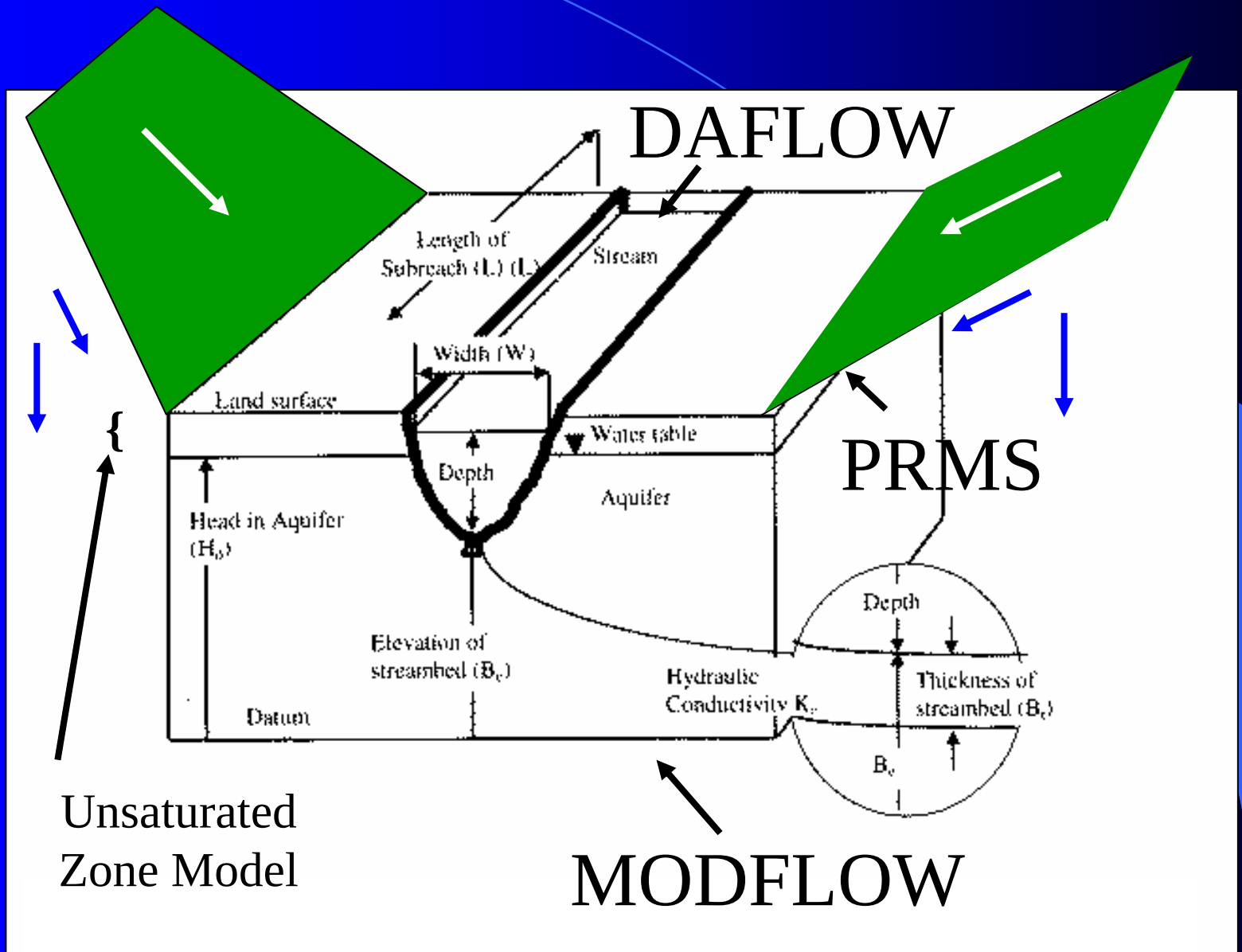
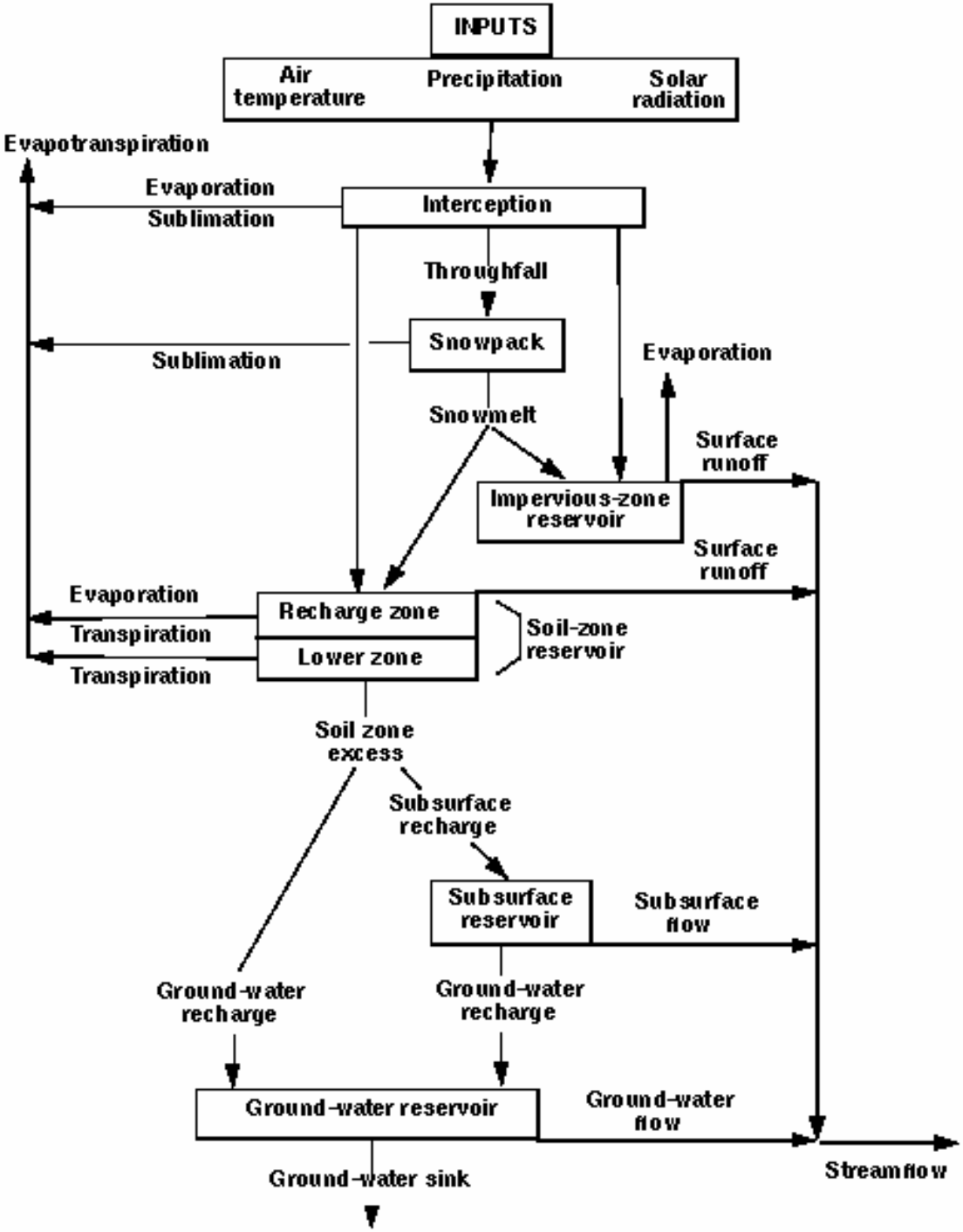
COUPLED GROUND WATER - SURFACE WATER MODELING

George Leavesley[1], Steve Markstrom[1], Rich Niswonger[2], Dave Prudic[2], Steve Regan[1], and Roland Viger[1]

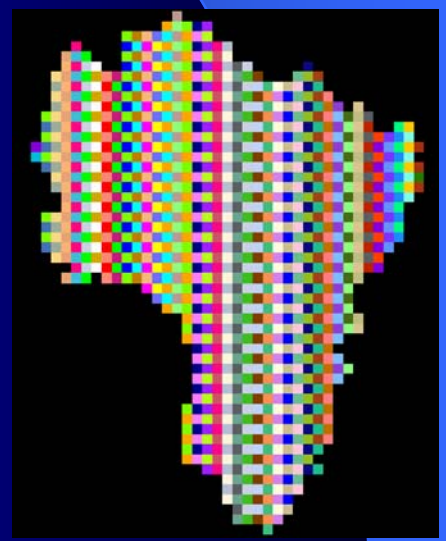
[1]USGS, Denver, CO
[2]USGS, Carson City, NV

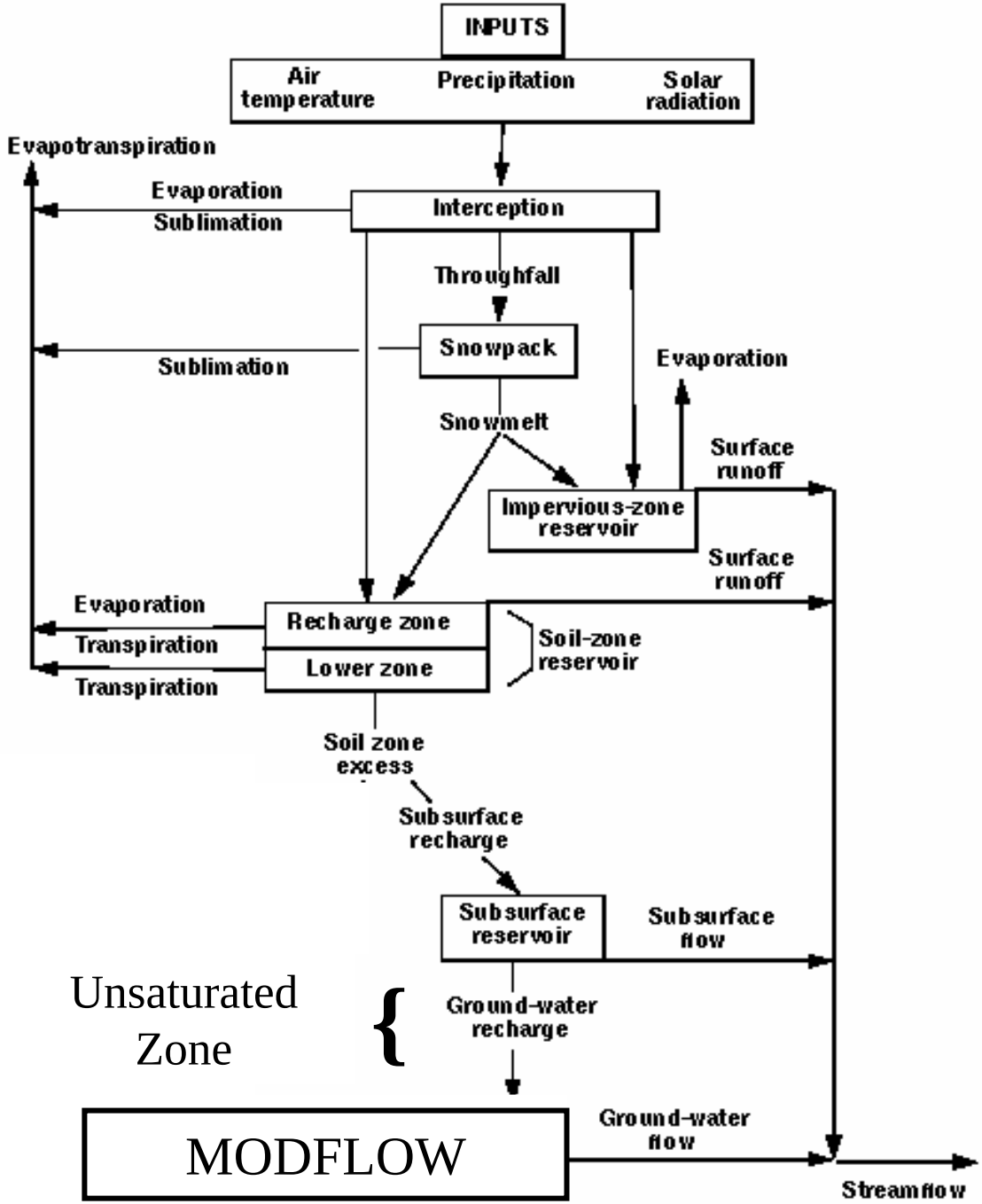
Ground Water - Surface Water Coupling




INPUTS
Air temperature
Precipitation
Solar radiation
Evapotranspiration
Evaporation
Sublimation
Interception
Throughfall
Snowpack
Sublimation
Evaporation
Snowmelt
Surface runoff
Impervious-zone reservoir
Surface runoff
Evaporation
Transpiration
Transpiration
Recharge zone
Lower zone
Soil-zone reservoir
Soil zone excess
Subsurface recharge
Subsurface reservoir
Subsurface flow
Ground-water recharge
Ground-water recharge
Ground-water reservoir
Ground-water flow
Ground-water sink
Streamflow

