LASCAM (LArge Scale Catchment Model)

LASCAM is a Rainfall runoff model plugin.

Adapted and re-written as a C# plugin for Source IMS framework by Joel Hall, Water Science Branch, Department of Water, Western Australia, 23/06/2011

Originally developed by Neil Viney and Murugesu Sivapalan, Centre for Water Research, University of Western Australia, 1996-2002

General Info

License	As-is, use at your own risk
Type	free
Current version	1.0

Plugin Description

LASCAM was developed with the aim of predicting the impact of land use and climatic changes on the daily trends of streamflow and water quality in large catchments ove long time periods. It was developed as a lumped, conceptual model, using sub-catchements as basic building blocks. Typical subcatchmetn sizes are 1 - 10 km2, although much larger subcatchments can be used.

LASCAM hydrology is built around three interconnected subsurface stores, the A store representing the near-stream aquifer system and riparian zone, the B store representing the permanent deeper groundwater system, and the F store representing an intermediate unsaturated infiltration store. These represent typical accumualations of soil water in duplex profiles where a shallow, gravelly or sandy and highly permeable A horizon overlies a clayey, less permeable B horizon.

For more information on how the fluxes and flows are explicitly modelled through these stores, refer to the literature presented below. It should be noted that many of the parameters in LASCAM were designed to only be estimated by calibration and then by comparison to observed streamflows.

The LASCAM hydrological routine is equivalent in LASCAM versions 2.0 - 2.6, and the Streamflow Quality Affecting Rivers and Estuaries (SQUARE), which is also used by the Department of Water in WA for nutrient modelling exercises.

AVAILABLE LITERATURE:

The following literature is available on the LASCAM rainfall runoff model:

- Sivapalan, M., Ruprecht, J.K., and Viney, N.R., 1996. Catchment-scale water balance modeling to predict the effects of land use changes in forested catchments. 1. Small catchment water balance model. Hydrological Processes, 10(3), 413-428 - Viney, N.R., Sivapalan, M., 1996. The hydrological response of catchments to simulated changes in climate. Ecological modeling, 86, 189-193- Viney, N.R., Sivapalan, M., 2000. Modelling catchment process in the Swan-Avon River Basin. Hydrolgoical Processes.
- Viney, N.R., Sivapalan, M., 2000. LASCAM: The large scale catchment model - user manual. Version 2. Research Report WP1392NV, Cenre for Water Research, Unviersity of Western Australia, Nedlands.

Description

The LArge Scale Catchment Model (LASCAM) is a physically-based conceptual model with a daily time-step. LASCAM was developed with the aim of predicting the impact of land use and climatic changes on the daily trends of stream flow and water quality in large catchments over long time periods. The basic building blocks are subcatchments organised around a river network. All hydrological and water-quality processes are modelled at the subcatchment scale; the resultant flows and loads are aggregated via the stream network to yield the response of the catchment at the main outlet, and at any of the subcatchment outlets in the stream network.
The responses of the catchment to rainfall and evaporation are conceptualised in terms of three interdependent subsurface water stores (Figure A-1). The responses of the stores (and the resulting fluxes of water) are characterized by a set of "constitutive relations", which involve a number of conceptual parameters. At this stage, many of these parameters can only be estimated by calibration by comparing observed and model predicted streamflows.

Soil water stores
The small catchment model is built around three interconnected subsurface stores (Figure 4.2):

- A, representing the near-stream perched aquifer system and the riparian zone;
- B, representing the permanent deeper groundwater system; and
- F, representing an intermediate unsaturated infiltration store.

These represent typical accumulations of soil water in duplex profiles where a shallow, gravelly, and highly permeable A horizon overlies a clayey, less permeable B horizon.

Canopy interception
Throughfall (denoted by p_g in Figure A-2) is the component of the incoming precipitation that is not lost to interception by the forest canopy and subsequent evaporation from the leaves back to the atmosphere. In LASCAM this component is modelled through a linear relationship with the incoming precipitation, with the coefficients depending on the magnitude and the type of vegetation cover (Ruprecht, 1990). Although the dynamics of the interception process operate at smaller time steps than one day, probably of the order of minutes to an hour, the high significance level of the empirical relationship developed justifies the use of this relationship instead of a more sophisticated formulation based on a smaller time step.

