WATER BALANCE TO IDENTIFY LUNUGAMVEHERA RESERVOIR MANAGEMENT REQUIREMENTS

Technical Paper that was awarded the Second Place at the "Water Related Infrastructure" competition, Sponsored by St. Anthony's Industries Group and conducted by IESL.

by

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Abstract

Lunugamvehera reservoir constructed across the Kirindi-Oya in the Southern Sri Lanka, is considered as a prominent water body not only because of its large size but also due to widespread accusations that this reservoir has failed to serve its farmers.

Water balance of a reservoir can easily identify the fluctuations of reservoir storage through the fluctuations of inflows to the reservoir, seepage from the reservoir, evaporation and water extractions for purposes such as cultivation and domestic.

Recent studies on small irrigation tanks have shown a possibility of the actual evaporation and seepage from a tank to far exceed the estimates done at the planning and design stage. The Irrigation Department which is the organization managing this reservoir has been measuring water inflows, reservoir water levels, and reservoir water usage through the sluices. These data along with evaporation data of the area were incorporated into a reservoir water balance to compare the variation and effects of water accounting components in the system. Water balance model constructed keeping in line with the Irrigation Department guide lines, identified the necessity of accurate water release measurements for efficient management of reservoir storage.

The water balance model outputs fitted to the observed data provide the opportunity to analyze the sensitivity of evaporation and seepage volumes from the reservoir thus providing management information. Reservoir water levels were compared with the estimates done using standard procedures for the assessment of the deviation from a manager's expectations, thus revealing management options such as strengthening the measurements and a review of forecasting methods.

1. General

Lunugamvehera reservoir is a large water body with a storage capacity of 170,000 Acft, constructed under the Kirindi Oya Irrigation and Settlement Project. The Kirindi Oya development project was commissioned in march 1986. Lunugamvehera reservoir under this project is located in the relatively dry zone in South-East quadrant of Sri Lanka at a distance of approximately 260km from Colombo (Figure 1). Lunugamvehera reservoir has a drainage area of 353 square miles. Drainage basin of Kirindi Oya is narrow and extends from Bandarawela at 6350 ft MSL for a distance of 75 miles to the sea at Kirinda. Total watershed area of Kirindi Oya is 455sq. miles (Dharmasena 1986).

The Lunugamvehera reservoir consists of a left bank and right bank canal system. It provides water to about 25 small villages with 5000 families located at close proximity. There is drinking water supply scheme to serve people in the region and water supply is extended to an animal and diary development project to develop livestock resource. Other than the above, approximately 10,500 acres in Tissa region receives water through a network of 5 old tank network downstream of the Lunugamvehera reservoir.

2. Reservoir Storage, Inflow, Water Releases and Evaporation

The Department of Irrigation (ID) collects and maintains the Lunugamvehera reservoir operation data. Operation-data pertaining to five years obtained from the ID and streamflow data from 1990-1994 at gauging point Kitulkote (Drainage Area 749km^2) were used for the water balance study. Daily pan evaporation data at Angunukolapellessa were obtained from the Department of Meteorology.

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Monthly inflow showed a two peak behaviour with a lower peak in April when compared with the November - December peak (Figure 2). This high April peak was observed only in the years 1992, 1993 and 1994. In the years 1990 and 1991 the Yala rains were more than the Maha rains.

