HYDROLOGICAL STUDY OF PROPOSED KHANAS DAM

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ABSTRACT

The objective of the present paper is to analyze the hydrological data, rainfall, runoff of the catchment area. The hydrological study aims at defining the average flow and its distribution, the peaks and volume of floods and the sediment discharge of Al-Gomal River down the site of proposed Khanas dam.

For the purposes of investigation and designing the following climatic elements are defined: monthly and annual rainfall, maximum wind velocity for the prevailing direction, free water surface evaporation, air temperature and relative air humidity. It is done on the basis of the records from the Duhok metrological station for the period 1970-2007.

For want of systematic observations on the river runoff the data used in this paper based on observations conducted at discharge site station at Gomal River for the period 1970-2007.

The catchment area of Proposed Khanas dam is equal to 416 km^2. The area is within Iraqi boundaries. The area has a moderate slope around the dam to steep slope in higher parts of the basin.

The estimation of annual rainfall depth on catchment area for different return periods (10, 20, 50, 100, and 1000 year) using Gumbel distribution with probabilities of 50% by using Weibull method. The result shows that the max annual rainfall depth is equal to 1460 mm for 1000 year return period.

The max daily rainfall depth is computed to estimate max annual runoff and max flood discharge for Gomal River using synthetic method (Snyder and SCS Hydrograph) and probability method with different return periods (Weibull formula, Gumbel formula, Gumbel and Log- person type III probability methods). Runoff Curve number method is used also, to calculate annual runoff depth. The result shows that the max flood discharge of Gomal River with return period of 1000 year is equal to 475 m^3/sec.

The sediment transport in Gomal River at proposed Khanas dam is calculated using The universal soil loss equation (USLS-equation) and the result show that the annual sediment is equal to 593 ton/km^2.

The reservoir area was surveyed and map of 1:1000 and contour interval of 1m were prepared. This survey and map covered all contour lines up to line 480 m. The regression analysis is used to find the best fit of area- capacity – elevation curve of proposed Khanas reservoir. The result shows that the capacity of the reservoir is equal to 5.0 MCM for the dam height of 30 m.

Keywords: Hydrology, Rainfall, Runoff, Flood, Sediment

1- INTRODUCTION

Hydrologic design is the process of assessing the impact of hydrologic events on a water resource system and choosing values for the key variables of the system so that it will perform adequately, Chow (1988).

Surface water hydrology deals with movement of water along the watershed as a result of precipitation Detailed analysis of surface water flow rate is highly important to such fields as water supply, flood control, reservoir design, stream flow forecasting, irrigation, and water quality control. For economic and efficient design of such hydraulic structures, such as spillways, bridges, drainage works and aqueducts, a reliable estimate of the flood discharge is essential.

However, flood is essentially a random phenomenon. It's, therefore, difficult to predict the exact maximum flood which can occur in future, Arora (2004).

The entire precipitation water does not reach the stream as runoff since a portion of precipitation is always lost due to various causes such as interception, depression storage, evapotranspiration and infiltration.

2- SITE DESCRIPTION

The catchment is within Iraqi boundaries. The area starts from north Bodul to Khanas village. The proposed Dam is Located on Gomal River south west of Dohuk City, Lat, 36 45.755 E, Long, 43 25.551 N. The Gomal River is a tributary of Khazer River. The Dam site is located near Khanas village, 45 km southwest of Dohuk City; Fig. (1) shows the location of catchment area and proposed Khanas Dam.

The catchment area of Khanas dam is equal to 416 km^2, Fig. (2). The area has a moderate slope around the dam to steep slope in higher parts of the basin. The discharge of the valley is about1.5 m^3/s in September and October while the discharge may reach 300 m^3/s during heavy rainfall storm and snow melting at March and April.

