World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

ICRAF-SE Asia

Brief report of GenRiver and SpatRain training course 14 – 16 April 2004, Bogor, Indonesia

Introduction

Various approaches exist for modelling watershed functions, ranging from directly data-driven (empirical) approaches to models based on concepts of a water balance, soil physics and hydrology. Hydrology models differ by temporal and spatial scale. A detailed level model use with detailed description of rainfall and infiltration may require a minute (or even seconds) time step, especially on slopes where water will become surface runoff if it cannot infiltrate within seconds of reaching the soil surface. At the other end of the spectrum we may find empirical equations relating annual water yield of a catchment to annual rainfall (or precipitation in climate zones where snowfall and ice rains are significant).

In this training course, we introduce 'GenRiver', a simple river flow model, as a tool to explore our understanding of historical changes in river flow due to land use change. GenRiver is a distributed process-based model that extends a plot-level water balance to subcatchment level. It was developed for data-scarce situations and is based on empirical equations. The model can be used to explore the basic changes of river flow characteristics across spatial scales – from patch level, sub-catchment to catchment.

Recent use of GenRiver is in exploring the basic explanation for steady river flow. The classic explanation of a steady river flow is the concept of forests as 'a sponge', that receive rainfall and gradually feed it to the stream. An alternative explanation is spatial heterogeneity of rainfall. Patchiness of rainfall can contribute to an increase of water yield stability over space. To evaluate the impact of spatial heterogenity of rainfall on river fall, we need a rainfall generator that simulate spatial heterogenity. Existing rainfall simulators tend to focus on station-level time series, not on space/time autocorrelation. The SpatRain model was constructed specifically to generate time series of rainfall that are fully compatible with existing station-level records of daily rainfall, but yet can represent substantially different degrees of spatial autocorrelation. SpatRain will also be introduced and used during the training course.

Objectives

- ??Participants will understand the basic principles of GenRiver as tool to evaluate impacts of land use change on watershed functions
- ??Participants will understand the backgrounds and use of SpatRain
- ??Participants will be able to apply GenRiver and SpatRain in a new application as a tool to analyse watershed function

Participants
The course was initially planned for partners in direct project cooperation with us, but 'demand' or requests for participation increased quickly, so a number of 'internal' trainees postponed till a next opportunity.

In the end 15 participants joined this training ; 6 participants from the Department of Meteorology at IPB (climatology and hydrometeorology lab) , 2 participants from CIFOR, 3 participants from ICRAF Bogor (one from the Sumberjaya field site and two PhD students), 2 participants from PT Tata Guna Patria (consultancy agency) and 1 participant from Soil Department of Brawijaya University. (Attachment 1)

Resource persons from ICRAF-SEA ecological modelling unit
Desi Ariyadhi Suyamto
Farida
Betha Lusiana
Meine van Noordwijk (day 1)

The course program is provided as attachment 2.

Follow up
This was the first attempt to share the models with an audie3nce of potential 'users' and as such provided valuable feedback to the model developers about the models as such, as well as the way backgrounds can be explained and understood. Attachment 3 summarizes the feedback obtained at the end of the 3 days.

Feedback will be used to improve the explanation and background material that is provided on the website where the models are downloadable, as well as on the CD-rom that will be released together with the 'Belowground Interactions in Tropical Agro-Ecosystems' book in May/June 2004.

In general, the training material developed and the way it was presented was well appreciated – although a number of questions remained unanswered at the end of the course. For the type of technical and fairly advanced audience that we had in this course, the 3 day program with 2/3 of the time for hands-on practice and development of users' own applications was about right. Three resource persons for a group of 15 participants was helpful during the exercises, as it allowed for intensive discussions.