PRMS




INPUTS
Air temperature
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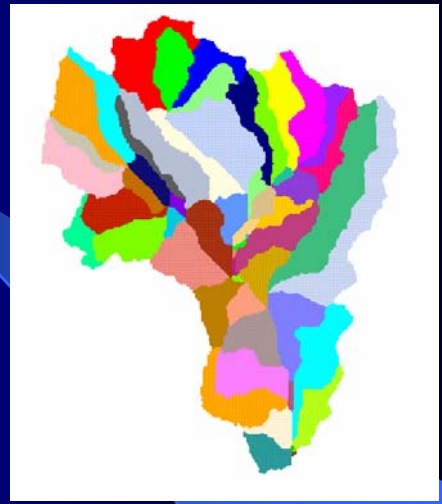
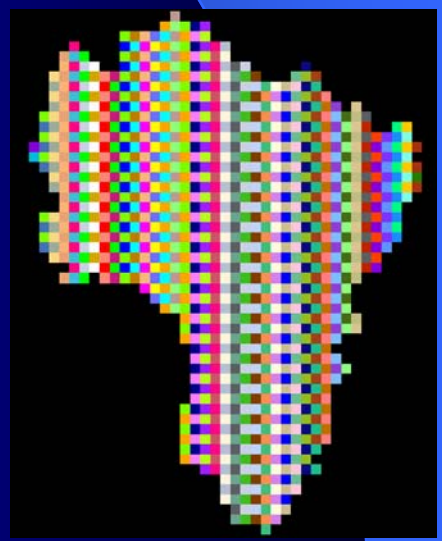
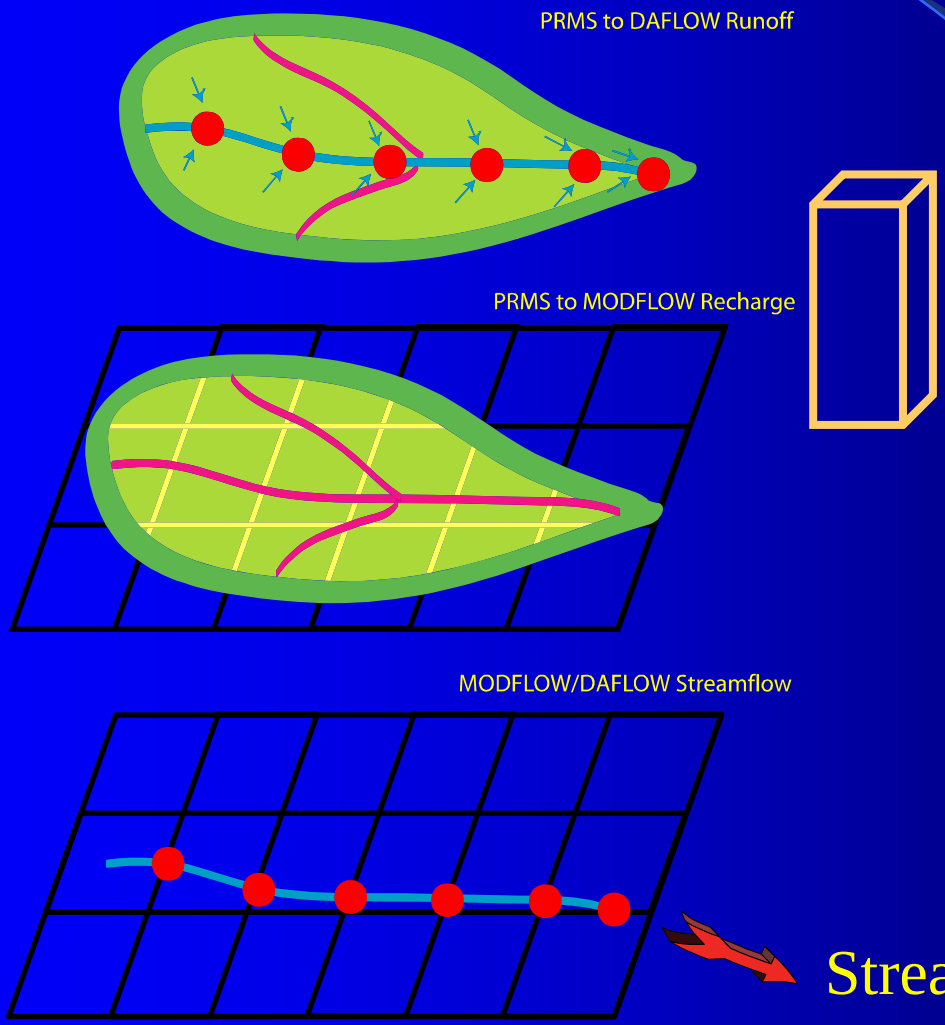
Evaporation
Snowmelt
Surface runoff
Impervious-zone reservoir
Surface runoff
Evaporation
Transpiration
Transpiration
Recharge zone
Lower zone
Soil-zone reservoir
Soil zone excess
Subsurface recharge
Subsurface reservoir
Subsurface flow
Unsaturated Zone
Ground-water recharge
MODFLOW
Ground-water flow
Streamflow

GSFLOW

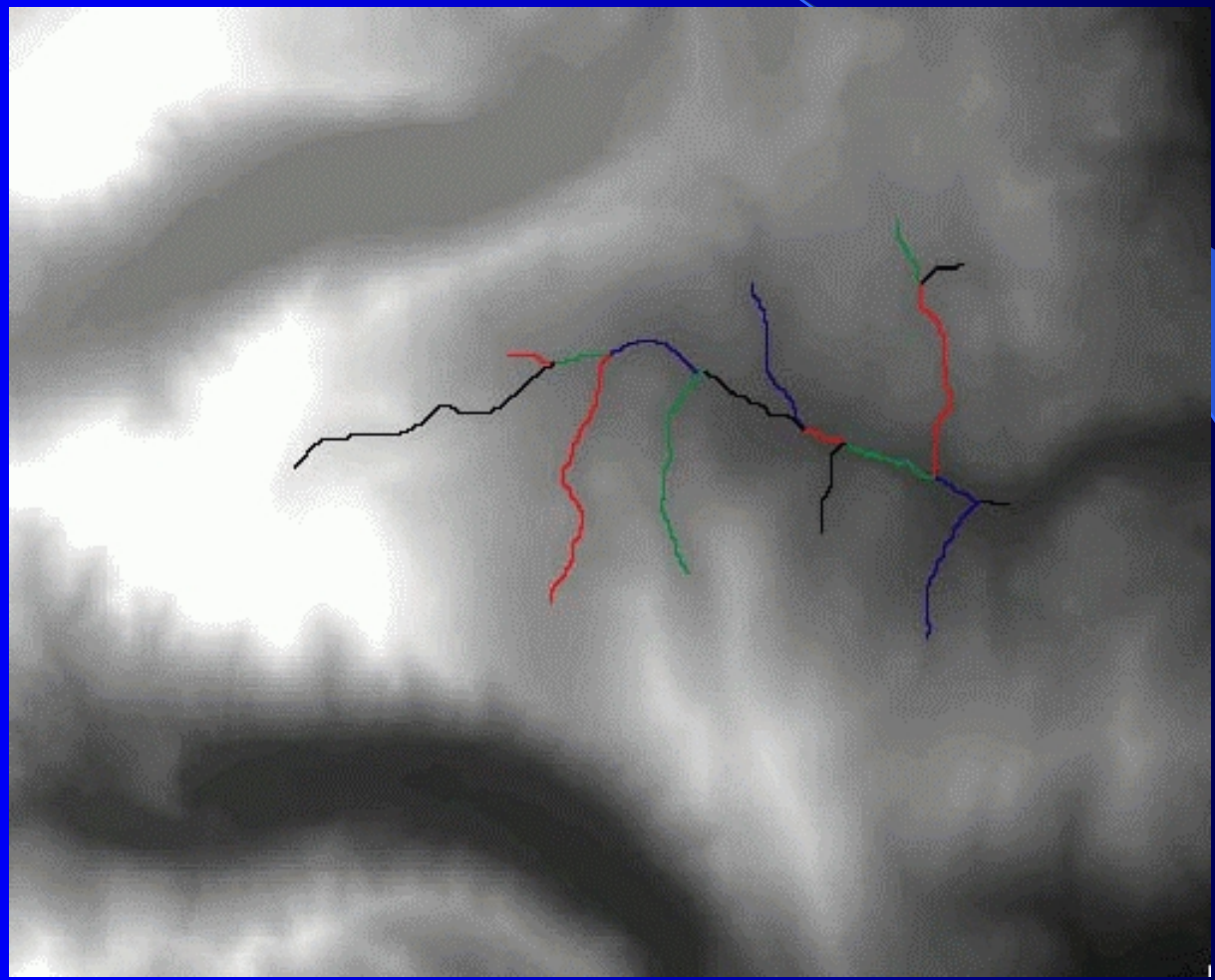




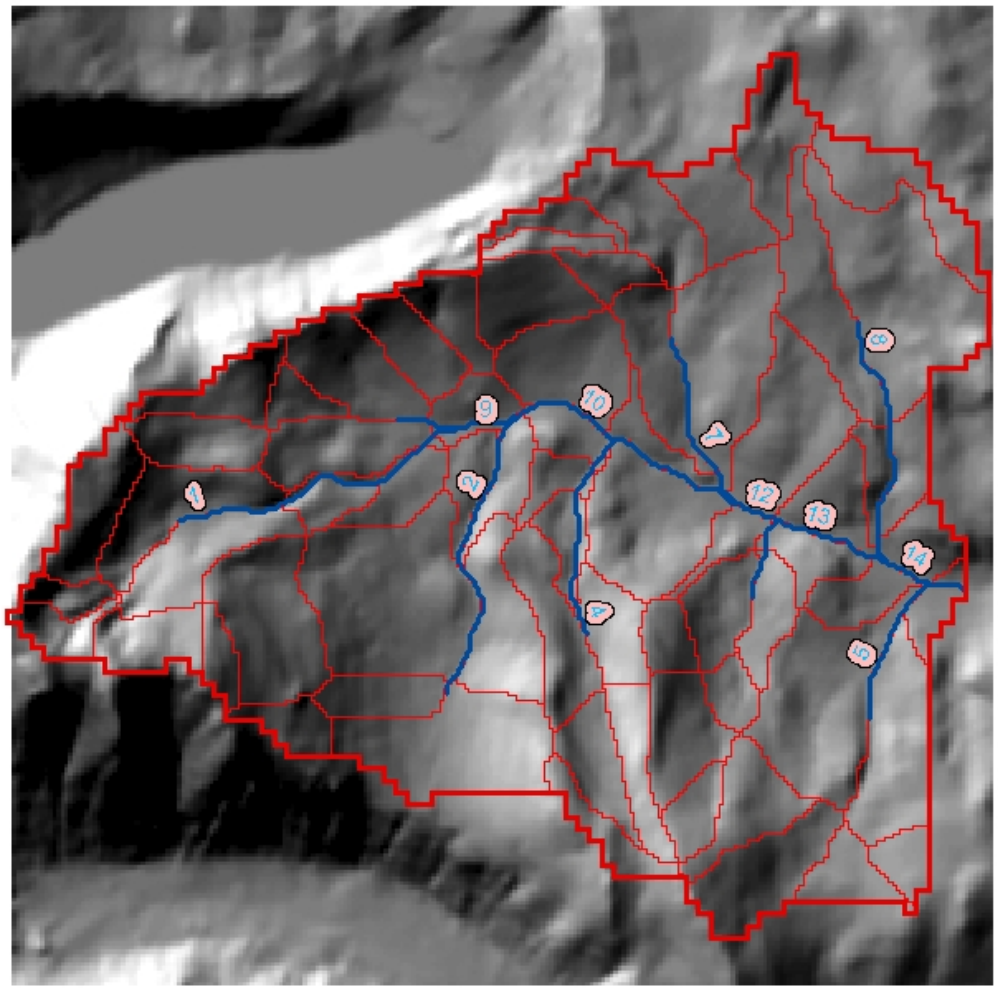
Ground-Water / Surface-Water Flow (GSFLOW) Model



