Module 9

Lecture 3: Major hydrologic models-HSPF, HEC and MIKE

Major Hydrologic Models

- HSPF (SWM)
- HEC
- MIKE

Hydrological Simulation Program-Fortran (HSPF)

Commercial successor of the **Stanford Watershed Model (SWM-IV)**

(Johanson *et al*., 1984):

- Water-quality considerations
- Kinematic Wave routing
- Variable Time Steps

HSPF is a deterministic, lumped parameter, physically based, continuous model for simulating the water quality and quantity processes that occur in watersheds and in a river network.

HSPF

❖**HSPF** incorporates watershed-scale **ARM** (Agricultural Run-off Management) and **NPS** (Non-Point Source) models into a basin-scale analysis framework

➔ fate and transport of pollutants in 1-D stream channels.

Data Requirements of HSPF:

❖Rainfall

❖Infiltration

❖Baseflow

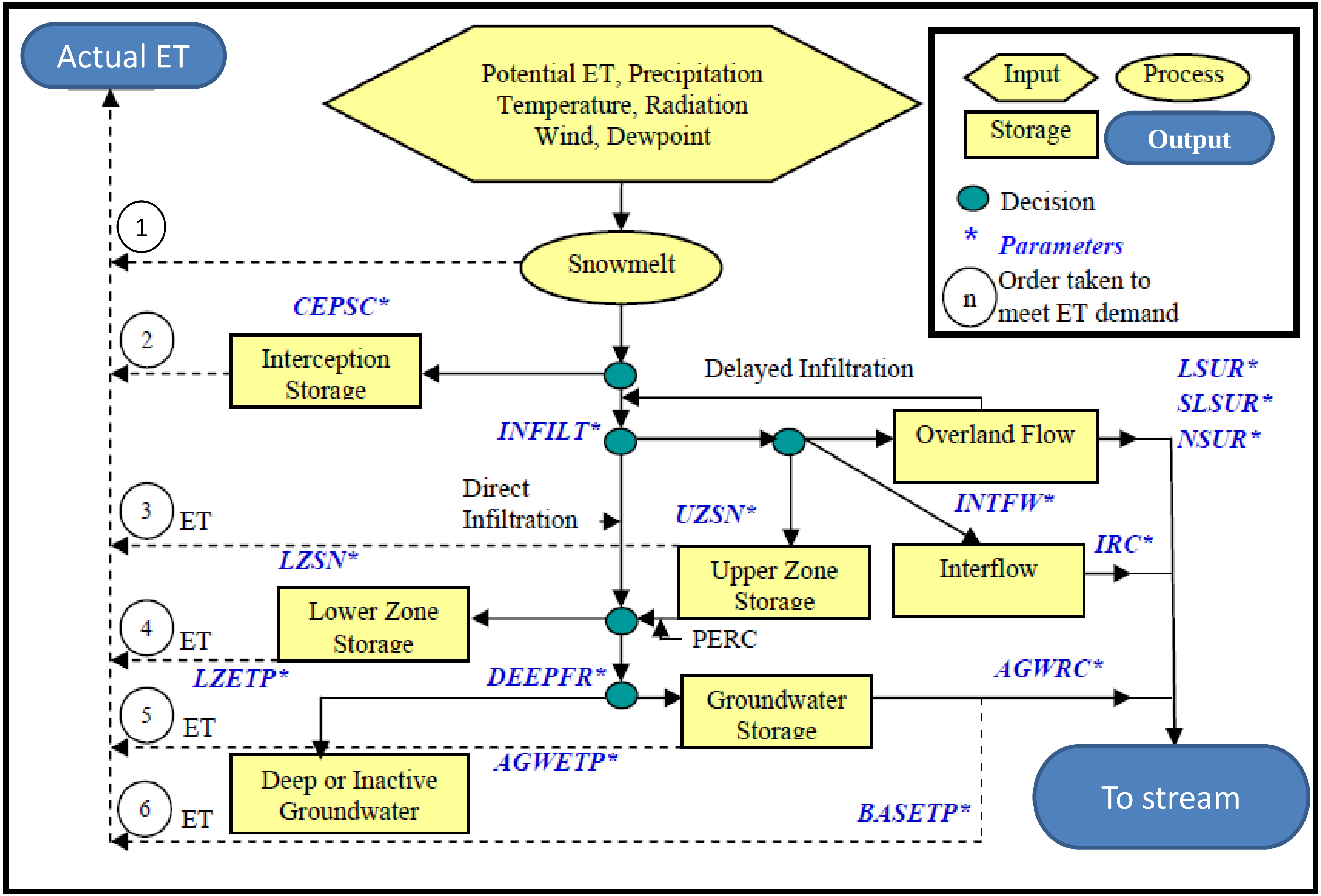
❖Streamflow

❖Soils

❖Landuse

- HSPF is one of the most complex hydrologic models which simulates:
  - **Infiltration:** Philip's equation, a physically based method which uses an hourly time step
  - **Streamflow:** Chezy – Manning's equation

- HSPF can simulate temporal scales ranging from minutes to days
- Due to its flexible modular design, HSPF can model systems of varying size and complexity;



Stanford Watershed Model (AquaTerra, 2005)

(Kate Flynn, U.S. Geological Survey, written commun., 2004)

CEPSC : interception storage capacity

LSUR : length of the overland flow plane

SLSUR : slope of the overland flow plane

NSUR : Manning's roughness of the land surface

INTFW : interflow inflow

INFILT : index to the infiltration capacity of the soil

UZSN : nominal capacity of the upper-zone storage

IRC : interflow recession constant

LZSN : nominal capacity of the lower-zone storage

LZETP : lower-zone evapotranspiration

AGWRC : basic ground-water recession rate

AGWETP : fraction of remaining potential evapotranspiration that can be satisfied from active ground-water storage

KVARY : indication of the behavior of ground-water recession flow

DEEPFR : fraction of ground-water inflow that flows to inactive ground water

BASETP : fraction of the remaining potential evapotranspiration that can be satisfied from base flow

