Water resources management and hydrological modelling

The use of HEC-HMS model for hydrologic simulations. Data preparation and simulations. Exercise with GIS and HEC-HMS.

By

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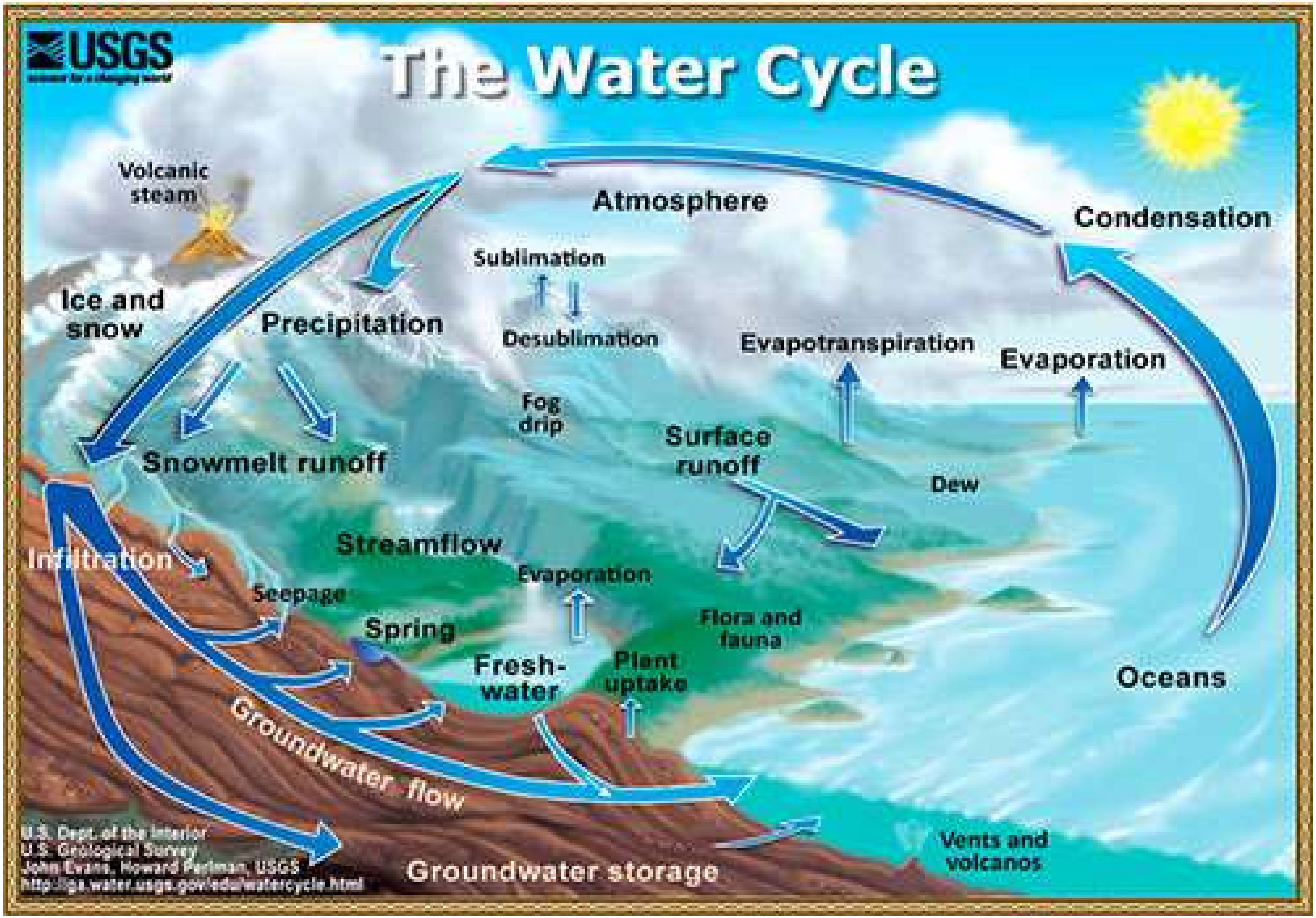

USGS
The Water Cycle
Volcanic steam
Atmosphere
Condensation
Sublimation
Desublimation
Ice and snow
Precipitation
Evapotranspiration
Evaporation
Fog drip
Surface runoff
Snowmelt runoff
Dew
Streamflow
Infiltration
Evaporation
Seepage
Flora and fauna
Spring
Fresh-water
Plant uptake
Oceans
Groundwater flow
Vents and volcanos
Groundwater storage
U.S. Dept. of the Interior
U.S. Geological Survey
John Evans, Howard Perlman, USGS
http://ga.water.usgs.gov/edu/watercycle.html

Hydrology models

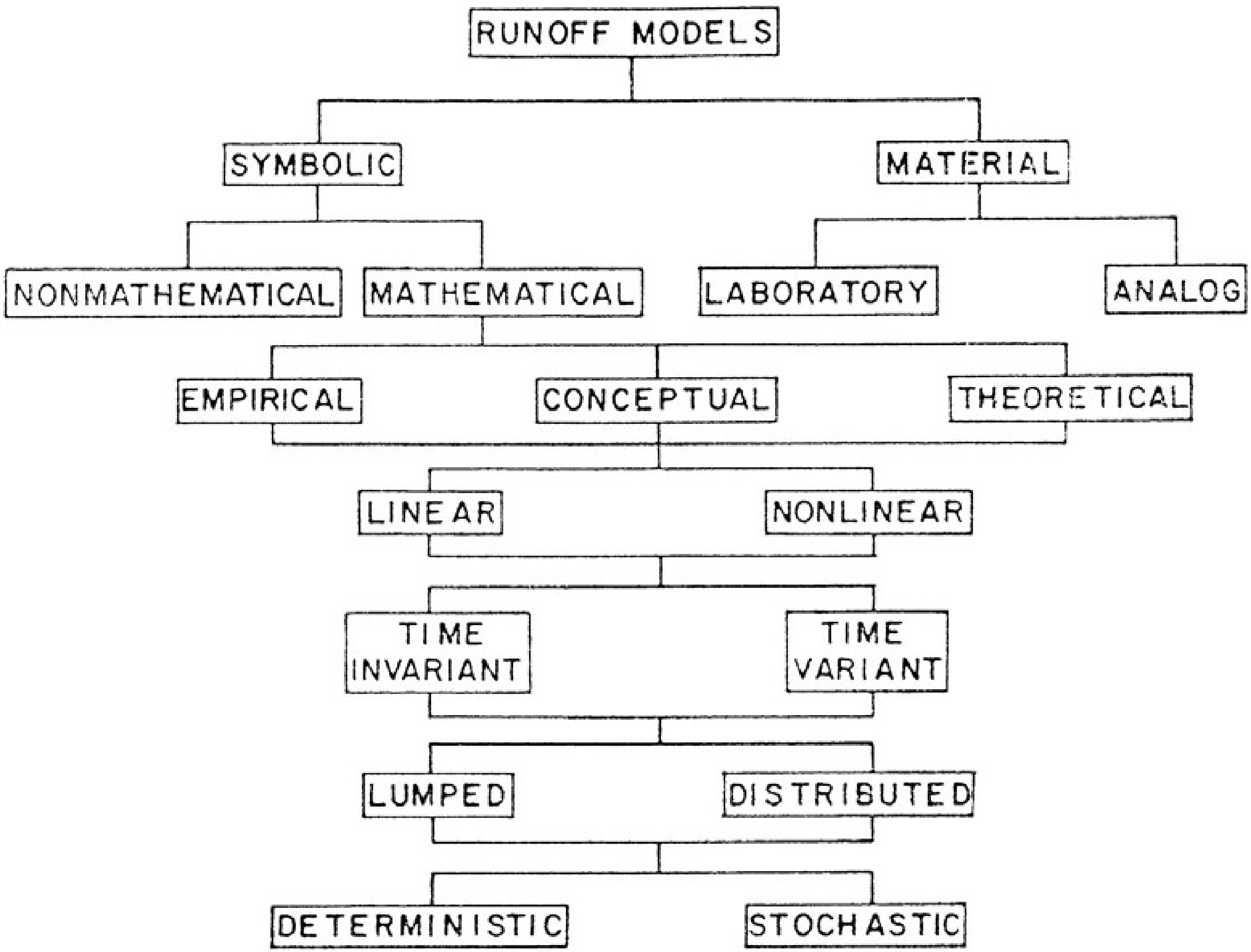
The catchment hydrologic models have been in general developed designed to meet one of the two primary objectives:

