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Next Generation Software tool for Sustainable urban water modelling : Aquacycle

Pooja Shrivastava* Himangshu Sarkar Dr. M.K.Verma*** Prof. Ishtiyaq Ahmad******

Abstract : At present century each city needs security of water to meet the future challenges arises due to the population growth, urbanisation, economy, latest technologies, energy demands and climate change. This will need a sustainable urban water management modelling which becomes a powerful tool in evaluating the probable water in urban areas. The new approach of modelling of urban water involves the application of water reuse that supports the multiplicity of water use from higher to lower quality needs. This paper presents software Aquacycle and its application for urban water modelling to integrate the water supply, waste water and storm water in to single frame work. Aquacycle model accounts for water pathway by simulating the subsystem of the urban water and its interfaces. Model is used for the simulating the locally generated waste water and storm water as an alternative for imported water alongside water use competence. It is one of the urban water cycle model performs a daily water balance with various water interfaces and estimating the potential solutions for urban water management considers issues related to water supply and distribution, waste water production and storm water in holistic framework.

Keywords : Urban water modelling, Aquacycle, sustainability, urban water balance.

1. INTRODUCTION

Sustainable urban water management strategies are being are investigated for their ability to provide long term water demand security and service integrity to urban water services. Urban water modelling gives its best possible outcomes in terms of water-food security, impacts on urban hydrology and understands importance of sustainability. The significant key features for urban water modelling are as follows; (1) Conceptual and holistic preliminary design tool (2) Integrated modelling for three urban water services. *i.e.* potable water, waste water and storm water (3) Analysis the rainfall-runoff model either its continuous or event based (4) Need simulation modelling (5) system should be integrated at a spatial scale. Along with this, the most important objective of sustainable urban water management is the identification of sustainable and effectiveness urban water system for future cities. A model needed to be developed having a capability of addressing different scenarios i.e. Climate change effects, population growth, with the latest sustainable technologies which provides sustainable output fundamental indicator includes mains water, runoff amount, life cycle energy, waste water discharged and economic cost (Ewan et al. 2007). Quantitative assessment and urban hydrological modeling are necessary for understanding changes in the urban water cycle due to the urbanisation in city areas (JihoLee et al. 2010). The water balance method used to develop Aquacycle tool to analysis the movement of water through rainfall-runoff and the waste water system and interaction between this two systems (Grace Mitchell et al. 1999).

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* Research scholar, Civil Engineering Department, National Institute of Technology, Raipur pooja.shrivastava@gmail.com

** Mtech scholar, Civil Engineering Department, National Institute of Technology, Raipur himangshu.ce.nitrr@gmail.com

*** Professor, Civil Engineering Department National Institute of Technology, Raipur Vice-chancellor, CSVTU, Bhilai mkseem670@gmail.com

**** Assistant professor, Civil Engineering Department, National Institute of Technology, Raipur iahmad.ce@nitrr.ac.in

2. URBAN WATER BALANCE

Water balance investigation is very important in the preliminary stage of the study of hydrological systems and strongly applied concept in the urban water hydrology (McPherson1973). The water balance provides a single framework idea for the studies of the elements of the urban hydrological cycle and interaction between them. Urban water balance mainly disturbed by the impervious covers which prevailing the surface runoff and storm water in the water budget equation, while reducing the chances of ground water storage and recharge. These disturbances adversely affect the quality and quantity of surface and ground water resources. The major reasons for the water balance studies in urban areas; such as identifying the water flow path in the system, computing the amount of discharge in the path, also computing pollutants load, identifying long term variations and change in the areas (F.H.M.van de ven 1990),

The water balance system expressed on an areal basis as a depth of water; by Grimmond and Oke 1978;

$$P + I = R + E + \Delta S$$

Where, P = Precipitation, I = Pipe in water supply, R = net runoff, E = Evapo-transpiration, ΔS= net water storage change.

This water balance will define the complete picture of the spatial and temporal complex of the water, waste water and storm water in urban water hydrological cycle in the conceptual framework (Mitchell et al. 2001) .In order to address this need, urban water balance model Aquacycle is adopted which precise the evapo-transpiration which is high variable parameter in dry periods.