HEC Models

HEC Models

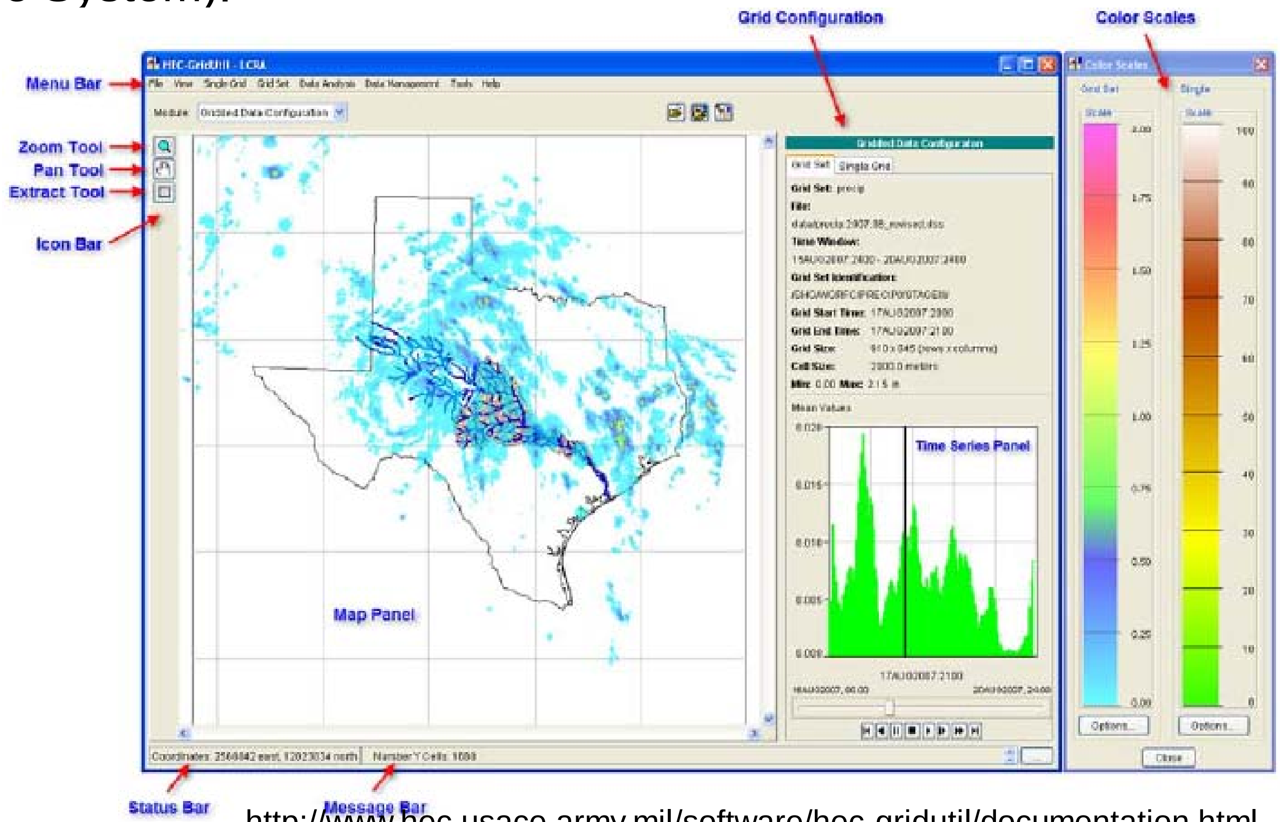
Modeling of the rainfall-runoff process in a watershed based on watershed physiographic data

- a variety of modeling options in order to compute UH for basin areas.
- a variety of options for flood routing along streams.
- capable of estimating parameters for calibration of each basin based on comparison of computed data to observed data

1. HEC-GridUtil 2.0
2. HEC-GeoRAS 10 (EAP)
3. HEC-GeoHMS 10 (EAP)
4. HEC-GeoEFM 1.0
5. HEC-SSP 2.0
6. SnoTel 1.2 Plugin
7. HEC-HMS 3.5
8. HEC-FDA 1.2.5a
9. HEC-DSSVue 2.0.1
10. HEC-RAS 4.1
11. HEC-DSS Excel Add-In
12. HEC-GeoDozer 1.0
13. HEC-EFM 2.0
14. HEC-EFM Plotter 1.0
15. HEC-ResSim 3.0
16. HEC-RPT 1.1

HEC-GridUtil 2.0

HEC-GridUtil is designed to provide viewing, processing, and analysis capabilities for gridded data sets stored in HEC-DSS format (Hydrologic Engineering Center's Data Storage System).



http://www.hec.usace.army.mil/software/hec-gridutil/documentation.html

HEC-GeoRAS

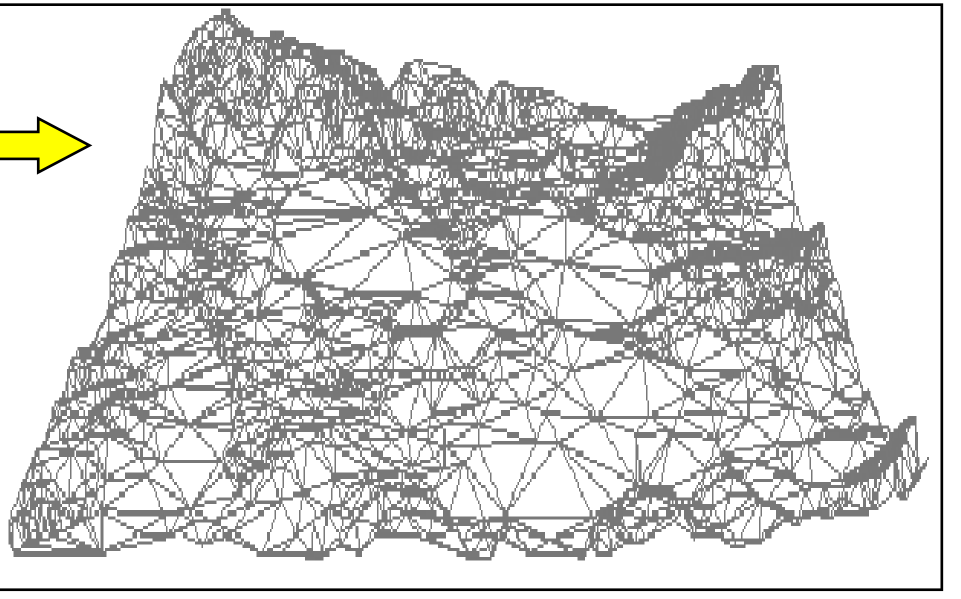
HEC-GeoRAS 10 (EAP)

GIS extension ➔ a set of procedures, tools, and utilities for the preparation of GIS data for import into HEC-RAS and generation of GIS data from RAS output.

- **ArcGIS w/ extensions**
  - 3D & Spatial Analyst
  - HEC-GeoHMS
  - HEC-GeoRAS
- **HEC-RAS**
  - Simulates water surface profile of a stream reach

Data Requirements

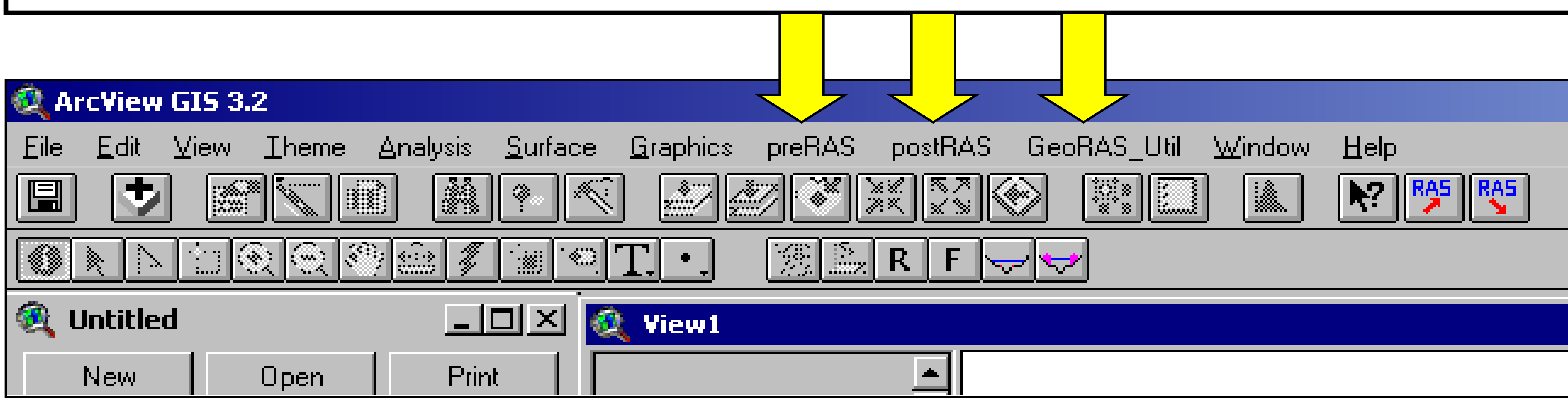
- Triangular Irregular Network (TIN)
- DEM (high resolution)
  - use stds2dem.exe if downloading from USGS
- Land Use / Land Cover
  - Manning's Coefficient