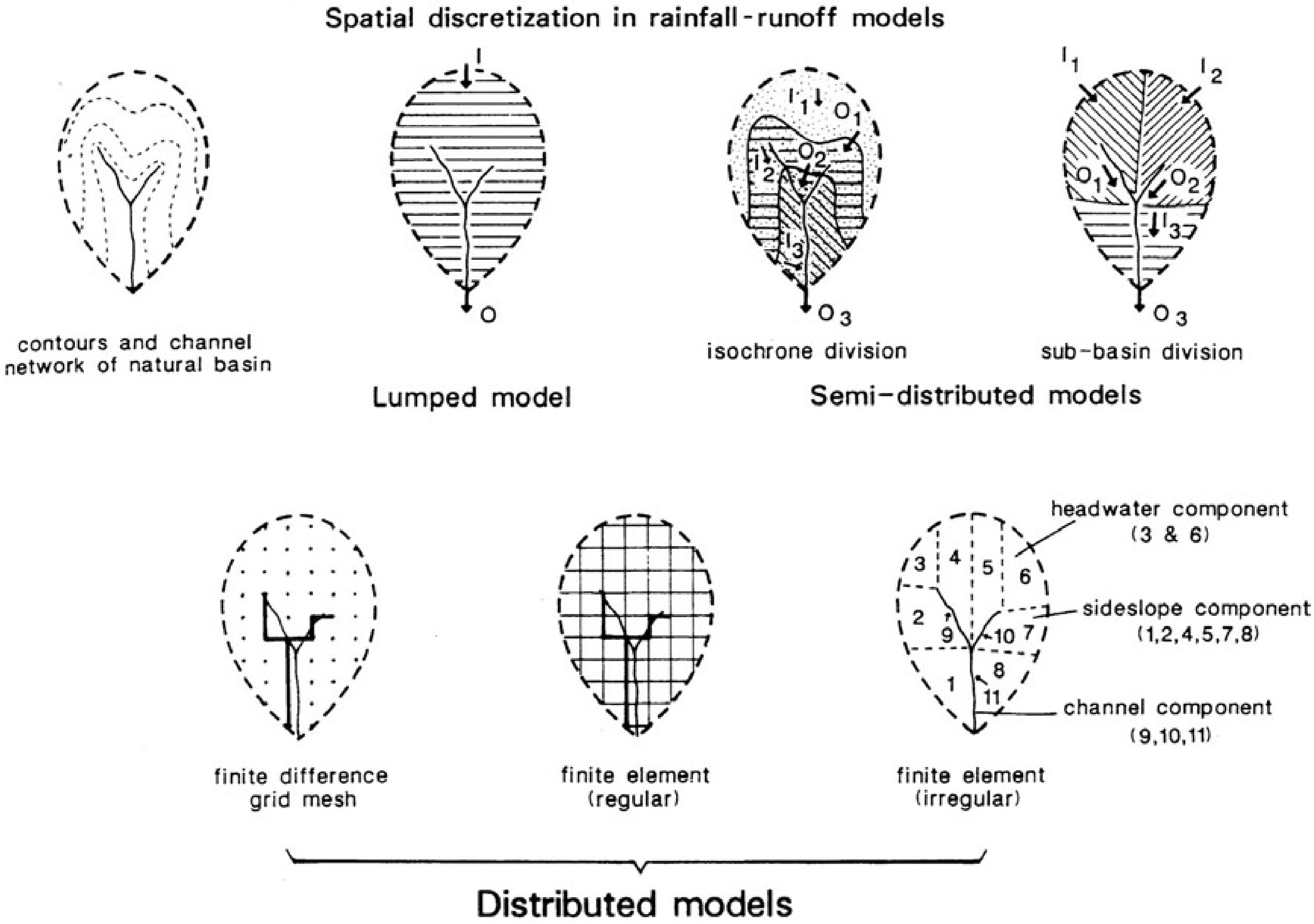
- **To gain a better understanding of the hydrologic phenomena operating in a catchment and to investigate how changes in the catchment may affect these phenomena.**
- **Generation of synthetic sequences of hydrologic data for facility design or for use in forecasting.**

The watershed can be considered as a hydrologic system:

- ***The system boundary: watershed boundaries***
- ***Input: Rainfall + snowfall***
- ***Output: streamflow , evaporation and subsurface flow***

Classification of hydrology models



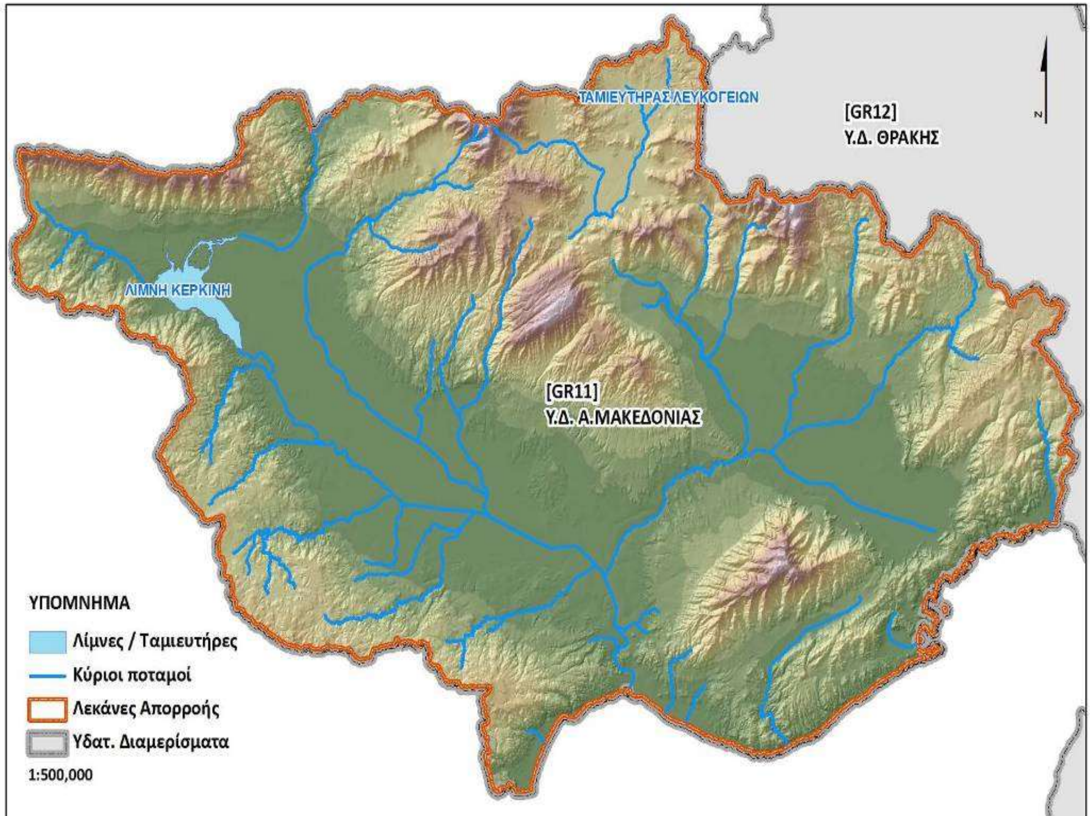


Graphic representation of geometrically – distributed and lumped models(Jones, 1997).