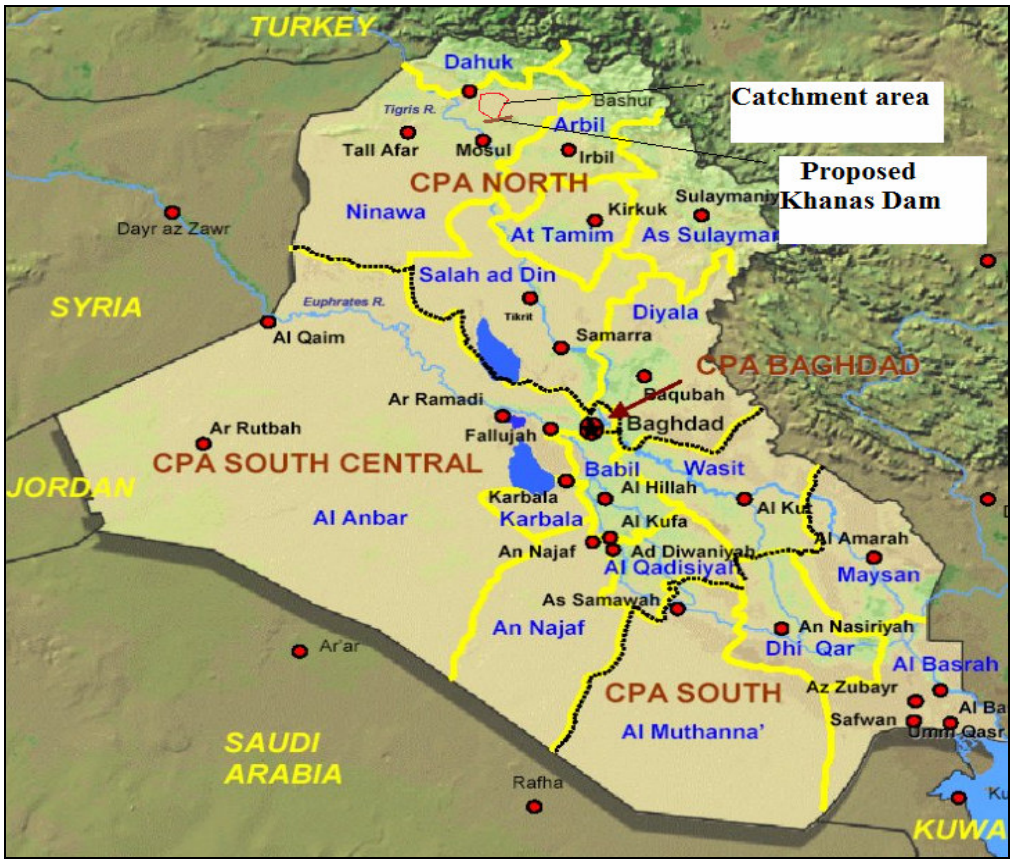

Fig. (1) Location of Catchment area and proposed Khanas Dam

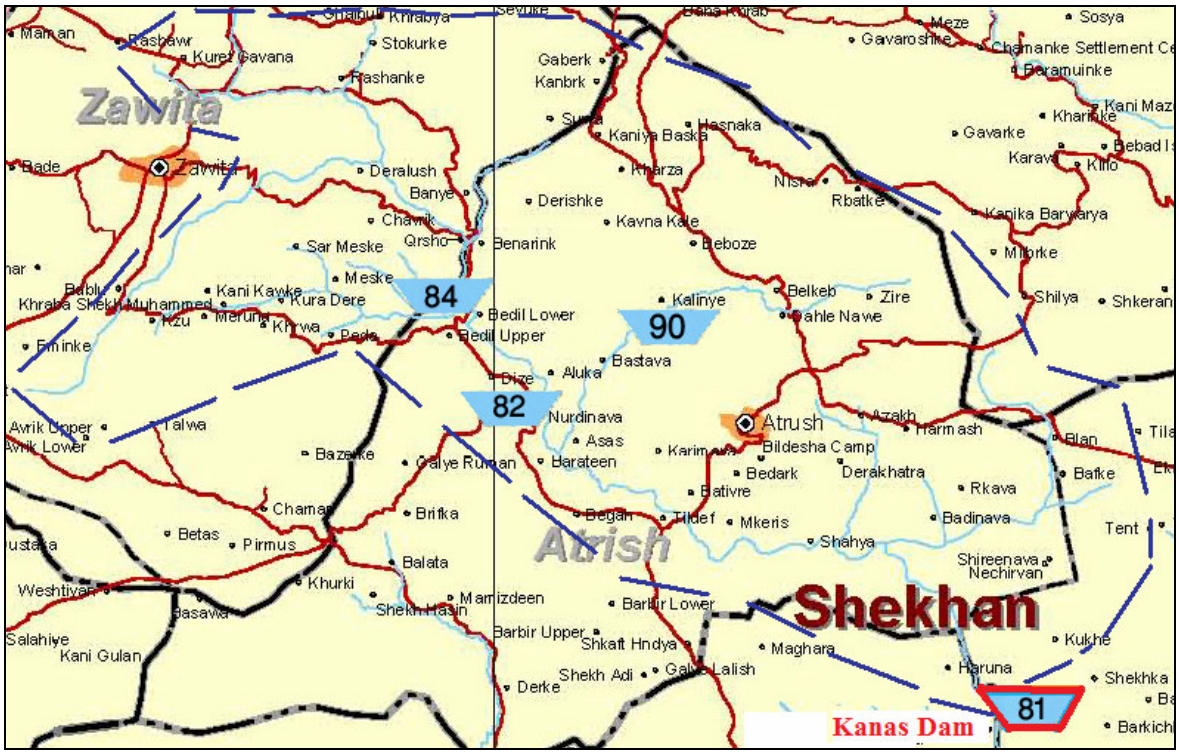

Fig. (2) Catchment area

3- GENERAL CLIMATE DATA

The Climatic Data were taken from available records of Duhok Metrological station covering the period of (1970-2007). Table (1) shows a summary of climatic factors.

Table (1) Summery of Climatic factor

Climatic factor	Maximum value	Minimum value	Average value
Temperature (°C)	24.33	11.44	18.30
Wind (km/hr)	10.85	3.93	7.39
Evapotranspiration (mm/month)	141.23	98.55	119.89
Precipitation (mm/month)	106.80	26.46	66.63

3-1- Rain fall

The estimation of total monthly rain fall was based on the available monthly rain fall data for the period of 1970 to 2007 recorded in Dohuk meteorological stations which is the nearest station to the dam site. The total annual rainfall depths in catchment area are calculated for several probabilities (50%, 60%, 70%, 80% and 90%). Results are shown in Table (2).

Table (2) Annual rainfall depth in Dohuk station for various probabilities using Weibull method for period 1989-2008

Distribution Weibull	Probability				
	50%	60%	70%	80%	90%
Annual rainfall depth (mm)	518	476	408	378	303

Tables (3) and (4) show the annual and monthly rainfall depths for different return periods (10, 20, 50, 100, and 1000) year, respectively.

Table (3) Annual rainfall depth in Dohuk station for different Return periods using Gumbel distribution for period 1989-2008

Distribution Gumbel	Return period (year)				