Follow up training sessions organized along similar lines may be desirable elsewhere in the region, to support the current work on watershed functions in the context of the ACIAR 'watershed functions of land use mosaics 'project and RUPES (Rewarding upland poor for the environmental service functions they provide) action research sites. CIFOR colleagues decided to include the model as tool in research proposals that are currently submitted

Acknowledgement
Staff time for course preparation and implementation of the course was provided by the ACIAR project

Attachment 1. List of Participants

No	Name	Institution (name, address, phone)	Email
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15	Akhmad Faqih	IPB Jl. Raya Pajajaran Bogor PH : 376817	akhmadfaqih@plasa.com

Attachment 2. Program & Schedule

Date / Time	Program	Resource Person
14 April 2004	**GenRiver model**	
09.00 – 09.30	Introduction to course (expectations, scope)	Meine van Noordwijk
09.30 – 10.30	Introduction to GenRiver and component process	Meine van Noordwijk
10.30 – 10.45	Coffee break	
10.45 – 11.15	Model implementation in Stella & excel	Farida
11.15 – 12.00	Familiarize with the model input & output parameter	Farida
12.00 – 13.00	Lunch break	
13.00 – 13.30	Parameterization & Sensitivity test	Farida
13.30 – 14.00	Example of model application (default)	Farida
14.00 – 14.30	Hands on exercise using default data	Farida & Desi Suyamto
14.30 – 14.45	Coffee break	
14.45 – 16.00	Hand on exercise using default data (continued) & data preparation for new application using your own data	Farida & Desi Suyamto
15 April 2004	**SpatRain module**	
09.00 – 10.30	Introduction to SpatRain	Desi Suyamto & Betha
10.30 – 10.45	Coffee break	
10.45 – 12.00	Hands on exercise using default data	Desi Suyamto
12.00 – 13.00	Lunch break	
13.00 – 14.30	Hands on exercise using your own data	Desi Suyamto & Farida
14.30 – 14.45	Coffee break	
14.45 – 16.00	Hand on exercise using your own data (continued)	Desi Suyamto & Farida
16 April 2004	**Exercise**	
09.00 – 10.30	Exercise using your own data & possible scenario	Farida & Desi Suyamto
10.30 – 10.45	Coffee break	
10.45 – 11.45	Exercise using your own data & possible scenario	Desi Suyamto & Farida
11.45 – 13.15	Friday prayer & lunch break	
13.15 – 14.30	Discussion & Closing	Farida, Desi Suyamto, Betha Lusiana

Attachment 3. Feedback, comments, input

GenRiver	SpatRain
• Participants still questioned about output fitness to the actual data point by point (not in term of exceedance). • Participants still questioned on how to prepare spatial properties for the model from GIS data. • Participants asked for improvement of the user interface, which currently seems too complicated and difficult to operate. • Participants asked for integration of statistical analysis into the model environment. • Participants still questioned about land use change effect captured by the model that only covers its surface properties. • Participants need guideline for parameterizing qualitative parameters related to land cover. • Participants need complete user manual • Participants need further explanation in interpreting the results. • Participants had questions about topographical variation (slope) in the model. • Participants asked for improving the model development to be more applicative, with regards to *e.g.* spatially explicitness. • Participants still questioned about biophysical properties *e.g.* LAI, which are not captured by the model.	• Participants asked for improvement of the user interface, covering graphical output – charting and progress report within calculation. • Participants still questioned on the underlying concept used by the model, which is still difficult to understand. • Participants asked for integration of statistical analysis into the model environment. • Participants need user guide manual. • Participants still questioned on topographical variability considered by the model, including orographical effects. • Participants still questioned on sensitivity of each parameter considered by the model. • •

Feedback, comments, input for training/reading material

- The reading material is good, it help in understanding the model
- Explanation of the model output on the exercise module is needed
- Current material might not be sufficient for self learning
- Relevant to the training
- Current material is good for the introduction but needs further development. It is good to have two parts : theory & hand on practice

Feedback, comments, input for explanation of the model

- The understanding of the concept of the model must be transferred perfectly to the audience
- Very well. I appreciate the time taken to respond on every question
- Increase my understanding about the model
- Explanation of the GenRiver model is very clear, should make it more clear for SpatRain especially in term of statistical analysis

Feedback, comment, input for model exercise

- The exercise is very useful to understand the concept of the model
- It is still not satisfied, specially on GIS data preparation
- Need to show a case of study to run the model and analysis of output as the result of the model

Feedback, comment, input for time allocation

- The time allocation is effective
- Slightly different with the schedule
- The time allocation is ok but time was lacking to go into the details.

