Analysis of the Diversion Requirements from the Deduru Oya Reservoir in Sri Lanka

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Abstract: The Deduru Oya reservoir project which is under construction is aimed to improve the livelihood of farmers in parts of the North Western Province by increasing the productivity of its land by regulating and diverting the Deduru Oya water by two main canals. The proposed Left Bank (LB) canal which is 44.1 km long with a discharge capacity of about 7.1 m^3/s at the intake will supply water to augment about 136 existing storage-based minor irrigation systems in the left bank of the Deduru Oya river. This study is focused on the analysis of the diversion requirements of the proposed reservoir. For each of the 136 rain-fed minor reservoirs(tanks) that will be supplied water by the LB canal, the relevant catchment areas, storage areas, natural streams, land use patterns and cascades were identified for modeling the system. Topographic, geology and land use details were collected from the digital data of the Survey Department of Sri Lanka and Arc GIS 9.2 was used as a tool for spatial analysis. HEC-HMS (Hydrologic Engineering Center– Hydrologic Modeling System) version 3.0.1 was calibrated and verified for the Tittawella Tank, which is a minor tank in Kurunegala District and also for the Deduru Oya river Catchment. HEC-HMS model was then used to develop rainfall runoff model for each of the rain-fed irrigation tank catchment and the Deduru Oya reservoir catchment. WEAP21 version 3.43 (Water Evaluation And Planning) model was used to study the water requirement from LB canal. The LB development area would require 62 MCM annually through the LB canal as a supplement to meet the LB irrigation demand of the existing and proposed new development areas in dry year while annual RB trans-basin diversion is 79 MCM, and annual downstream release for hydropower, irrigation and environmental requirements is 502 MCM in 2009. With long term forecast rainfall data, the WEAP model can be used for predictability studies in the Deduru Oya LB development areas. The model developed is a useful tool for planning water resources development in the Deduru Oya reservoir project.

Keywords: *Deduru Oya Project, HEC-HMS, WEAP, Irrigation development*

Introduction:

The Deduru Oya river carries flash floods during rainy season and very low flow during dry season owing to the significant temporal variation of its basin rainfall. Presently, it releases 1000 MCM of water to the sea annually. The Deduru Oya reservoir project which is under construction is aimed to improve the livelihood of farmers in parts of the North Western Province by increasing the productivity of its land by regulating and diverting the Deduru Oya river water by two main canals. The proposed Left Bank (LB) canal which is 44.1 km long with a discharge capacity of about 7.1 m^3/s at the intake will supply water to augment about 136 existing storage-based minor irrigation systems in the left bank of the Deduru Oya proposed reservoir (Figure.1). The proposed irrigable area under LB canal including new developments is about 3000 ha (Pre-feasibility Report, 2000).

This study is focused on the setting up WEAP21 version 3.43 (Water Evaluation And Planning) model (SEI, 2001) to study different water management scenarios at LB development area. WEAP21 model is a microcomputer-based tool for integrated water resource planning and it provides a comprehensive, flexible and user friendly framework for the policy analysis. It operates at a monthly step on the basic principle of water balance accounting.

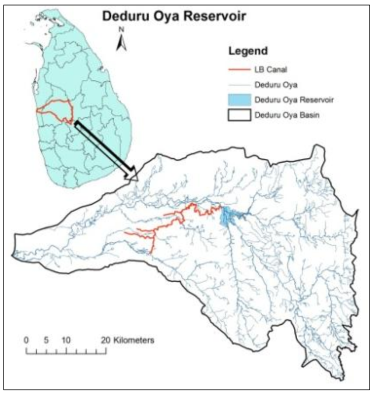

***Figure 1** : Deduru Oya LB Canal Development Area*

Methodology:

For each of the 136 rain-fed minor tanks that will be supplied water by the LB canal, the relevant catchment areas, storage areas, natural streams, land use patterns and cascades were identified for modeling the system. Also 12 directly feeding demand sites were identified. Topographic, geology and land use details were collected from the digital data of the Survey Department of Sri Lanka, and Arc GIS 9.2 was used as a tool for spatial analysis. In the WEAP model, LB canal was modeled as a "Diversion links" and the minor tanks were connected by

"Diversion elements" to LB canal. Demand sites and minor tanks were connected using 188 "Transmission links". Minor tanks were connected to LB canal with 136 diversions.