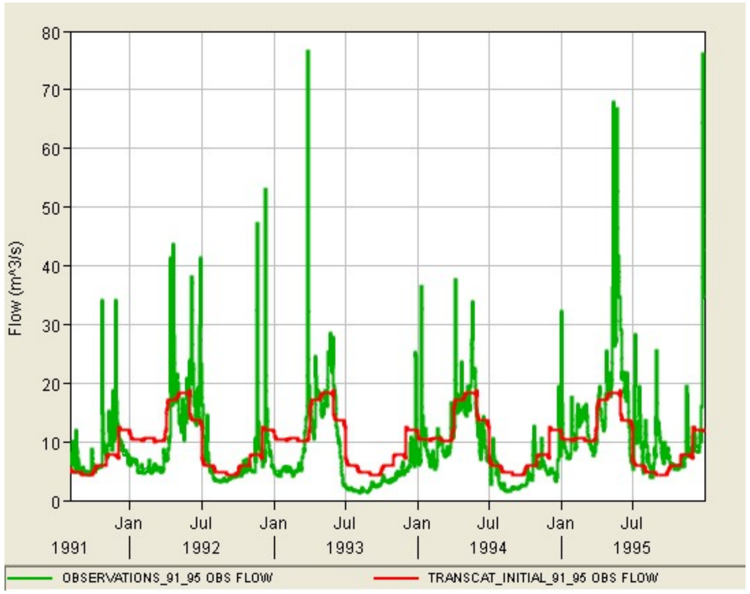
Hydrology model HEC-HMS

HEC-HMS is a Hydrologic Modeling System (HMS), created by the Hydrologic Engineering Centre (HEC) from the U.S. Army Corps of Engineers.

It's a semi-distributed model dedicated to simulate the precipitation-runoff processes of dendritic watershed systems and to be applicable in a wide range of areas for solving the widest possible range of problems.



Σχ. 1.3. Λίμνες και ταμιευτήρες Υ.Δ. Ανατολικής Μακεδονίας [GR11]



Geospatial Hydrologic Modeling System GeoHMS

U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC)

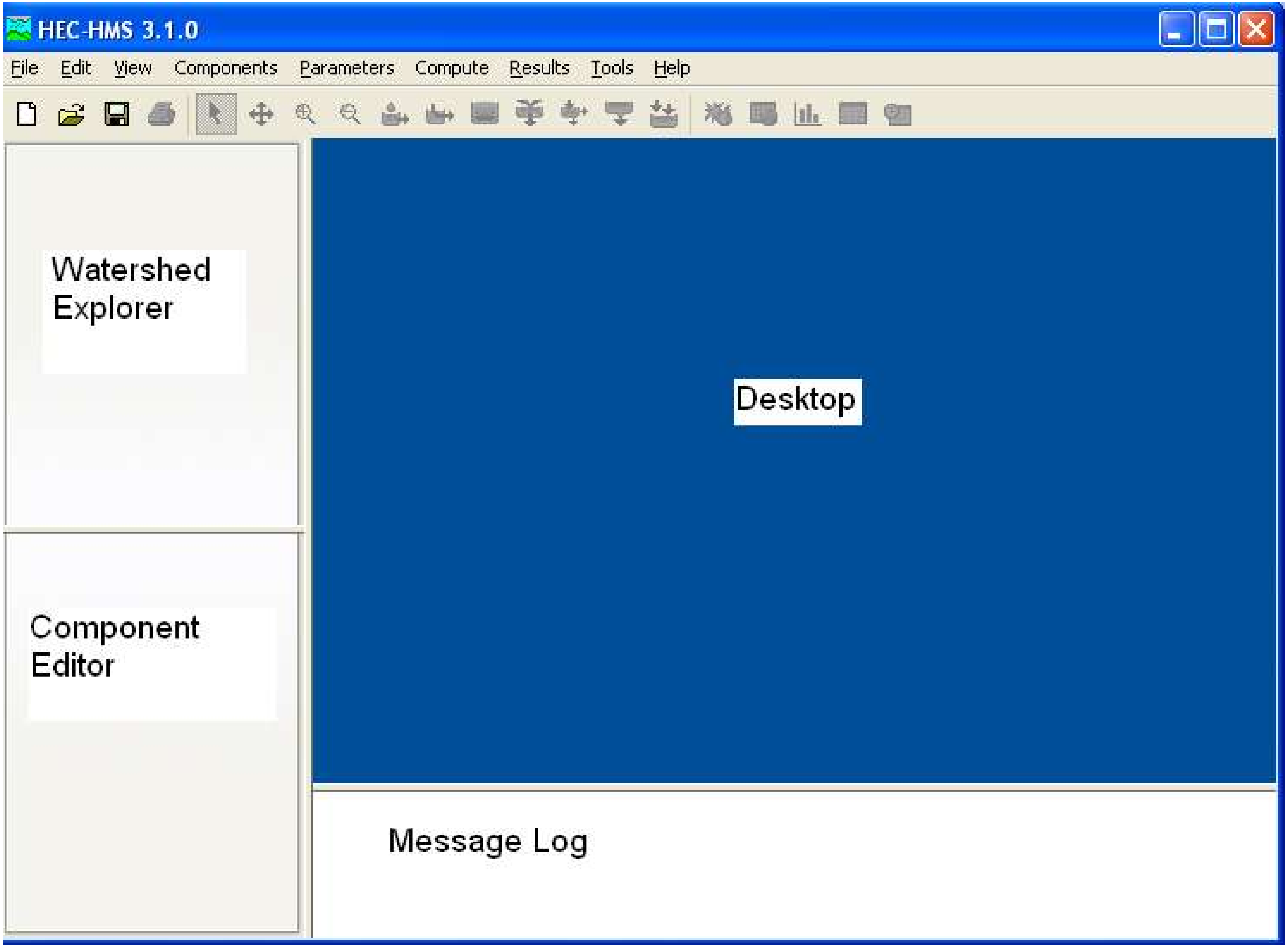
- HEC-HMS: Hydrologic Modeling System

http://www.hec.usace.army.mil/software/hec-hms/

- HEC-GeoHMS: Geospatial HMS

http://www.hec.usace.army.mil/software/hec-geohms/index.html

Hydrology model HEC-HMS



HEC-HMS structure

Every new project in HEC-HMS requires three input “models”. They are linked together in order to simulate the runoff.

✓**Basin model** : The basin model consists of a network of subbasin, reach and junction elements. Other possible elements are reservoirs, diversions, sources and sinks. They cover information about the physical characteristics of a basin, an important input for all the calculations. A basin model can be created with the help of HEC-GeoHMS.

✓**Meteorological model**: This model is required to provide information about precipitation, evapotranspiration and snowmelt. *How this information is provided depends on the user choice.* A meteorologic model needs *to* be linked to one or more basin models before river flow can be simulated.

✓**Control model**: In a control model the time settings are specified. These include both the start and end time, and the modeling time interval.