Feedback, comment, input for training facilities

- One computer had a problem during the training but basically the facilities is fine
- It will be very convenient if performance of the PC meets minimum requirements of the model
- Computers sometimes blocking the view (CPU)

Attachment 4. Introduction to the course

Meine van Noordwijk

Issues to be solved in 'integrated watershed management'

Watershed functions can be defined from a 'supply' side on the basis of the quantity, timing and quality of river flow, or from the 'demand' side on the expectation of an adequate supply of clean water and the absence of flooding, landslides and mudflows (Fig. 1). Lack of access to clean water is still a major determinant of poverty and lack of health, and as such recognized as part of the Millenium Development Goals. Inadequate or untimely supply of water to lowland populations is conventionally 'addressed' by either of two approaches:

1) an ***engineering*** approach, often focussed on the river bed in the middle section of the watershed, where the speed of drainage is enhanced to reduce flooding in sensitive places (but generally displacing the problem downstream) and/or opportunities for temporary storage are created in reservoirs and dams; pipes, containers or bottles bring clean drinking water from upland sources to the households where it is consumed
2) a ***regulatory*** approach to upland land use, declaring protection forest reserves and threatening to enforce the rules through ***evictions*** (and sometimes doing this to set an example).

Two additional instruments are now added to this repertoire:

3) ***Spatial planning***: based on the realization that a lot of human damage by flooding is based on 'living on the wrong place at the wrong time', efforts to enhance downstream spatial planning can avoid/reduce damage

4) ***Payments and other rewards for environmental services***: as a complement to the 'stick' of regulation, the 'carrot' of positive incentives is now part of policy dialogues and public debate – although not yet widely practiced.

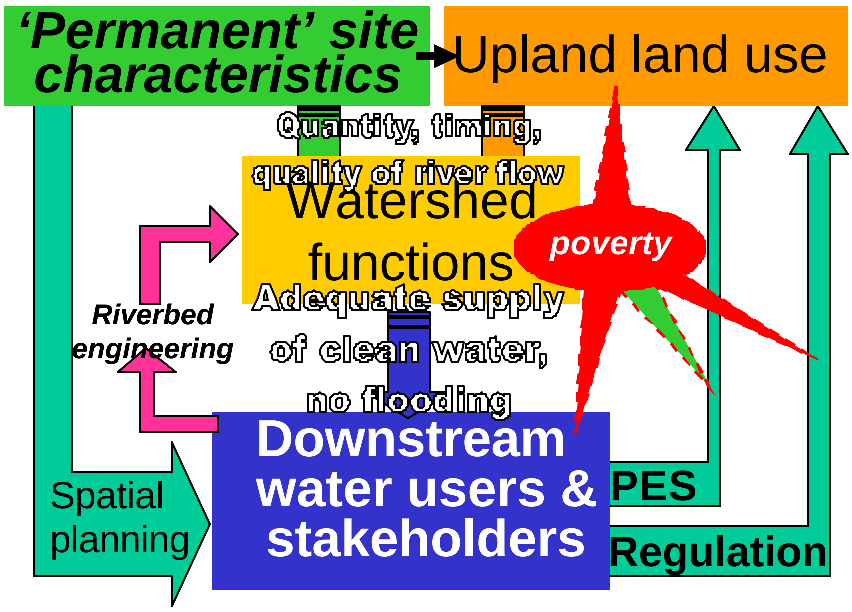


Figure 1. Relationships between upland determination of quantity, timing and quality of river flows through permanent site characteristics and upland land use, and the downstream impacts on water users and other stakeholders, with a range of 'feedback' solutions

Poverty due to lack of access to adequate water supply occurs both in the lowland areas as well as in the uplands, and often requires local technical solutions in the forms of wells, reservoirs and pipes. The 'regulatory' approach, however, can also directly enhance and induce poverty for upland land users, as the victims of evictions often get displaced to environments less favourable to them, apart from the immediate harm done during evictions. Expectations of 'pro-poor' payments for watershed functions are based on

a) poor upland people as 'sellers' of environmental services, either through their labour or based on the opportunity costs of avoided degradation,

b) poor downstream and urban people who get a cost-effective supply of watershed functions, paid by or on behalf of them through use of public funds.

