An integrated water assessment model for future scenario studies of Sabarmati River Basin in India

M. Gopalakrishnan, A.D. Mohile, L.N. Gupta & R. Kuberan. ICID. icid@icid.org

ABSTRACT

A broad based hydrological model was developed to simulate the impact of land and water use on water resources in the Sabarmati River Basin of India to provide a tool for understanding the effects of future development and management actions; and through these results, to obtain an insight into desirable policy changes. The model deals with the entire land phase of the hydrological cycle, from precipitation to evapo transpiration and outflow to sea including withdrawals and returns. The model was calibrated using present conditions of river flow and groundwater recharge, and applied to derive responses to past (1960) conditions (used as reference year), and to analyse future (2025) scenarios. The results showed that non-beneficial evapo transpiration exceeds the annual river flow. Therefore, reduction of non-beneficial evapo transpiration is a potential strategy for improved water management. Import of water from the adjacent Narmada River Basin is necessary to sustain the present withdrawals and to meet the future needs, including that for improving low flows in order to enhance the environmental state. Present groundwater use is unsustainable. While the situation would improve slightly in future due to large additional Narmada imports, composition of return flow indicates much higher risk of groundwater pollution.

Keywords: River Basin Management, Water Assessment Model, Policy Intervention, Water for People, Water for Food, Water for Environment

Introduction

The International Commission on Irrigation and Drainage (ICID) launched a Country Policy Support Programme (CPSP) in the year 2002 with a funding support from The Netherlands Government in order to address the need for an integrated approach for evolution of water policies for the 'food', 'people', and 'nature' sectors. Under the CPSP, a Basin Wide Holistic Integrated Water Assessment (BHIWA) Model has been developed as a tool to help water policy planners to analyse water resources development with respect to various policy options at river basin level. This paper presents the development of the model as well as its application to the water deficit Sabarmati River Basin lying on the west coast of India.

The CPSP looks at water resources in the context of integrated development and management of water, land and related resources, integrating the needs of various uses including vital needs of terrestrial and aquatic ecosystems. Policies and programmes in other sectors particularly those dictating land use influence not only the demand on the resources but also have implications in the availability of water supplies. For example, the conversion of barren lands either into forests or into irrigated or rain fed agriculture tends to increase the evapo transpiration and reduces the flows. Similarly rainwater harvesting and soil and water conservation practices influence the total as well as inter-distribution of surface and ground water. Impact of internal changes in land use which invariably occurs in the long run, as well as changes in policies and programmes in regard to soil and water conservation can be properly tested only when overall water balance for the entire land phase of hydrologic cycle is studied. Further, dry season flow in rivers is contributed by shallow aquifers. Large scale ground water use for agriculture is becoming more common in some basins particularly in India and Pakistan. Such a use severely affects the base flow in rivers besides causing depletion of water tables. The separate water accounts for the river-surface and groundwater systems enable a study of this in order to achieve integration of supply sources and consider the natural and human induced interaction between the surface and ground water components.

Sabarmati River Basin

Sabarmati River Basin (Figure 1) is one of the 24 river basins of India. This water deficit basin lies on the west coast of India between latitudes 22^0 N to 25^0 N and longitudes 71^0 E to 73^0 30' E and is spread across the States of Rajasthan and Gujarat. Sabarmati River originates at an altitude of 782 m in the Aravalli Hills in Udaipur in the Rajasthan State and flows for a length of 371 km in a south-west direction, of which 48 km lies in the Rajasthan State and 323 km lies in the Gujarat State. The river out falls in the Gulf of Cambay in the Arabian Sea. The basin has a total drainage area of 21,565 km^2 of which 17,441 km^2 is in the Gujarat State and 4,124 km^2 is in the Rajasthan State. The Sabarmati River has five tributaries.

Sabarmati River Basin has a tropical monsoon climate. The average annual temperature varies between 25 and 27^0C. The rainfall occurs almost entirely during the monsoon months. The average rainfall of the entire basin is 749 mm. The rate of evaporation is maximum during April to June due to rise in temperature and increase in wind speed. The average annual evaporation losses in the basin are in the order of 1500-2000 mm.