HMS: symbols used to represent individual hydrologic element

 **Subbasin** – Used for rainfall-runoff computation on a watershed.

 **Reach** – Used to convey (route) streamflow downstream in the basin model.

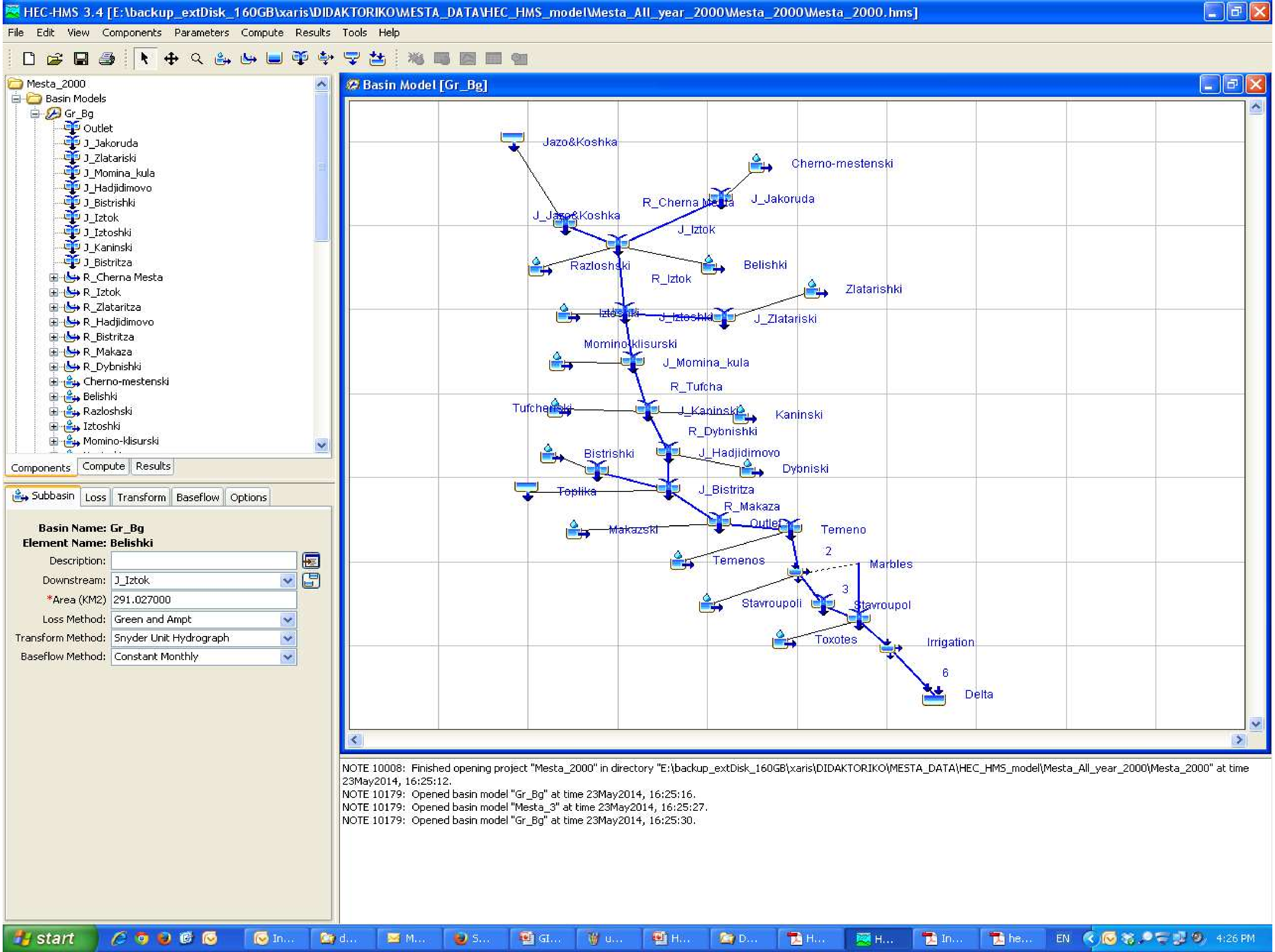
 **Reservoir** – Used to model the detention and attenuation of a hydrograph caused by a reservoir or detention pond.

 **Junction** – Used to combine flows from upstream reaches and sub-basins.

 **Diversion** – Used to model abstraction of flow from the main channel.

 **Source** – Used to introduce flow into the basin model (from a stream crossing the boundary of the modeled region). Source has no inflow.

 **Sink** – Used to represent the outlet of the physical watershed. Sink has no outflow.


HEC-HMS 3.4 [E:\backup_extDisk_160GB\xaris\DIDAKTORIKO\MESTA_DATA\HEC_HMS_model\Mesta_All_year_2000\Mesta_2000\Mesta_2000.hms]
File Edit View Components Parameters Compute Results Tools Help
Mesta_2000
Basin Models
Gr_Bg
Outlet
J_Jakoruda
J_Zlatariski
J_Momina_kula
J_Hadjidimovo
J_Bistrishki
J_Iztok
J_Iztoshki
J_Kaninski
J_Bistritza
R_Cherna Mesta
R_Iztok
R_Zlataritza
R_Hadjidimovo
R_Bistritza
R_Makaza
R_Dybnishki
Cherno-mestenski
Belishki
Razloshski
Iztoshki
Momino-klisurski
Components
Compute
Results
Subbasin
Loss
Transform
Baseflow
Options
Basin Name: Gr_Bg
Element Name: Belishki
Description:
Downstream: J_Iztok
*Area (KM2) 291.027000
Loss Method: Green and Ampt
Transform Method: Snyder Unit Hydrograph
Baseflow Method: Constant Monthly
Basin Model [Gr_Bg]
Jazo&Koshka
Cherno-mestenski
R_Cherna Mesta
J_Jakoruda
J_Jazo&Koshka
J_Iztok
Razloshski
Belishki
R_Iztok
Zlatarishki
Iztoshki
J_Iztoshki
J_Zlatariski
Momino-klisurski
J_Momina_kula
R_Tufcha
Tufchenski
J_Kaninski
Kaninski
R_Dybnishki
Bistrishki
J_Hadjidimovo
Dybniski
Toplika
J_Bistritza
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Outlet
Makazski
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2
Marbles
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Stavroupol
Toxotes
Irrigation
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Delta
NOTE 10008: Finished opening project "Mesta_2000" in directory "E:\backup_extDisk_160GB\xaris\DIDAKTORIKO\MESTA_DATA\HEC_HMS_model\Mesta_All_year_2000\Mesta_2000" at time 23May2014, 16:25:12.
NOTE 10179: Opened basin model "Gr_Bg" at time 23May2014, 16:25:16.
NOTE 10179: Opened basin model "Mesta_3" at time 23May2014, 16:25:27.
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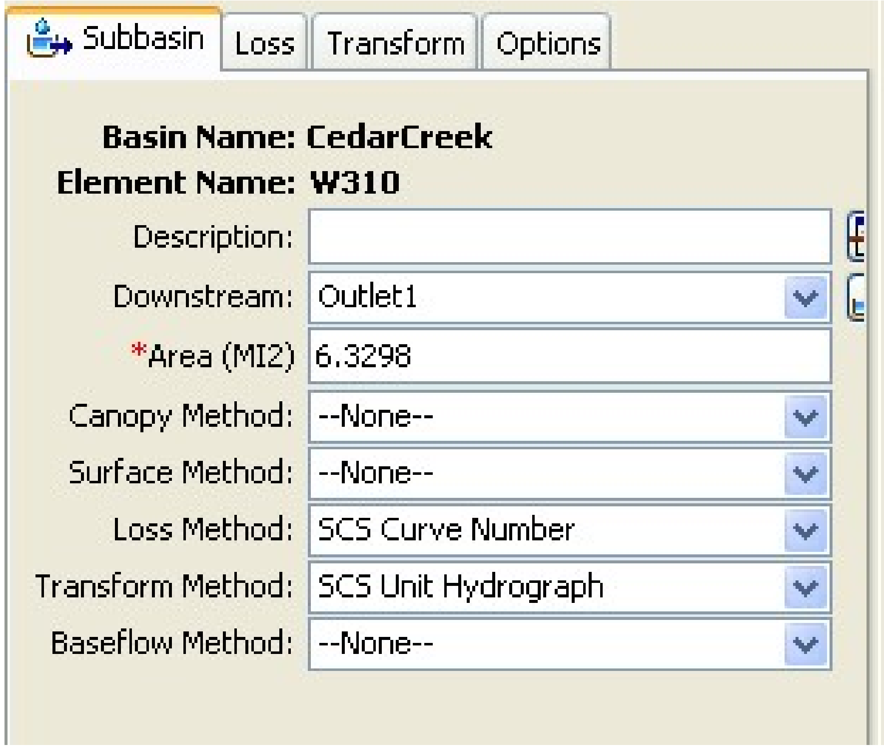
Subbasin parameters



1. **Canopy method *(optional)***
2. **Surface method *(optional)***
3. **Loss method**
4. **Transform method**
5. **Baseflow method**

•Canopy method: Represents the presence of plants in the landscape. Plants intercept some precipitation from the soil (evaporation and transpiration)

•Surface method: Represents the ground surface where water may accumulate in surface depression storage (percentage of soil saturation, initial storage and max storage in mm)

Subbasin parameters

- Loss methods

The loss method allows you to choose the process which calculates the rainfall losses absorbed by the ground (infiltration).

The part of precipitation used for infiltration can not be used for surface runoff in further calculations. For all calculation methods, the conservation of mass is respected: **the sum of infiltration and precipitation left is equal to the total incoming precipitation**.