Although water is actually one of the best understood renewable resources (it all starts with rainfall (or other precipitation) and flows downhill…), the figure illustrates that the complexity of the upland – midstream – lowland relationships and the associated human interactions quickly exceeds our ability to take rational decisions based on weighing all the options. Simplistic solutions and slogans tend to get the upper hand…

Both the regulatory and the positive incentive approach are built on assumptions of *attribution* or an ability to disentangle the cause-effect chains involved in water flows. Preventing or encouraging certain types of human activity will not in itself modify major determinants of river flow, such as rainfall, soil type, land form and geological substrate. 'Watershed functions' in the usual definition are based on 'permanent' site characteristics (with large spatial variation…) plus impacts of land use (in a broad definition including all human activities). An effort can be made (see below) to define indicators of watershed functions that take the permanent site properties (and especially rainfall) into account, and thus increase the sensitivity of the indicators to local land use change, rather than to geographical variation in permanent site characteristics. We need to recognize the complementary sources of 'knowledge': local ecological knowledge, public policy assumptions and (eco)hydrology (Fig. 2).

The GenRiver and SpatRain models were developed as contributions to the 'modellers ecological knowledge' domain, to be used as 'negotiation support' tools for finding real-world solutions to improving watershed functions, that maximize the clarity of attribution and the exploration of plausible scenarios for multiple change in driving forces.

The GenRiver model consists of essentially two parts:

- a 'plot-level' approach to tracking the daily water balance on the basis of inputs, outputs and changes in stored resources, and
- a 'transport network' that determines how the various plot-level outputs aggregate to determine river flow at observation points of particular interest (e.g. the overall outflow of the catchment, the location of floodplains and/or cities…).

SpatRain provides spatially explicit representations of daily rainfall that can be used as inputs to the GenRiver model (or for other similar models…).

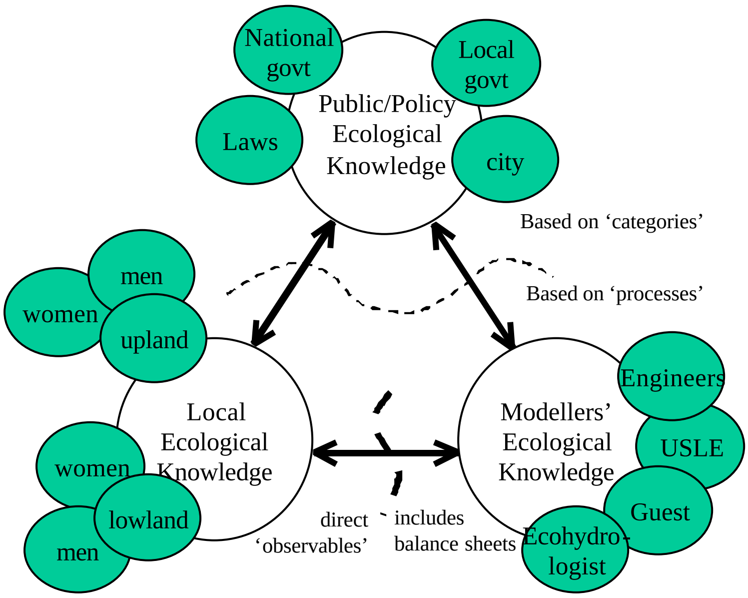


Figure 2. Three complementary knowledge domains on 'watershed functions'