Surface runoff generation
The ground precipitation (throughfall) is partitioned into surface infiltration (p_c in Figure A-1) and surface runoff. The latter is generated by both the infiltration excess (q_{ie}) and saturation excess (q_{se}) mechanisms.

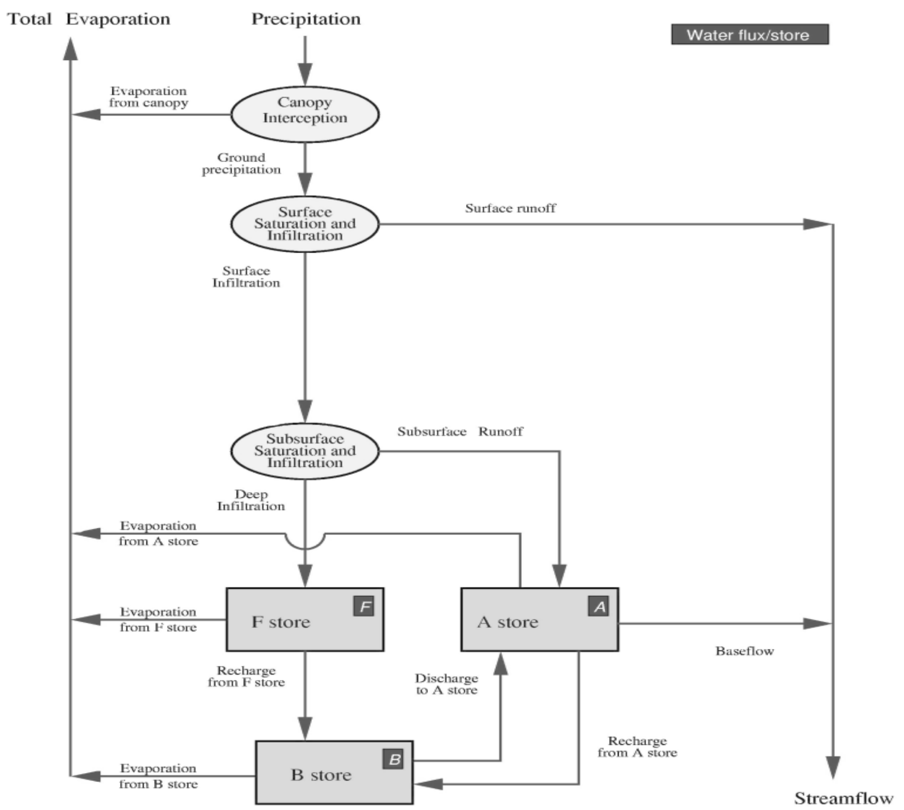
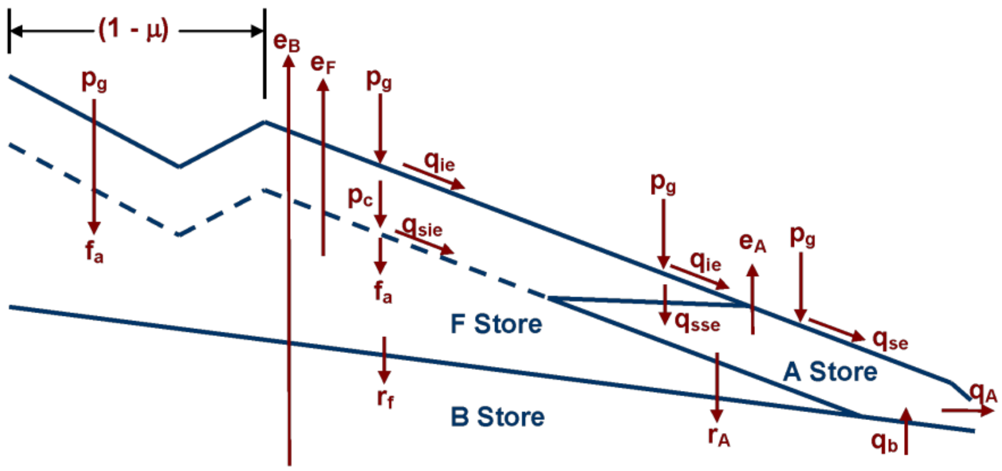