- Deficit and Constant
- Exponential
- Green and Ampt

- Initial and Constant
- SCS Curve Number
- Smith Parlange
- Soil Moisture Accounting Loss

Subbasin parameters

Initial and Constant

This method requires an initial abstraction of the precipitation. When this is satisfied, infiltration and surface runoff can take place. Infiltration will then happen with a constant rate. The following formula describes this.

$$P_e(t) = P(t) - I_{loss} - C_{loss}\,(t - t_0)$$

As the method is quite simple it is most suitable for watersheds that lack detailed soil information. However, as it does not take into account recovery of the initial loss in the periods between precipitation events, it is not very suitable for continuous simulation.

Subbasin parameters

SCS Curve Number

This method calculates the infiltration volume per time interval, with help of the curve number: a representation of the specific soil group and land use combination. The following formula is used to calculate the effective precipitation

$$P_e = \frac{\left(P - 0.2\left[\frac{1000}{CN} - 10\right]\right)^2}{P + 0.8\left[\frac{1000}{CN} - 10\right]}$$

CN can be produced with the use of GIS!

SCS Curve Number

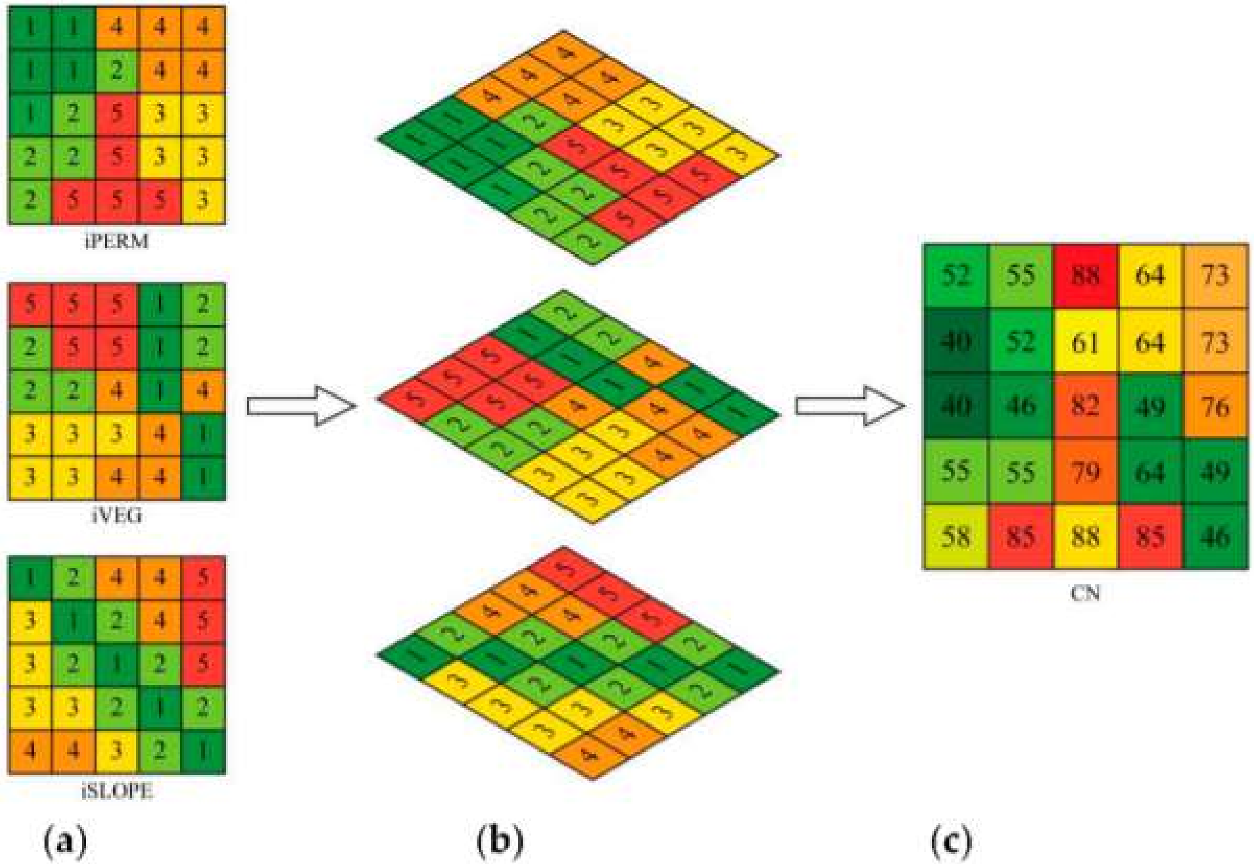


Figure 1. (**a**) Layers of geographic information for permeability classes (i_{PERM}), vegetation density classes (i_{VEG}) and drainage capacity classes (i_{SLOPE}); (**b**) layer overlay; (**c**) CN parameter map.

Savvidou, E.; Efstratiadis, A.; Koussis, A.D.; Koukouvinos, A.; Skarlatos, D. The Curve Number Concept as a Driver for Delineating Hydrological Response Units. Water ***2018****, 10, 194.*
https://doi.org/10.3390/w10020194

Subbasin parameters

- Transformation methods

After subtracting the losses from the precipitation, the excess precipitation is used for the runoff calculations, performed by the transform methods.

These methods take care of delay and attenuation phenomenon's, caused by storage for instance, and by the shape of the basin.

- Clark Unit Hydrograph
- Kinematic wave
- ModClark Transform
- SCS Unit Hydrograph Transform

- Snyder Unit Hydrograph
- User-Specified S-graph Transform
- User-Specified Unit Hydrograph Transform

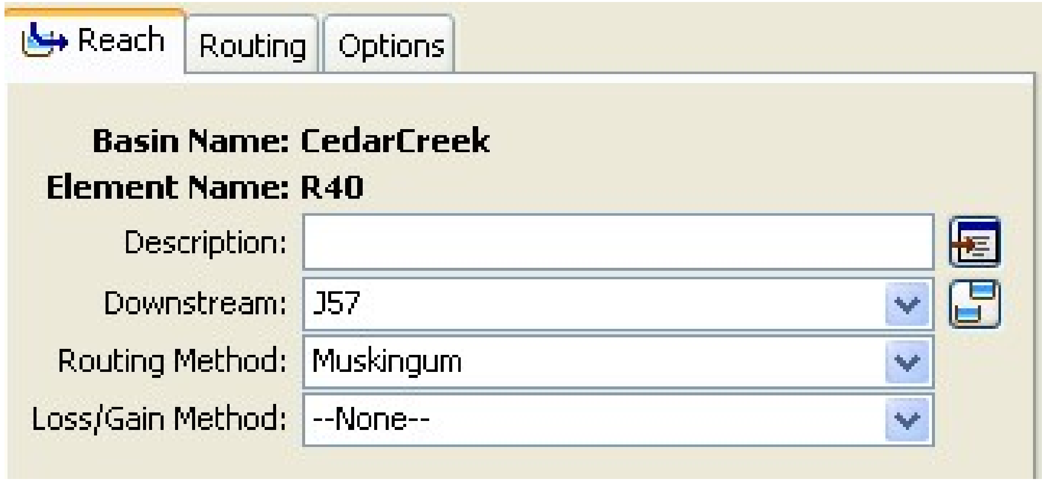
Subbasin parameters

Kinematic wave
This method makes a clear distinction between pervious and impervious areas, and is therefore mainly applicable in urban areas. It makes use of the same meteorological model, but different parameters should be added for both areas. The kinematic wave equations are derived from the St. Venant equations.

SCS Unit Hydrograph Transform
This method makes use of a dimensionless hydrograph suitable for general applications. This dimensionless hydrograph is the outcome from analyzing a large number of unit hydrographs. As the time lag is the only parameter required for scaling the final hydrograph, it is also called the one-parameter hydrograph.

Routing methods (Reach)

'a process used to predict the temporal and spatial variations of a flood hydrograph as it moves through a river reach or reservoir. '



'The effects of storage and flow resistance within a river reach are reflected by changes in hydrograph shape and timing as the floodwave moves from upstream to downstream.'