The total population in the basin (2001) is 11.75 million, of which 5.99 million is urban and 5.76 million is rural. The projected population of the basin for the year 2025 is 19.86 million, of which 10.81 million is urban and 9.05 million is rural. The projected population of the Rajasthan portion in 2025 is 0.39 million and the entire population is rural.

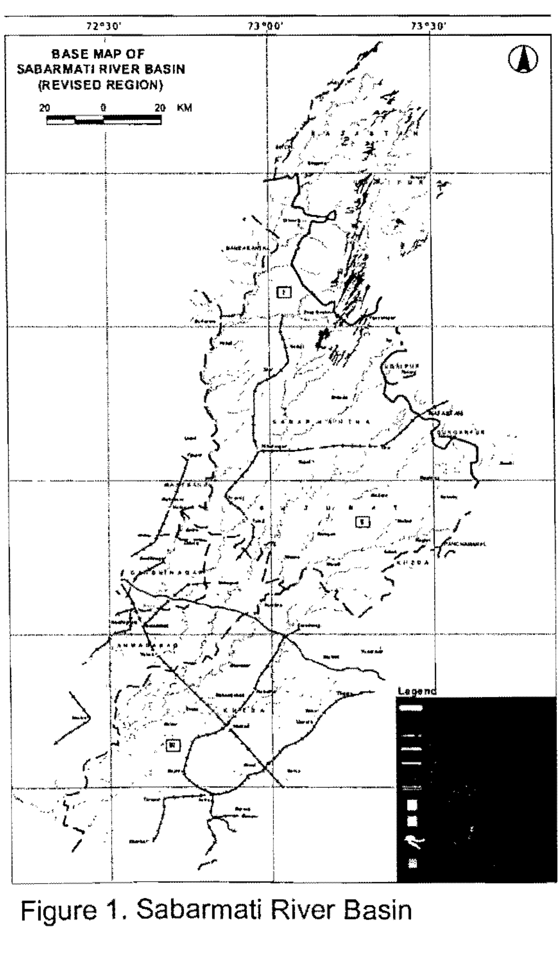

Figure 1. Sabarmati River Basin

The annual mean water resource in the basin is estimated as 3,810 million m^3. Water consumption of surface water for irrigation has been estimated to be 3,465 million m^3 per year including Mahi command within the Sabarmati basin (1,663 million m^3). The ground water contribution to the agriculture use is estimated as 2,279 million m^3. The total demand for the year 2001 was in the order of 5,744 million m^3. The irrigation demands considering the future expansion of areas and development of commands works out to 4,554 million m^3 in some scenarios (which includes import from Mahi and Narmada rivers). The ground water demand for irrigation will be restricted to the present use and it will be 2,279 million m^3. Water requirement for human and livestock in 2001 is worked out as 510 million m^3 and the requirement for the year 2025 is estimated as 898 million m^3. Water requirement for the existing 20 industrial estates in the basin is 99.64 million m^3 and the demand is likely to be 245 million m^3 in 2025.

BHIWA Model

Figure 2 shows the schematic of BHIWA model. The model covers the entire land phase of the hydrologic cycle, right from precipitation, various water uses, river flow, ground water recharge, returns, and outflow to sea. The entire river basin is divided into sub basins and several homogeneous land parcels depicting different land use categories such as forest land, pasture, waste land, wet land, land under infrastructure, land under reservoirs, rain-fed agricultural land, irrigated agricultural land, etc. The agricultural land can be further subdivided into parcels which represent broad seasonal cropping patterns (such as perennial crops, land with single crop in two four-monthly seasons and not cropped in the third season, land under two different crops in two seasons and fallow in the third season, land that is cropped only in one season and remain fallow in two seasons, etc). The main inputs to the model include hydrological data, crop parameters, land use and land parcel areas, soil moisture capacity for each type of land parcel, irrigation system efficiencies, coefficients for return flow accounts, changes in reservoir storages etc.