(Source: "GIS – Employing HEC-GeoRAS", Brad Endres , 2003)

Major Functions of GeoRAS

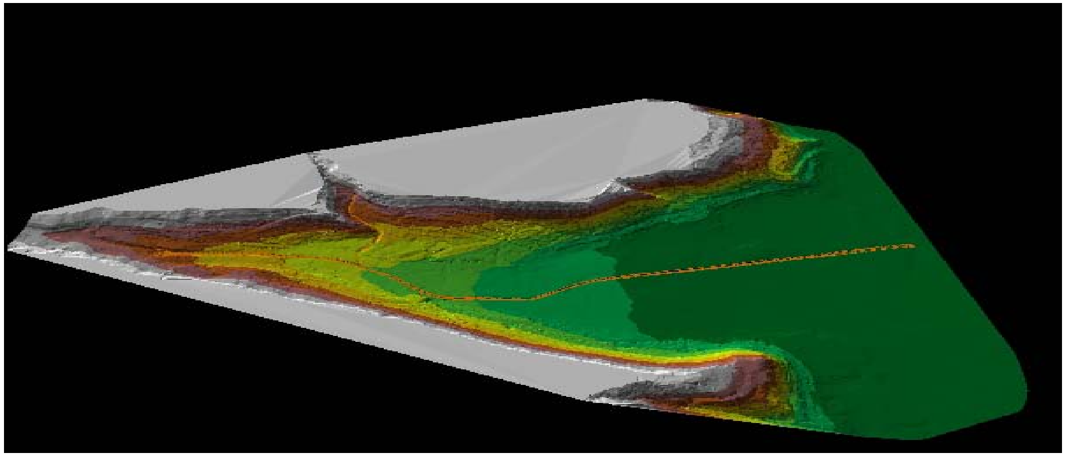
- Interface between ArcView and HEC-RAS
- Functions:
  - **PreRAS Menu** - prepares Geometry Data necessary for HEC-RAS modeling
  - **GeoRAS_Util Menu** – creates a table of Manning's n value from land use shapefile
  - **PostRAS Menu** – reads RAS import file; delineates flood plain; creates Velocity and Depth TINs



