Chapter – 5
Hydrology and Water Resources

5.1 General

The Par-Tapi portion of the link canal traverses through six basins of west flowing rivers viz. Par, Auranga, Ambica, Purna, Mindhola and Tapi. Seven storage cum diversion sites viz. Jheri, Mohankavchali and Paikhed in Par basin, Chasmandva in Auranga basin, Chikkar and Dabdar in Ambica basin and Kelwan in Purna basin were identified. However no diversion site is proposed in Mindhola basin. The reservoir sites have been considered on the basis of preliminary investigations by state irrigation departments and NWDA's own studies based on toposheets. The water balance studies have been carried out for each of the basins as a whole as well as at each of the reservoir sites to estimate the surplus water available.

5.2 Methodology adopted for working out water balance

The methodology adopted for working out water balance is discussed in the following paragraphs.

5.2.1 Surface water availability

The rainfall data of the raingauge stations located in and around the basins have been collected. The period of availability of data of these stations varies and in most of cases the data is available for short duration. The data for short duration of such stations is extended by generating long term series with the help of the long term available rainfall data of the adjacent stations by statistical methods. The weighted average monsoon rainfall figures for the catchment have been estimated by thiessen polygon method for the period 1901-02 to 1984-85.

The gauge and discharge data for as many G & D sites as available within and around the basin are collected. The data on the existing surface water utilizations of all the irrigation projects upstream of the G & D site which has been considered for the study, has been collected. Regeneration from the existing major projects has been computed at 10% of their net utilizations. The gross monsoon yields upto G & D sites have been worked out by adding

the observed flows, the upstream utilizations and evaporation losses of the reservoirs less then regeneration flows.

Using the gross monsoon yields and the corresponding weighted average monsoon rainfall, rainfall-runoff relationships have been developed by regression analysis. Considering the best fit equation, the monsoon yield series have been generated. From the data of the non-monsoon observed flows and the corresponding monsoon virgin flows, the average percentage of non-monsoon flows has been worked out. Adopting this percentage, the non-monsoon yields have been worked out. The monsoon and non-monsoon yields are added to arrive at the gross annual yield series, from which the 75% and 50% dependable gross annual yields have been obtained.

5.2.2 Water requirement

The water requirements for various uses viz. domestic, irrigation, industry, hydropower generation and salinity control have been determined as follows.

5.2.2.1 Domestic uses

The norms given by the Ministry of works and housing in its manual "water supply and treatment" on the per capita daily needs for the urban, rural and livestock population were adopted for assessing the domestic water requirements. The per capita daily needs for the urban, rural and livestock population are considered as 200, 70 and 50 litres respectively. The urban water requirement and 50% of rural water requirement are proposed to be met from surface water sources. The requirement in respect of livestock population and remaining 50% of rural population are proposed to be met from ground water sources.

5.2.2.2 Irrigation uses

Details of the gross command area, culturable command area, designed annual irrigation and designed annual utilization for the existing, ongoing and future projects were collected and tabulated separately for major and medium projects. The gross command area and culturable command area figures are not available in case of minor schemes and as such, the designed annual irrigation and utilisation only were collected. Water uses in the existing and ongoing projects were kept undisturbed. Water use in respect of identified future major, medium and minor projects was estimated considering weighted average deltas determined on climatological approach.

5.2.2.3 Industrial needs

Actual data on the existing, ongoing and future industries and their water requirement are not available. As such the industrial water requirement has been assumed to be of the same order as the total domestic water requirement. The entire industrial water requirement is proposed to be met from surface water resources.

5.2.2.4 Water requirement for hydro-power generation

Evaporation losses in the reservoirs proposed for hydro-power generation were assumed as 15% of utilizable water and provision was made for this consumptive use.

5.2.2.5 Salinity control

15% of the utilizable yield was considered for preventing salinity ingress in the river near the estuaries. This is 15% more than the figure recommended by the committee set up by planning commission for the assessment of the water resources of the west flowing rivers.

5.2.2.6 Regeneration

The quantum of return flows as regeneration from surface water use was considered as (a) 10% of the net water utilisation for irrigation from all the existing, ongoing and identified future major and medium projects which have a designed annual utilization of 85 Mcm or more and (b) 80% of the domestic and industrial water use to be met from surface water sources.

5.2.3 Ground water

The ground water potential and existing draft have been assessed from the “Report of the Central Ground Water Board (1991) “.