Table 1. Land Parcels Used in the Study

Parcel Designation	Description
P1	Forest and miscellaneous trees
P2	Permanent pastures
P3	Land not available for cultivation, waste, & fallow
P4	Land under reservoirs
P5	Kharif Paddy (rain fed) only
P6	Rain fed two seasonal (Kharif and Rabi)
P7	Rain fed perennials
P8	Rain fed other Kharif and Rabi and fallow in hot weather
P9	Rain fed other Kharif and fallow in Rabi and hot weather
P10	Rain fed other Kharif, Irrigated Rabi, and fallow in hot weather
P11	Irrigated Kharif paddy and fallow in Rabi and hot weather
P12	Irrigated perennials
P13	Irrigated two seasonal (Kharif-Rabi) and fallow in hot weather
P14	Irrigated two seasonal (Rabi and hot weather)
P15	Irrigated other Kharif, irrigated Rabi and fallow in hot weather
P16	Fallow in Kharif, irrigated Rabi and irrigated hot weather
P17	Fallow in Kharif, irrigated Rabi and irrigated hot weather paddy
P18	Fallow in Kharif, irrigated Rabi and fallow in hot weather
P19	Irrigated Kharif and fallow in Rabi and hot weather
P20	Irrigated Kharif, fallow in Rabi, and irrigated hot-weather

Note:
Kharif: Wet season, June – September/October
Rabi: Autumn season: October/November – February
Hot weather: February/March – May

Starting with the monthly rainfall and the initial soil moisture content, soil moisture capacity, potential crop evapo-transpiration and other parameters, the model calculates quick runoff including interflow, ground water recharge, irrigation withdrawal and return, evapo-transpiration for nature and agriculture sectors for each land parcel. These various fluxes obtained for each land parcel in terms of millimetres, are multiplied with the area of the corresponding parcel to get the volume of water and the volume is aggregated for the entire basin. Then the model calculates the domestic and industrial withdrawals, use and returns. Finally, surface and river water balance as well as ground water balance are calculated.

Interactions between surface and ground water components are provided in the natural mode, through deep percolation of a part of excess rain, and through a base flow from a linear, lumped ground water reservoir. The human induced interactions are provided through planned withdrawals from both the components, returns to both, additional withdrawals from ground water to supplement shortages in surface irrigation, as also through the provision of an induced recharge from rivers to ground water.

The model has been developed in Microsoft Excel Software. The model is first to be run in the calibration mode using the past or present data in order to decide the model parameters. The user may decide whether the model is to be calibrated for a single average year or a sequence of years. For many basins which are not very dry and where a quick solution is required, calibration for a single year for which verification is sought may suffice using average rainfall and average land and water use conditions. However for dry basins, it may be necessary to conduct verification for a sequence of years. With various values of model parameters, the model generated values of river flows, ground water fluctuations; annual ground water recharge and annual surface and ground water withdrawals are compared with the actual measured data to determine the model parameters. Once the calibration is done, the model can be applied to a desired scenario.

Discretisation of the basin

The Sabarmati River Basin was divided into three sub basins as follows:

- Sub Basin 1 (SB1): Main stem up to Narmada canal crossing (10,050 km^2)
- Sub Basin 2 (SB2): Watrak tributaries up to Narmada canal crossing (4,363 km^2)
- Sub Basin 3 (SB3): Downstream basin (7,152 km^2)

Table 2. Scenarios Studied

No.	Scenarios	Description
1	Past (1960)	No water development
2	Present (1995)	Considerable storage, ground water and surface irrigation, and imports
3	Future I (2025)	Business as Usual. Irrigation expansion with similar composition. Additional import from adjacent Narmada River Basin
4	Future II (2025)	Business as Usual. No Narmada import
5	Future III (2025)	Gujarat Plan. Large imports and exports, pumping imported water in upper reservoir
6	Future IV (2025)	Less export & less import to recognize competition amongst basins in obtaining imported water.
7	Future V (2025)	Agriculture seasonal shift. Irrigation expansion mostly in wet season.
8	Future VI (2025)	Similar to Future V but ground water irrigation reduced. Reduced pumping to reservoirs.
9	Future VII (2025),	Similar to V, less irrigation expansion. Less groundwater irrigation. Improved water management. More drip irrigation.
10	Future VIII (2025)	Smaller seasonal shift and improvements in water management.

The SB1 comprises most of the surface storages, SB2 has some and SB3 has none but has areas irrigated through import of Mahi River waters and groundwater. The three sub basins were further subdivided into twenty types of land parcels as given in Table 1 based on the land use data, and cropping pattern.