Demonstration of Capabilities

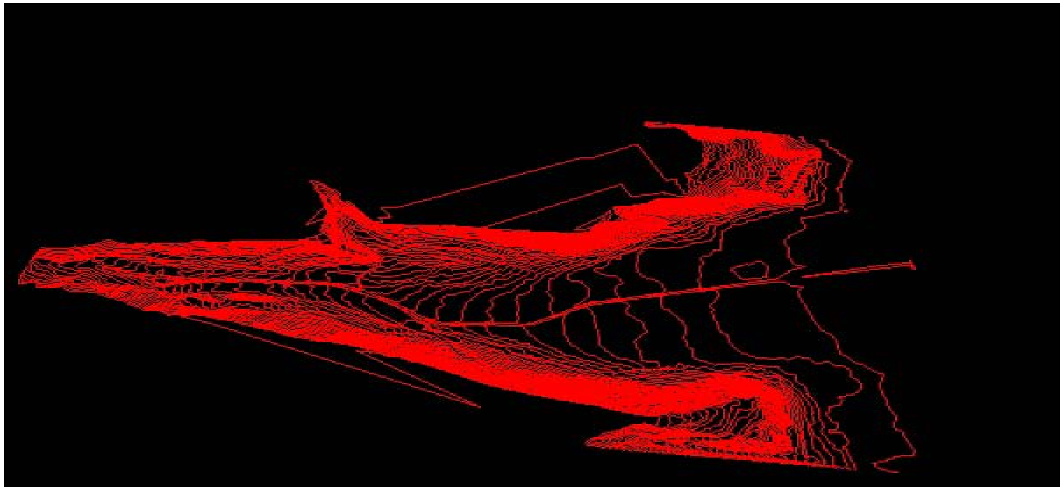
- Load TIN

3-D Scene



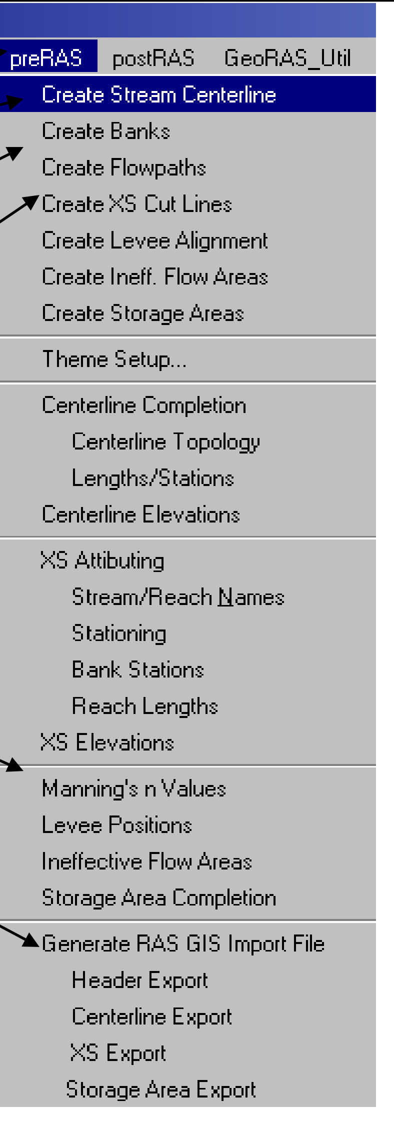
- Create Contour Lines

3-D Scene

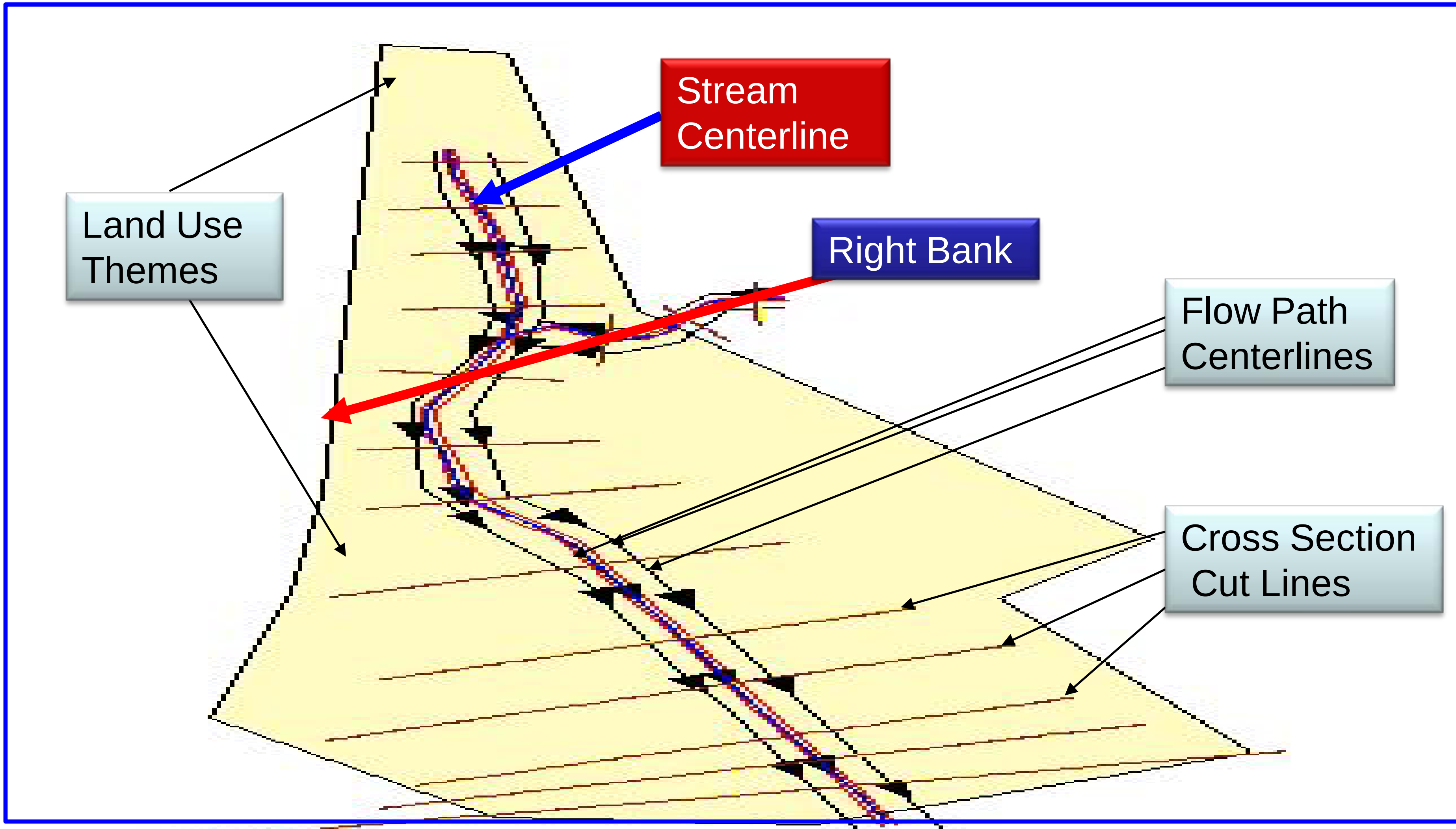


Demonstration of Capabilities **Contd…**

- Create Stream Centerline
- Create Banks Theme