	1000	100	50	20	10
Annual rainfall depth (mm)	1460	1100	1011	971	840

Table (4) Average Monthly rainfall depth in Dohuk station for different Return periods using Gumbel distribution for period 1989-2008

Distribution Gumbel	Return period (year)				
	1000	**100**	**50**	**20**	**10**
Monthly rainfall depth (mm)	282	179	156	131	114

3-2- Daily Rainfall Depth

Estimation of the expected peak flood discharge in Khanas catchment area for unit rainfall Snyder and SCS methods was used, Gupta (2008), depending on max daily rainfall record at Dohuk station for period (1970-2007).

1- Snyder Method

The correlation between the lag to peak (t_p, hours) and basin length is as follows:

$$t_p = C_t\,(LLc)^{0.3} \tag{1}$$

where:

L: Length of main stream from outlet to divide (miles)

Lc: Distance from the outlet to a point on the stream nearest the centroid of the basin.

C_t: Empirical constant (1-2.2)

The peak discharge, Q_p is given by the relation;

$$Q_p = \frac{2.78\,C_p\,A}{t_p} \tag{2}$$

where:

Q_p = Peak discharge in cumecs per 1 cm of rainfall

A = area of basin in km^2

C_p = Coefficient which depends upon the retention and storage characteristics of basin. Its value varies from 0.3 to 0.93.

The base period of unit hydrograph is given by:

$$T = 3 + 3\frac{t_p}{24} \tag{3}$$

where:

T = base period of unit hydrograph in days, and

t_p = the basin lag in hrs

The unit duration of storm is given by:

$$t_r = \frac{t_p}{5.50} \tag{4}$$

where t_r is the unit duration of storm in hours.