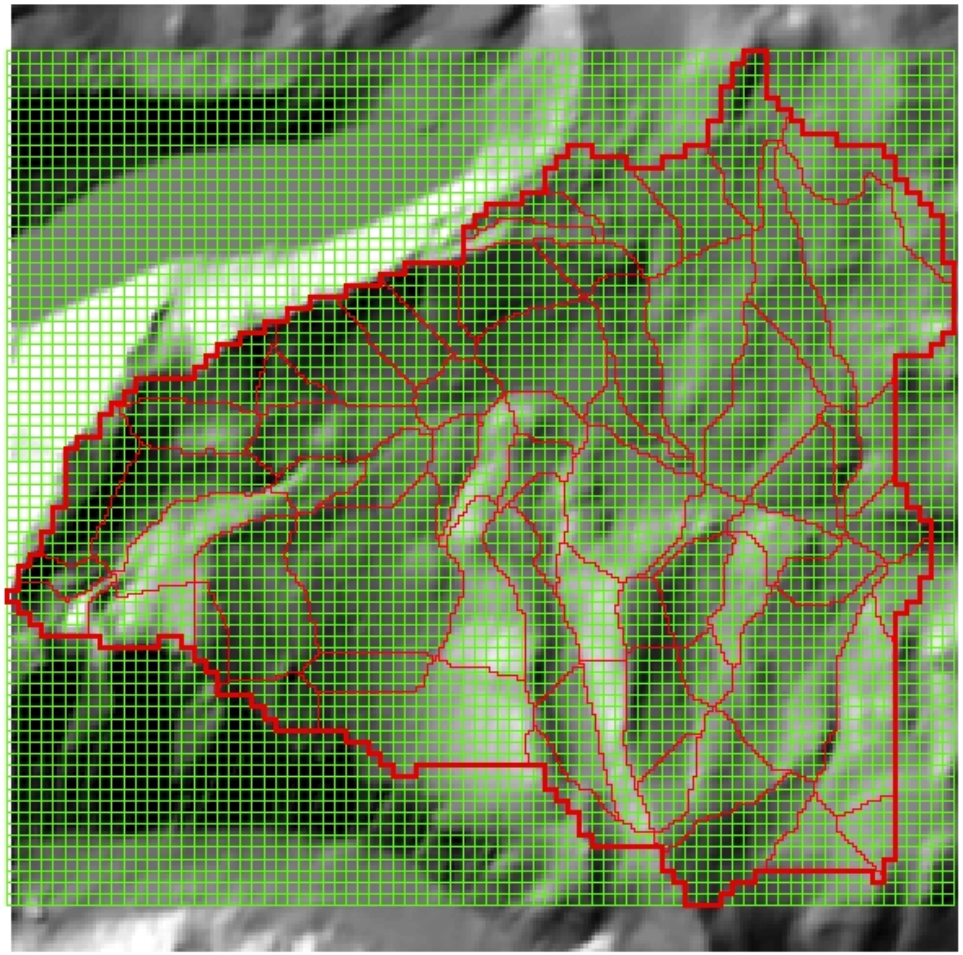
DEM/Branch



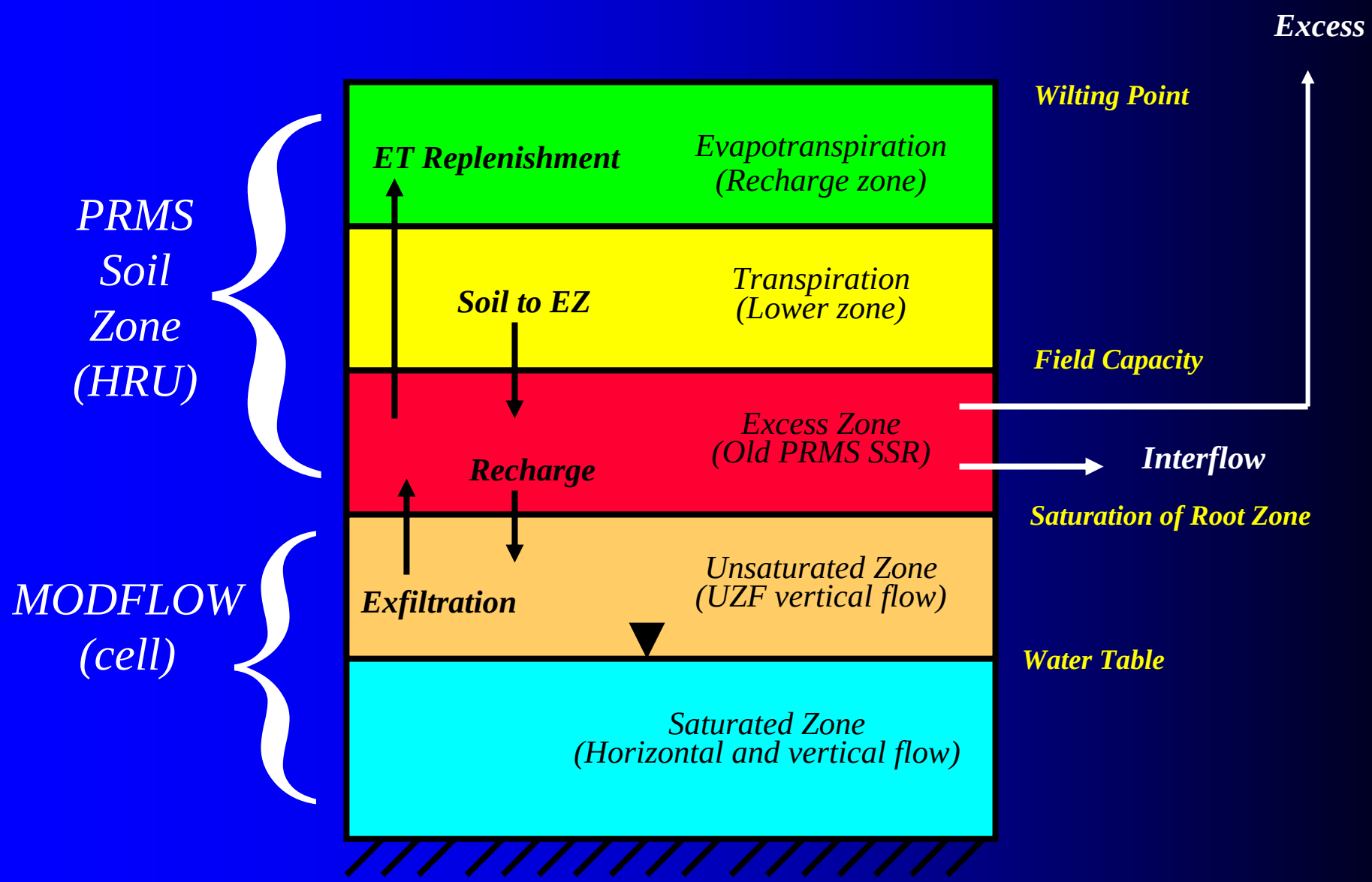
HRU/Stream Segments



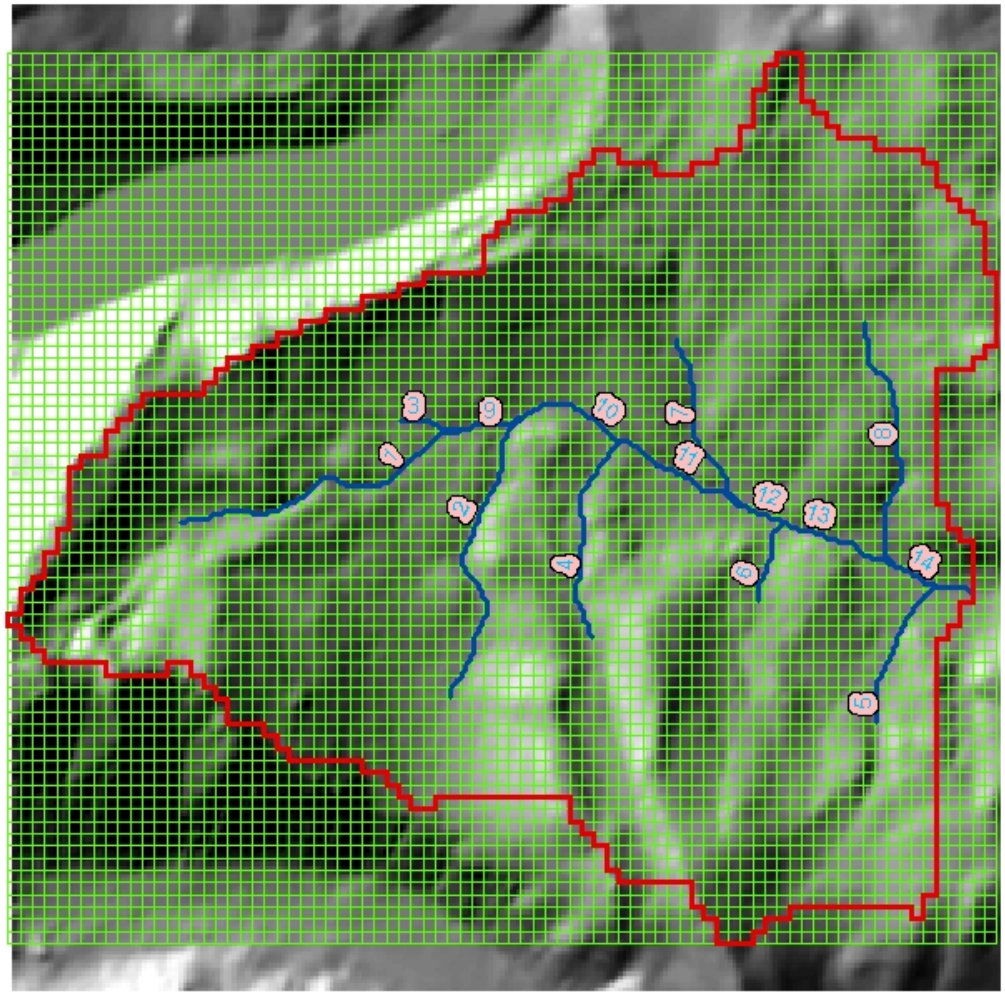
HRU/GW Cells



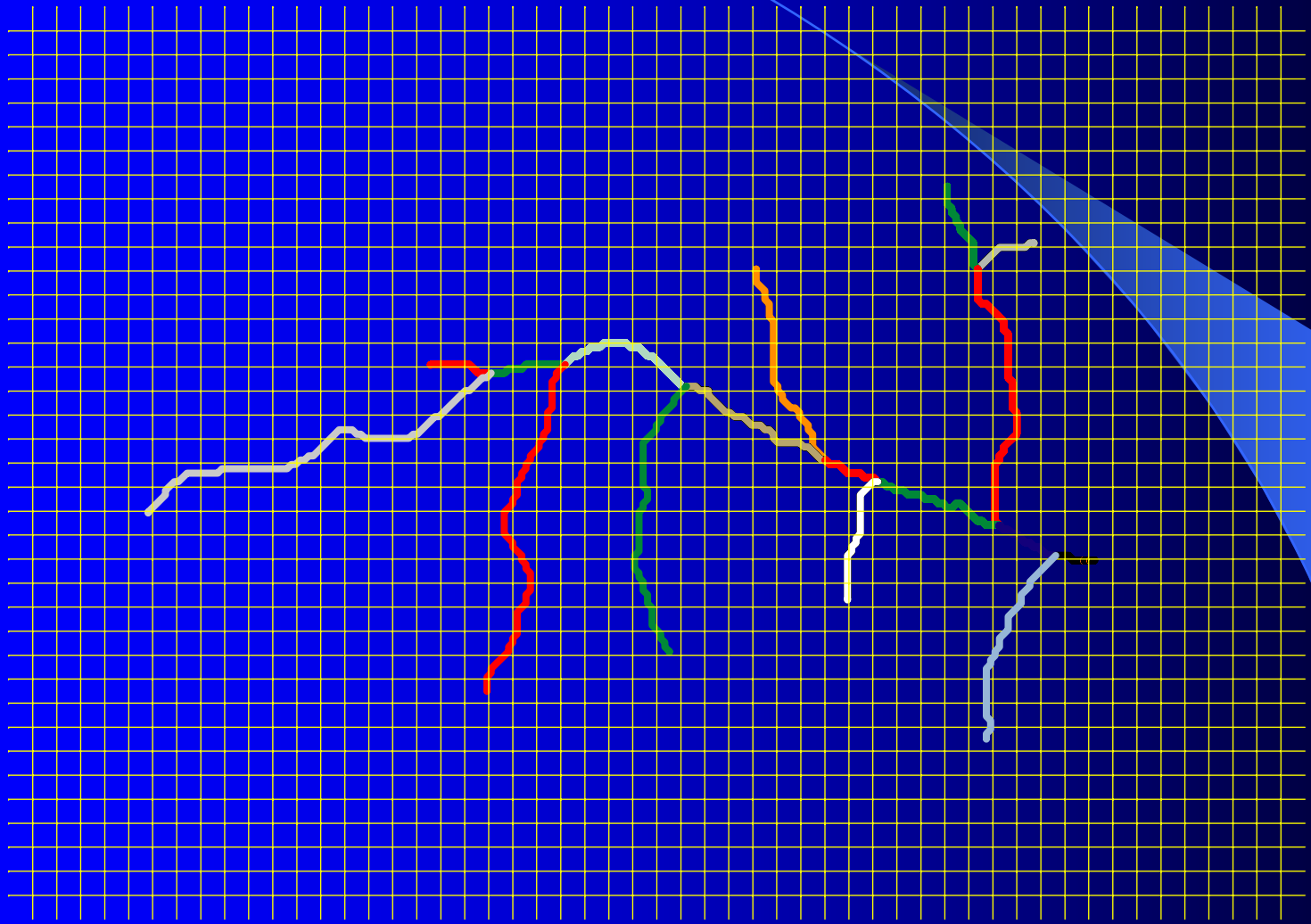
HRU/GW Cells


Excess
Wilting Point
ET Replenishment
Evapotranspiration
(Recharge zone)
PRMS
Soil
Zone
(HRU)
Soil to EZ
Transpiration
(Lower zone)
Field Capacity
Excess Zone
(Old PRMS SSR)
Interflow
Recharge
Saturation of Root Zone
MODFLOW
(cell)
Exfiltration
Unsaturated Zone
(UZF vertical flow)
Water Table
Saturated Zone
(Horizontal and vertical flow)