5.3 Water balance studies

5.3.1 Water balance in the basins

The water balance studies of the five river basins viz. Par, Auranga, Ambica, Purna and Mindhola have been carried out by NWDA using the above

methodology. The position of water availability, utilisation and balance as indicated in the water balance studies of these basins is given in Table-5.1.

Table - 5.1
Water availability and balance in the basins

Unit: Mm^3

Basin	Catch-ment area (Sq km)	Gross annual Yield at		Im-port	Ex-port	In basin water require-ment	Rege-nerati on	Water balance at	
		75% Dep.	50% Dep.					75% Dep.	50% Dep.
Par	1648	1522	2119	71	-	691	51	953	1550
Auranga	748	705	962	122	-	637	60	250	507
Ambica	2685	1818	2390	902	-	1765	235	1190	1762
Purna	2193	1206	1585	578	80	1213	136	627	1006
Mindhola	1056	427	612	854	-	1098	185	368	553
Total	**8330**	**5678**	**7668**	**2527**	**80**	**5404**	**667**	**3388**	**5378**

However all the balance water available in the basins can not be diverted. For assessment of divertable water, the water balance exercise has been carried out at those points of the river where diversions are planned. In this case the reservoir sites have been considered as the diversion sites and therefore water balance has been carried out at such sites.

5.3.2. Water balance at storage / diversion sites

The water balance studies at seven storage cum diversion sites viz. Jheri, Mohankavchali, Paikhed, Chasmandva, Chikkar, Dabdar and Kelwan have been carried out on similar lines as that of the water balance studies of basins. The results of studies are given in Table-5.2.

Table - 5.2
Water balance at storage/diversion sites

Unit : Mm^3

Storage/ diversion	Main river basin	Catch-ment area (sq km)	Gross annual yield at 75% Dep.	Gross annual yield at 50% Dep.	Imp-ort	Exp-ort	In basin water requi-reme-nt	Rege-nerat-ion	Water balance at 75% Dep.	Water balance at 50% Dep.
Jheri	Par	425	358	487	-	-	115	8	251	380
Mohanka-vchali	Par	206	174	236	-	57	4	3	116	178
Paikhed	Par	315	244	327	-	40	44	4	164	247
Chasman-dva	Auranga	89	76	112	-	16	2	1	59	95
Chikkar	Ambica	323	243	300	-	-	132	13	124	181
Dabdar	Ambica	482	289	397	-	-	96	10	203	311
Kelwan	Purna	733	435	555	-	-	202	20	253	373
Total		**2573**	**1819**	**2414**	**-**	**113**	**595**	**59**	**1170**	**1765**

5.3.3 Water availability at reservoir sites

The Par-Tapi-Narmada link is proposed to transfer the available surplus water from the seven reservoirs i.e. Jheri, Mohankavchali, Paikhed, Chasmandva, Chikkar, Dabdar and Kelwan. The water balance studies of these seven sites estimated the surplus as 1170 Mm^3 and 1765 Mm^3 at 75% and 50% dependabilities respectively. This estimate was based on the unregulated annual river flows. Monthly distribution of inflows and requirement and regulatory effect of reservoir were not considered for estimation of surpluses. With their regulatory effect the reservoirs influence the reliability of yield. Therefore reliability of an estimated natural yield can be increased by considering reservoirs in position. Alternatively, for the same reliability of supplies, the quantity of yield available would be more with the reservoirs in position. With this in view, simulation studies were carried out for each of the reservoirs. The parameters involved in the studies include monthly inflows into the reservoirs, demands, evaporations, elevation area capacity relationship of the reservoirs after 50 year sedimentation etc. Most of these parameters, including sizing and fixation of levels of the reservoirs have been discussed in Chapter-7 on ' Reservoirs'. However, the inflows and the simulation results in form of yield available from the reservoirs are discussed in the following paragraphs.

5.3.3.1 Inflows

Monthly inflow data for 16 to 21 years have been used in the simulation studies. As there is no discharge site at the proposed reservoir locations the observed monthly discharge data of nearby sites were used to derive monthly flows at the reservoir location. The flow at the reservoir locations were estimated in proportion to the catchment area of the reservoir as compared to the catchment area of the nearby reference sites. Nanivahial discharge site on Par river with the discharge data from 1967 to 1983 was used as reference site for Jheri, Mohankavchali and Paikhed reservoirs. Sidhumber site on Man river with the monthly discharge data from 1963 to 1983 was used for calculating the flow at Chasmandva site. For the rest three reservoirs, Chikkar, Dabdar and Kelwan, Sara site on Ambica river with the discharge data from 1963 to 1978 was used as a reference site.