- Create Flow Path Centerlines
- Create Cross Section Cut Lines
- Add/Create Land Use Theme
- Generate RAS Import File

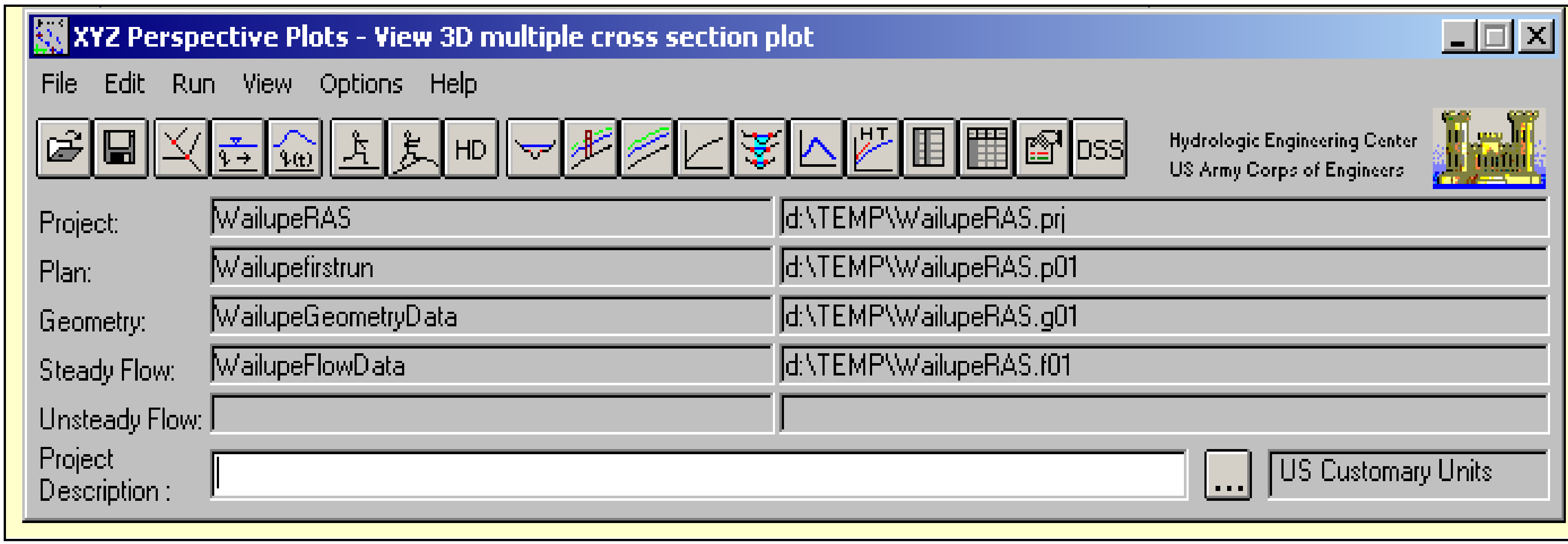


Demonstration of Capabilities **Contd…**



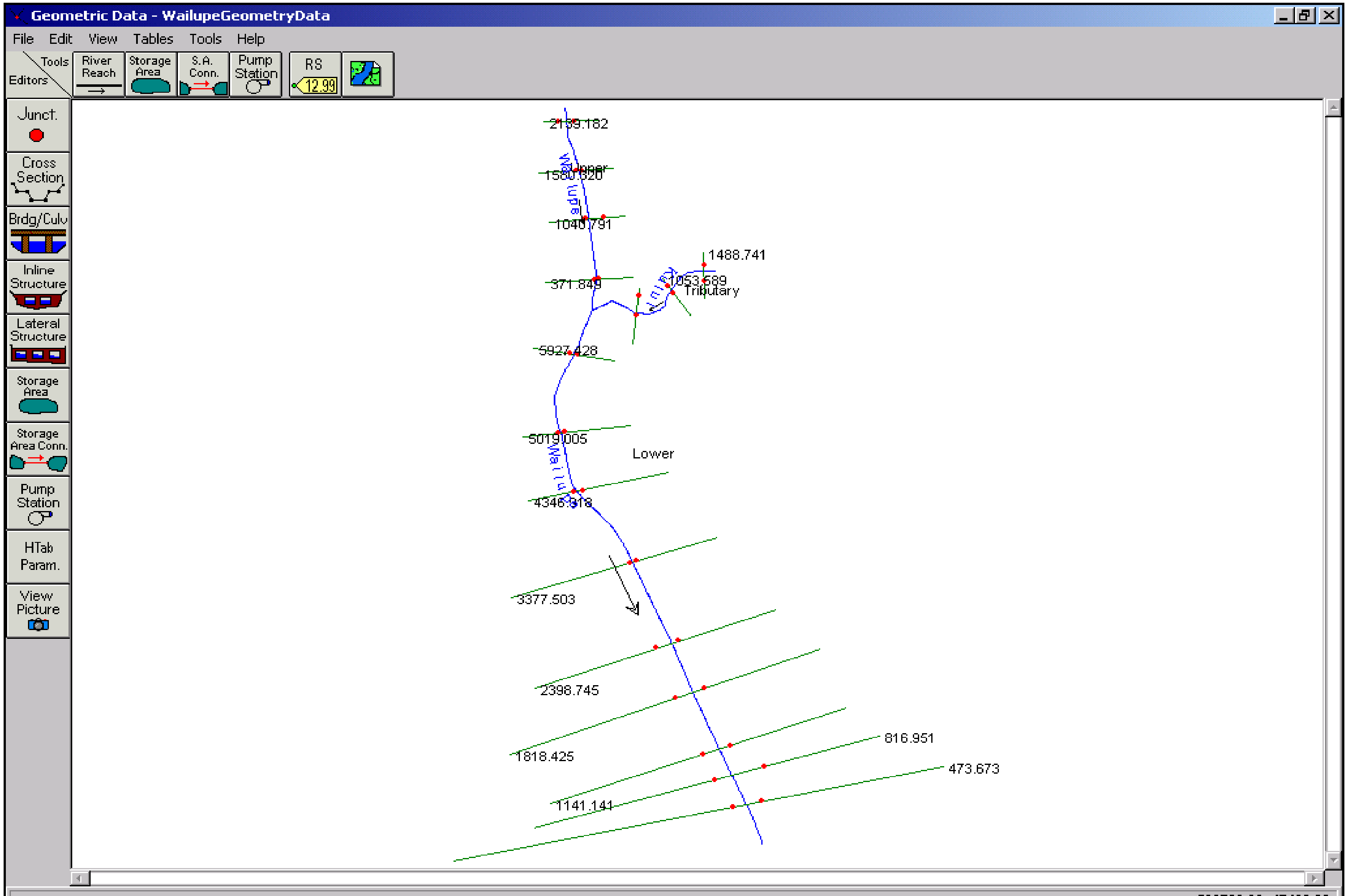
Demonstration of Capabilities **Contd…**