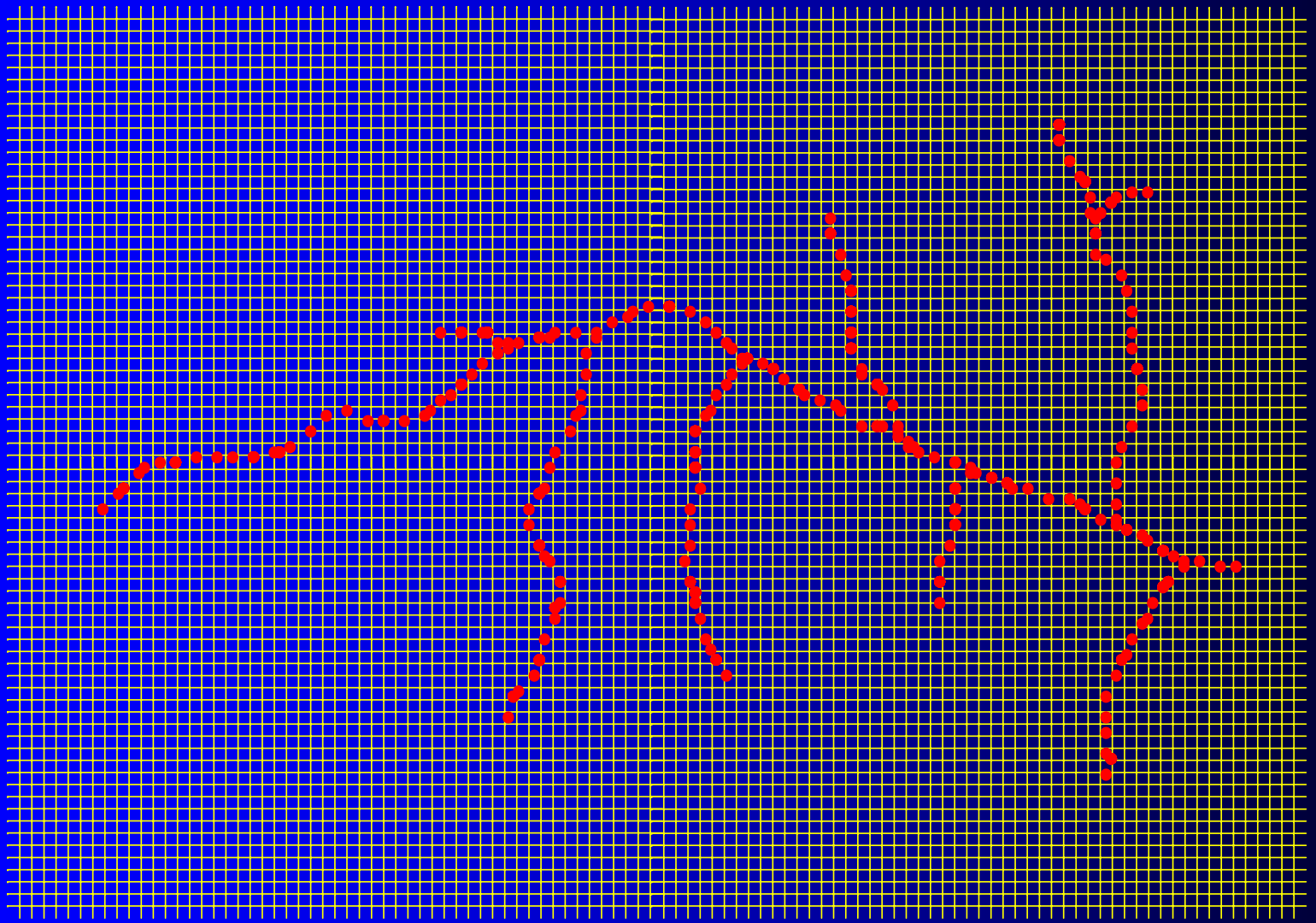
Stream Segments/GW Cells



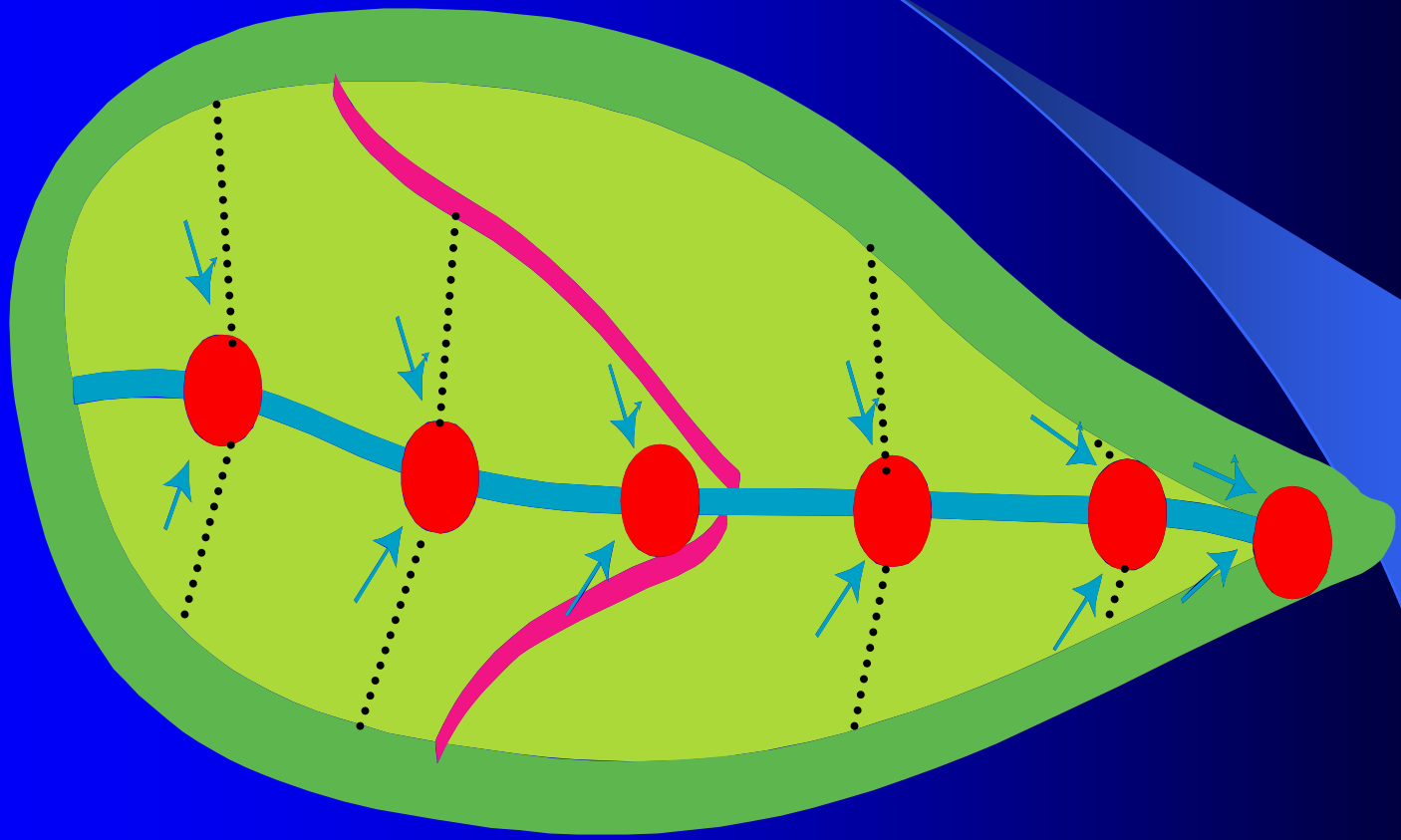
Branch/GW Cells



Nodes to GW Cells

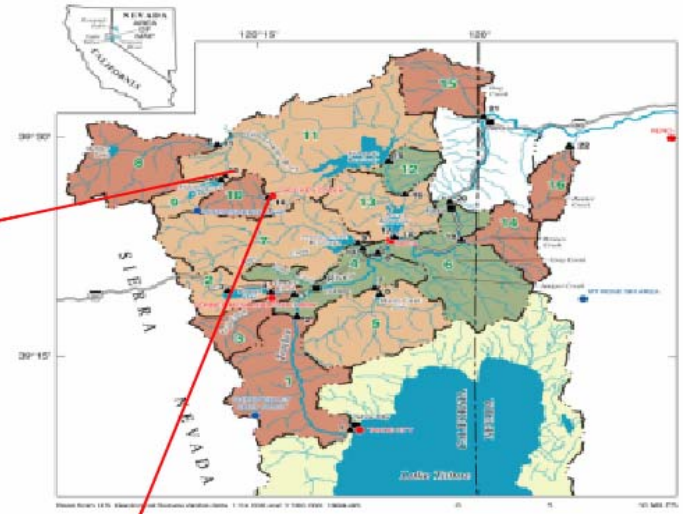


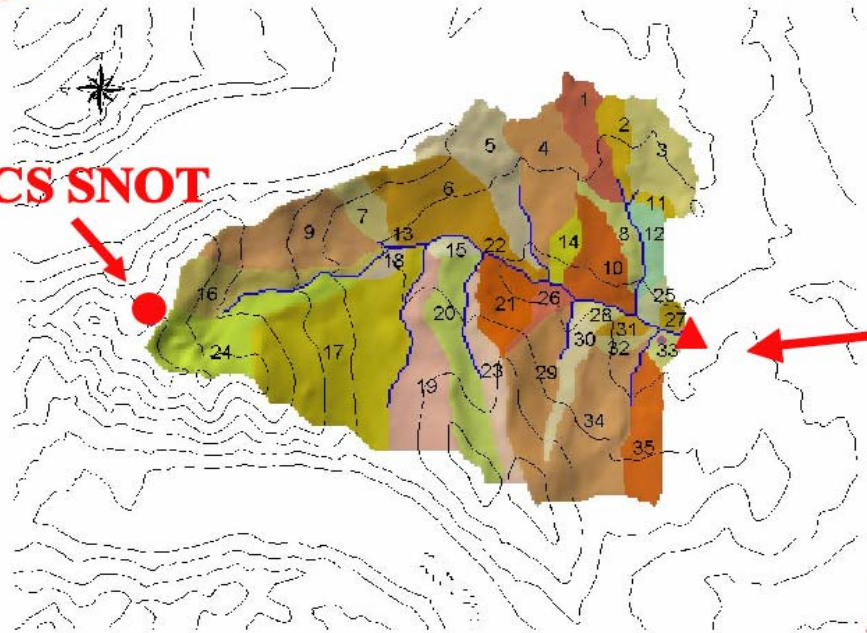
HRU/Stream Segments



Sagehen Creek

Area = 27 km²
Elevation = 1930 to 2540 m

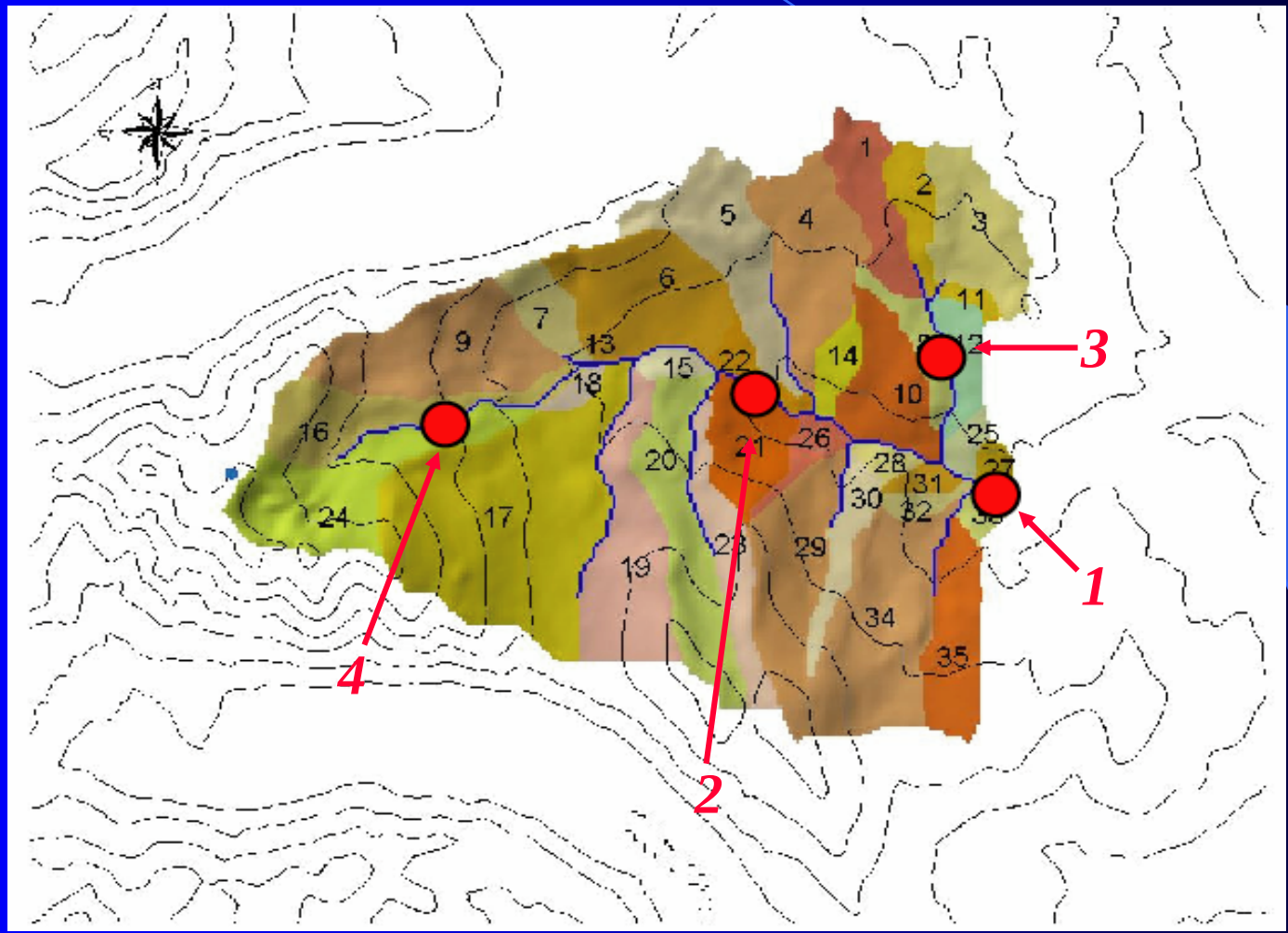




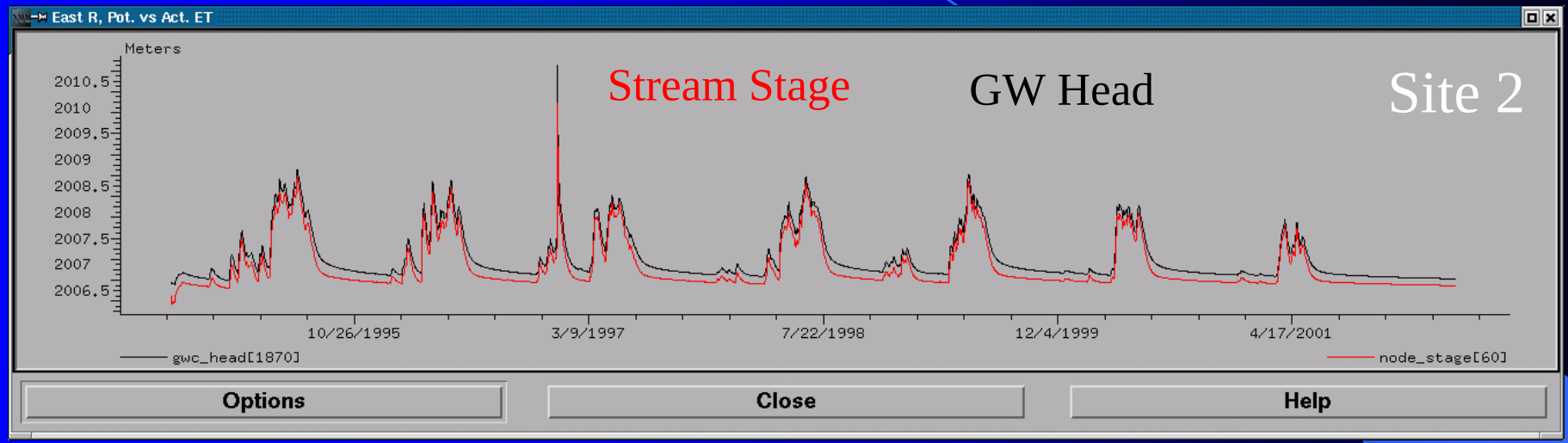
NRCS SNOT

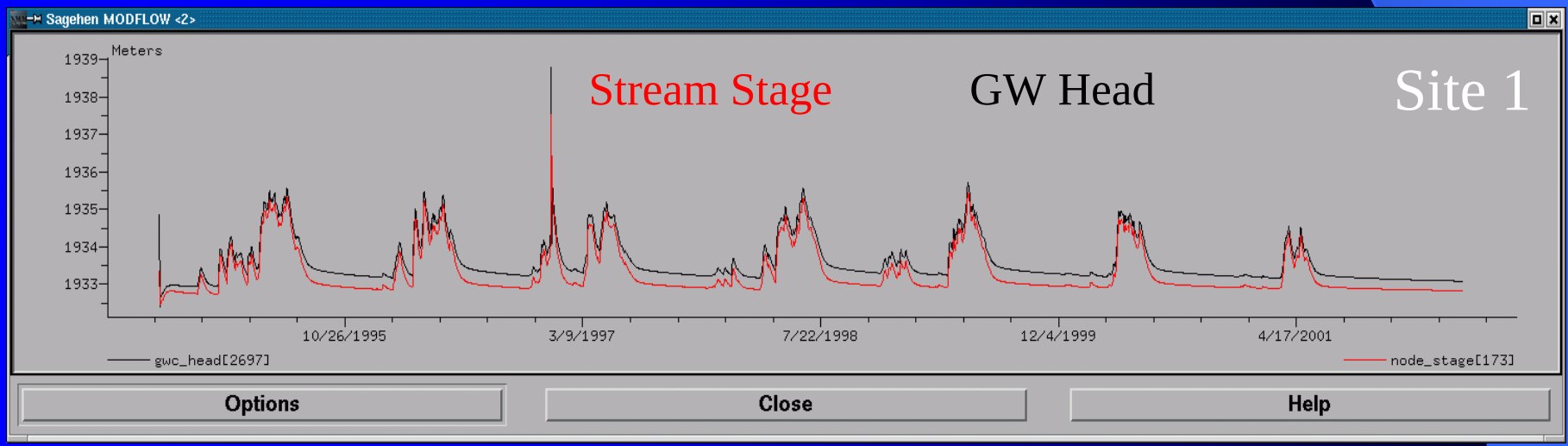
USGS Streamgage