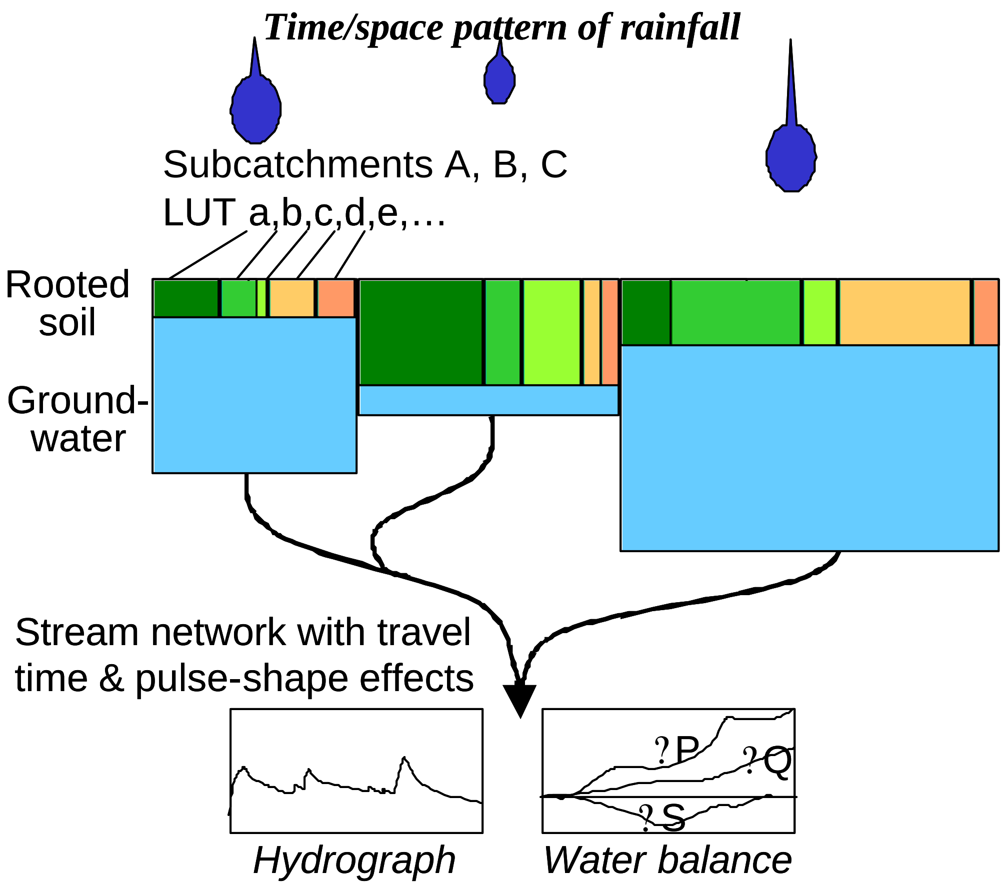


Figure 3. General design of the GenRiver model, with its identification of spatially defined '***subcatchments***' with their space/time pattern of rainfall and characteristic soil depth and water storage, representation of generic ***land use types*** (LUT's) in each subcatchment (potentially changing with time), common groundwater pools at subcatchment scale, and a stream network that influences travel time and shape of pulses that arrive at multiple '***observation points***'

GenRiver component A. Plot-level water balance
The GenRiver model partitions incoming rain over 5 pathways in (Fig. 4).