Inflow Estimation:

Rainfall or runoff data are not available for the rain-fed tanks. Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) version 3.0.1 developed by US Army Corps of Engineers in USA (Scharffenberg at al, 2006) was used to develop rainfall runoff model for each of the catchment. HEC-HMS model was calibrated and verified for the Tittawella Tank in Kurunegala District where data has been recorded (Irrigation Department, 1998) which has a hydrologically similar catchment of 2.95 km^2 in the same ago-climatic region of the minor tank catchments in Deduru Oya LB canal development area. Modeling was done as continuous simulation and the model parameters were optimized so that the simulated hydrograph matched the observed hydrograph during the calibration. These optimized parameters were used for model verification. Calibrated HEC-HMS model for the Tittawella Tank and rainfall data at Nikaweratiya and Ridi Bendi Ella stations were used to develop inflows to the minor tanks.

Flow simulation of Deduru Oya river

Thirty years daily rainfall data from 6 rain gauge stations in the Deduru Oya river basin and runoff data at Moragaswewa from 1984 to 1989 together with monthly evaporation data at Batalagoda agro-meteorological station was used in the simulation. Diversions, reservoir storages and losses were also accounted in the study. Calibrated HEC-HMS model of Deduru Oya river and rainfall data at Millawa, Kurunegala, Ridi Bendi Ella and Wariyapola stations were used to develop inflows to Deduru Oya reservoir. Modeling was done as both event based and continuous simulations.

Demand Estimation

WEAP model was developed to Deduru Oya LB development area. For WEAP model application, four types of data viz: Area cultivated annually, Annual water use rate, Monthly variation and Consumption are required at each of the demand sites. Crop water requirement was calculated assuming 105 day low land paddy will be cultivated. For the other field crops 180 days chillies was used. Crop water requirement was calculated for each crop type on monthly basis. Rainfall data at Nikaweratiya and Ridi Bendi Ella station in year 2000 to 2010, Mahailuppallama reference crop evapotranspiration rates and crop factors for each growth stages were used for the calculation of crop water requirements. Computations of irrigation water requirements were made using 60% application efficiency and 75% conveyance efficiency. Land soaking and tiling requirement were also taken into account (Pre-feasibility report, 2000).

Calculated crop water requirements and irrigable area data was used to develop demand site Annual water use rate and Monthly variation. Different "Supply preference" and "Priorities" were used to model the diversion link and transmission links.

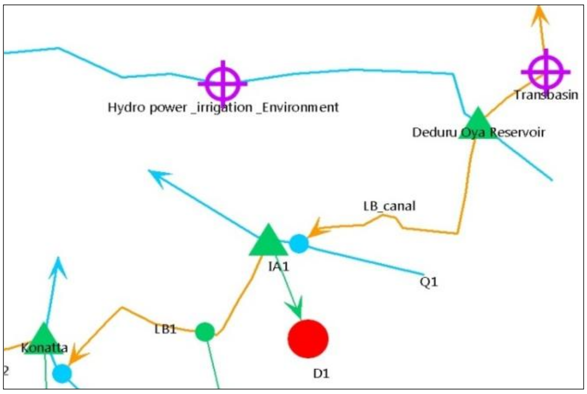

***Figure 2** : Graphical User Interface of WEAP model*

In WEAP model two Flow Requirement elements were used to model Right Bank (RB) trans-basin diversion and downstream hydropower, environmental and irrigation requirements. RB trans-basin diversion water requirement was calculated based on irrigable area and crop water requirements. The minimum value of hydropower and environmental requirements were used as 7m^3/s (Pre-feasibility report, 2000). Downstream irrigation water requirement was calculated and the maximum requirement was used as downstream irrigation flow requirement.

Results and Discussion:

Calibration and validation results of HEC-HMS models for Tittawella Tank and Deduru Oya Reservoir were analyzed both graphically and statically. The goodness of fit of calibration and average validation events according to Normalized Objective Function *(NOF)*, Nash–Sutcliffe efficiency (R^2_{NS}), and Percentage bias (δ_b) values (Ehret et al., 2011) are shown in Table 1.