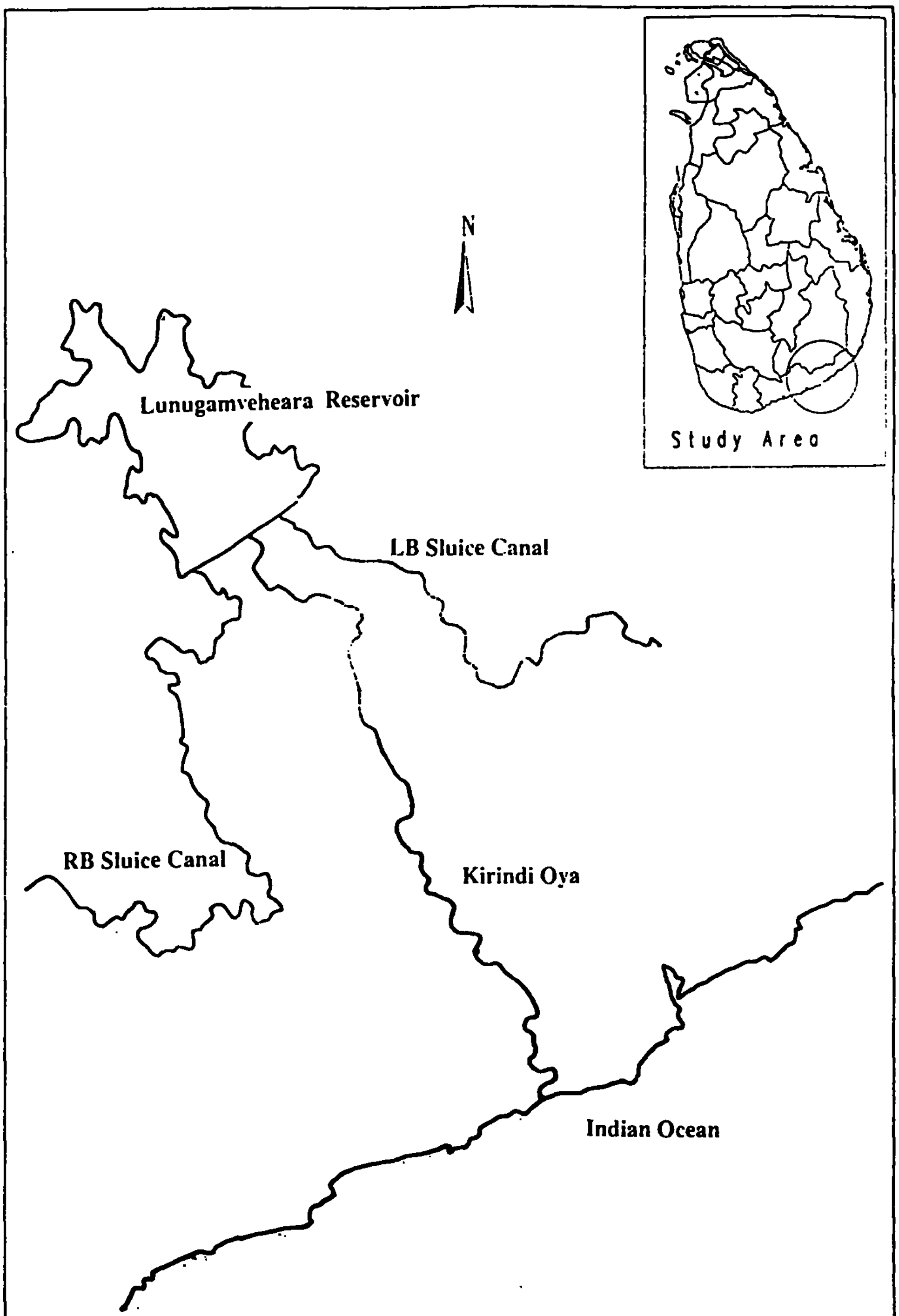

Figure 1: Map of the Study Area

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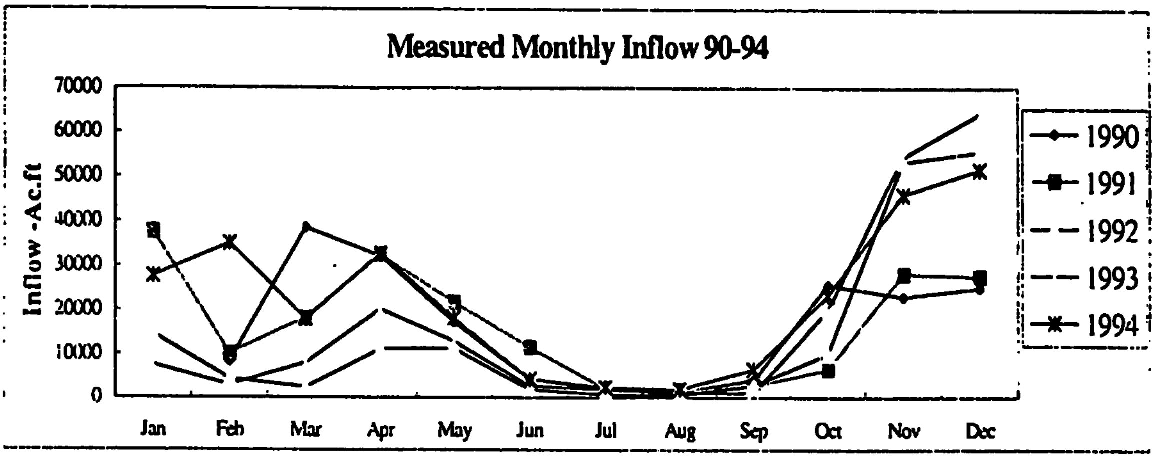