Scenarios studied

The scenarios studied considered emerging possibilities, the developmental plans, improved water and soil management plans etc. In Sabarmati River Basin, there is little possibility of increasing the storage capacity. Moreover, the available storage capacity in SB1 and SB2 is not fully utilised. There are plans for large imports from the Narmada River. The Gujarat State Government has also prepared a plan for using monsoon surpluses from the Narmada River, for pumping and filling up of the high level storages, including those in Sub Basin 1 and Sub Basin 2. Although there could be various pros and cons about these plans; the possibility needed a study. Similarly possibility of constraints on imports due to inter-state issues also exists and this needed a study. The present irrigation, with stress on post wet season (Rabi) irrigation was found to be causing large reduction in river flows, and hence the idea of changing the emphasis and having increased irrigation in wet season (Kharif) instead of post wet season required to be studied. Similarly at present, ground water is the predominant source of irrigation, and is already over exploited. If this trend continues the situation may become totally unsustainable. Hence, a comparative reduction in ground water use was studied in various scenarios. Improved water management through improving irrigation system efficiency, evaporation control, by adopting measures like mulching, weeding of barren areas and increased area under micro-irrigation were also important strategies, which needed a study. The various scenarios studied have been listed in Table 2.

Calibration of the Model

The BHIWA Model was calibrated for the present conditions and applied to derive responses corresponding to past and future scenarios using monthly time steps. The calibration can normally be done for a single average year. This approach was followed initially, but as it was desired to improve the accuracy of the parameters, the calibration was done for a five-year period (1995-96 to 1999-2000). This allows a sequential continuous operation of the model, including the storages in the soil and groundwater. Rainfall data of the individual years were used. The graphical comparison between monthly observed and computed flows, as also the computation of standard error, allowed the user to obtain a good hit through manipulation of parameters without any rigorous optimisation. The approximate comparison of surface flows computed by the model (with natural recharge from river to Groundwater) with the observed flows is shown as follows:

Sub-Basin/ Basin	Average flow computed by the model ($10^6 m^3$/year)	Estimated observed flow at the outlet of sub basin ($10^6 m^3$/year)
SB 1	358	373 (Indira Bridge)
SB 2	1075	580 (Watrak at Khera)
Total basin (included in SB3)	1933	1711

The general validation of the model was accepted with the following values of main parameters:

- Soil moisture storage capacity varies with soil type and land use: 200 mm for forests, 100 mm for permanent pasture, 75 mm for agricultural lands (but 150 mm for paddies) and 50 mm for land not available for cultivation, 30 mm for land under reservoirs. Higher capacity values would lead to higher evapo-transpiration and lower flows after rainfall has ceased, thus giving a better calibration but values higher than these were not tried as such capacities were unlikely to be available.
- The excess water was divided assuming that 80 percent yields to surface and sub surface (or quick runoff) flow and the rest 20 percent yield to groundwater. With this assumption, reasonable annual recharge was realised.
- A groundwater recession coefficient of 0.25 allowed

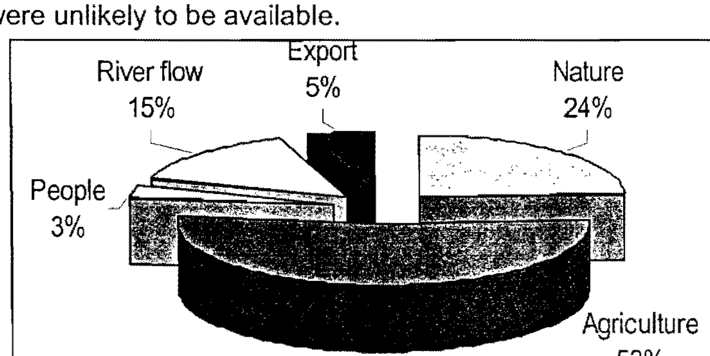

Figure 3. Utilization in Future VIII scenario

the persistence of good base flows, in the absence of withdrawals, up to say February, as was experienced in the prototype in the past. Currently, with very high ground water withdrawals, base flow ceases much earlier, both in the prototype and in the model.

Results and discussion

Table 3 shows the overall water balance for various scenarios in the Sabarmati River Basin for an average rainfall year. Table 4 gives the consumptive use of water by various sectors for each scenario and Table 5 gives the requirement of ground water pumping to meet the shortage of surface water and natural or induced recharge from river to ground water.