The monthly inflows as derived would be natural inflow. Since there are upstream utilisations planned, the inflows to the reservoir would get reduced to that effect. To take into account the reduction in inflow due to upstream utilization a factor smaller than unity is adopted to multiply the natural inflows to arrive at actual inflows into the reservoir. The multiplying factor 'R' is defined as

$R = (X - Y) / X$

Where X = 75% dependable natural flows

Y = sum of consumptive needs from irrigation, domestic, industrial and hydropower minus regeneration upstream of the reservoir.

Table - 5.3 shows the multiplying factor and the basis of their calculation for inflows into different reservoirs.

Table - 5.3
Multiplying factors for inflows

Unit : Mm^3

Reservoir	75% dep. flow 'X'	Consumptive needs u/s of reservoir					Multiplying factor R= (X-Y) / X
		Irrigation	Domestic plus industrial	Hydro-power	Regeneration	4+5+6-7 'Y'	
Jheri	358	62	6	45.58	8	105.58 *	0.702
Mohankavchali	532					358.00	0.327
Paikhed	244	22	4	18	4	40	0.836
Chasmandva	76	0.2	1.3	0	1	0.5	0.980
Chikkar	243	129	3	0	13	119	0.510
Dabdar	289	92	4	0	10	86	0.702
Kelwan	435	196	6	0	20	182	0.582

** 75% dependability flow at Jheri.*

5.3.3.2 Net yields available for diversion

The annual yields likely to be available from the reservoirs as per simulation studies are given in Table - 5.4. The net yield available at each of the reservoir for diversion has been obtained by subtracting the committed downstream requirement from the available annual yield at the reservoir.

Table - 5.4
Regulated annual yield from reservoirs

Unit: Mm^3

Sr. No	Reservoir	Annual yield	Committed d/s requirement	Net yield for diversion
1	Jheri	242	-	242
2	Mohankavchali	201	64	137
3	Paikhed	252	40	212
4	Chasmandva	92	16	76
5	Chikkar	146	-	146
6	Dabdar	267	-	267
7	Kelwan	270	-	270
	Total	**1470**	**120**	**1350**

It can be seen from the table that a total quantity of 1470 Mm^3 of water is available annually. After accounting for the downstream requirements, a net quantity of 1350 Mm^3 of water will be available for diversion from the seven reservoirs.

5.4 Design flood

In order to optimally design the spillway and energy dissipation structures, studies to estimate the design flood have been carried out for each of the dam sites.

The design flood (Probable maximum flood) was estimated from synthetic unit hydrographs using the physiographical characteristics and from the observed G & D data of the historical floods. The 24 hrs. probable maximum precipitation (PMP) has been obtained from IMD. These values have been increased by 15% to represent 24 hrs. storm values for obtaining the probable maximum storm (PMS). These 24 hrs. PMP values have been converted into point PMP values of the required duration by extrapolating from curves for Konkan and Malabar coast sub-zones 5 (a) & 5 (b) in the CWC publication " Flood estimation report for west coast region Konkan and Malabar coasts sub-zones 5(a) & 5(b)". This point rainfall values were then used to obtain the aerial rainfall values of the required duration using the area to point rainfall ratio (percentage) v/s area. The duration of PMS has been taken as the base period of the unit hydrographs adjusted to the next 24 hrs. Cumulative hourly precipitation was then derived using distribution co-efficients obtained from the mean average time distribution curves of storms of various durations given in the CWC publication. The incremental hourly precipitation was then rearranged on the unit hydrograph ordinates to derive the probable maximum storms.

Initial loss was assumed to be 2 mm and the loss rate was taken as 1.9 mm/hr. Design base flow was taken as 0.15 cumec/sq km of the catchment area as per the CWC report.

All the above analysis have been carried out using the computer programme. The final results of the design flood studies for seven reservoirs of Par-Tapi-Narmada link are furnished in Table - 5.5.

Table - 5.5
Design flood for the reservoirs

Sl. No.	Reservoir	Catchment area (Sq km)	PMF obtained from synthetic unit hydrograph (Cumecs)
1	Jheri	425	3974
2	Mohankavchali	206	6783
3	Paikhed	315	3792
4	Chasmandva	89	2303
5	Chikkar	323	2676
6	Dabdar	482	4181
7	Kelwan	733	5456