Fig 2 - Monthly inflow to the lungamvehera Reservoir

Reservoir water release fluctuations do not show a uniformity in the pattern except a vague presentation of peak and lean water release periods (Figure 3). Monthly water release show a vast variation in the pattern and also in the magnitude of release during each month. However the years 1990 and 1994 show a similarity in the pattern. The water release in the year 1994 had been about 65% more than average in the period 1990-1993. The monthly water release variation shows two minimum releases, with one during April and the other during September, showing the boundary of the Maha & Yala seasons. On the average the Maha (Oct-Mar) season and Yala (Apr-Sep) season water releases are 90,750 ac.ft and 65,000 ac.ft respectively.

From a comparison of Tissamaharama, Angunuko lapellassa and Hamabantota evaporation data. Angunukolapellessa data had been chosen by the ID for reservoir operation computations (Dharmasena 1986). Monthly pan evaporation fluctuations during the period are between 90 mm-180 mm (ie 2.9-5.9 mm/day) with an average value of 140 mm (ie 4.5 mm/day).

Monthly variation of reservoir storage does not show a uniform pattern over the period under study (Figure 4). Reservoir storage has fallen to very low levels below 40,000 ac.ft in the years 1992 and 1993 and this has a direct link to the low rainfall experienced in those years. The year 1994 appears as an exceptional year showing a near constant reservoir storage from beginning of January upto about 150 days.

