.39	4.62	1.97	8.51	0.21	0.65	24.14	24.14	1119.90	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	7-Jun	1141.39	6.14	1.97	8.51	0.21	0.65	25.53	25.53	1120.02	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	8-Jun	1141.39	0	1.97	8.51	0.21	0.65	27.80	27.80	1111.62	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	9-Jun	1141.39	7.46	1.97	8.51	0.21	0.65	26.48	26.48	1120.39	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	10-Jun	1141.39	15.81	1.97	8.51	0.21	0.65	29.04	29.04	1126.19	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	11-Jun	1141.39	16.18	1.97	8.51	0.21	0.65	30.77	30.77	1124.83	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	12-Jun	1141.39	10.55	1.97	8.51	0.21	0.65	26.60	26.60	1123.36	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	13-Jun	1141.39	4.38	1.97	8.51	0.21	0.65	22.29	22.29	1121.50	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	14-Jun	1141.39	6.20	1.97	8.51	0.21	0.65	15.24	15.24	1130.38	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	15-Jun	1141.39	40.32	1.97	8.51	0.21	0.65	22.96	22.96	1156.78	0	1156.78	1149.08	86.20	282.81	0.61	0	1156.17
	16-Jun	1156.17	44.24	1.97	8.51	0.21	0.65	35.26	35.26	1163.17	0	1163.17	1159.67	86.28	283.06	0.64	0	1162.53
	17-Jun	1162.53	15.92	1.97	8.51	0.21	0.65	37.41	37.41	1139.07	0	1142	1152.27	86.22	282.89	0.61	1.36	1141.39
	18-Jun	1141.39	13.16	1.97	8.51	0.21	0.65	27.51	27.51	1125.07	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	19-Jun	1141.39	8.17	1.97	8.51	0.21	0.65	32.93	32.93	1114.66	0	1142	1141.69	86.15	282.63	0.61	1.36	1141.39
	20-Jun	1141.39	153.77	1.97	8.51	0.21	0.65	32.83	32.83	1260.36	0	1260.36	1200.87	86.58	284.06	0.64	0	1259.72
	21-Jun	1259.72	237.31	1.97	8.51	0.21	0.65	34.93	34.93	1460.13	0	1460.13	1359.92	87.67	287.64	0.69	0	1459.44
	22-Jun	1459.44	78.30	1.97	8.51	0.21	0.65	44.40	44.40	1491.36	0	1491.36	1475.40	88.44	290.15	0.73	0	1490.63
	23-Jun	1490.63	96.70	1.97	8.51	0.21	0.65	41.59	41.59	1543.76	0	1543.76	1517.19	88.68	290.96	0.73	0	1543.02
	24-Jun	1543.02	113.24	1.97	8.51	0.21	0.65	33.96	33.96	1620.33	0	1620.33	1581.68	89.06	292.20	0.78	0	1619.55
	25-Jun	1619.55	56.38	1.97	8.51	0.21	0.65	44.71	44.71	1629.25	0	1629.25	1624.40	89.32	293.03	0.78	0	1628.46
	26-Jun	1628.46	26.82	1.97	8.51	0.21	0.65	37.83	37.83	1615.49	0	1615.49	1621.98	89.30	292.98	0.78	0	1614.70
	27-Jun	1614.70	2.61	1.97	8.51	0.21	0.65	32.61	32.61	1582.73	0	1582.73	1598.72	89.16	292.53	0.78	0	1581.95
	28-Jun	1581.95	5.27	1.97	8.51	0.21	0.65	26.88	26.88	1558.36	0	1558.36	1570.16	89.00	291.98	0.76	0	1557.60
	29-Jun	1557.60	10.72	1.97	8.51	0.21	0.65	22.58	22.58	1543.76	0	1543.76	1550.68	88.88	291.61	0.76	0	1543.00
	30-Jun	1543.00	11.54	1.97	8.51	0.21	0.65	12.55	12.55	1540.02	0	1540.02	1541.51	88.83	291.43	0.76	0	1539.26

Table 1: Sample Calculation for Reservoir Operation

5) *Example Calculation*

Table 2 shows basic calculation for June-1990.