For the current condition, the total consumptive use is 14,663 million m^3. It comprises 5,118 million m^3 (35%) for nature sector, 9,415 million m^3 (64%) for agriculture sector and 130 million m^3 (1%) for people sector (D&I). The agricultural use of 9,415 million $m^3$is made up of ET from rainfall and soil moisture, in rain-fed lands as well as irrigated lands, additional ET met from irrigation and reservoir evaporation. The consumptive use includes considerable non-beneficial ET for nature sector (1,813 million m^3) and for agriculture sector (1,459 million m^3). These two together exceed the quantum of the river flow itself. Thus, reduction of non-beneficial ET through rain harvesting and soil water management can lead to a significant improvement in river flows. Figure 3 shows the water utilisation in Future VIII scenario.

In the model, the ET in the future 'business-as-usual' scenario is 17,397 million m^3. Through the various water saving measures, in Future VII it could be reduced by 18% to 14,238 million m^3. The Scenario Future VIII has been attempted to get the maximum practicable expansion of irrigated area, without reducing the river flows much below the present level, and that too with limited imports. In this combination, the natural and induced recharge, as necessary to maintain the ground water balance and also the need for pumping of ground water to canals has been minimized. In this scenario, the total consumptive use is 15,366 million m^3. Since this is almost same as the current value of 14,663 million m^3, the scenario VIII does not further deplete the water resources.

Table 3: Overall annual water balance (steady state, average rainfall year) (10^6 m^3)

Component	Past (1960)	Present (1995)	Future I (2025) B As U With Narmada import	Future II (2025) B As U without Narmada import	Future III (2025) Gujarat Plan	Future IV (2025) Less export & less import	Future V (2025), agriculture shift	Future vi (2025), same as V but Groundwater prop. Reduced & Narmada pumping	Future VII (2025), similar to V, less expansion & Groundwater, better Water Management	Future VIII (2025), limited agriculture shift, Larger exports and small environmental flow
Inputs										
Rainfall	16162	16162	16162	16162	16162	16162	16162	16162	16162	16162
Imports	0	1584	3084	1581	3938	2334	3084	3084	3081	2834
GW flow from other basins	0	0	0	0	1	0	0	0	0	0
TOTAL inputs	*16162*	*17744*	*19246*	*17743*	*20101*	*18496*	*19246*	*19246*	*19243*	*18996*
Outputs										
Consumptive use	11694	14663	17397	17402	16566	16441	14508	14570	13920	15068
River flows	4468	2821	1465	122	2119	1664	4313	4252	4899	2897
Export (surface)	0	260	425	260	1417	425	425	425	425	1024
GW flow to other basins	0	0	0	0	0	0	0	0	0	0
Direct GW flow to sea	0	0	0	0	0	0	0	0	0	0
Total Outputs	*16162*	*17744*	*19287*	*17785*	*20102*	*18529*	*19247*	*19247*	*19244*	*18989*
Storage change										
Surface storages	0	0	0	0	0	0	0	0	0	0
GW storage	0	0	-41	-42	-1	-33	0	0	-1	-4
Total storage change	*0*	*0*	*-41*	*-42*	*-1*	*-33*	*0*	*0*	*-1*	*-4*
Imbalance	0	0	0	0	1	0	0	0	0	11
Soil moisture storage change	0	0	0	0	0	0	0	0	0	0

Surface water

Around 1960, in average condition, as per the model, the withdrawal of surface water was only 4 percent of the total inputs, and return flow contributed only 2 percent of inputs, the base flow was available from August to May. This is considered to represent near pristine conditions. In the current situation, with average rainfall, return flows contribute 9 percent of total inputs and withdrawals are equal to 35 percent of the inputs. Thus both cause risk of pollution of downstream waters. In the future scenarios, although further import of Narmada river waters could maintain the withdrawal to input ratio around the current figure, the return flows would constitute about 12 to 13 percent of total inputs, thus indicating a somewhat larger hazard of pollution of groundwater. However, the base flow availability improves (Figure 4).