- Generate RAS GIS import file
- Open HEC-RAS and import RAS GIS file
- Complete Geometry, Hydraulic, & Flow Data
- Run Analysis
- Generate RAS Export file



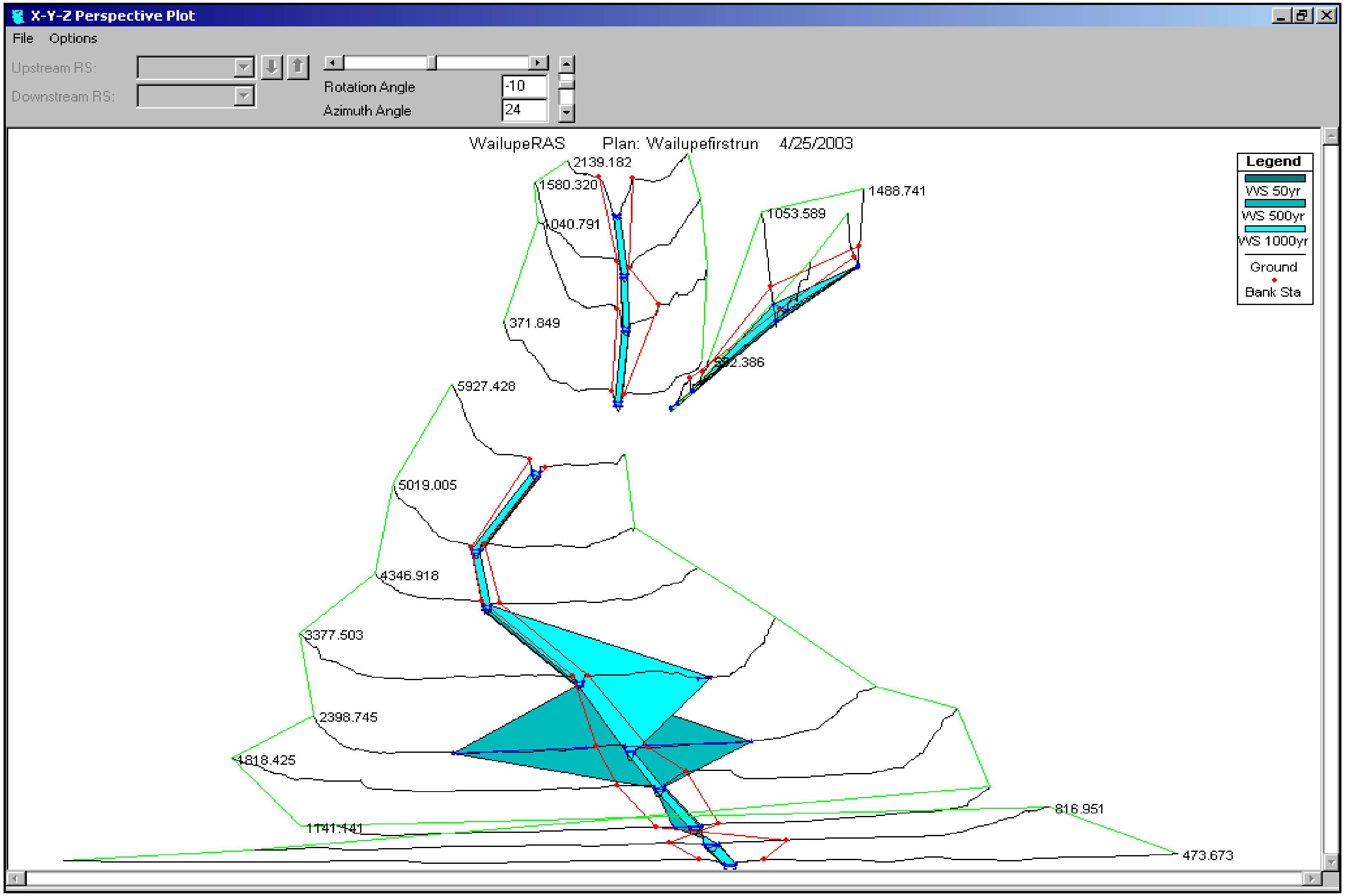
Demonstration of Capabilities

RAS GIS import file



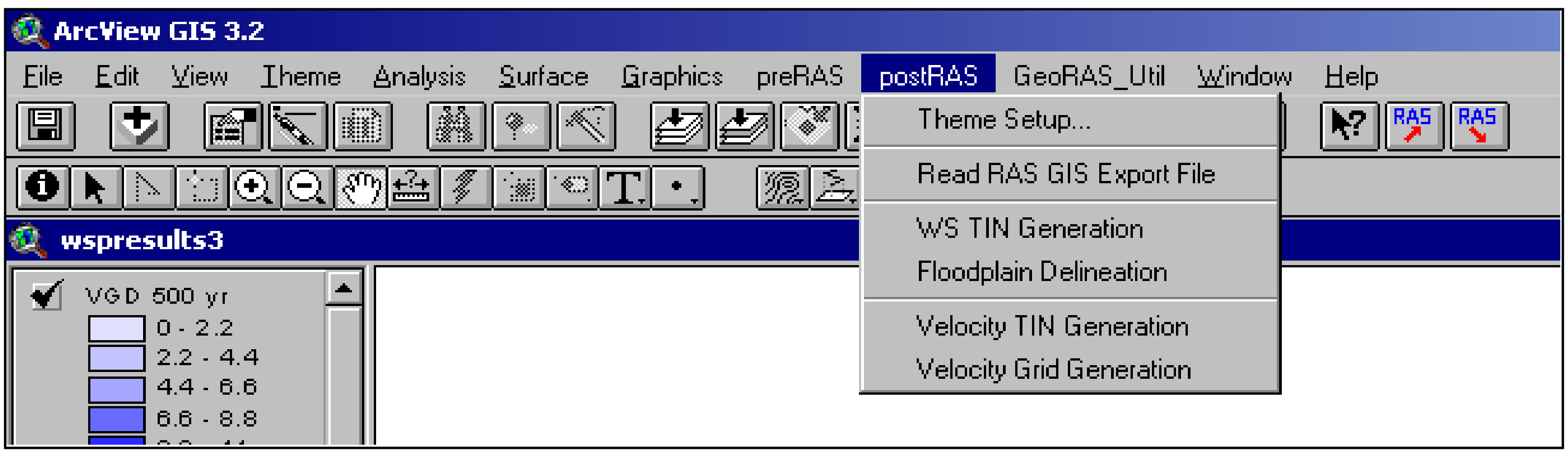
Demonstration of Capabilities Contd…

RAS GIS export file



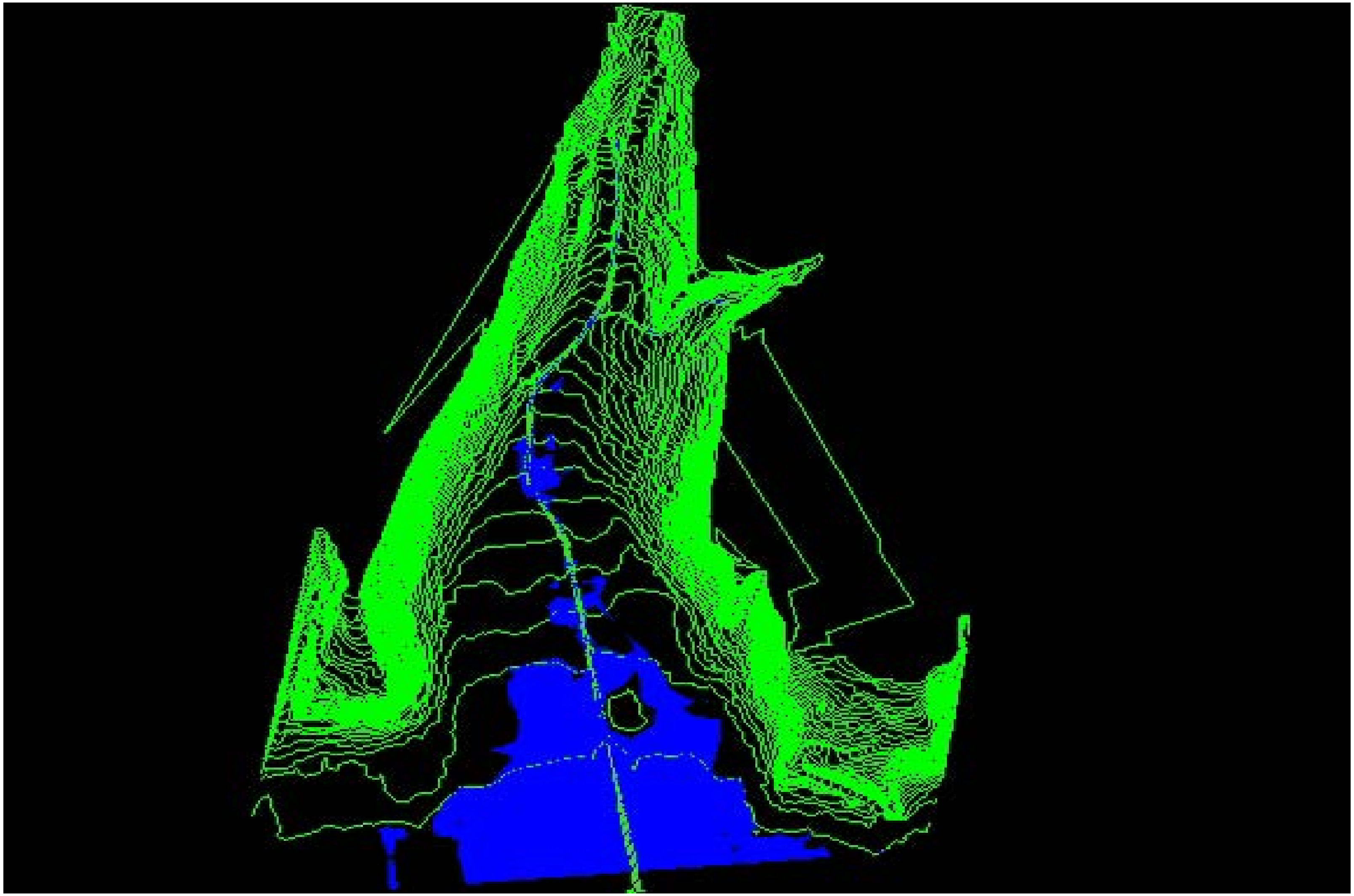
Demonstration of Capabilities **Contd…**

- New GIS data
- PostRAS features
  - ❑ Water Surface TIN
  - ❑ Floodplain Delineation – polygon & grid
  - ❑ Velocity TIN
  - ❑ Velocity Grid