– Initial Storage in starting of day = 1142 Mm3 + Inflow 41.07 Mm3
= 1183.07 Mm3 total Storage.

– Computed release through hydro
Case-I Actual hydro > D/S Irrigation+ Domestic+ Industrial
= Actual Hydro

Case-II D/S Irrigation+ Domestic+ Industrial > Actual hydro
= D/S Irrigation+ Domestic + Industrial
– Demand deduction = ULBC Requirement 1.97 Mm3 + Computed release through hydro 20.97 Mm3
= 22.94 Mm3
– Final storage at month end = Total storage – Release
= 1183.07 Mm3 –20.97Mm3
= 1160.12Mm3

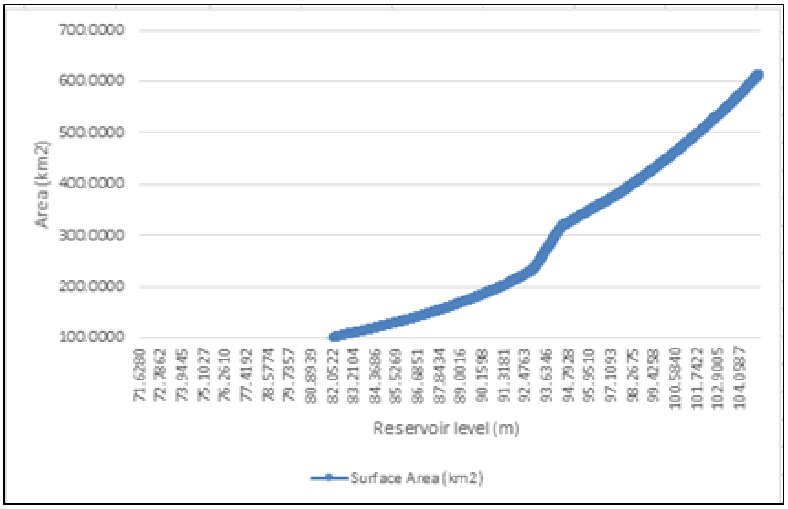

Fig. 1: Graph between Area Vs Elevation

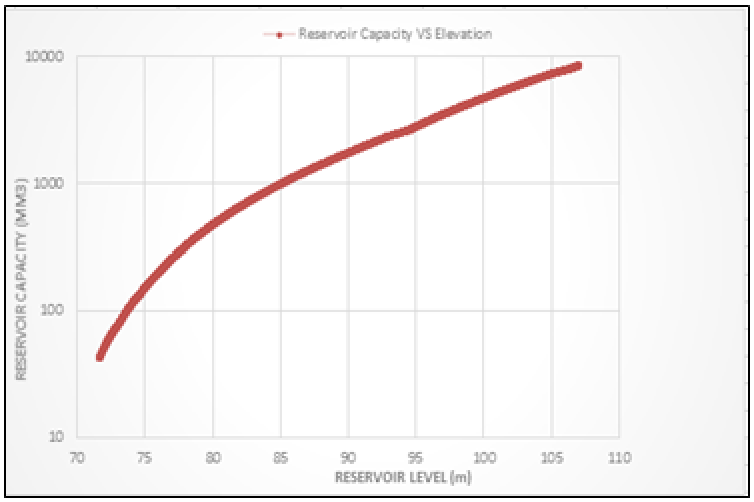

Fig. 2: Graph between Capacity Vs Elevation

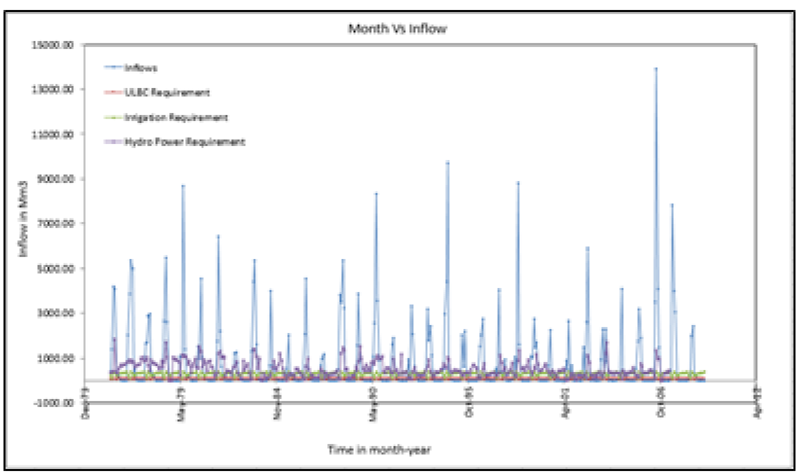

Fig. 3: Graph between Inflow Vs Time