Hydrologic routing 'employs the continuity equation and an analytical or an empirical relationship between storage within the reach and discharge at the outlet'

Hydraulic routing methods on the other hand make use of the full unsteady flow equations of open channel flow. Therefore they are much more detailed and physically based

Routing methods (Reach)

- **Straddle Stagger**
- **Muskingum-Cunge**
- **Muskingum**
- **Modified Puls Routing**
- **Lag**
- **Kinematic wave**

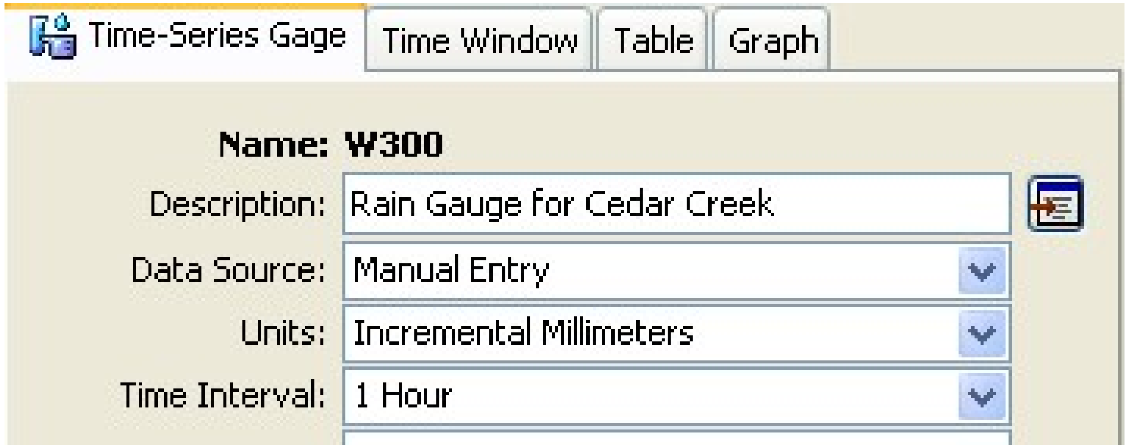
Lag method: Uses only the lag time to account for the translation of the flood wave. Attenuation is not taken care of. It is therefore mainly suitable for 'short stream segments with a predictable travel time that doesn't vary with flow depth'

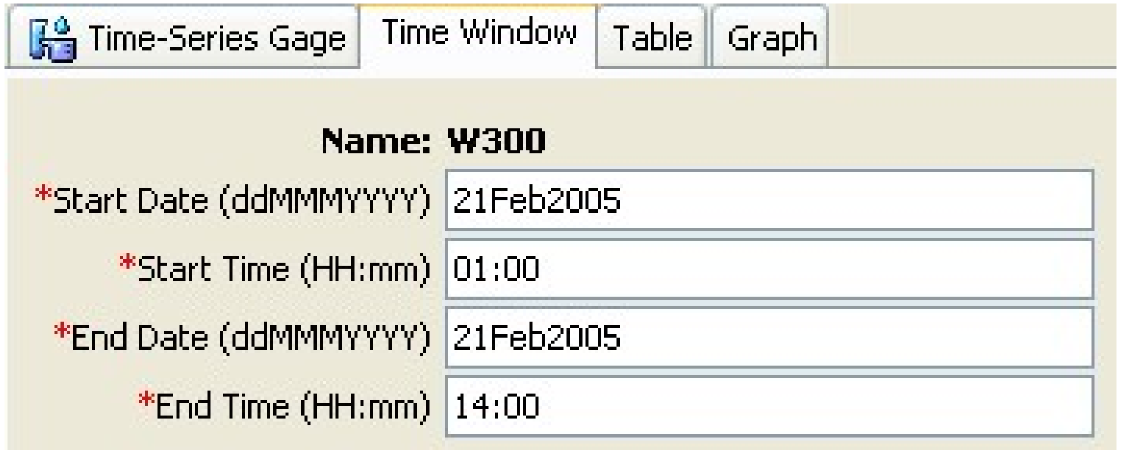
Muskingum-Cunge: 'a nonlinear coefficient method that accounts for hydrograph diffusion based on physical channel properties and the inflowing hydrograph'.

As the parameters of this method are physically based, it will present accurate results.

Meteorological model

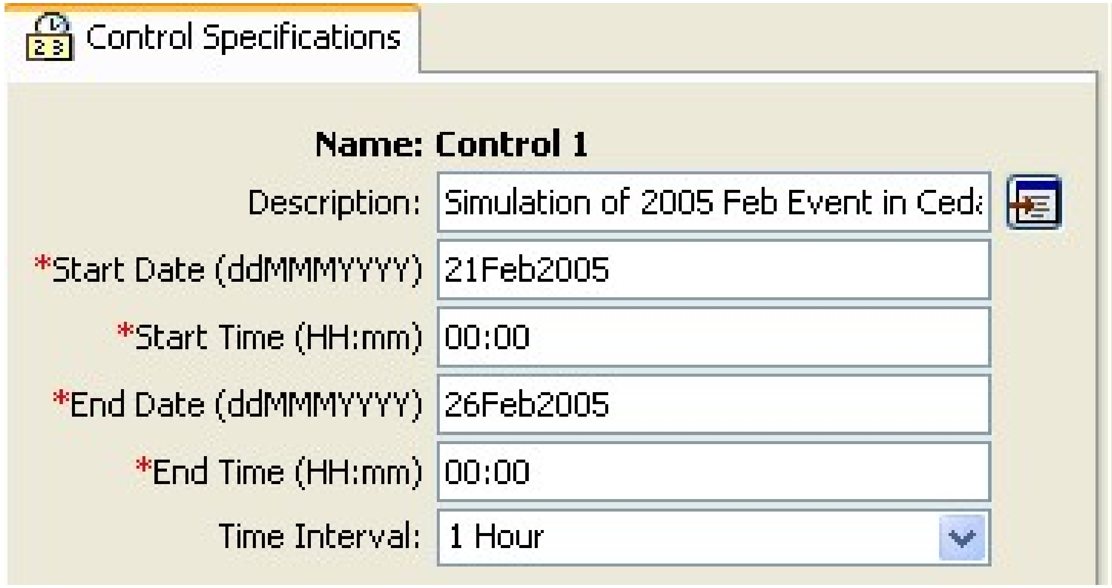
Specifying a time series of rainfall at a Rainfall gauge, and associating this gauge with each individual sub-basin or all sub-basins.