Groundwater

In the basin, extensive groundwater use has been practiced. In the current situation, return flows, natural and human induced together constitutes 54 percent of the inputs. At the same time withdrawals are 112 percent of the input, thus signifying mining of unsustainable groundwater balance, which would be made good by further surface to ground water transfers. The situation would improve slightly in future due to large additional Narmada imports. But even then, return flow would continue to constitute about 40 percent of the inputs, indicating risk of pollution. The withdrawals would constitute 66 to 86 percent of the input, thus leaving only small quantity to contribute to the base flow.

Table 4: Consumptive use (evapo-transpiration) by sector (10^6m^3)

Sector	Past (1960)	Present (1995)	Future I (2025) B As U With Narmada import	Future II (2025) B As U without Narmada import	Future III (2025) Gujarat Plan	Future IV (2025) Less export & less import	Future V (2025), agriculture shift	Future VI (2025), same as V but Groundwater prop. Reduced & Narmada pumping	Future VII (2025), similar to V, less expansion & Groundwater, better Water Management	Future VIII (2025), limited agriculture shift, Larger exports and small environmental flow
Nature sector										
Beneficial	3306	3305	3188	3188	3188	3188	3188	3188	3188	3190
Non-beneficial	2474	1813	1477	1477	1477	1477	1477	1477	1477	1455
Total	5780 (49%)	5118 (35%)	4665 (27%)	4665 (27%)	4665 (28%)	4665 (28%)	4665 (32%)	4655 (32%)	4655 (33%)	4645 (30%)
Agriculture sector										
Beneficial	5038	7956	10386	10391	9639	9585	7880	7880	7674	8646
Non-beneficial	823	1459	1771	1772	1688	1617	1389	1450	1334	1500
Total	5861 (50%)	9415 (64%)	12157 (70%)	12163 (70%)	11327 (68%)	11202 (68%)	9269 (64%)	9330 (64%)	9008 (63%)	10146 (66%)
People sector (D&I)	54 (1%)	130 (1%)	575 (3%)	575 (3%)	575 (4%)	575 (4%)	575 (4%)	575 (4%)	575 (4%)	575 (4%)
Total of all sectors	11695	14663	17397	17403	16567	16442	14509	14560	14238	15366

Table 5: Ground water pumping and recharge ($10^6 m^3$)

Description	Past (1960)	Present (1995)	Future I (2025) B As U With Narmada import	Future II (2025) B As U without Narmada import	Future III (2025) Gujarat Plan	Future IV (2025) Less export & less import	Future v (2025), agriculture shift	Future vi (2025), same as V but Groundwater prop. Reduced & Narmada pumping	FUTURE VII (2025), similar to V, less expansion & Groundwater, better Water Management	Future VIII (2025), limited agr. Shift, Larg exports and small environmental flow
Natural & induced recharge from river to Groundwater for balancing the Groundwater	0	200	2150	2100	1450	1350	500	200	0	500
Groundwater pumping to surface canals for meeting shortages in surface irrigation	523	3637	6610	6626	5419	5341	3271	2804	1983	3657

The heavy withdrawals from surface and ground water represent the demands, which have been fulfilled from the available surface and groundwater. When the surface water was not available, additional pumping from ground water to the surface canals was required to be done to fulfil the demands. Similarly, because of these heavy ground water withdrawals, the sustainability of the ground water storage, under the average recharge conditions was disturbed. This required the assumption of natural and induced recharge from surface to ground waters, as has been already discussed. The scenario-wise position about the need for groundwater pumping into canals (for meeting deficits in Surface water irrigation) and of natural and induced recharge (to make ground water position on sustainable) is given in Table 5. The ground water pumping to canals is necessary mostly in June and in the low flow months, whereas the natural & induced recharge from river to GW is mostly in the high flow months.