V. RESULTS

Simulation of the reservoir operation based on 24 years daily available historical inflow reveals the following result as shown in Table No.2.Figure 4 and Figure 5 indicates the actual discharge and computed discharge for flood event August-2006 and September-2013.

Month	*Suggested Rule Level in Mt.*	*Existing Rule Level in Mt.*	*Difference*	*Flood absorption volume (Mm3)*
JUNE	*92.93*	*90.00*	*2.93*	*597.99*
JULY	*94.70*	*97.86*	*3.16*	*1130.94*
AUGUST	*100.54*	*101.52*	*0.98*	*471.75*
SEPTEMBER	*103.58*	*104.55*	*0.97*	*565.23*
OCTOMBER	*103.63*	*105.18*	*1.55*	*901.38*
			Total	*3667.30*

Table 2: Proposed Rule Level

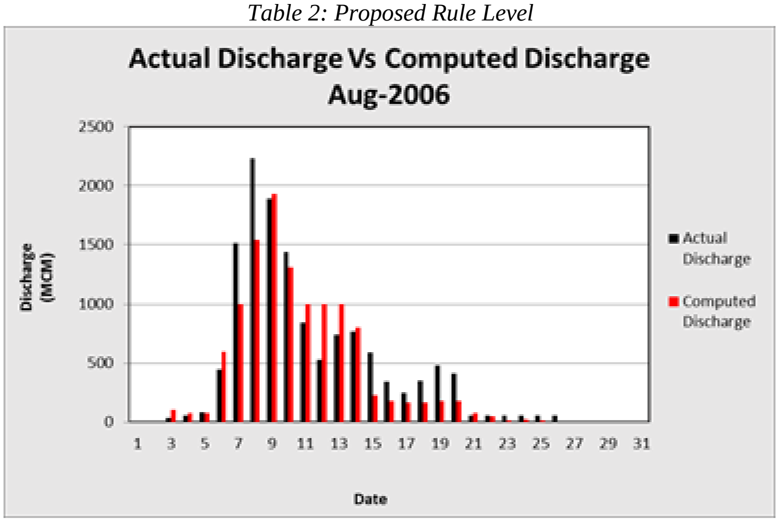

Fig. 4: Graph between Actual Discharge Vs Computed Discharge (Aug-2006)