The above equation is sufficient to construct a synthetic unit hydrograph by Snyder method for storm duration t_r. For any duration $t_r^{'}$, eq. (1) is modified as follows:

$$t_p^{'} = t_p + \frac{(t_r^{'} + t_r)}{4} \tag{5}$$

and $$Q_p^{'} = \frac{2.78 C_p A}{t_p^{'}} \tag{6}$$

$$T = 3 + 3\frac{t_p^{'}}{24} \tag{7}$$

For Khanas Catchment area, L = 40 km, L_c = 20 km, C_t = 1.2, C_p = 0.5.

t_p = 8.91 hr,

For 24 hr rainfall:

$t_r^{'} = 1.62$
$t_p^{'} = 15.32$
q_p = 0.09 m^3/sec/km^2.cm
Max daily rainfall for 1000 year return period = 119 mm
Max flood discharge is 446 cumecs

2- SCS Dimensionless Unit Hydrograph

The SCS dimensionless hydrograph is a synthetic hydrograph in which the discharge is expressed by the ratio of discharge q to peak discharge q_p and the time t to the time of rise of unit hydrograph, T_p. Given the peak discharge and lag time for the duration of excess rainfall, the unit hydrograph can be estimated from the synthetic dimensionless hydrograph for given basin. It can be shown that:

$$q_p = \frac{C A}{T_p} \tag{8}$$

where:

C = 2.08 and A = drainage area in km^2, T_p = Time of rise,
B = 1.67 T_p where B = recession time in hr, and
t_p= 0.6 T_c where T_c = time of concentration of watershed

For Khanas catchment area,

$t_r^{'}$ = 1.62

$t_p^{'}$ = 15.32

T_p = 16.13 hr

q_p = 2.08 x 416/16.13 = 27.85 cumec/cm

Q_p = 27.85 x 11.9 = 332 cumecs

Figure (3) shows SCS hydrograph.

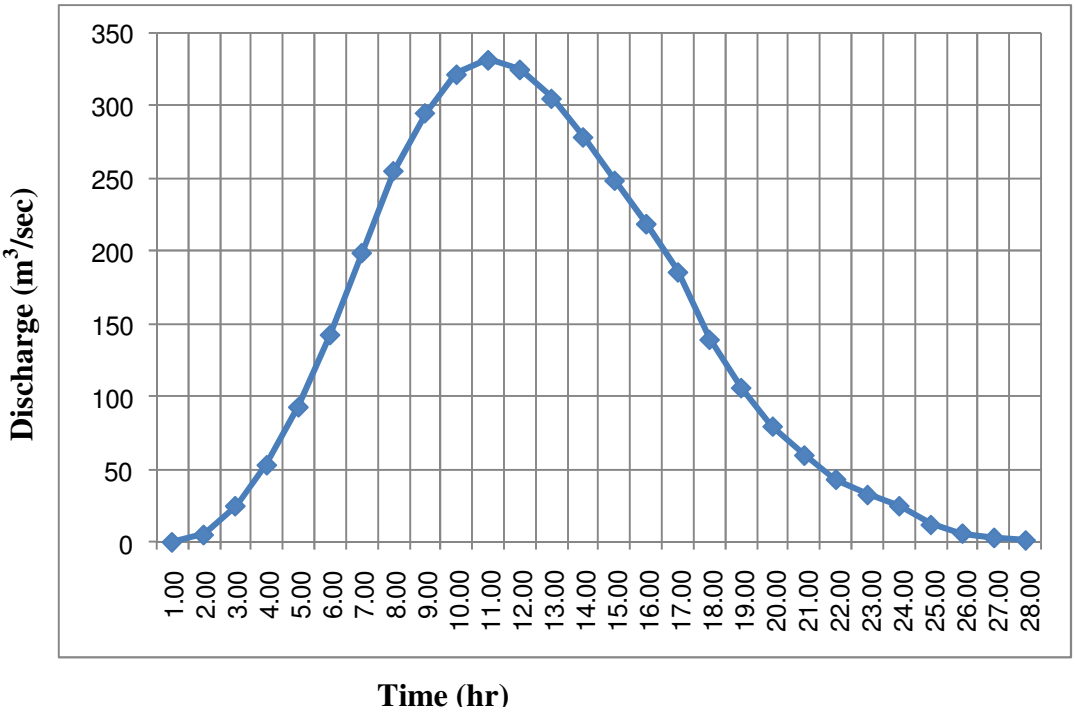

Fig. (3) SCS hydrograph for khanas Dam catchment area for 1000 year return period

3-3 Daily Rainfall depth using probability methods

The observed data, of the annual daily max rainfall were used to predict the future max daily rainfall for one, two and three days rain by using Gumbel and Log-person type III distribution methods as shown in Table (5).