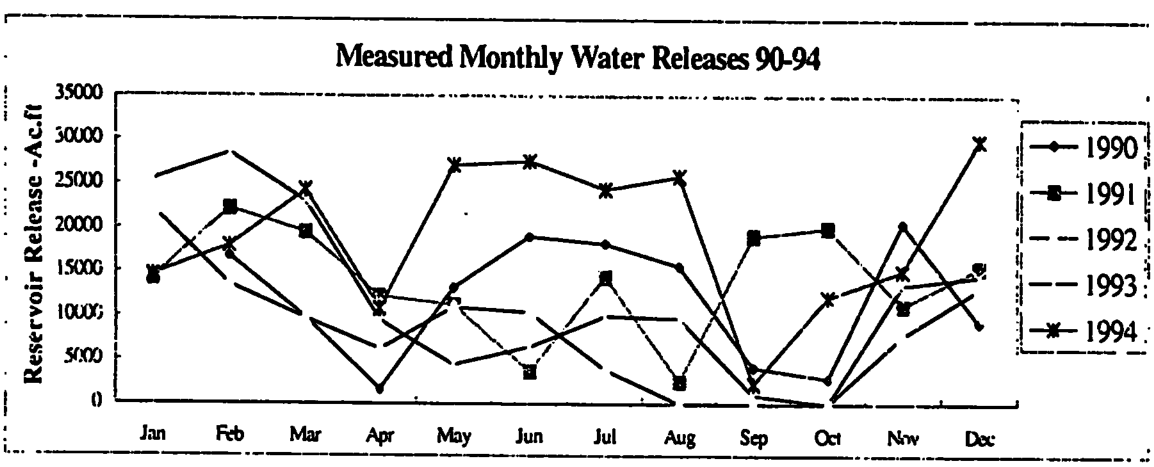

Fig 3 - Monthly Water Releases from the Lunugamvehera reservoir

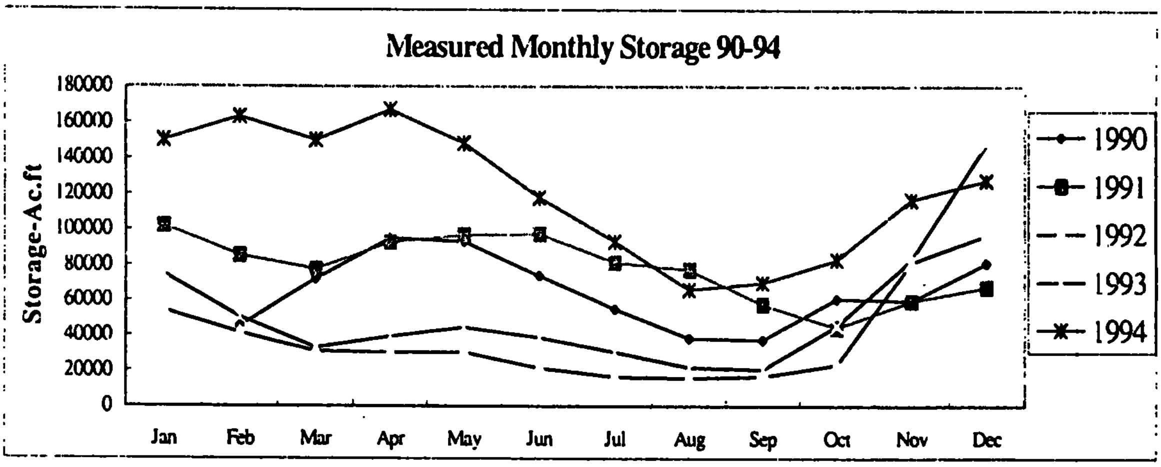

Fig 4 - Monthly Storage in the Lungamvehera Reservoir

3. Water Balance Modelling

A monthly water balance model was developed for the reservoir in which the change of storage within a month was equal to the difference between the reservoir inflows and outflows.

Drainage area at the stream gauging point Kitulkote when compared with that of the Lunugamvehera reservoir is less by 63 sq miles. The additional extent of drainage area at the Lunugamvehera reservoir is located in the drier region of the entire catchment. As such, for water balance computations it was assumed that the reservoir inflows are same as the gauged streamflows at Kitulkote.

Evaporation per unit area from the surface of reservoir was taken as equal to the same of pan evaporation. It was considered to commence with pan evaporation values rather than attempting to find an appropriate coefficient to relate pan evaporation with the reservoir surface evaporation. Seepage computations were based on the Irrigation Department (ID)

Guidelines (ID 1980) which recommends to assume a seepage loss in a given period as 0.5% of the water in the reservoir during that time period.

Reservoir actual water storage measured by the ID were compared with the reservoir storage values from water balance model computations. The continuous simulations indicated an accumulation of reservoir storage gap in the observed and calculated values over the years (Figure 5). The gap on some occasions increased to a value approximately equal to 40,000 ac.ft. The deviation which of a significant magnitude is on the average accounted to more than 10 times the evaporation values used for the water balance model.

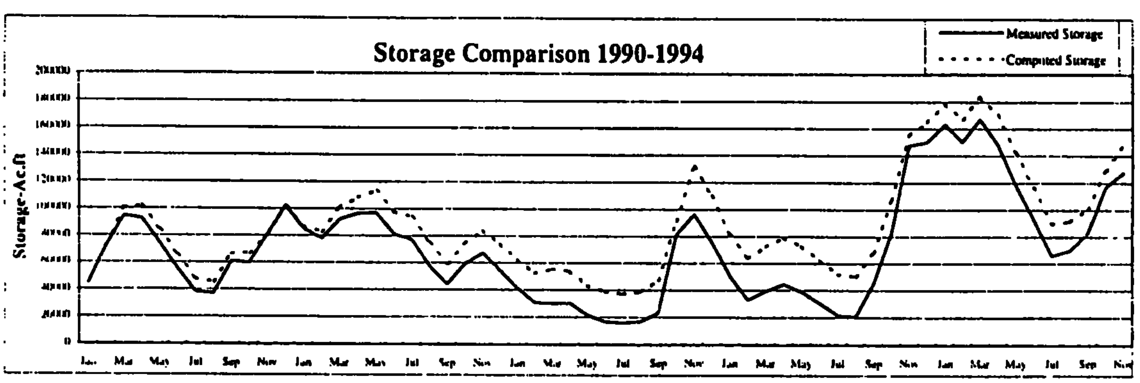

Fig 5 - Comparison of Reservoir Storage Through the Water Balance Model

4. Rectification of Water Releases

Investigation of model inputs using the order of magnitude identified that the mismatch of modelled reservoir level with measured value would be either due to inflow or water release values. The inflow gauging station Kitulkote is equipped with an automatic recorder and hence the chances for error is extremely low. Hence a maximum adjustment value of +-5% (WMO 168) was affected to the inflows and model computations were performed to match observed storage values with calculated storages through the model while adjusting the water releases from the reservoir. The water releases were kept at non-negative values.