NWS COOP

GSFLOW Results

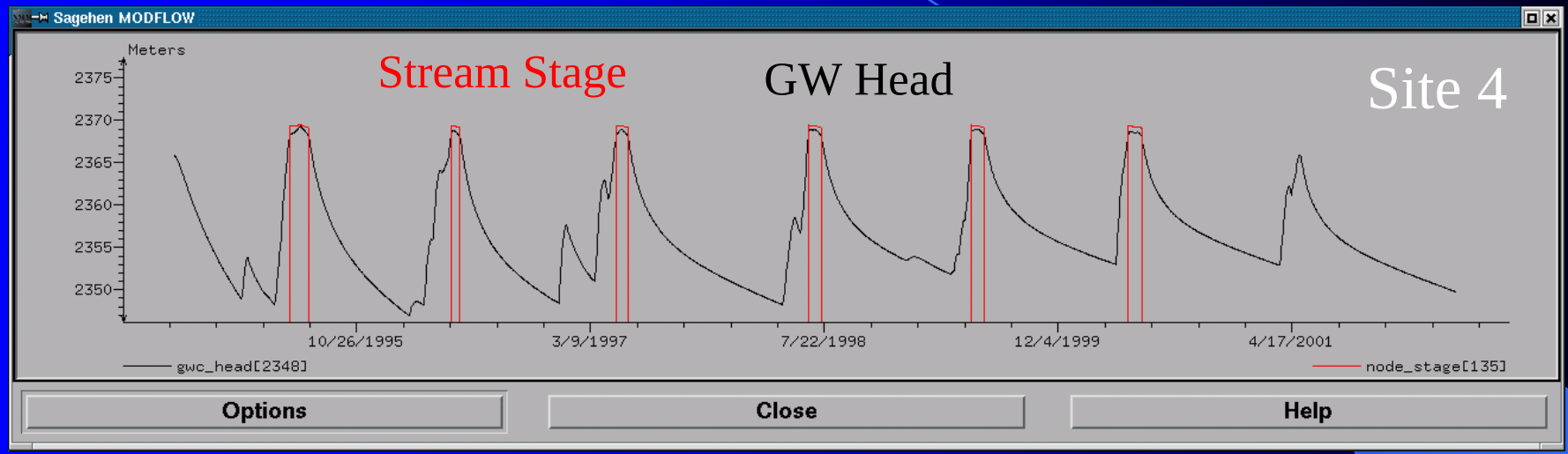


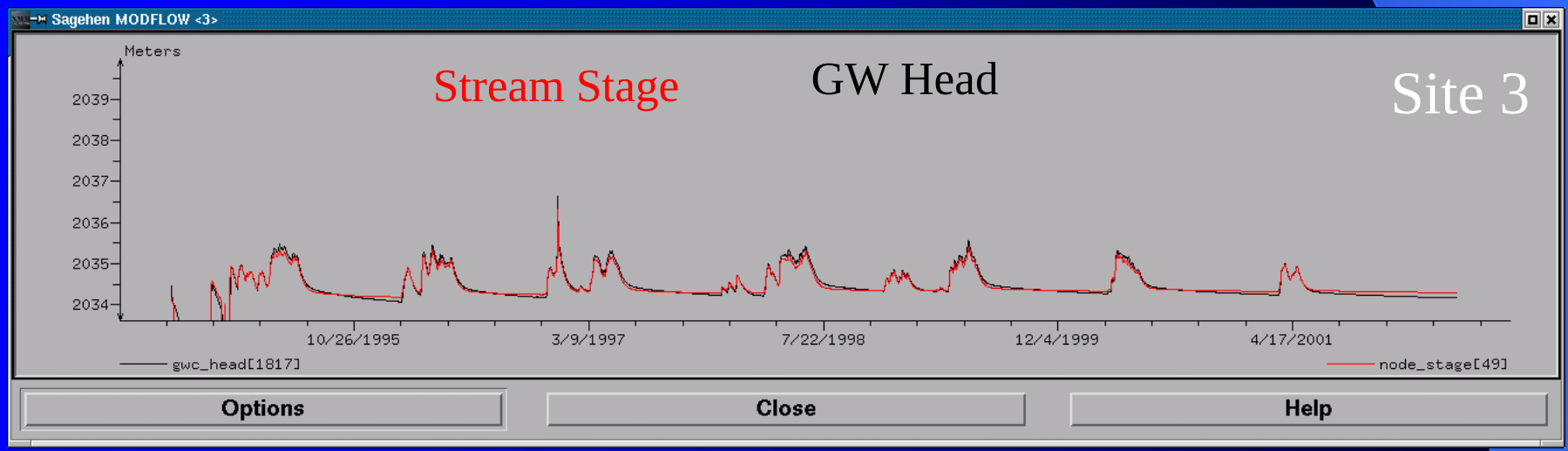
GSFLOW Results





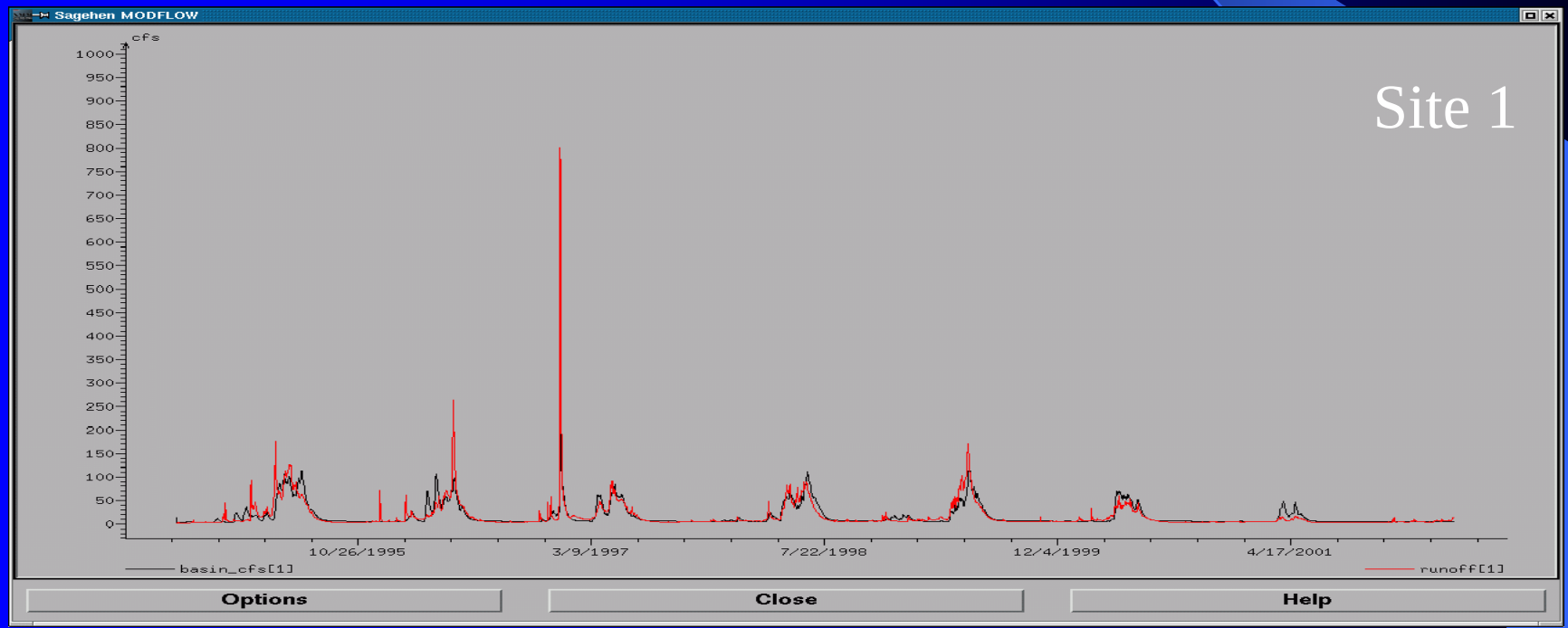
GSFLOW Results





GSFLOW Results

Observed *&* ***Predicted*** *Streamflow*

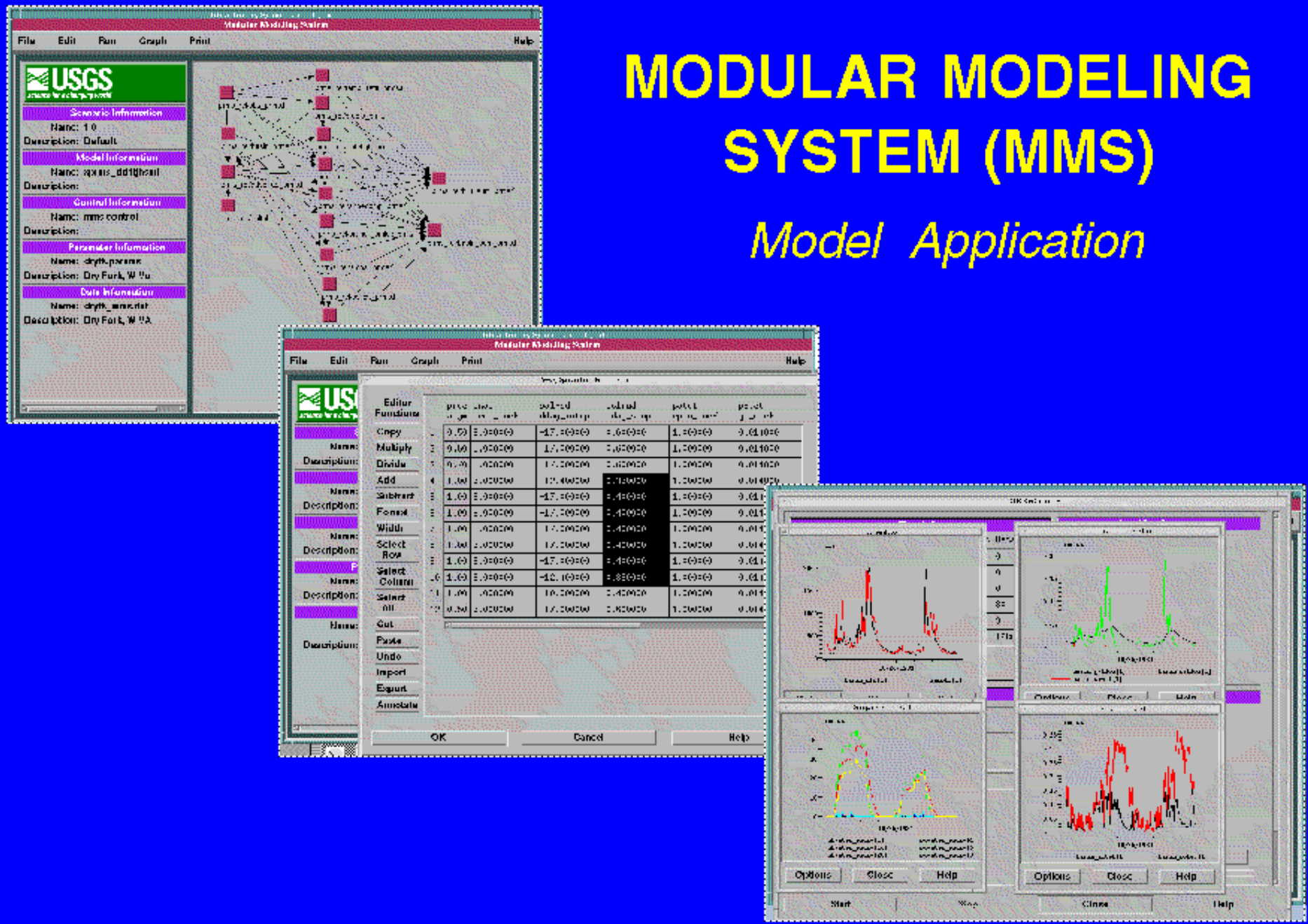


GSFLOW is distributed in

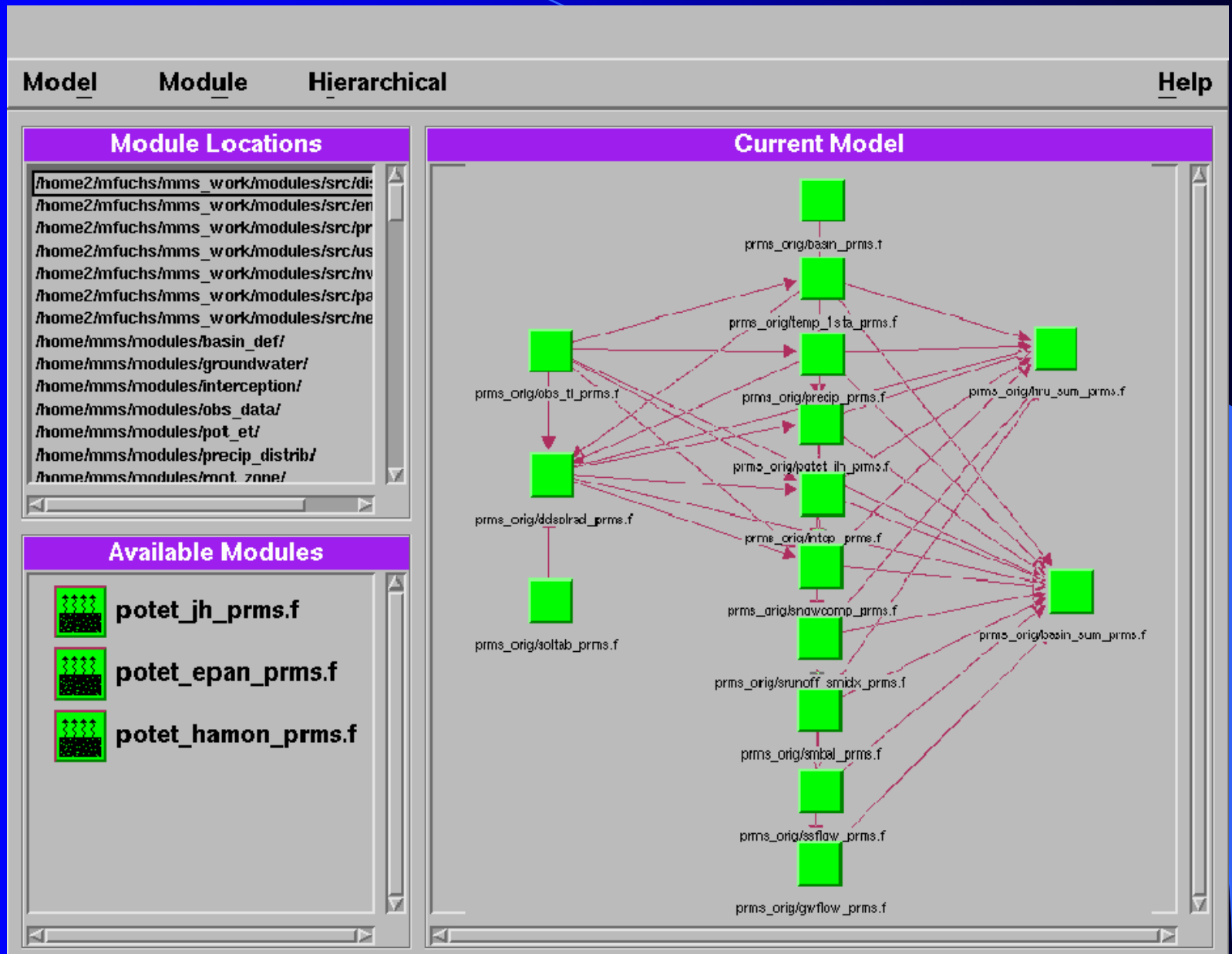
The Modular Modeling System (MMS): A Toolbox for Water- and Environmental Resources Management