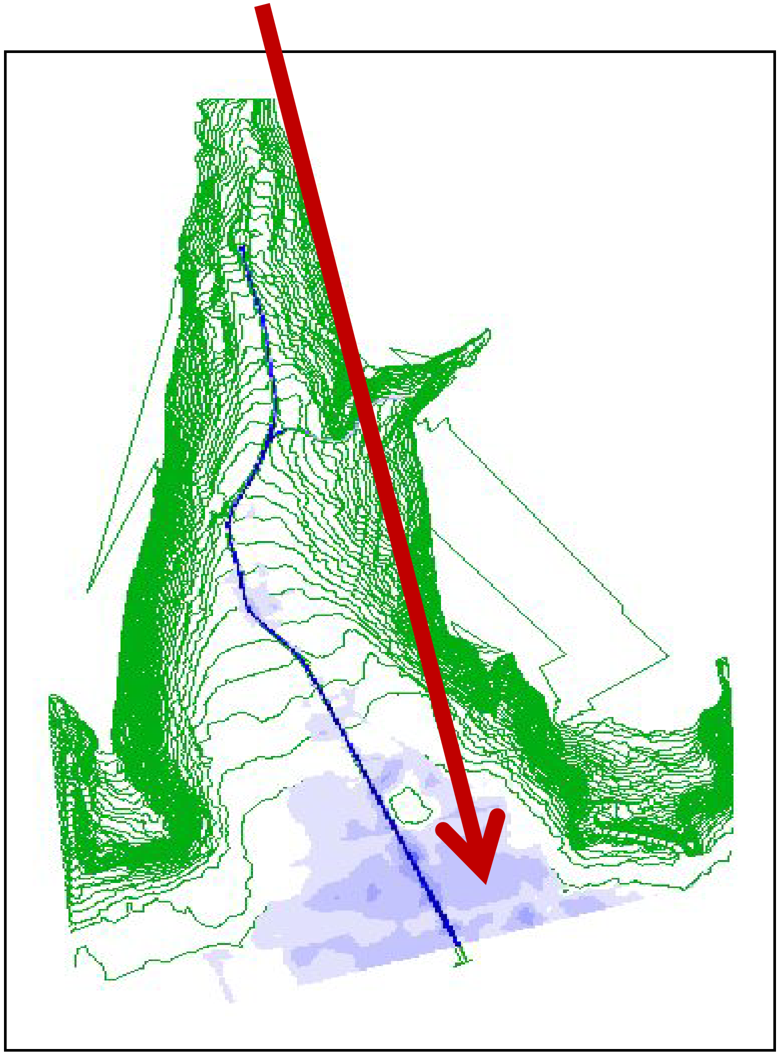


Demonstration of Capabilities Contd…

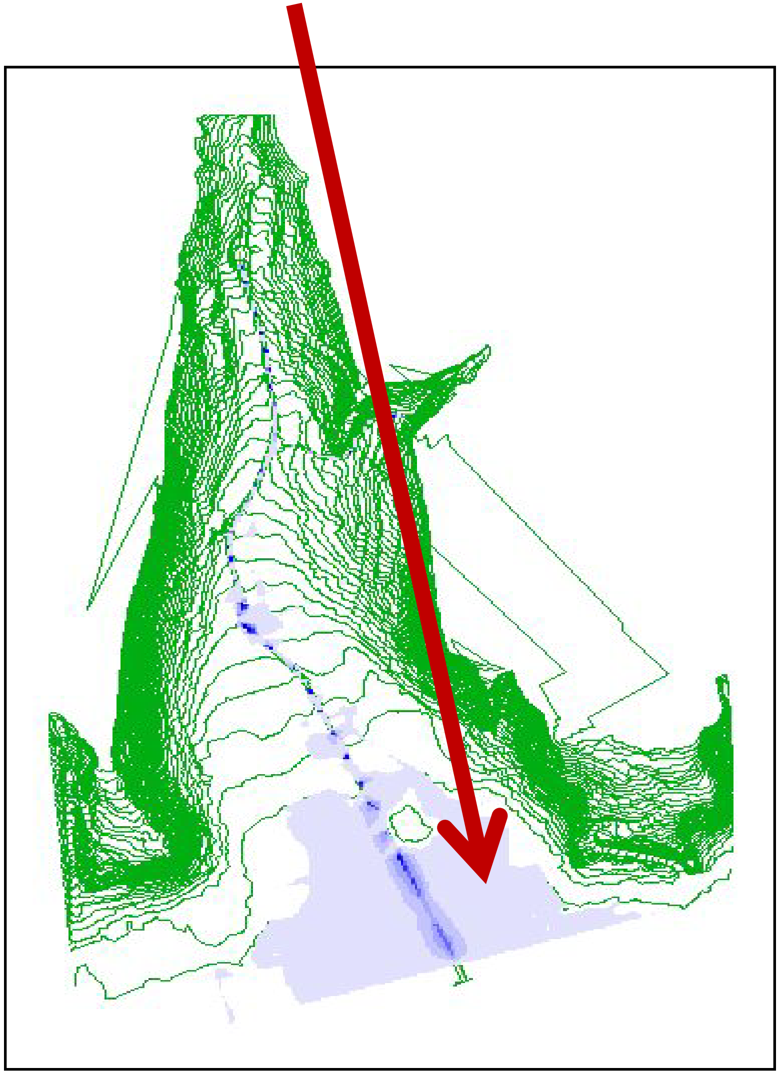
Floodplain Delineation (3-D Scene)



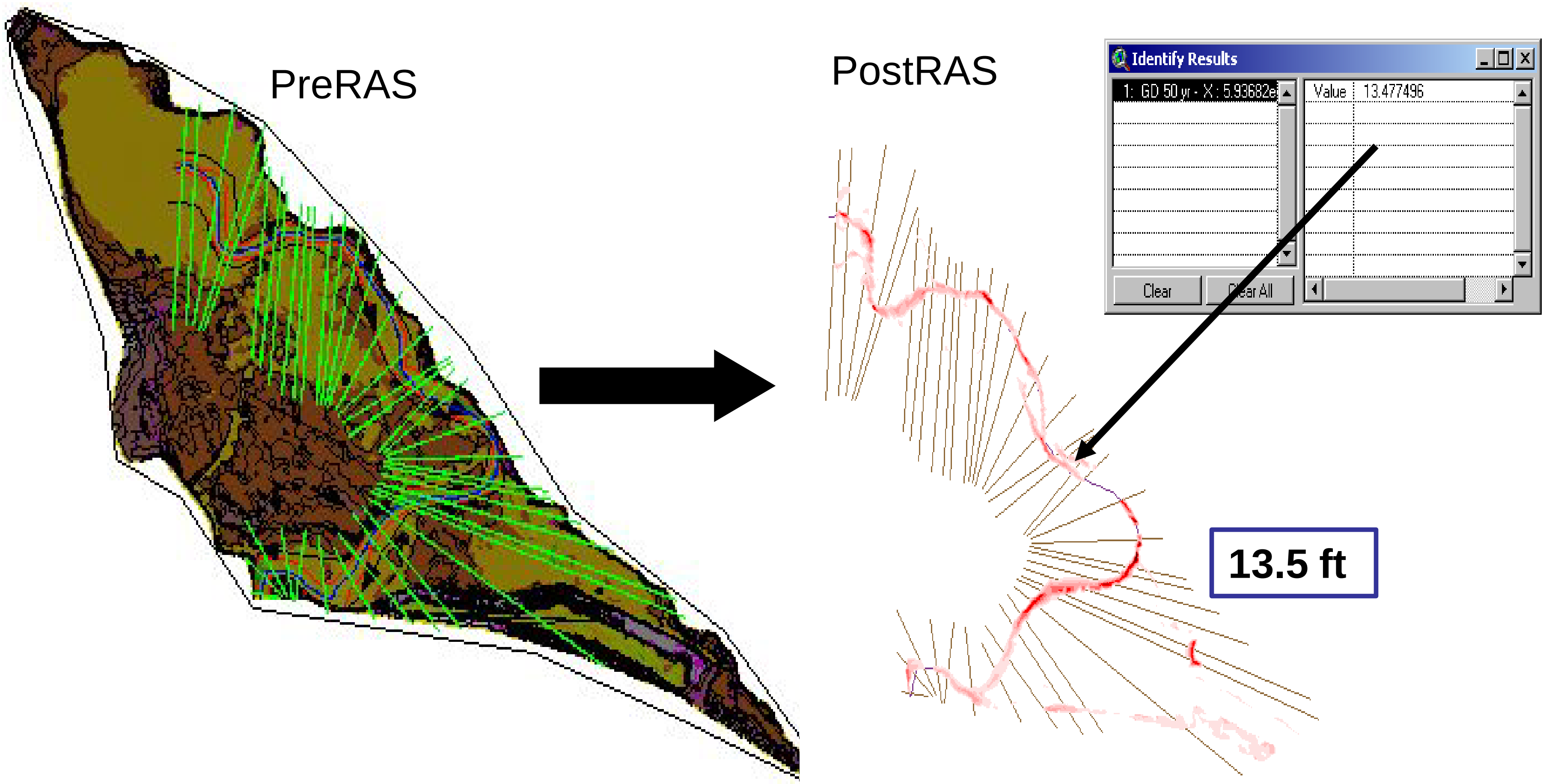
Depth Grid (Darker = Deeper)