Figure B-1: *Small catchment model (building block model) of water fluxes in use within LASCAM (Viney et al., 2000).*



Symbol	Definition
e_A	Evaporation from A store
e_B	Evaporation from B store
e_F	Evaporation from F store
q_A	A store discharge to stream
q_B	B store discharge to A store
q_{se}	Saturation excess surface runoff
q_{ie}	Infiltration excess surface runoff
q_{sie}	Infiltration excess subsurface runoff
q_{sse}	Saturation excess subsurface runoff
p_g	Throughfall
p_c	Surface infiltration
f_a	Subsurface infiltration
r_A	Recharge from A store to B store
r_F	Recharge from F store to B store
μ	Upslope perching factore

Figure B-2: *Schematic of a hill-slope cross-section, water fluxes and stores assumed in SQUARE (Viney & Sivapalan 2001)*

Saturation excess runoff (Dunne mechanism) is generated on variable SOURCE areas which are saturated prior to rainfall, or which become saturated during the course of the rainfall. This variable contributing area is predicted as a function of the current level of the perched aquifer storage.

Infiltration excess runoff (Hortonian mechanism) is modelled in two ways: i) direct runoff from impervious areas in urban areas; and ii) infiltration capacity of the surface soil layer, which is assumed to depend on vegetation cover and land use. Any precipitation in excess of the infiltration capacity and the direct runoff is assumed to run off.

The infiltrating water, on the other hand, is assumed to percolate vertically to the bottom of the surface soil layer where it encounters the less permeable clayey horizon. However due to the high permeability of the A-horizon soils, this percolation is assumed to occur rapidly enough, insofar as not requiring a more sophisticated model for the percolation process.

Subsurface runoff generation

The model assumes that subsurface runoff is generated at the top of the clayey B-horizon by both infiltration excess and saturation excess processes. Subsurface saturation excess runoff (q_{sse}) is generated on variable SOURCE areas, which are saturated due to the presence of a perched water table. Subsurface runoff by the infiltration excess mechanism (q_{sie}) is estimated using a modified version of the catchment-scale infiltration capacity equation developed by Robinson and Sivapalan (1995). This equation relates the catchment scale infiltration capacity to the state of the infiltration store F and to the value of the water deficit in the groundwater store.

Subsurface stormflow

Subsurface stormflow (q_A) is modelled as a function of soil water storage in the near-stream A store. The A store does not discharge directly into the stream unless its volume is greater than a parameterised threshold value.

Recharge to the deeper groundwater store

Recharge to the deeper groundwater is generated by percolation from both the intermediate infiltration store F and the perched groundwater store, A. The continuous recharge of water from the intermediate infiltration store (F store) to the deeper permanent groundwater system (r_F) is expressed as a function of the quantity of water in the F store and a parameter representing a subsurface detention time. The recharge per unit of area from the perched water store (r_A) is assumed to occur at a rate given by the catchment-scale infiltration capacity discussed previously.

Discharge from the deeper groundwater store

The model assumes that the deeper groundwater system releases water slowly to the A store and not directly into the stream. This discharge (q_B) occurs at a rate dependent on the volume of water in the B store and increases with a rising groundwater table.

Evapotranspiration
Evapotranspiration, apart from the component covered under interception losses, is assumed to take place from all the three soil water stores, A, B and F. Non-linear functions of the relative levels of storage are used to estimate the actual evaporation from each of the three stores as a fraction of the potential evaporation rate.
Evapotranspiration from the A-store (e_A) takes into account both evaporation from the bare soil and plant transpiration in the riparian zone. Evaporation rates from the B (e_B) and F (e_F) stores are strongly governed by the extent of deep-rooted vegetation in the non-riparian zone that is present in the landscape to facilitate tree transpiration.