MODULAR MODELING SYSTEM (MMS)

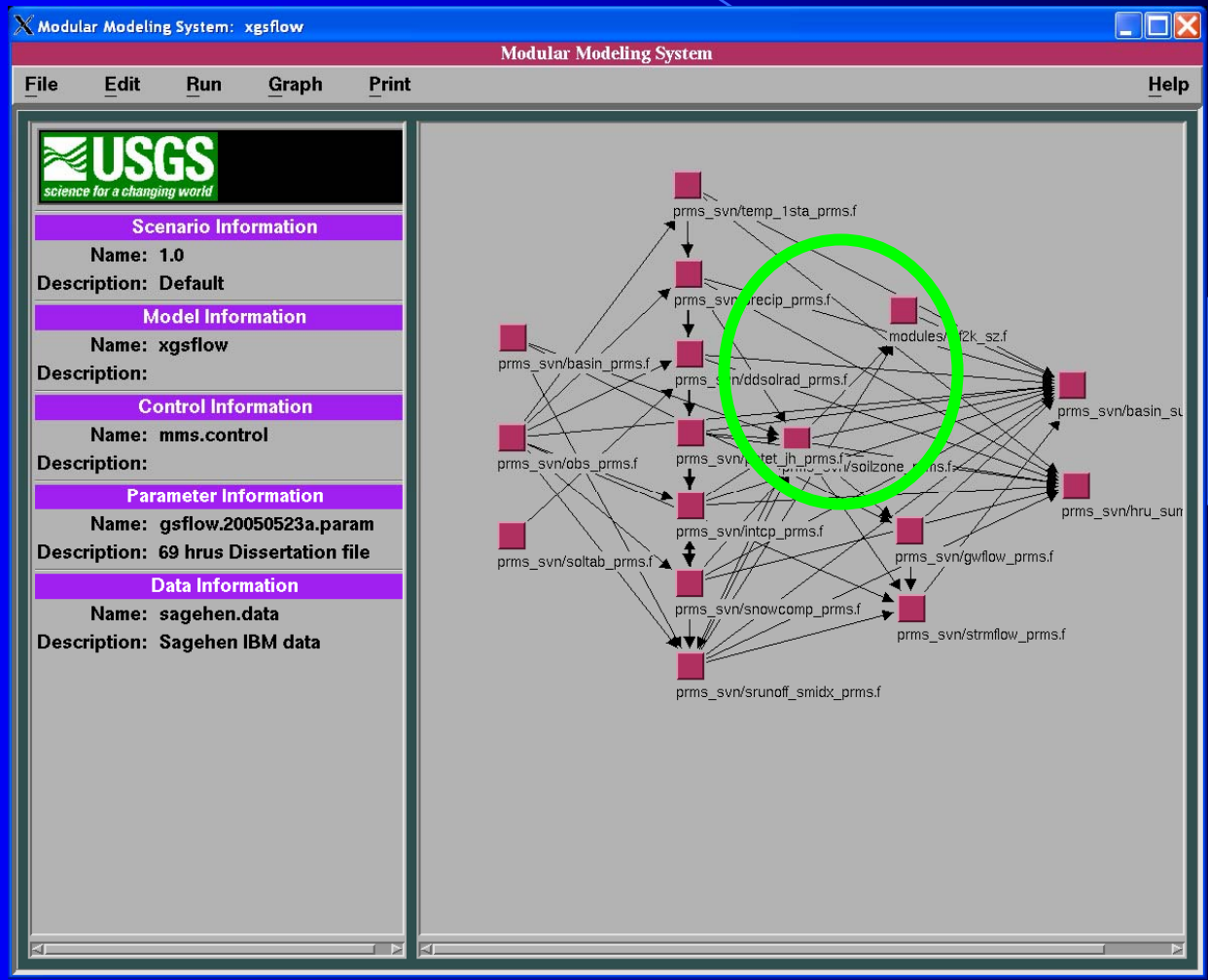
Model Application



MODEL BUILDING TOOL - XMBUILD



GSFLOW


Modular Modeling System: xgsflow
Modular Modeling System
File
Edit
Run
Graph
Print
Help
USGS
science for a changing world
Scenario Information
Name: 1.0
Description: Default
Model Information
Name: xgsflow
Description:
Control Information
Name: mms.control
Description:
Parameter Information
Name: gsflow.20050523a.param
Description: 69 hrus Dissertation file
Data Information
Name: sagehen.data
Description: Sagehen IBM data
prms_svn/temp_1sta_prms.f
prms_svn/basin_prms.f
prms_svn/obs_prms.f
prms_svn/soltab_prms.f
prms_svn/ddsolrad_prms.f
prms_svn/intcp_prms.f
prms_svn/snowcomp_prms.f
prms_svn/srunoff_smidx_prms.f
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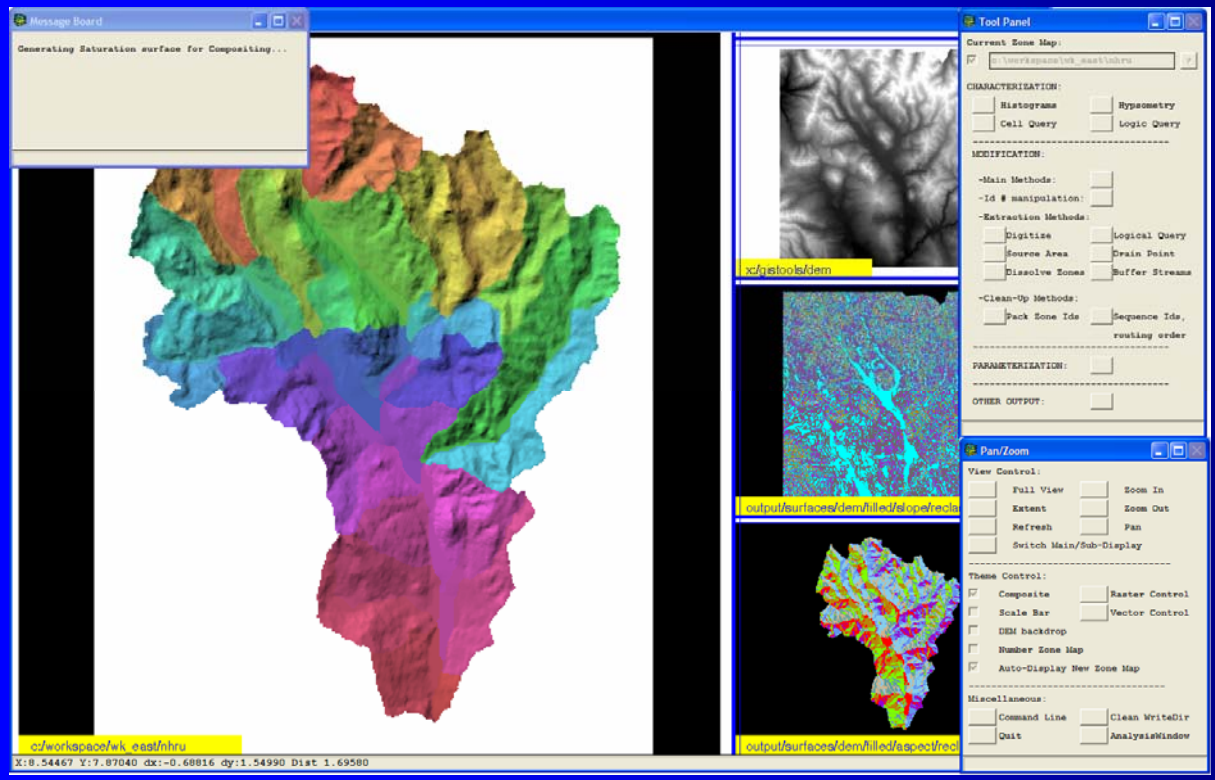
prms_svn/strmflow_prms.f

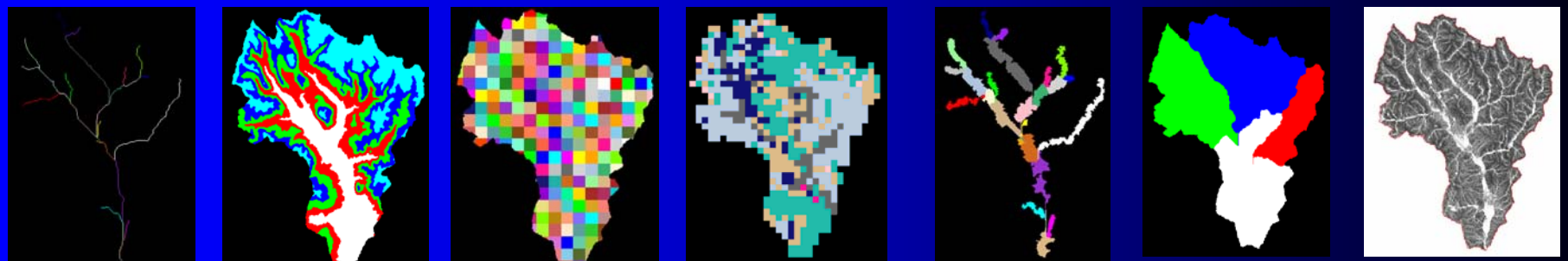
GIS WEASEL



Delineation:

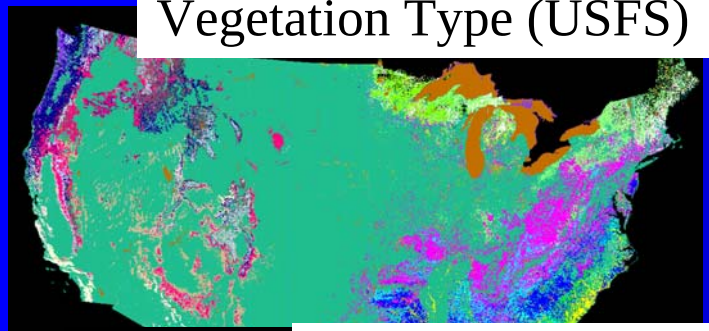
- Only requires elevation Grid as input

- Interactively delineate
  - Area of Interest
  - Many kinds of features
    - Streams
    - Elevation bands
    - Landuse
    - Contributing areas
    - Topographic index
    - ……

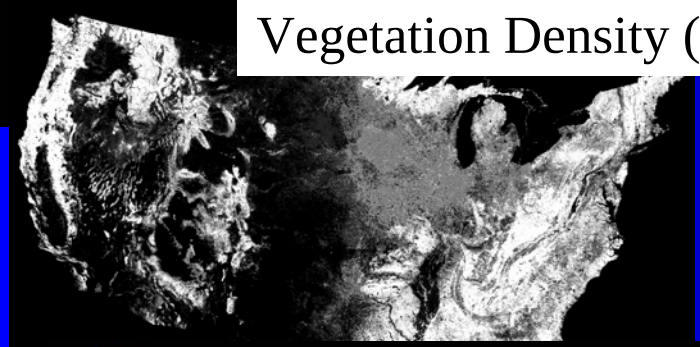


DIGITAL DATABASES

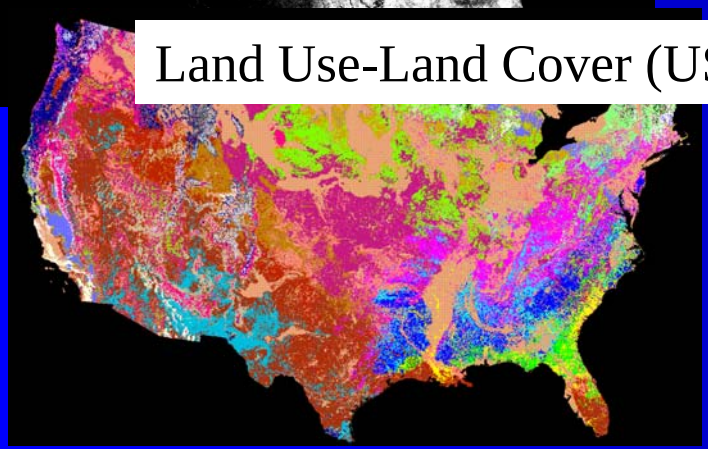
Vegetation Type (USFS)



Vegetation Density (USFS)