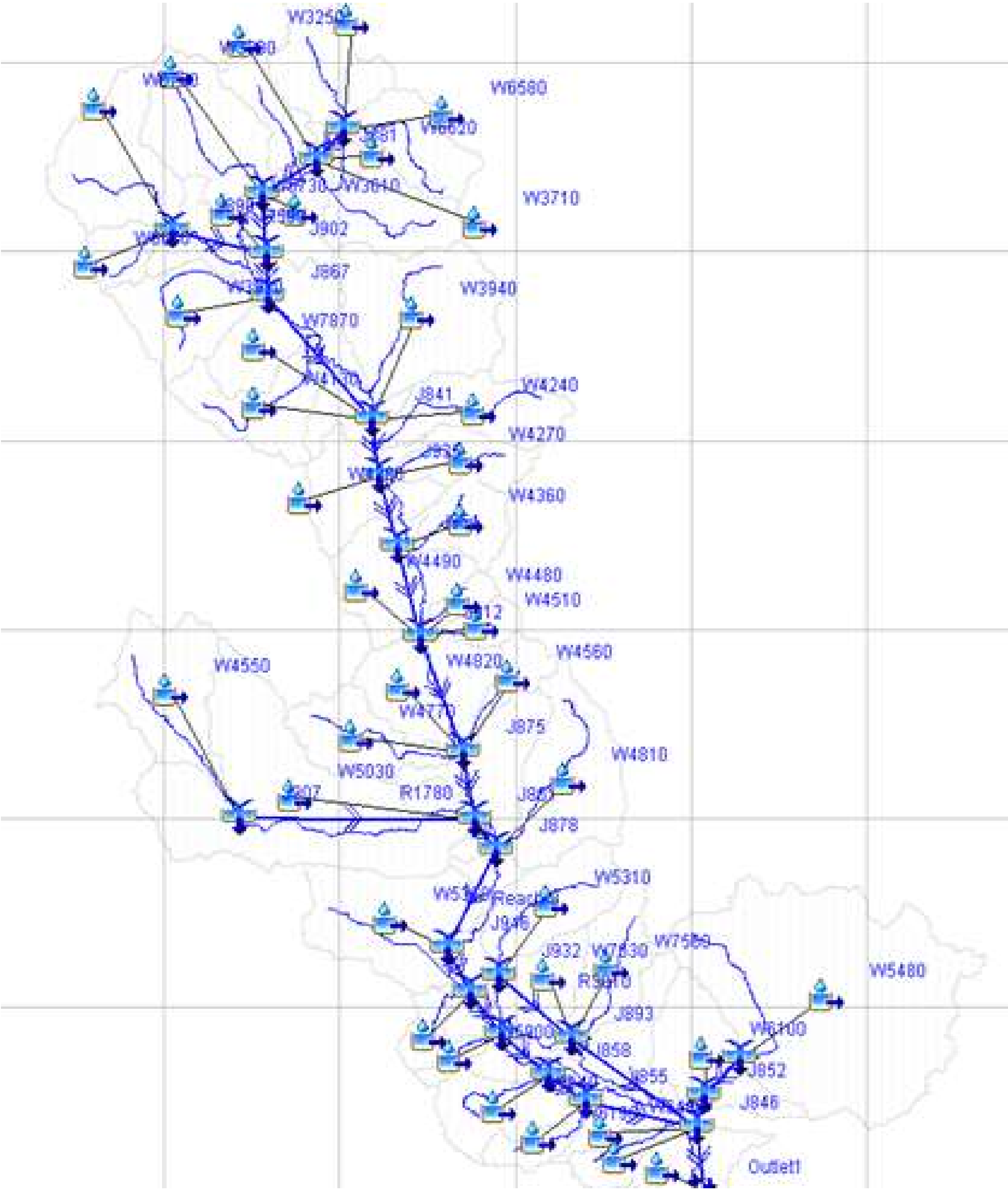


Control model

Specifying information relative to the under simulation event, such as time step of simulation



HEC-HMS: Application to the Struma basin



• **Transform method**:

SCS Unit Hydrograph Model

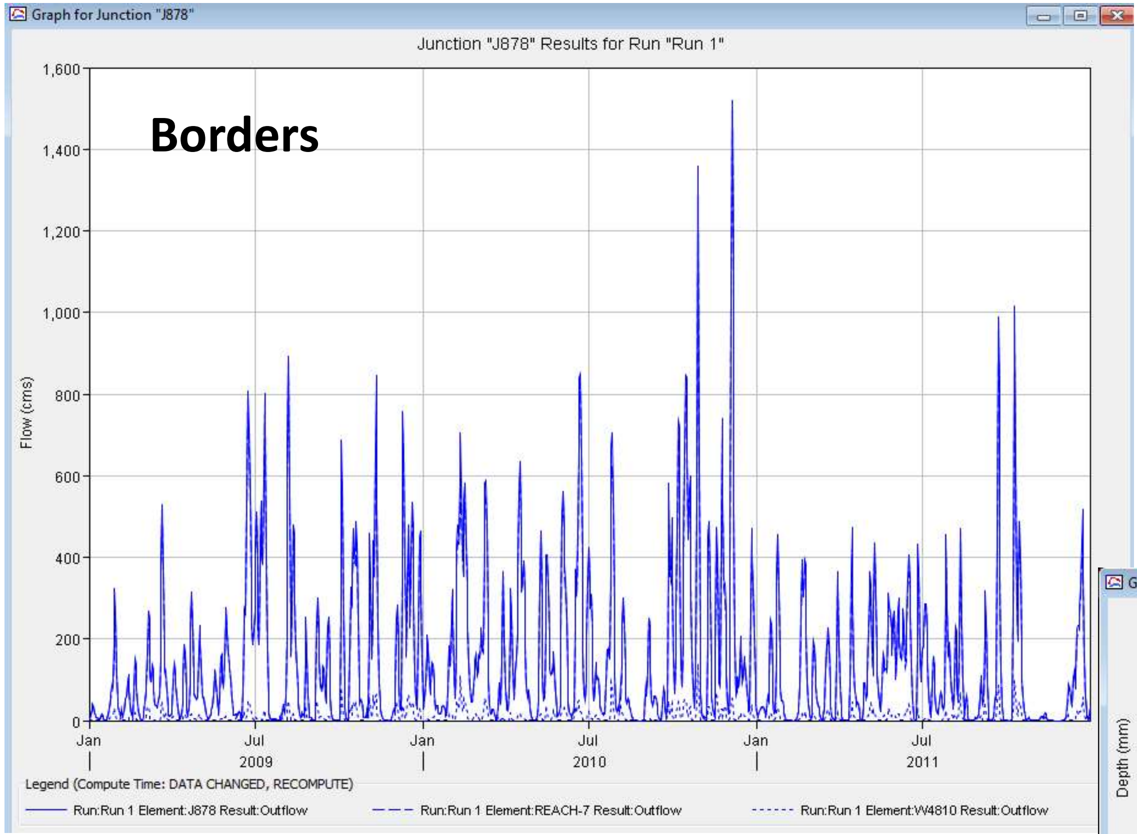
Lag time: 60% of concentration time (Giandotti formula)

$$t_g = \frac{4\sqrt{A} + 1.5L}{0.8\sqrt{\Delta H}}$$

• **Loss Method** :