Table (5) Max annual daily rainfall

Method	Max rainfall for 1000 year return period		
	1000 year		
	One day	Two days	Three days
1- Gumbel's method	119	237	299
2- Log- person type III method	103	223	267

3-4 Evaporation

The North part of Iraq is characterized by moderate evaporation rates; monthly evaporation data available in Dohuk station for the years of (1970-2007) were utilized to estimate the annual evaporation losses from the reservoir of Khanas Dam.

The total average annual evaporation from Khanas reservoir is 1008 mm with max value of 1187 mm.

3-5 Runoff

The expected volume of annual runoff for various probabilities (50%, 60%, 70%, 80% and 90%) were estimated for Khanas dam using total annual rainfall depth in Dohuk station for the period (1970-2007). 50% probability was used as an average for Dohuk station to estimate volume of surface runoff as shown in Table (6).

Table (6) Expected volume of annual runoff for various probabilities

Probability	Annual rainfall (mm)	Annual Rainfall (MCM)	Annual runoff * (MCM)	Equivalent Runoff depth (mm)
50%	**518**	**215**	**101**	**244**
60%	476	198	93	224
70%	408	170	80	192
80%	378	157	74	178
90%	303	126	59	143

* Using runoff coefficient method

$$R = kP \tag{9}$$

where:

R = runoff depth (mm),
k = coefficient of runoff and = 0.47 (Sogreah, 1978)
P = rainfall depth (mm)

Depending on annual rainfall depth with return period of 1000y, Table (7) gives the expected runoff depth is equal to:

Table (7) Expected runoff depth with 1000 year return period

Distribution (Gumbel)	Return period (year) (1000)
Annual Rainfall Depth (mm)	1460
Annual Rainfall Vol x 10^6 (m^3)	607
Annual Runoff Vol x 10^6 *	213
Equivalent Runoff Depth (mm)	511

Coyn and Bellier (1978) show that annual rainfall in Gomel catchment area = 787 mm, annual runoff = 419 mm and annual evaporation = 368 mm.

Therefore, the annual volume runoff from Khanas catchment area is 174 MCM.

3-6 Runoff Curve number method

The runoff curve number method is procedure for hydrological abstraction developed by the USDA Soil conservation service. The runoff curve number method was developed based on 24-hr rainfall-runoff data:

$$Q = \frac{R\left[CN\left(\frac{P}{R}+2\right)-200\right]^2}{CN\left[CN\left(\frac{P}{R}-8\right)+800\right]} \qquad (10)$$

where:

$R = 2.54$, P = rainfall (cm), Q = runoff (cm), CN = runoff curve number

CN for the reservoir catchment area calculated from *CN* tables according to hydrologic soil groups and the nature of the antecedent moisture condition for the basin. The total catchment area (416 km^2) is divided to two parts according to the topography and the characteristics of the area.

From eq. (10), the expected max discharge = **404 m^3/sec**.

Table (8) shows the different methods which used for calculating max annual daily discharge for Gomal River in Khanas Dam location.

Table (8) Max Annual Daily for Gomel River in Khanas Dam location

Method	Design discharge for different return period				
	10	20	50	100	1000
Weibill's formula	119	127	285	335	370
Gumbel's formula	121	128	287	340	375
Gumbel's method	177	217	269	308	475
Log-person type III method	166	218	245	281	380

From the above, the max flood discharge value is 475 m^3/s.

4- SEDIMENT TRANSPORT IN GOMEL RIVER AT KHANAS RESERVOIR

The Khanas reservoir basin has small capacity (5 MCM) and the Gomal River having large inflow (174 MCM), the capacity inflow ratio is low and corresponding trap efficiency is also small, Morgan (1986). Most of the inflow is quickly discharged to downstream and the suspended sediments are not able to settle fully. In general the greater the capacity – inflow ratio, the greater is the trap efficiency. In other words, the sedimentation rate is high in relatively larger reservoirs.