The model provided a near perfect match (Figure 6). Only the months of 1992 Nov, 1993 Oct and 1993 Dec were showing a discrepancy in matching. Water release adjustments for water balance indicated that on most occasions the water release needed to be more than the recorded values (Figure 7). This was mostly concentrated in the period from Jan-June, where low rainfall were observed. Modeled water releases on a seasonal basis were compared with assumed paddy cultivation requirements for Yala (8 ac.ft/ac) and Maha (6 ac.ft/ac). Computations showed that an average of about 9000 ac (Yala) and 15000 ac (Maha) could have been cultivated paddy with this water releases.

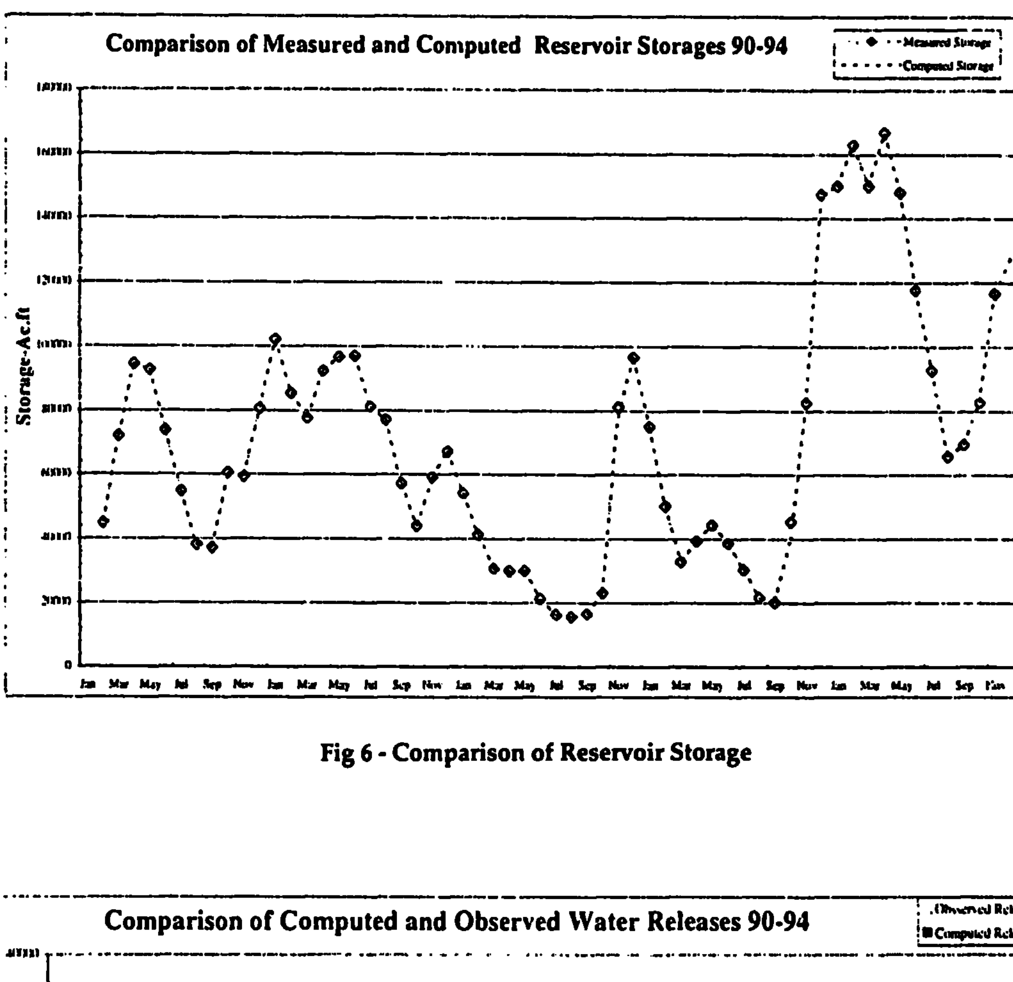

Fig 6 - Comparison of Reservoir Storage

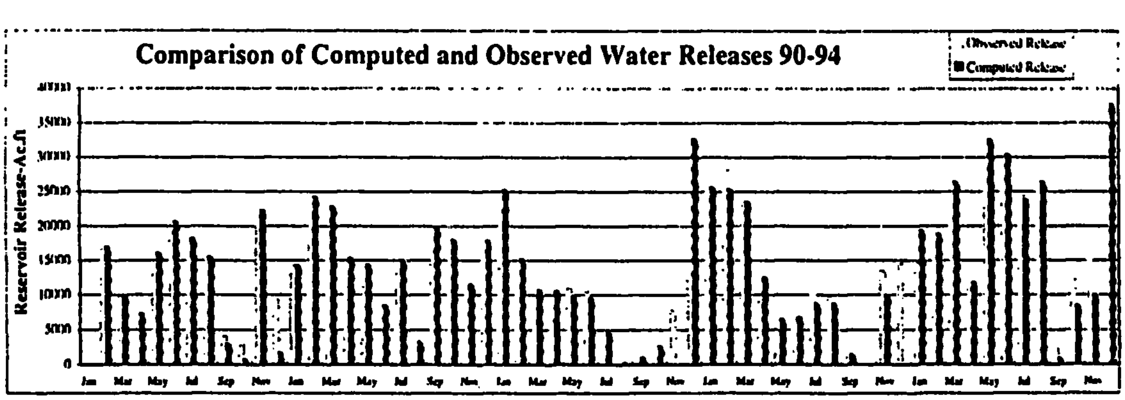

Fig 7 - Comparison of Reservoir Storage Releases

5. Evaporation from Reservoir

Water balance modelling exercises were carried out to ascertain the required modifications in seepage and evaporation to achieve a good water balance model. This identified which proportions would be required to adjust either evaporation or seepage to achieve a water balance. Computations revealed that the changes so desired are highly unrealistic reaching extremely high percentages. This indicated that evaporation values were not a major cause of the mismatch.

Water balance model (Figure 6) was used to check the sensitivity of the evaporation data on model outputs. Evaporation values were changed from pan evaporation to a value of 1.5 times pan evaporation in steps of 0.1 (Table 3). It was found that evaporation accounted for only 8% of the effective water in the reservoir. The effective water in the reservoir was defined as the addition of total water released during a period and the remaining water at the end of that period. Percentage of effective water consumed by evaporation with varying conversion coefficients show that even if pan evaporation increases by another 50% to a highly unrealistic value, the