SCS Curve Number method

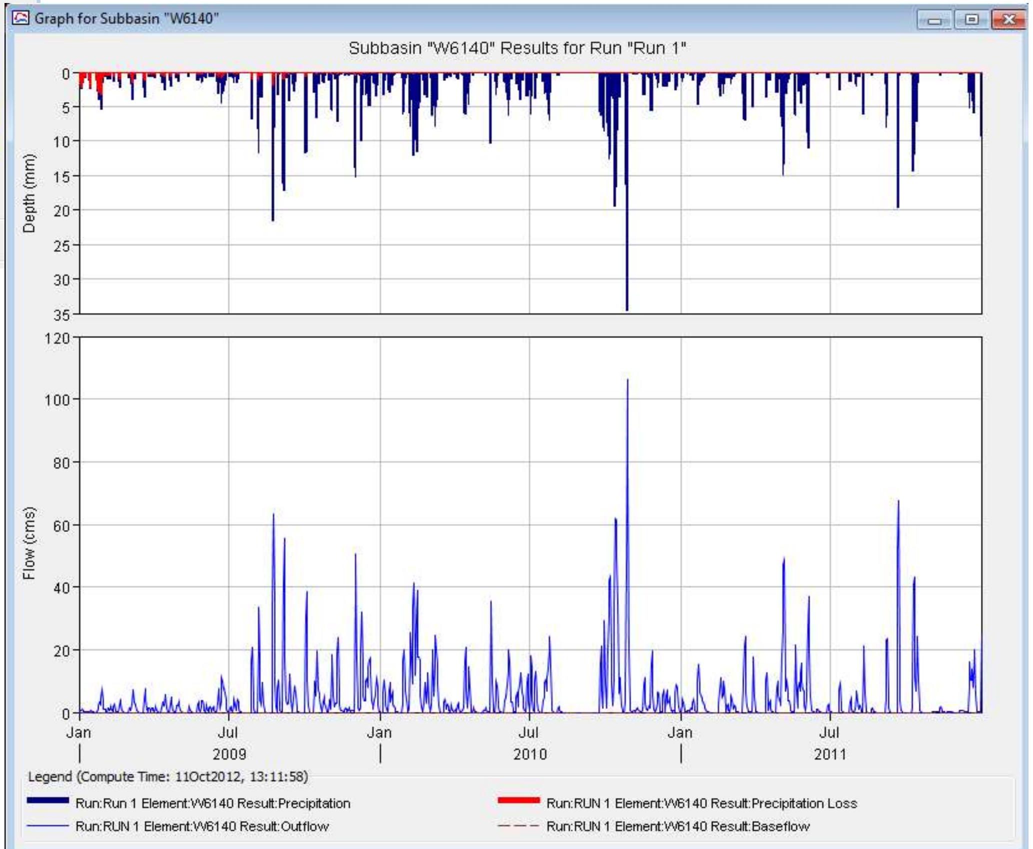
HEC-HMS: Results



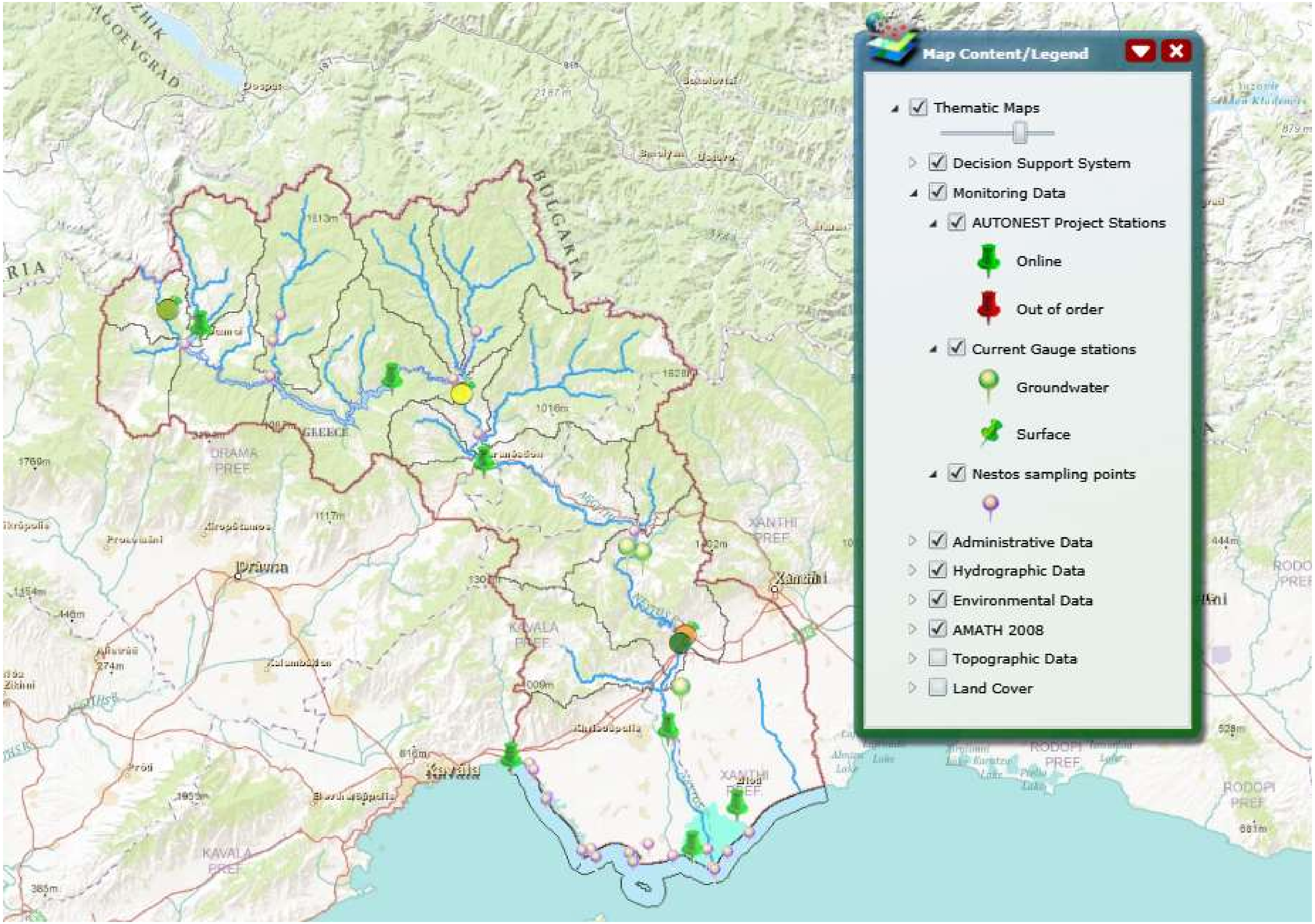
Borders: Max Discharges 1550m³/s, < 3,000m³/s (100y Return period) Summer :Qmax = 800m³/s < 1800 m³/s

Subbasin Xiropotamos: Max discharges 107m³/s < 183 m³/s (100y return period)

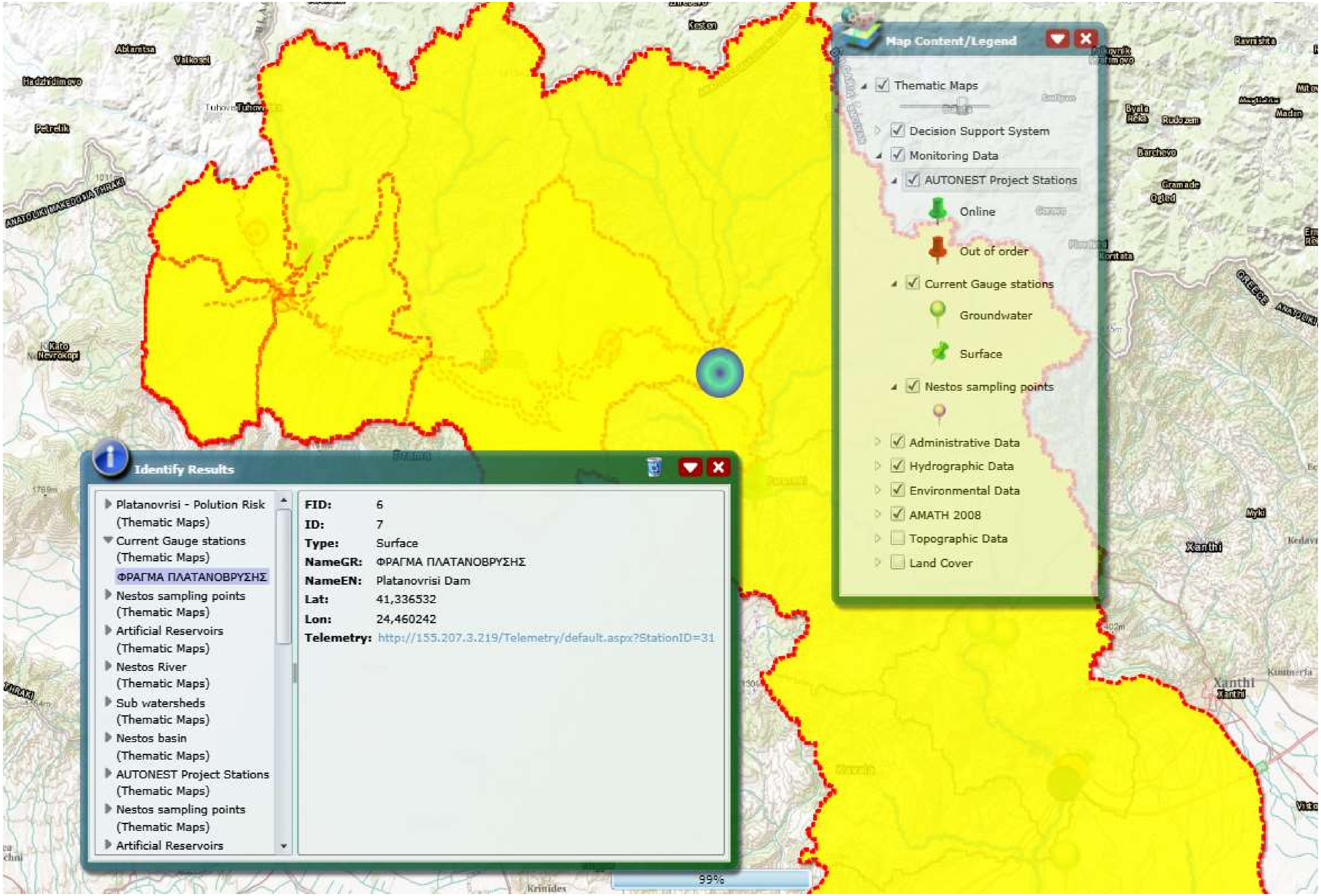
Ξηροπόταμος



WebIMS technologies



WebIMS technologies




airphotos
Merci beaucoup!