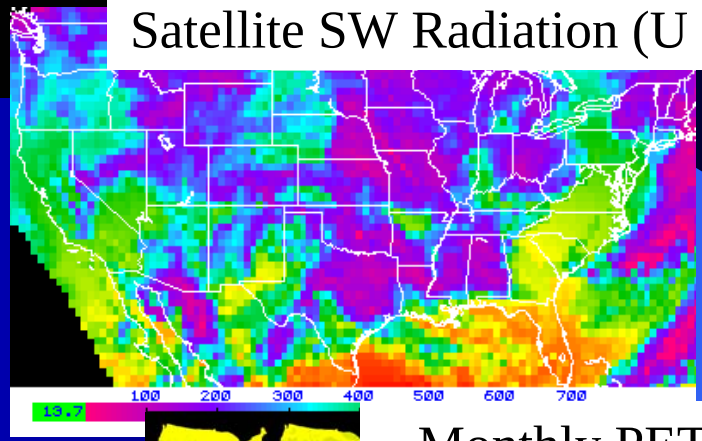


Land Use-Land Cover (USGS)

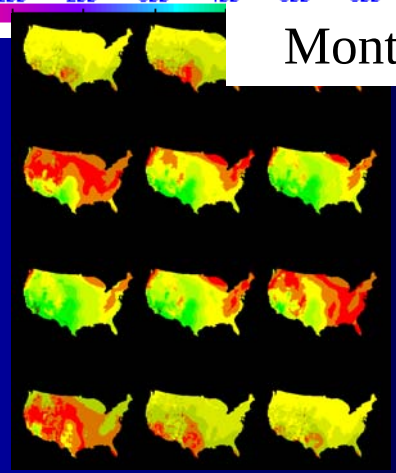


STATSGO Soils (USDA)

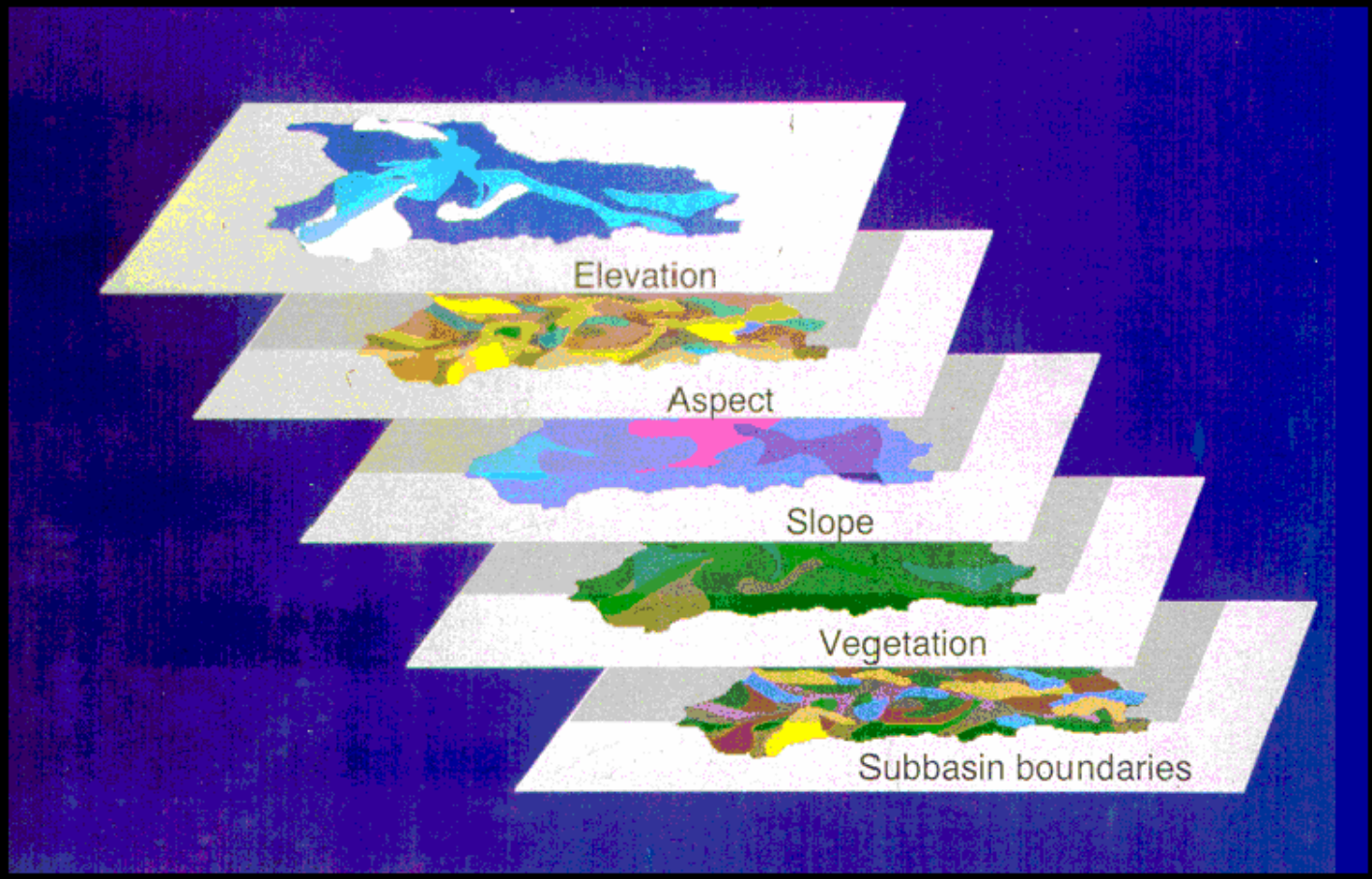
Satellite SW Radiation (U Md)



Monthly PET



AUTOMATED PARAMETER ESTIMATION USING THE GIS WEASEL

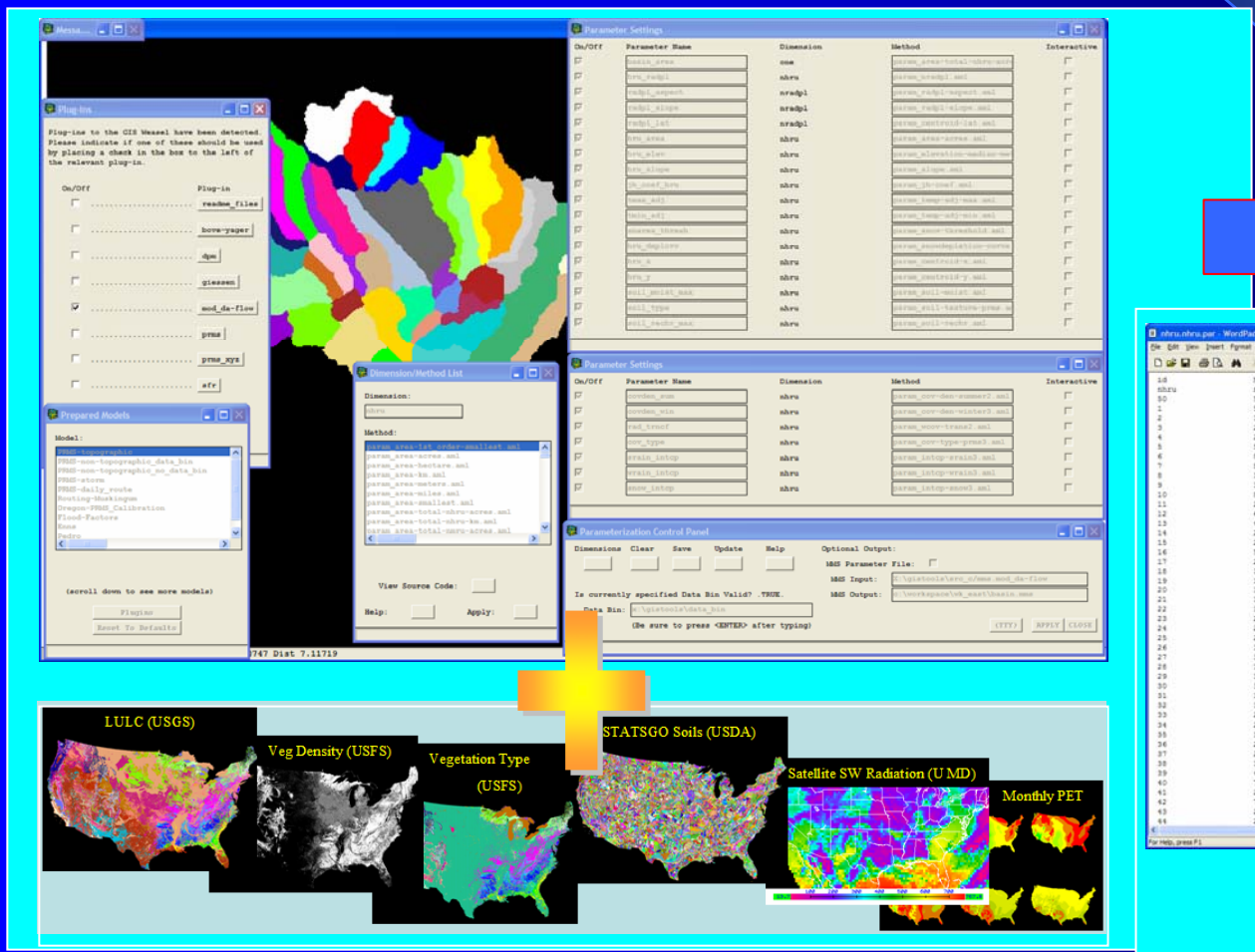


GIS WEASEL

Parameterization:

- 200+ methods available
- Easily add custom methods
- Configure recipes
- Apply to feature maps

- Exploit many types of data
- Produce maps and ASCII files of parameters



Forecast Methodologies

- Historic data as analog for the future

Ensemble Streamflow Prediction (ESP)

-Synthetic time-series

Weather Generator

- Atmospheric model output

Dynamical Downscaling

Statistical Downscaling

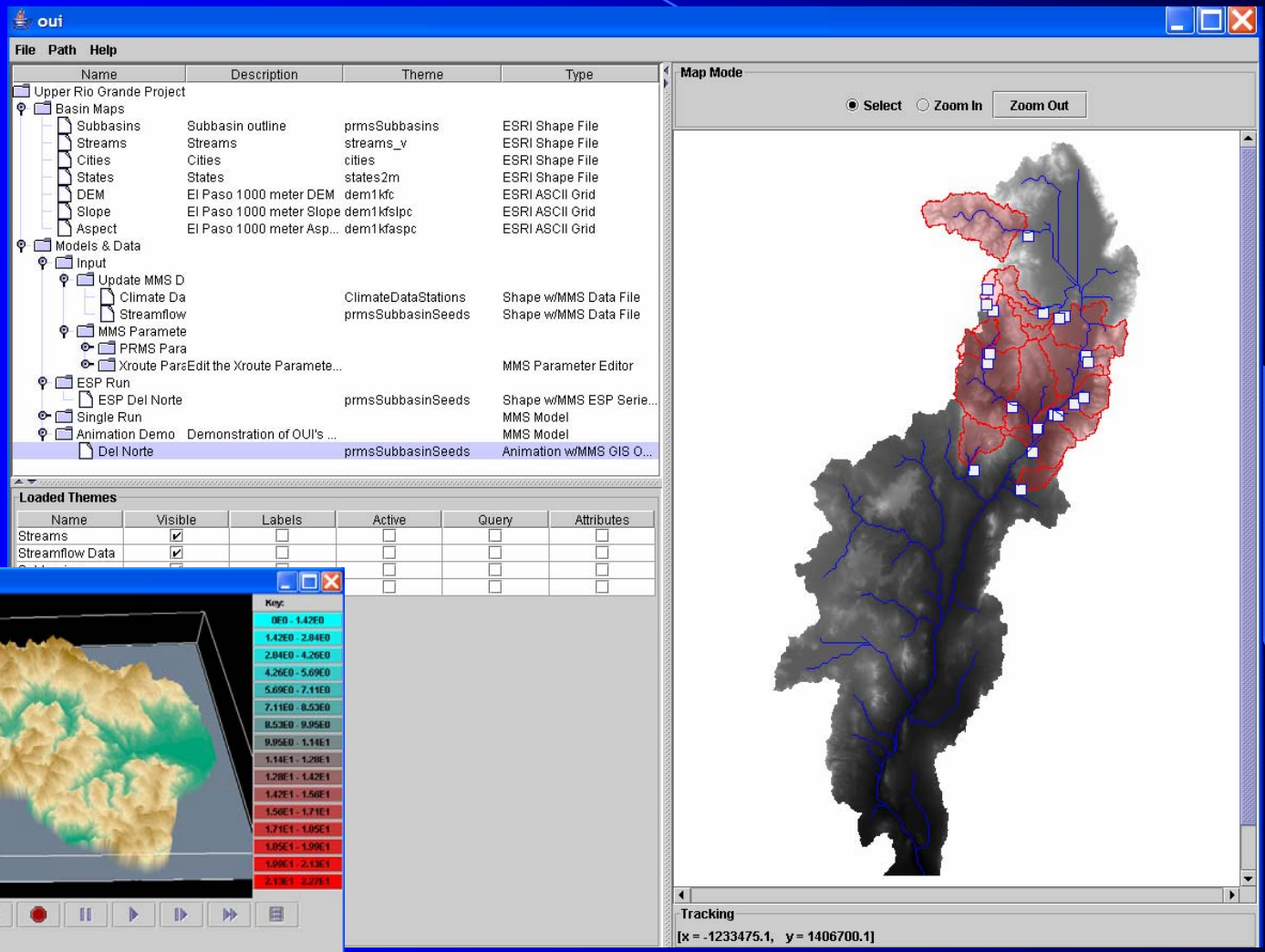
Socio-Economic Factors

(University of New Mexico, Desert Research Institute, University of Arizona)

- **Population and Demand Forecasts**
- **Water Markets**
  - (change in ownership in perpetuity)
- **Water Banking**
  - (lease options over some period of time)

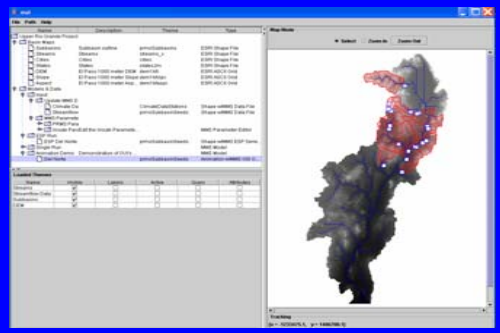
Issue: The better the prediction of the spatial and temporal distribution of water, the better the markets can perform.