total water loss would be 12% on the average and that the 50% increase would effect only an additional 4% loss of water, which is small in magnitude when compared with other inputs. Efforts to further increase the pan evaporation to check the sensitivity showed that such increases resulted in large evaporation quantities leading to negative reservoir storage.

Table 1- Lunugamvehera Reservoir Parameters

Catchment Area	353sq.miles
Gross Capacity	214,000 ac.ft
Dead Storage	10,000 ac.ft
Full Supply Level	195.0 ft msl
High Supply level	198.0 ft msl
Maximum Annual Yield	537,500 ac.ft
loiMinimum Annual Yield	86,500 ac.ft
Average Annual Yield	277,000 ac.ft

Table 2- Reservoir Inflow, Water release and Storage

	Average Reservoir Inflows and Outflows 90-94		
	River Inflows-Ac.ft	Water Releases-Ac.ft	Storage at End the of Month-Ac.ft
Jan	656887.40	17393.09	87537.54
Feb	341291.38	19740.78	77069.10
Mar	526281.65	17246.70	72744.58
Apr	773069.27	8030.56	84705.52
May	502228.31	13341.56	82512.84
Jun	147411.04	13387.93	69770.37
Jul	55445.06	14145.58	55190.88
Aug	39448.69	10722.45	43727.73
Sep	102466.19	5286.28	40242.37
Oct	528711.80	6979.27	51238.23
Nov	1225927.49	13595.57	79891.34
Dec	1386540.18	16420.92	104015.39

Table 3- Evaluated Sensitivity of Evaporation

Evaporation Coeffcient over Pan Evaporation	Evaporation as a percentage of Effective Water					
	1990	1991	1992	1993	1994	Average
x 1	10.2	10.4	6.9	6.0	8.3	8.4
x 1.1	11.1	11.4	7.4	6.5	9.6	9.2
x 1.2	12.1	12.3	8.0	7.0	10.4	10.0
x 1.3	12.9	13.3	8.6	7.5	11.2	10.7
x 1.4	13.8	14.2	9.1	8.0	11.9	11.4
x 1.5	14.6	15.0	9.6	8.4	12.7	12.1

6. Seepage from Reservoir

It is widely discussed that the assumption in which a 0.5% of volume of water in the reservoir is the quantity lost by seepage does not appear realistic and that seepage amounts to much more. In order to identify this, the seepage coefficient was changed from 0.5% to 2% that means a four fold increase from the ID guide lines which had been practiced for decades (Table 4).