***Table 1** : Skill metrices of model calibaration and validation*

		(NOF)	(R^2_{NS})	(δ_b) / %
Deduru Oya River	Calibration	0.3	0.96	4.88
	Average Validation	1	0.73	17.5
Tittawella Tank	Calibration	1.16	0.77	4
	Average Validation	1.60	0.72	14

Annual minimum supply for RB trans-basin diversion is 90 MCM and downstream hydropower, irrigation and environmental requirements were calculated according to irrigation water requirements and downstream command areas (Pre-feasibility report, 2000). Accordingly to WEAP model results, annual LB diversion is 62 MCM, annual RB trans-basin diversion is 79 MCM, and annual downstream release for hydropower, irrigation and environmental requirements is 502 MCM in 2009. 2009 is the dry year when consider period from 2000 to 2010. Diversion quantities which are required to fulfill water needs in each area in year 2009 are shown in figure 3. The model developed is a useful tool for planning water resources development in the Deduru Oya river.

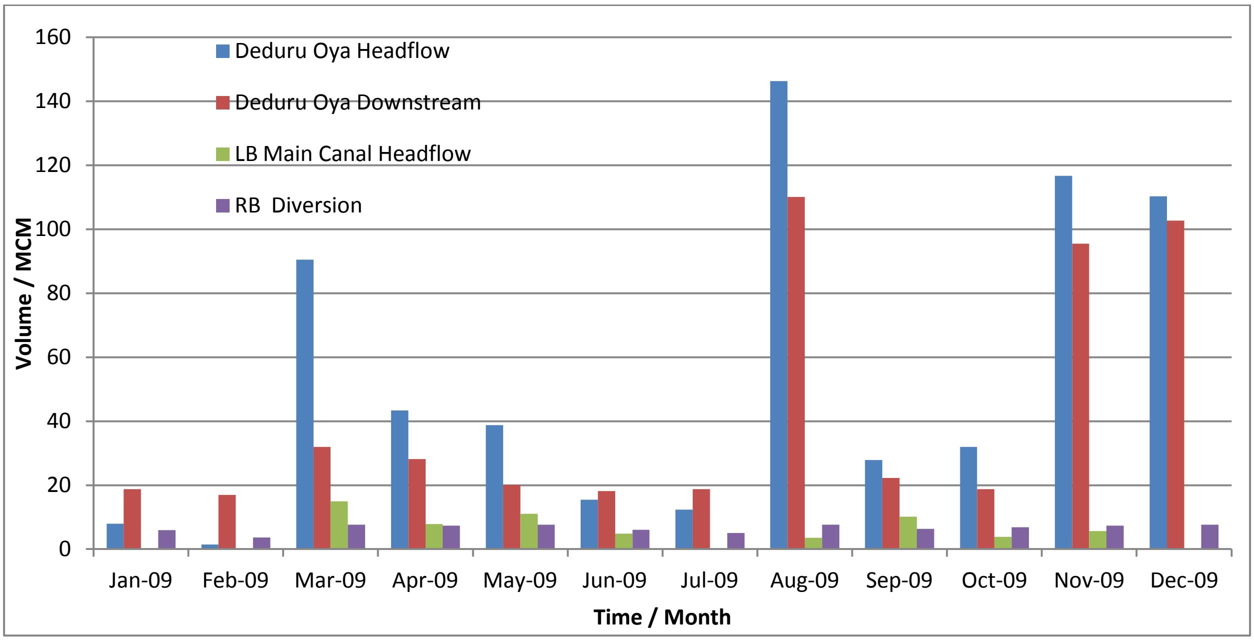

Figure 3 *: Water diversion quantities in year 2009*

Conclusion:

WEAP model was developed for the Deduru Oya LB irrigation scheme and it was employed to investigate the water requirement from LB canal for the resilience of the irrigation development in the LB development area where water resources in the existing cascade systems and the diverted water from LB canal are conjunctively used.

Water resources analysis of each of the tank irrigation systems in the LB irrigation region was carried out. The LB development area would require 62 MCM annually through the LB canal as a supplement to meet the LB irrigation demand of the existing and proposed new development areas in dry year while annual RB trans-basin diversion is 79 MCM, and annual downstream release for hydropower, irrigation and environmental requirements is 502 MCM in 2009. With long term forecast rainfall data, the WEAP model can be used for predictability studies in the Deduru Oya LB development areas. The model developed is a useful tool for planning water resources development in the Deduru Oya reservoir project.

Acknowledgement

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