The universal soil loss equation (USLS-equation) is used to calculate the annual soil loss from the watershed:

$$A = R.K.L.S.C.P \quad \ldots\ldots\ldots (11)$$

where:

A = annual soil loss in tons / Donum / year
R = Rainfall factor: a coefficient designed to measure the combined effect of temperature and moisture on the formation of soil humus; it is obtained by dividing the annual rainfall (in millimeters) by the mean annual temperature (in degrees Celsius),
K = soil erodibility factor
L = slope length factor,
S = slope gradient factor,
C = crop management factor, and
P = erosion control practice

For Khanas catchment area:

K = 0.41, Karim et al. (1998)
LS = 0.70 (of 328 ft length and 5% gradient)
C = 0.12, P = 1 for Pasture, grassland,
R = 787/18.3 = 43, Nikolov (1983)

Annual soil loss = 592 ton/km^2/year

Assuming that 50% of the soil loss by erosion will deposit in the dam reservoir, thus the total annual sediment deposit in the reservoir equal to 296 ton/km^2/year.

5- RESERVOIR CAPACITY

Water-management calculation requires reservoir characteristics in the form of curves relating volume, level, and water surface areas (**Volume – area stage Curve**). These relationships are based on topographic description of the reservoir in the form of a relationship between its water surface area and level.

The reservoir area was surveyed and map of 1:1000 and contour interval of 1m were prepared. This survey and map covered all contour lines up to line 480 m. The characteristic curves indicating the area- capacity – elevation relation of Khanas reservoir is shown in Fig. (4). The best fit for the data obtained from the following equations:

$$A = 1445\ (\text{elev.} - 452)^{1.845}$$
$$V = 603.25\ (\text{elev.} - 452)^{2.787}$$

where: A = surface area in m^2 and V = volume in m^3.

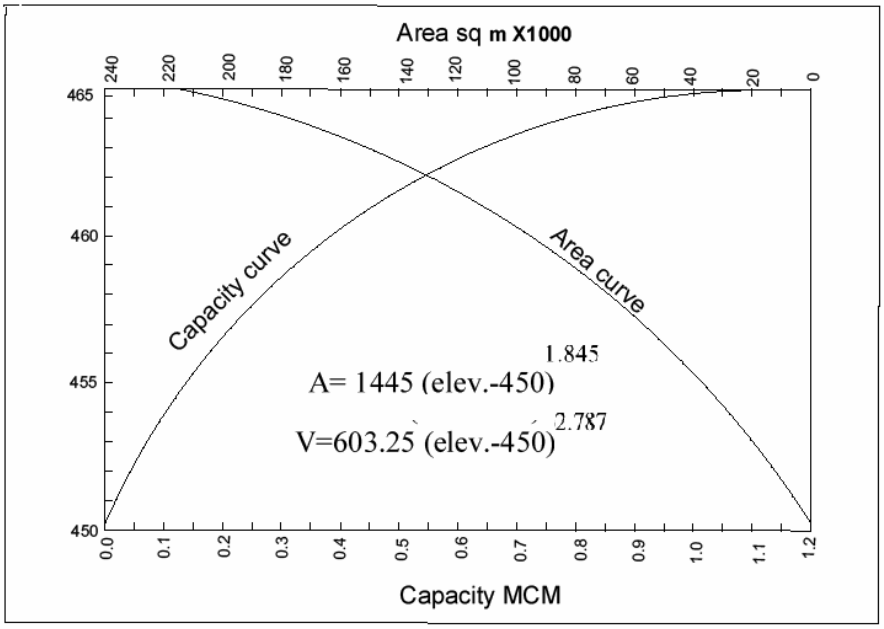

Fig. (4) Area-Capacity Curve for Proposed Reservoir

6- CONCLUSIONS AND RECOMMENDATIONS

In the light of the above results the following points can be concluded:

1. The catchment area at the proposed Khanas Dam site basin is 416 km^2.
2. The annual rainfall depth in Dohuk station for 50% probability is equal to 518 mm.
3. The annual rainfall depth in Dohuk station with 100 and 1000 year return period is equal to 1100 mm and 1460 mm, respectively.
4. The average monthly rainfall depth in Dohuk station with 100 and 1000 year return period is equal to 179 mm and 282 mm, respectively.
5. The average evaporation from Khanas reservoir surface area is equal to 1008 mm.
6. The volume of annual runoff from Khanas catchment area is equal 244 for 50% probability which is equivalent to 101 Mm^3.
7. Maximum flood discharge for 1000 year return period is equal to 475 m^3/s.
8. Total annual soil loss is 592 ton/km^2/year.

It is recommended to:

1. Widen the downstream sections of the proposed Khanas dam to satisfy the capacity of flood discharge.
2. Annual cleaning of the Khanas reservoir because of highly sediment deposition from the catchment area.

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