It shows that water consumed by seepage as a percentage of effective water in the reservoir does not exceed 6% even with a four fold increase in the present coefficient. Variations higher than 2% for the seepage coefficient could not be incorporated since such increases led to negative storage in some months.

Table 4 - Evaluated Sensitivity of Seepage

Seepage Coeffcient	Seepage as a percentage of Effective Water					
	1990	1991	1992	1993	1994	Average
0.05%	1.7	2.1	1.1	1.0	2.0	1.6
1.00%	3.2	4.0	2.1	1.9	4.0	3.0
1.50%	4.7	5.9	3.0	2.8	5.8	4.5
2.00%	6.2	7.6	4.0	3.6	7.5	5.8

7. Seasonal Water Management

Water balance model was utilized to compare the forecast of reservoir water levels against the measured water levels during each season.

Comparisons were done to each season considering that the reservoir manager was aware of the initial storage but had to resort to reservoir inflows based on 75% probable inflows. Therefore the initial storage for the model at the beginning of a season was made equal to the measured value at that time. Computations showed (Figure 8) that except in 1994, the reservoir storages had fallen below the expected levels which were computed utilizing probabilistic inflows. This showed that a planner who attempted reservoir operation had failed in 6 out of 10 seasons in the period from 1990 to 1994, giving a strong support to the widespread accusations that this reservoir has failed to serve itfs farmers.