Modelling of urban catchments
Specific algorithms in LASCAM deal with urban and "urbanising" catchments. In urban or urbanising catchments, a significant proportion of the rainfall is likely to be diverted away from the mainstream channel by man-made structures, with rainfall falling on impervious areas. A key input variable in urban catchments is the fraction of the catchment, which is made "impervious" by the presence of houses, roads, parking lots etc. The chief mechanism of runoff generation in these catchments is of the infiltration excess type.

Upslope perching factor
In catchments where the potential exists for the runoff generated to be intercepted along its pathway to the stream, a modification of the runoff generation algorithm has become necessary. An upslope perching component has been included for this reason, which is also noted in Figure A-2. This modification assumes that upslope perching is proportional to stream network density, which in turn, is assumed proportional to the mean annual rainfall. The throughfall occurring on this part of the hillslope is assumed to directly percolate to the unsaturated water store, F, whereas throughfall occurring on the remaining part of the hillslope is assumed to follow the water flow pathway that has been described previously.

Differences between LASCAM 2.0 and LASCAM for SOURCE
The LASCAM hydrological routine was adapted and re-written as a C# plug-in for SOURCE IMS framework by the Water Science Branch, Department of Water, Western Australia. Some minor changes were made to the code to integrate the hydrology to the SOURCE Framework. These changes included:

- evaporation from throughflow (e_g) is calculated
- total evapotranspiration (e_t) includes evaporation from throughflow (e_g) (to satisfy mass balance)
- initial store parameters abar, bbar and fbar have been removed, and replaced by the half full stores (see the function initStoresFull() in Appendix B)
- the default parameters are different to the literature, and are based on a calibration from Nambeelup Brook, WA
- LAI and potential evaporation are entered as a time-series at the same time-steps the rainfall (the original code calculated EP, and LAI was a monthly function of an annual value)
- no store disaggregation equation is used to initialise the stores
- no separate LAI for the riparian zone (as this can be done from within SOURCE IMS framework if desired)

The code was tested for completeness using the nUnit test program, and validated against the original LASCAM modelling results for the Nambeelup catchment, which was modelled as part of the Peel Harvey Nutrient Modelling project (Kelsey et al, 2010).

Inputs

Symbol	Symbol in code	Variable type	Definition	Units
L	grn	Input	Leaf area index	-
R	annrain	Input	Mean annual rainfall	mm/day
e_p	ep	Input	Potential evaporation	mm/day
imperv	imperv	input	Impervious area	proportion
p	p	Input	Observed daily rainfall	mm/day