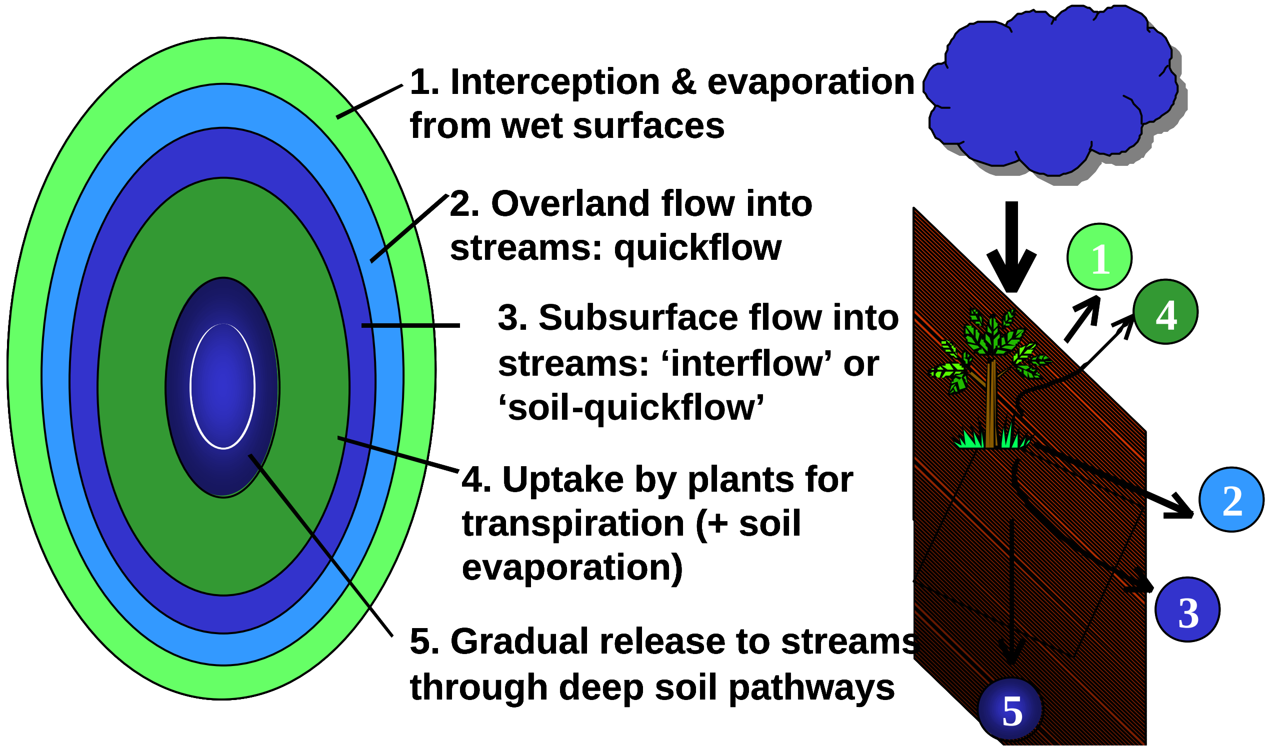


Figure 4. Partitioning of an average incoming drop of rain over five pathways, two of which return to the atmosphere (evaporation from wet surfaces that intercepted rainfall, and evapotranspiration of water temporarily stored in the soil), and three of which reach the stream and river network, but with different time constants (overland flow, rapid subsurface flows and gradual release of groundwater)

1) Interception

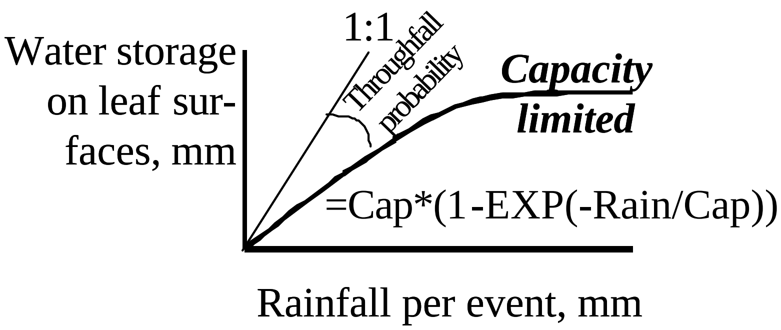


Figure 5. Assumed relationship between daily rainfall and the amount of 'intercepted' water stored on leaf and other surfaces (and likely to evaporate the same day) (similar to the HYLUC model of Calder, 2004)

2) Infiltration
Two conditions lead to overland flow:
•Surface infiltrability less than required during storm ('Hortonian' overland flow, 'sealing' of the surface'); slope, surface roughness and rainfall intensity determine the time available for infiltration

•Saturation-limited: surface soil layers are saturated and rate of outflow determines possible rate of inflow

3. Subsurface flow into streams: 'interflow' or 'soilquickflow'

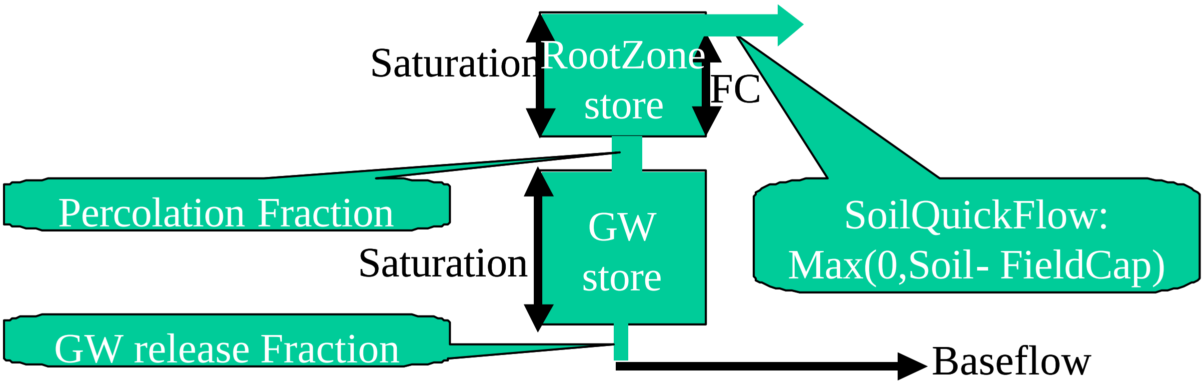


Figure 6. Two-tank model of water storage in rooted soil and (below-rootzone) groundwater; the width of the outflow pipe between the tanks determines the proportionality actor of the outflow; soil quick-flow is an unconstrained 'overflow' for any water in excess of field capacity