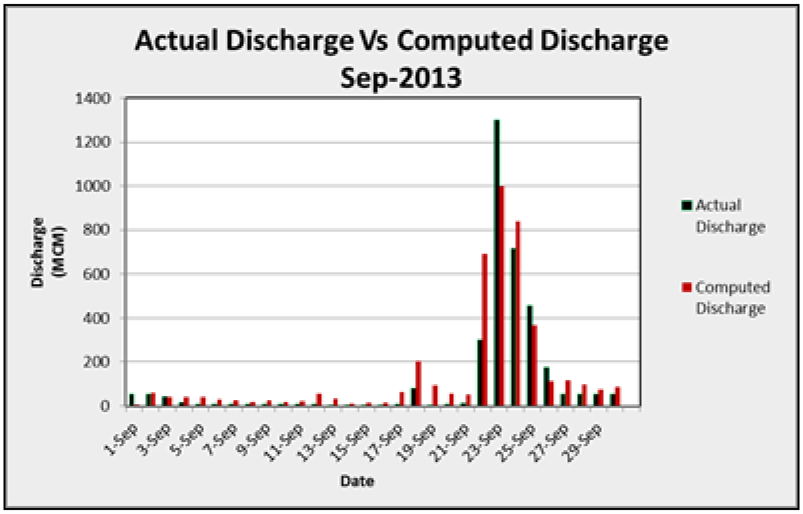

Fig. 5: Graph between Actual Discharge Vs Computed Discharge (Sept- 2013)

VI. CONCLUSION

Ukai dam on Tapi River is designed for the FRL situation. The PMF with a peak value of 21.16 lac cusecs (46,270 cumec) from the dam spillway, and maximum water level of 351.0 Ft (106.99 m) in the reservoir. The capacity of Tapi River along downstream side of Ukai dam near the Surat city is inadequate to safely carry the flood of such high order. Therefore, the effort is to restrict the downstream flood to around 7 lac cusecs (19,822 cumec).

As the safety of dam is a prime importance, the reservoir level under no circumstances shall be allowed to go above the MWL of 351.00 ft. In the present study simulation of the reservoir operation is carried out for proposing the new rule level for Ukai Reservoir operation to minimize the effect of flood on the downstream side of the Ukai dam. It is clearly observed that 3667.30 Mm3 volume of flood water must be absorbed with the use of proposed rule level.

REFERENCES

[1] Johnson W. A., “Optimal Operation of an Upstream Reservoir for flood Control” The University of British Columbia, Department of Civil Engineering, October 1970.
[2] Windsor J. S., “Optimization model for the operation of flood control systems.” Water Resources Res. 9 (5), 1219–1226, 1973.
[3] Yeh W.W.-G., “Reservoir management and operation models: a state-of-the-art review.” Water Resource Res., 21, 1797–1818, 1985.
[4] Unver O. I., and L. W. Mays “Model for real-time optimal flood control operation of a reservoir system” Water Resources Management, 4, 2146, 1990.
[5] Victoria B.C., "Final Report of the Fraser River Board on Flood Control and Hydro-Electric Power in the Fraser River Basin", 1963.
[6] Wurbs R. A. “Reservoir-System Simulation and Optimization Models,” J. Water Resource Planning Management, ASCE, 119(4), 455-472, 1993.
[7] Needham, J. T., David W.W.J. & Jay R.L “Linear programming for flood control in the Iowa and Des Moines Rivers”, Journal J. Water Resources Planning and Management ASCE, 126 (3), 118–127, 2000.
[8] Labadie J. W. “Optimal operation of multi-reservoir systems: State of-the-art review”, J. Water Resources Planning and Management ASCE, 130, 93–111, 2004.
[9] Dr. P. G. Agnihotri & Dr. J. N. Patel "Preparation of flood reduction plan for Surat city and surrounding region (India)" WSEAS Transactions on Fluid Mechanics, 2(3):116-125, 2008.
[10] Dr. G. I. Joshi and Dr. A. S. Patel “Optimal solution for prevention of Tapi River Flood Impacts-Surat” in Indian Journal IWRS Vol.No.30, 2010.
[11] Satabdi Saha “Simulation of operation of Damodar velly corporation reservoir system using HEC-5”, 2013.
[12] Azhar Husain “Simulation of Karangkates Reservoir Operation” IJIRSET Volume 2, Issue 5, 2013.