Parameters

Symbol	Symbol in code	Variable type	Definition	Units	Fixed	Decimal places	Default	Min	Max
$\underline{A}$	abar	parameter	Initial catchment A store volume	mm/day	fixed	0	1	0	500
$\underline{B}$	bbar	parameter	Initial catchment B store volume	mm/day	fixed	0	840	0	15000
$\underline{F}$	fbar	parameter	Initial catchment F store volume	mm/day	fixed	0	120	0	1200
α_g	alphag	parameter	Throughfall parameter	-	fixed	2	-0.05	-0.20	0.20
β_c	betac	parameter	Surface saturation parameter	-	fixed	2	1.00	0.00	5.00
β_g	betag	parameter	Throughfall parameter	-	fixed	2	0.08	0.00	0.20
β_{ss}	betass	parameter	Subsurface saturation parameter	-	fixed	2	1.00	0.00	5.00
A_{min}	amn	parameter	A store reference minimum	mm/day	calibrate	1	5.0	0.0	500.0
A_{max}	amx	parameter	A store reference maximum	mm/day	calibrate	1	355.0	80.0	1000.0
B_{max}	bmx	parameter	B store reference maximum	mm/day	calibrate	0	640	500	2500
F_{max}	fmx	parameter	F store reference maximum	mm/day	calibrate	1	350	200	900
f_{s0}	fs0	parameter	Surface infiltration parameter	-	calibrate	3	70.000	0.001	200.000
f_{s1}	dfs	parameter	Surface infiltration parameter	-	calibrate	3	125.000	0.001	200.000
t_d	td	parameter	F store rechrage parameter	-	calibrate	1	600.0	0.1	1500
α_a	alphaa	parameter	A store discharge parameter	-	calibrate	3	8.800	0.001	10.000
α_b	alphab	parameter	B store discharge parameter	-	calibrate	3	0.300	0.001	10.000
α_c	alphac	parameter	Surface saturation parameter	-	calibrate	4	0.6500	0.0001	10.0000
α_f	alphaf	parameter	Subsurface infiltration parameter	-	calibrate	3	1.030	0.001	10.000
α_{ss}	alphass	parameter	Subsurface saturation parameter	-	calibrate	3	3.080	0.100	11.000
β_a	betaa	parameter	A store discharge parameter	-	calibrate	1	220.0	0.01	10000
β_b	betab	parameter	B store discharge parameter	-	calibrate	5	0.00026	0.00001	10.00000
β_f	betaf	parameter	Subsurface infiltration parameter	-	calibrate	3	2.850	0.001	10
γ_a	gammaa	parameter	A store evaporation parameter	-	calibrate	3	1.300	0.001	10
γ_b	gammab	parameter	B store evaporation parameter	-	calibrate	5	0.5960	0.1000	1.0000
γ_b	gammaf	parameter	F store evaporation parameter	-	calibrate	4	0.5000	0.1000	0.7000
δ_b	deltab	parameter	B store evaporation parameter	-	calibrate	3	2.500	0.100	5.000
δ_f	deltaf	parameter	F store evaporation parameter	-	calibrate	3	0.400	0.300	1.000
$d\mu_1$	dmu1	parameter	upslope percing parameter	-	calibrate	3	0.500	0.000	2.000
$d\mu_2$	dmu2	parameter	upslope percing parameter	-	calibrate	1	900	100	2500
$d\mu_3$	dmu3	parameter	upslope percing parameter	-	calibrate	3	0.900	0.100	2.000
anrain	anrain	parameter	upslope percing parameter	-	set	0	700	300	3000

State variables

Symbol	Symbol in code	Variable type	Definition	Units	Default
A, A_j	a	State	A store volume (in subcatchment j)	mm/day	0
B, B_j	b	State	B store volume (in subcatchment j)	mm/day	0
B_{τ}	maxb	State	Equilibrium B store level under matur	mm/day	0
F,F_j	f	State	F store volume (in subcatchment j)	mm/day	0
L_{max}	lmax	State	Notional leaf area index for mature v	-	0
e_A	ea	State	Evaporation from A store	mm/day	0
e_B	eb	State	Evaporation from B store	mm/day	0
e_F	ef	State	Evaporation from F store	mm/day	0
e_T	et	State	Total store evaporation	mm/day	0
f_a	fa	State	Subsurface infiltration	mm/day	0
f'_s	fs	State	Surface infiltration capacity	mm/day	0
f'_{ss}	fss	State	Subsurface infiltration capacity	mm/day	0
p_g	pg	State	Throughfall	mm/day	0
p_c	pc	State	Surface infiltration	mm/day	0
q_A	qa	State	A store discharge to stream	mm/day	0
q_B	qb	State	B store discharge to A store	mm/day	0
q_t	gt	State	Total runoff generation	mm/day	0
q_{ie}	qie	State	Infiltration excess surface runoff	mm/day	0
q_{se}	qse	State	Saturation excess surface runoff	mm/day	0
q_{sie}	qsie	State	Infiltration excess subsurface runoff	mm/day	0
q_{sse}	qsse	State	Saturation excess subsurface runoff	mm/day	0
q_{ss}	qss	State	Total subsurface runoff (throughflow)	mm/day	0
r_A	r2	State	Recharge from A store to B store	mm/day	0
r_F	r1	State	Recharge from F store to B store	mm/day	0
Φ_c	phic	state	Surface saturation area	proportion	0
Φ_{SS}	phiss	state	Subsurface saturation area	proportion	0

Source Code

Source code available here.