4. Uptake by plants for transpiration (+ soil evaporation)

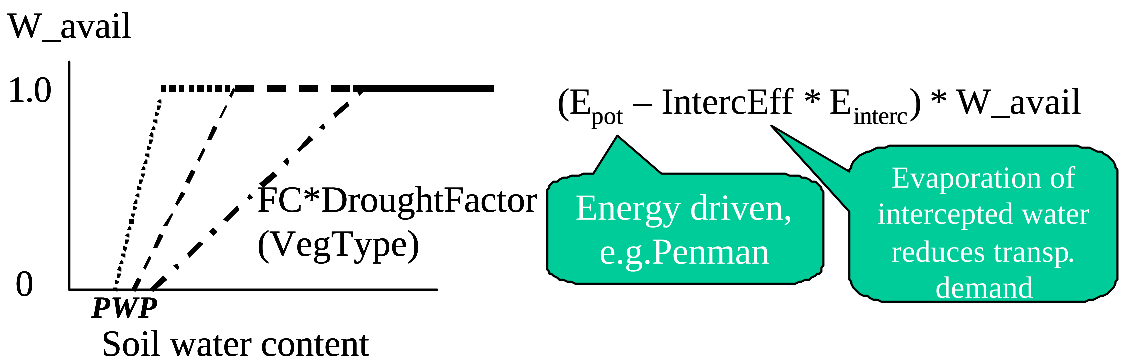


Figure 7. Assumed relationship between soil water content and soil water availability for evapotranspiration as fraction of the (energy-limited) potential ET (pwp = permanent wilting point)

5. Gradual release to streams through deep soil pathways

As explained in fig. 6.

By integration over these 5 pathways we can get an overview of the water balance

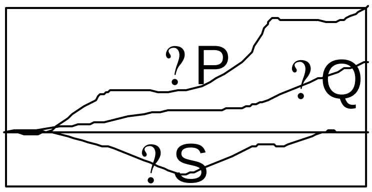
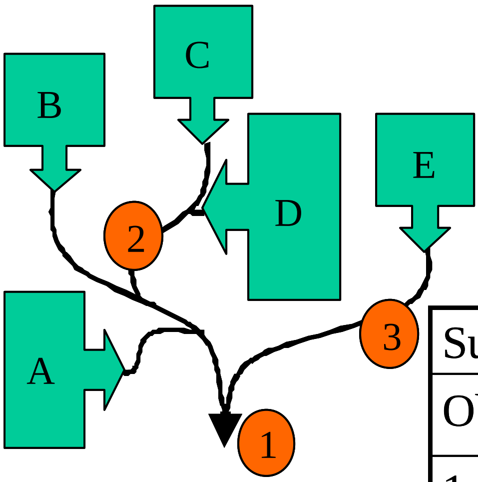
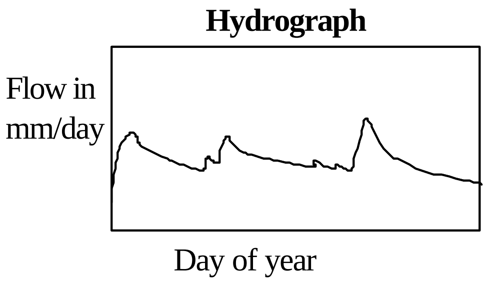


Figure 8. Water balance as derived fro m the accumulation of rain fall (P), river flow (Q) and changes in water storage (? S)

GenRiver component B. Stream and river network





Subcatchm	A	B	C	D	E
ObsPoint:					
1	4	7	10	8	6
2	-1	-1	4	3	-1
3	-1	-1	-1	-1	2
..					

Figure 9. Stream network representation based on 'effective distance' (with the option for correcting for slope and allowing a single mean flow velocity to be used); values of –1 represent observation points upstream of subcatchments

Options exist to include lakes and artificial reservoirs in the stream network.