3. URBAN WATER MODEL: AQUACYCLE

Aquacycle is a water balance continuous model that characterises the each components of the urban water hydrological system i.e. water supply and recycle, waste water and storm water (Mitchell et al., 2001). Aquacycle can operates the urban water balance at three spatial scales are in order to permits modelling of system for various reuse and recycle schemes. The first spatial scale, unit block represents the single household, industries, institutions and any commercial unit which refers to smallest scale management of supply and reuse of water. This modelling scale stands for the effects of individual actions on the whole catchment and divides the spatially into previous and impervious surface such as roof, road and garden. The next spatial scale, cluster represents the group of unit blocks that can be form a community or locality in which locality or community supply and disposal process may be controlled. The last catchment spatial scale represents the group of clusters which may relate to the residential areas. The catchment contains cluster units which may have same or different characteristics such as population density, impervious and previous cover and hydrological rainfall events.

The characteristics of Aquacycle (Mitchell et al.1999) are as follows :

1. Spatial and Temporal scale and resolution: Spatial scale divide into three scales; unit block, cluster and catchment scale, while temporal scale is daily time scale or step scale.
2. Classification of surfaces: It distinguishes three types of land surface: residential, road and open space. Open space considers as previous surface, roads are impervious while the residential areas further classified into paved, roofs and open space.
3. Input requirements: Input data required by Aquacycle i.e. indoor water usage (kitchen, bathroom, laundry and toilet) site characteristics and meteorological data.
4. Operations
    - (*a*) **Unit block scale :** This operation includes estimation of indoor and outdoor water uses, storm water, groundwater recharge, waste water discharge, evapo-transpiration from roof and paved and garden areas.
    - (*b*) **Cluster scale :** It involves calculation of storm water runoff from road surface and public open space, leakage of the system, inflow and infiltration of stormwater into waste water network, ground water recharge, storage and base flow, evapo-transpiration from road and public open space areas, and cluster scale storm water and waste water reuse schemes.
    - (*c*) **Catchment scale :** It calculates catchment scale stormwater and waste water.

5. Model Output: It provides daily, monthly and annual water demand estimation, storm water yield, waste water yield, evapo-transpiration. The model output in three groups;
   (*a*) **Water use :** Water uses and losses due to leakage.
   (*b*) **Storm water runoff :** Discharge estimation from impervious and previous areas.
   (*c*) **Waste water discharge :** Discharge estimation of waste water produced in the sewerage system.

3.1. Methodology

Modelling steps consists of system and area characteristics, data input, defining strategies and model simulation.

The model takes input from six input parameters are indoor water usage profile, climate data, unit block, cluster, catchment and parameter with initial values. This requires three distinct class input: climate data, measured parameters and calibration parameters (Mitchell, 2003). Climate data includes daily precipitation, temperature and evapo-transpiration. Daily temperature and precipitation was obtained from the local rain gages and evapo-transpiration calculated by the Hargreaves method. Model operates on a daily time step which starts when entering precipitation or water in order to meet the demands in the system. Model basically works in the subsystem of urban water and its interfaces along with rainfall system and waste water system. The input of rainfall system not only includes rainfall but also the water in the piped system and water uses. In order to perform water balance in the urban area, all water in any form need to be integrated in the single framework which is simulated by Aquacycle. In urban water modelling the application of the principle of conservation of mass to water is applies in a specific domain of catchment (Grimmond et al.1986) which allowing water study at spatial and temporal scale. A water balance model can be modelled with the simple assessment of inputs and output parameters in the defined range. This complex modelling transforms all inputs into output at spatial scale of unit block, cluster and catchment scale. There are many alternatives to integrate the water, waste water and storm water in the urban areas but for appropriate resolution of modelling it need to be evaluated at the spatial scale.

Measured parameters : These parameters are directly related to the catchment characteristics and can be obtained from the measurement, observation, and surveys. All measured parameters are listed in Table-1.

Table 1. Measured Parameters

S.No.	*Spatial scale*	*Measured parameters*	*Units*
1.	Unit block	Average unit block occupancy	Persons
		Average block size	m^2
		Average garden size	m^2
		Average roof area	m^2
		Average paved area	m^2
		Average % of garden irrigated	%
2.	Cluster	Number of unit blocks	Number
		Cluster area	Hectare
		Leakage from the reticulation system	%
		Road area within the cluster	Hectare
		Cluster storm water output flows into cluster number	Number
		Cluster waste water output flows into cluster number	Number
		Public open space area within the cluster	Hectare
		% public open space irrigated	%
3.	**Catchment scale**	**Catchment area**	**Hectare**

Calibrated parameters : Calibrated parameters are estimated parameters according to the objective functions. It should be adjusted accordingly during the calibration. Mitchell et al. 2001.