OBJECT USER INTEFACE (OUI)



Database-Centered Decision Support System

Resource Management Alternatives



Object User Interface

Interface for data visualization and modeling

DMI

DMI

DMI

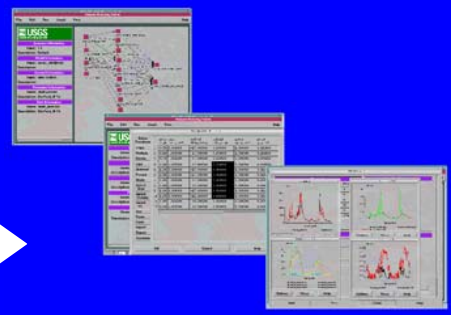
DMI

DMI

SIMPPLLE

Vegetation Dynamics Models

Resource Database



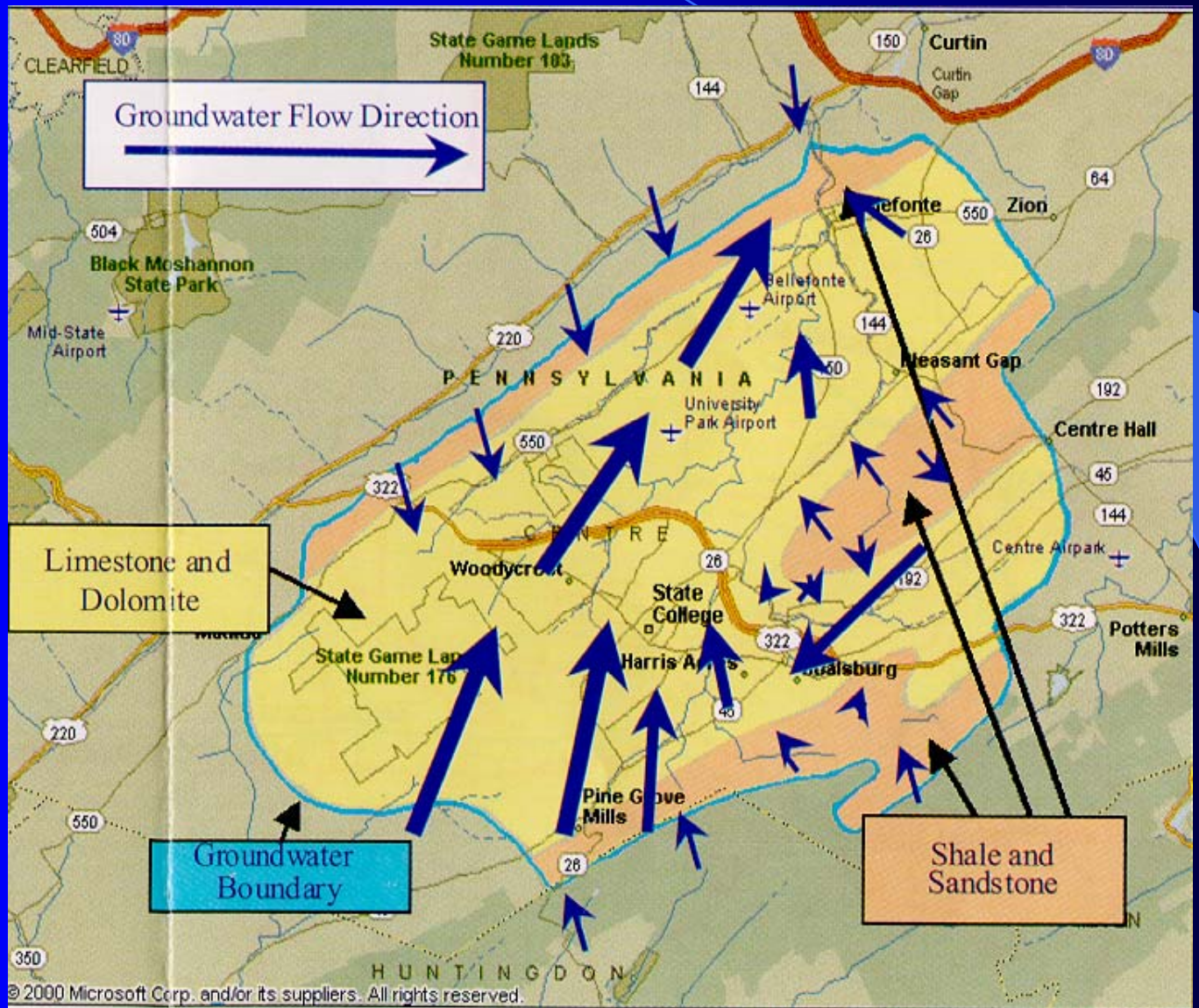
Modular Modeling System

Physical Process Models

GSFLOW Test Sites

- Sagehen Creek, California
- Spring Creek, Pennsylvania
- Trout Creek, Wisconsin
- Middle Rio Grande, New Mexico
- Esperstedter Ried, Thueringen, Germany

Spring Creek Basin, PA GSFLOW Model



GSFLOW Capabilities

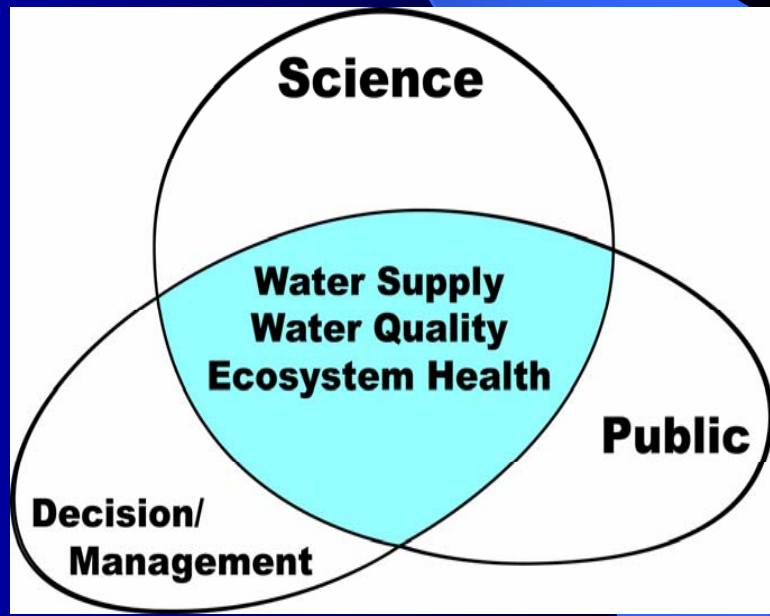
1. **Any PRMS climate distribution modules**
2. **Any PRMS ET modules**
3. **MODFLOW lake package**
4. **MODFLOW well package**
5. **MODFLOW boundary conditions**
6. **MODFLOW transport**

GSFLOW
Future Enhancements

- **Unsaturated zone vertical and lateral flow**
- **Calibration and uncertainty tools**
- **2D (or 3D) hydraulic routing**
- **MODFLOW / SWAT integration in MMS**
- **Temperature / Chemistry / Transport**
- **Economics: water banking and water trading**
- **Add ecosystems modules**
- **Expanded user interface and scenario generation GUI**

Integrated Modeling and Decision-Support Systems

- Facilitates multi-disciplinary integration of models and tools to address the issues of water and environmental-resource management.
- Allows rapid evaluation of the effects of decision and management scenarios.
- Allows incorporation of continuing advances in physical, social, and economic sciences.
- Provides an effective means for sharing scientific understanding with stakeholders and decision makers.



SUMMARY

- Toolbox approach to model and system development
- Supports multi-disciplinary model integration for decision support systems
- Open source software design allows many to share resources, expertise, knowledge, and costs
- Flexible framework approach enables the incorporation of continuing advances in science, databases, and computer technology

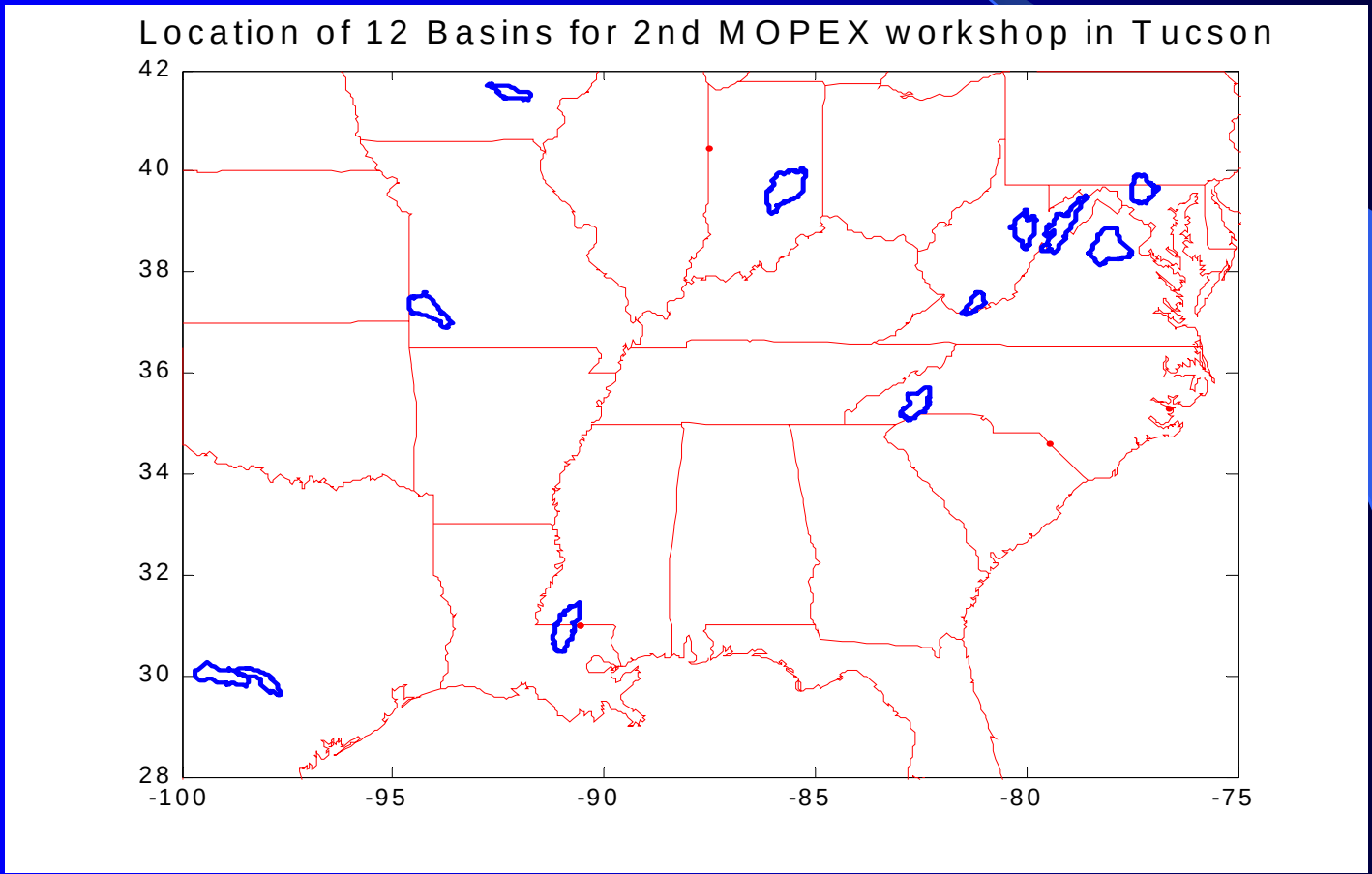
MORE INFORMATION

http://wwwbrr.cr.usgs.gov/mms

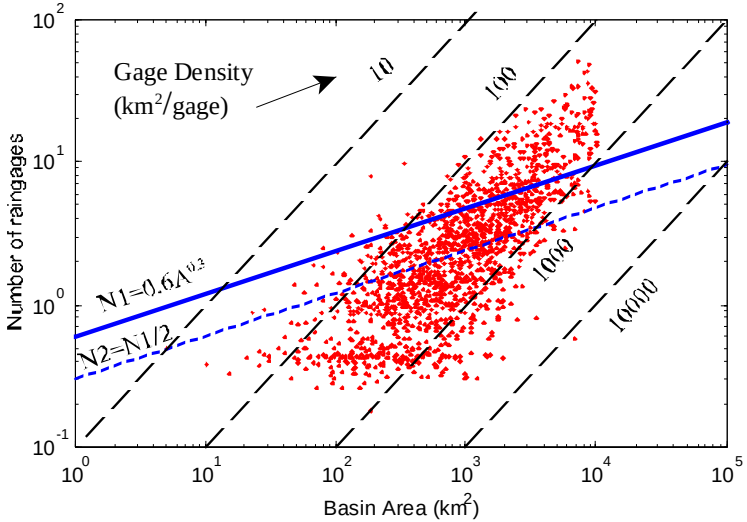
http://wwwbrr.cr.usgs.gov/weasel

Model Parameter Estimation Experiment (MOPEX)

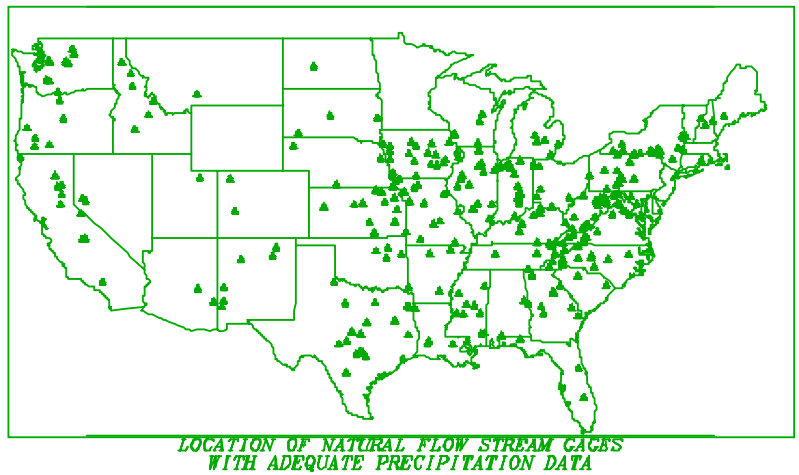
Location of MOPEX Basins – Workshop I



438 U.S. Basins
Meet Criteria for MOPEX Basin Selection



Gage Density vs Basin Size



Location of basins with
Adequate gage density