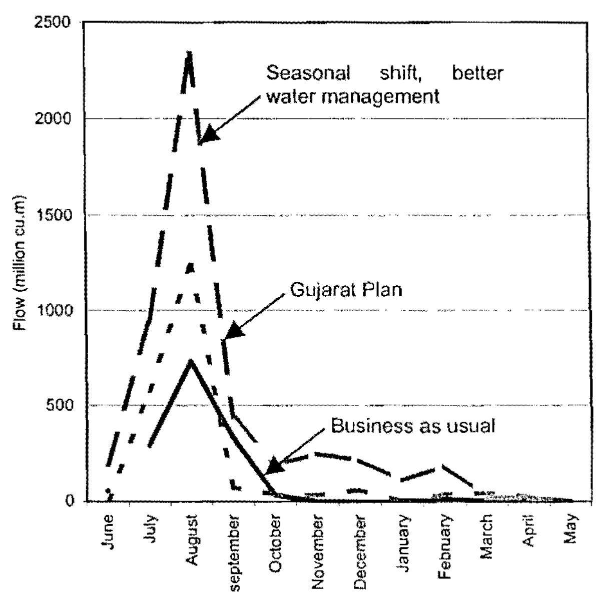

Figure 4. Monthly river flow

The NBD after registration or even in its present form shall continue collaborating with IUCN in implementing activities related to NBD. IUCN should continue to assist the NBD to formulate the management and administration structure and internal systems of operations. The NBD shall continue to engage partnership with reputable institutions in the region as it grows towards achieving full autonomy.

CONCLUSION

This paper has analysed the challenges and importance of involving CS in the Nile basin development projects. The NBD project demonstrated that involving CS in the NBI government process is beneficial and can ensure sustainable and equitable utilisation of water resources of the Nile basin. The obstacles for a viable, organised and an effective CS development and action include:

- Lack of coordination among CSOs
- Lack of information sharing
- Lack of a framework or political space for CSOs
- Lack of Government support and independence of CSOs, competition between governments and NGOs for donor funding

The NBD project experience showed how the NBI government process can benefit from CS participation. The following are some of the examples:

- Gathering and dissemination of information that improve awareness of local communities
- Promote development of relations between different actors and establish links with the grassroots (reach where the government cannot reach)
- Ensure proper management of resources
- Serve as a forum for the support of traditional livelihoods
- Provide of expert practical and technical assistance in specific areas such as resettlement, sustainable use of natural resources, Environmental Impact Assessment (EIA), etc.
- Ensure projects are not purely technically oriented but human and social concerns are integral parts of the projects

The recommendation that can be emphasized here is that in the formulation of NBI government projects to highlight the following:

- Need for participation of public and CSOs in the design and preparation of the projects before the implementation.
- Mechanisms of CS involvement to be highlighted in the Institutional and Implementation arrangements,
- It should also highlight the link and the role that public and other stakeholders can play as a key partners in the projects

In conclusion, strengthening CS participation in River Basin Management projects ensure trust and confidence between all actors, ownership and conflict prevention and resolution over water resources sharing. Below are some of the recommendations to strengthen CSOs' participation from the African Civil Society water Resources Development Workshop which was held on 2-4 October 2003, Nairobi, Kenya:

- Legal and official requirements such as registration should be complied with
- CSOs activities should be coordinated by mapping out objectives, capacity building and outreach (promoting national networks at project level)
- Maintaining correct data, documenting best practices and disseminating information
- Analyzing strengths and weakness and building capacity on relevant themes
- Maintaining transparency and accountability
- Funding-raising and lobbying for African governments to allocate funds for CSO activities.
- Working through existing networks, or creating a new one and participating fully in the activities of the network(s).
- CSOs need to change now from making protests to proposal
- CSOs need to move from theoretical advocacy to developing research data from the field, producing documents and publishing, etc. In this way, they will be seen to be the real experts
- They should adopt the right strategies, build relationships and identify whom to influence, understand procedures and take initiatives.
- CSOs should participate in developing the capacity of national governments and regional institutions
- CSOs should strive to be part of any negotiations from the beginning.
- They should lobby to be part of national delegations (perhaps as observers) during important international meetings
- CSOs should involve the people in their activities as well as network with other CSOs
- To strengthen African ownership of water development processes, Africa should self finance more initiatives, rather than depending on donor support.

REFERENCES

Diana Rizzolio Karyabwite, 2001. Water sharing in the Nile River Valley, UNEP/DEWA/GRID-Geneva

Nile Basin Discourse website www.nilediscourse.org

Jean Bigagaza, 2004. NBD Technical Report

Esther W.Dungumaro, Ndalahwa F.Madulu, 2002. Public Participation in Integrated Water Resources Management: the case of Tanzania. Proceedings of a symposium, 30-31 October 2002 in Dar es Salaam

Aly M. Shady, 2003. Public Participation in the Nile River Basin: past experience and prospects for the future. Proceedings of a conference, 18-19 April 2003 at University of Virginia, school of law, USA