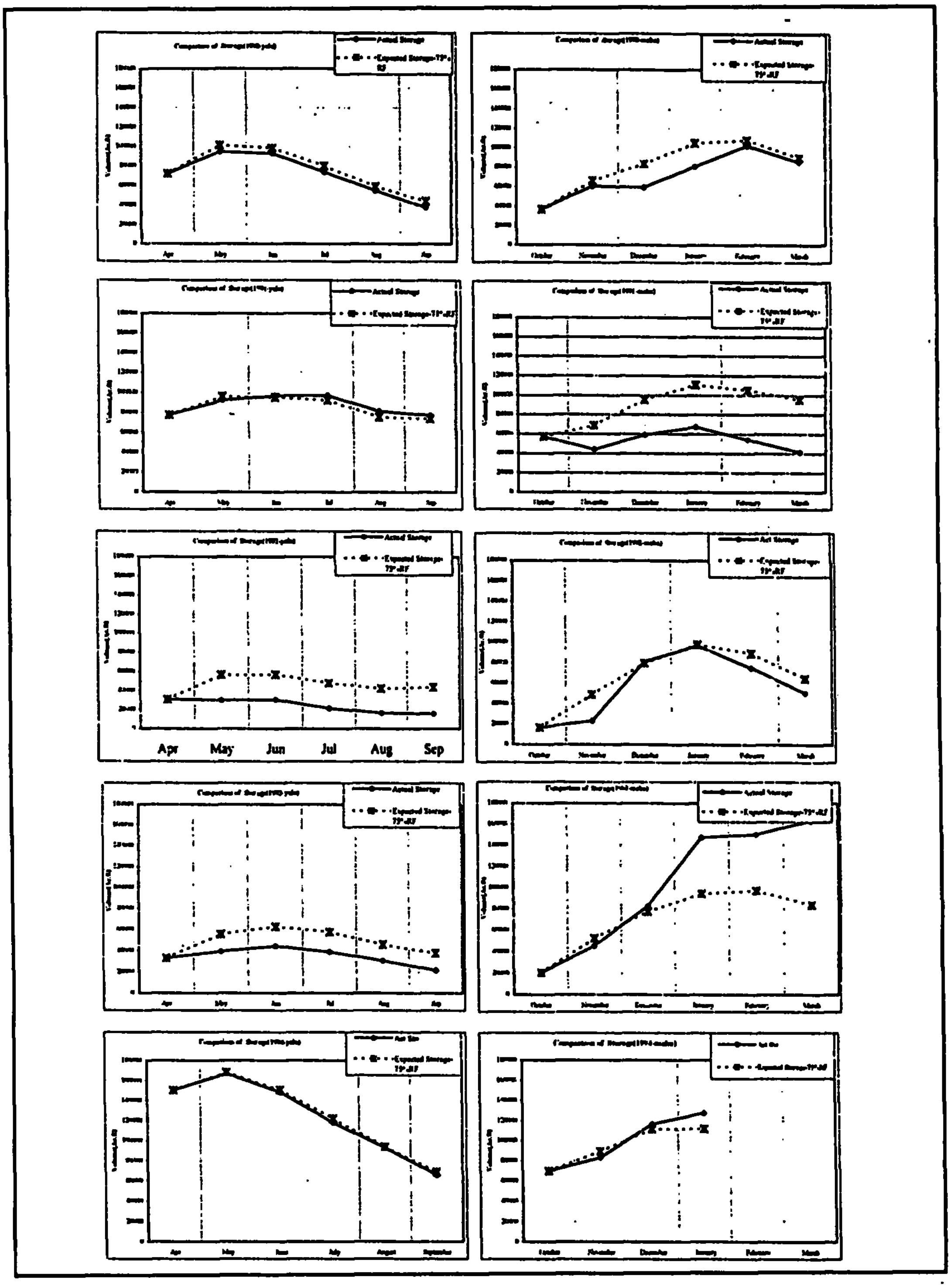

Fig. 8 - Seasonal Predictions and Measured Storage at Lunugamvehera Reservoir

8. Discussion

Reservoir operation according to the Irrigation Department guidelines showed a significant disparity. This was investigated in detail to identify the reasons. The model identified a high incompatibility of water release observations. This could be due to recording errors or calibration errors at reservoir discharge outlets. Therefore such recording and measuring devices/mechanisms needs checking. Water balance model indicated that the reservoir in the period from 1990-1994 may have released water sufficient to cultivate paddy in about 12000 acres.

A comparison of Pan evaporation variation throughout the years and a sensitivity analysis indicated that the order of magnitude of water evaporated from the reservoir was about 10% and that an increase in the pan evaporation values by 50% effected only an additional increase in 4% in the volume lost from evaporation. When the order of magnitude of effective water in the reservoir is considered this increase is very small. Therefore evaporation values in the region could be used for reasonable water balance modelling.

A comparison of seepage coefficient change from 0.5% to 2.0% indicated that the order of magnitude of seepage when compared with the effective water in the reservoir was very low. Even with a seepage coefficient of 2.0% the average seepage quantity accounted to about 6% of effective water in the reservoir. A four fold increase in seepage coefficient effected only an increase of 4% in the volumes seeped from the reservoir.

Water balance model computations using actual storage values at the beginning of seasons showed that the reservoir has mostly failed to perform as expected. These computations assumed that the demand values obtained through water balance remained as the demand for a particular season under consideration. Also it was assumed that the planning was based on the 75% probable rainfall and yield estimates of Department of Irrigation. This consecutive failure in planning shows that either the considered years had poor rainfall than what was assumed in the designs or that water releases from reservoir had been excessive. This doubt with water releases would certainly be reflected in an examination of planned and actual water releases from the reservoir during the concerned years, along with measurements. It would be prudent to analyze long term catchment rainfall records to identify trends and check the accuracy of the 75% probable rainfall estimates for the concerned area.

The order of magnitude of seepage and evaporation is low when compared with other water balance inputs. This fact can be effectively used for reservoir planning and management in data deficient periods. However a comparison of evaporation and seepage volumes with water releases especially during specific seasons in the year reveals that the monthly quantities could be of significance. Therefore a seepage coefficient study using soil moisture parameter measurements may provide better estimates for better management of water in the reservoir. Similarly identifying pan evaporation values from the reservoir would also provide a better controlled water management over the reservoir.

9. Conclusions

1. Water balance modelling performed on a monthly basis can be used for effective planning and management of reservoir water, through rational rectification of poor quality data.
2. Water balance modelling of the Lunugamvehera reservoir indicated that the water release data from reservoir requires a close checking for effective water management.
3. Water balance modelling could easily identify differences in the measurements and raise issues pertaining to the assumptions. This will provide opportunities for a manager to closely monitor the system performance, data collection, data extraction and data recording.
4. In case of Lunugamvehera Reservoir a reasonable water balance modelling for planning and management purposes could be obtained using the pan evaporation values for the region and using seepage coefficient as recorded by the Department of Irrigation. This is possible since reservoir water is not much sensitive to pan evaporation and seepage coefficient values.
5. A long term rainfall study for the watershed, and evaporation & seepage parameter measurements at site, would lead to finer management of water in the reservoir. This may be very effective in this reservoir where farmers had been agitating for more water.

10. References

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