Table 2. Calibrated Parameters

S.No.			*Description*	*Units*	*Range*
1.	Water use	Garden trigger to irrigate	Ratio representing the level of soil wetness that the garden irrigat or wishes to maintain. If the level of soil water storage in the irrigated land drops below this trigger level, irrigation water from the various sources is required	Ratio	0-1
		Public open irrigate to irrigate	Ratio representing the level of soil wetness that the open space irrigator wishes to maintain. If the level of soil water storage in the irrigated open space drops below this trigger level, irrigation water from the various sources is required	Ratio	0-1
2.	Waste water	% of surface runoff as inflow	Proportion of surface runoff generated in the Cluster, and flowing into the wastewater pipe system and not in the stormwater system	%	0-100
		Infiltration index	The proportion of excess water overflowing from the soil stores into the temporary infiltration store	Ratio	0-1
		Infiltration store	Ratio of water flow from temporary infiltration stores into waste water pipes	Ratio	0-1
3.	Storm water	Percentage area of storage 1	The proportion of the pervious area (garden and open space) which is covered by storage 1	%	0-100
		Pervious storage 1 Capacity	The maximum depth of water that pervious storage 1 can store	mm	≥ 0
		Percentage area storage 2	The proportion of the pervious area (garden and open space) which is covered by storage 2	%	0-100
		Pervious storage 2 Capacity	The maximum depth of water that pervious storage 2 can store	mm	≥ 0
		Roof area initial loss	The amount of water captured in the roof surface before runoff occurs	mm	≥ 0
		Effective roof area	The proportion of roof area directly connected to the roof drainage system	%	0-100
		Paved area initial loss	The amount of water captured into the paved surface before runoff occurs	mm	≥ 0
		Effective paved area	The proportion of paved area directly connected to the unit block stormwater system	%	0-100
		Road area initial loss	The amount of water captured into the road surface before runoff occurs	mm	≥ 0
		Effective road area	The proportion of road area directly connected to the cluster stormwater system	%	0-100
		Base flow index	The ratio of excess water overflowing from the soil stores and recharging groundwater storage	Ratio	0-1
		Base flow recession constant	Ratio of the groundwater contributing to the stormwater runoff of the cluster	Ratio	0-1

Simulated period : Simulated time period is defined for which all time series for meteorological data are provided. The same time period is used in validation .The minimum proposed length should be one year.

4. CALIBRATION AND VALIDATION

To calibrate and validate the performance of the Aquacycle model in an urban area with the parallel water supply, waste water and storm water discharge data is needed. It is not easy to calibrate and validate the Aquacycle model; different model outputs of water use, waste water and storm water needed to fitted to the observed values and numbers of parameters disturb the one parameter. This model does not have the capability of self- calibration. Sometimes the modelling results do not match the observed values precisely, but simulations represented the importance of the water demand and waste water system. For validation it needs to be developed a x-y graph between daily simulated versus daily recorded stormwater flows and also between weekly simulated versus weekly recorded water use. Sometimes data from the urban area will be coarser description applying with the assumptions used for the simulation observations. It is important to compeer the observed and predicated values for the purpose of the urban water management planning.

4.1. Limitation of Aquacycle: There are limitations of Aquacycle; are as follows:

1. Aquacycle model was not able to assess the total quantity of water in the urban water hydrological cycle due to which do not calculate the peak flow discharge and not produce hydrograph.
2. This model is also not included various processes of hydrological cycle such as waste water leakage, storm water pipe infiltration, water application for impervious surface and waste water overflow.
3. Water qualities parameters are also not analysis by the Aquacycle.

5. CONCLUSION

Various urban areas are facing pressure to satisfy water demands by urban organisations and reducing the ecological impacts caused by waste water and storm water. Aquacycle is basic water balance model can be applied to any urban cities. This model is also designed for the alternative urban water supply and waste water schemes with the specifications of store storm water and waste water and utilise it as energy source. It cannot predict the water qualities but its simulation results reduce quantity and volume of storm water and waste water discharge from the urban catchment area. Aquacycle as a urban water balance developing a conceptual single framework for the water, waste water and storm water needs to be planning for urban water management. This model also linked the urban water energy and its impact on the climate change. The Urbanization Impact investigation will focus on recognizing the likely impacts associated with the growing Urbanization on water resources in the cities. Aquacycle elaborate the future demand of the city with their outputs parameters and also evaluate reuse schemes of storm water and waste water. It has also demonstrated that along with the population growth impacts on the urban water, water distribution have significant uncertainties and need to be exploring for future planning and strategies with others modeling tools. On other hand, evapo-transpiration has insignificant effects on urban water balance and precipitation increasing by 15% which likely result to the change of urban water cycle.

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