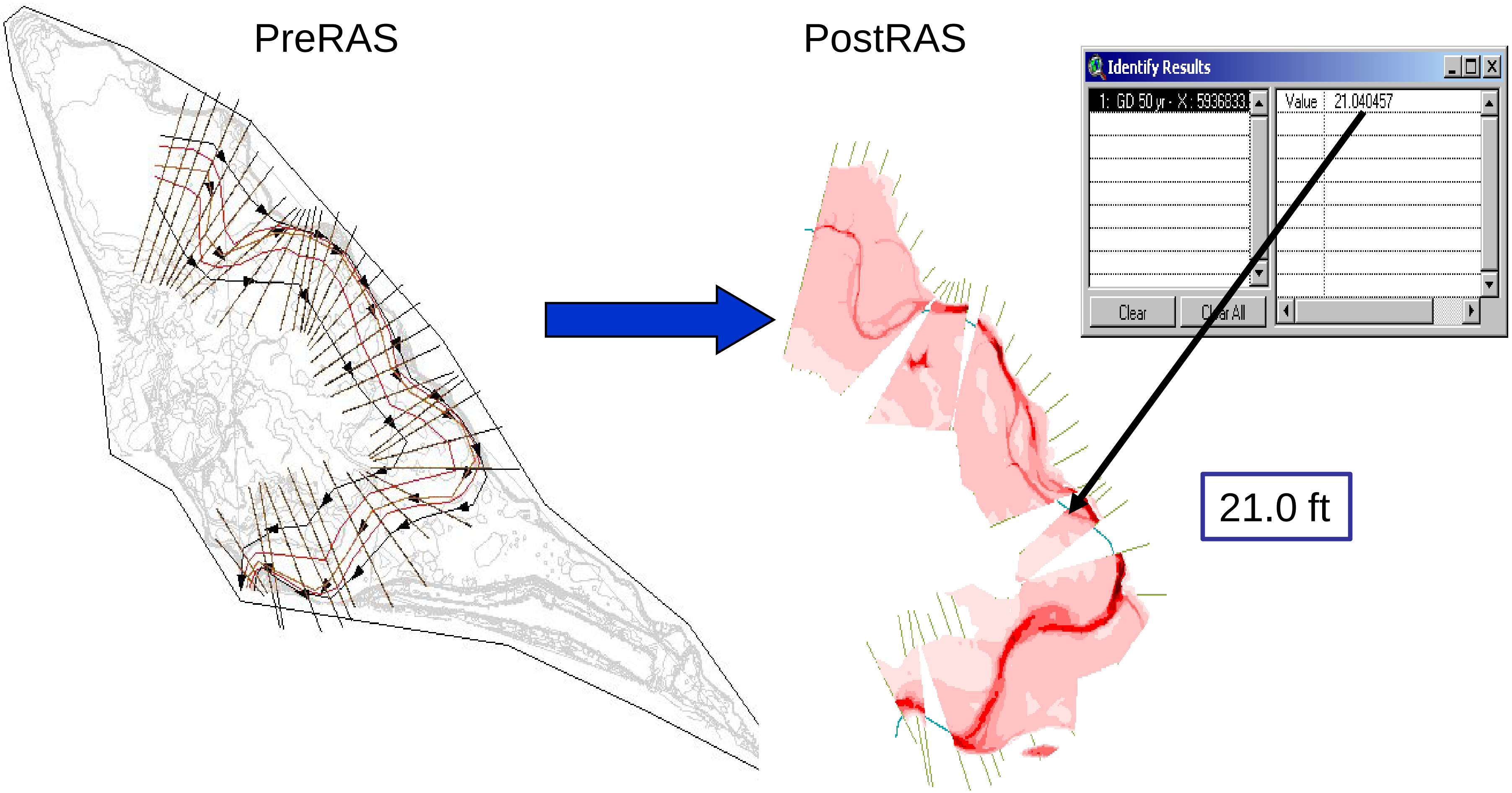
Velocity Grid (Darker = Faster)



Employing ArcView, GeoRAS, and RAS for Main Channel Depth Analysis (1968)



Employing ArcView, GeoRAS, and RAS for Main Channel Depth Analysis (1988)



Overall Benefits

- Elevation data is more accurate with TIN files
  - Better representation of channel bottom
- Rapid preparation of geometry data (point and click)
  - Precision of GIS data increases precision of geometry data
- Efficient data transport via import/export files
- Velocity grid
- Depth grid

Overall Benefits

Contd…

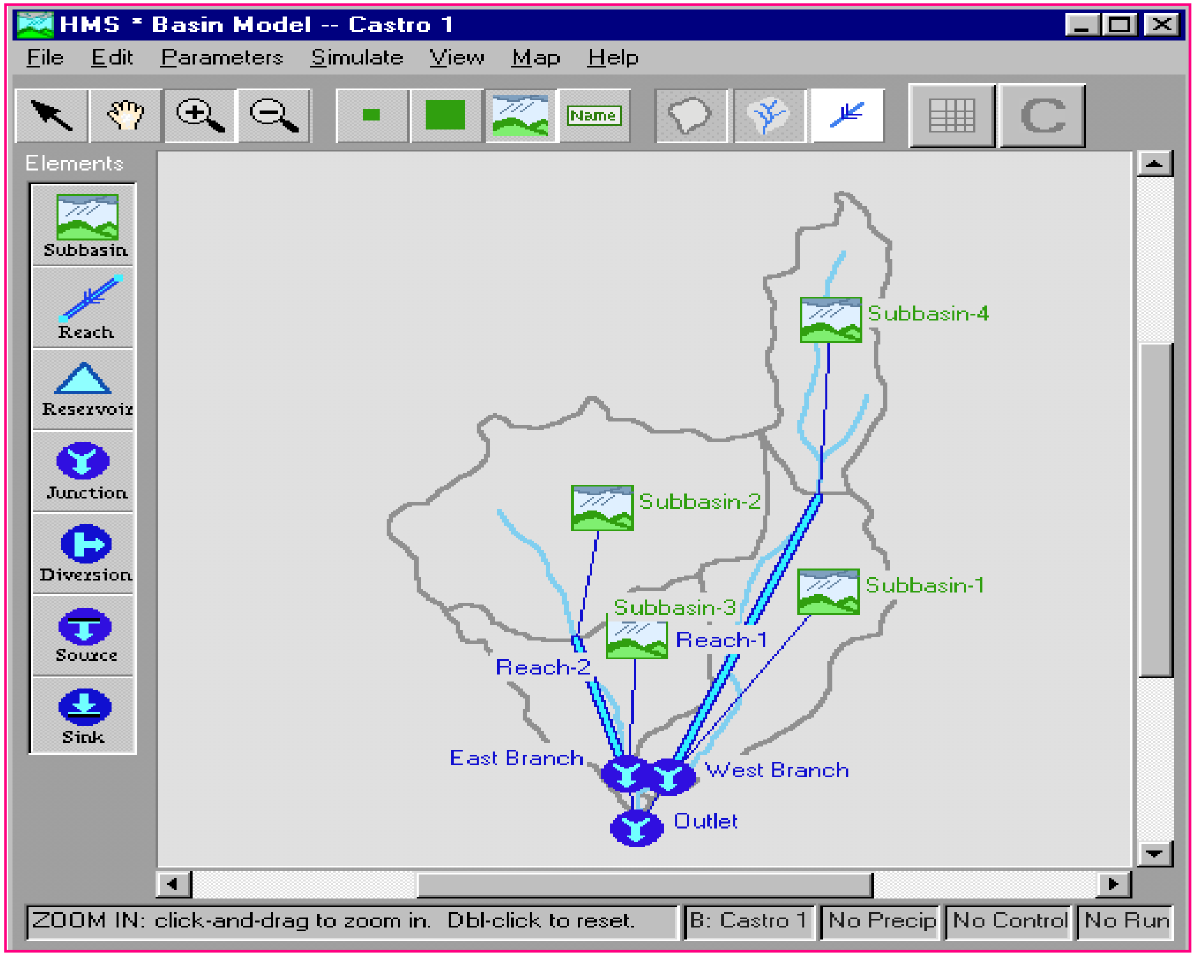
- Floodplain maps can be made faster
  - several flow scenarios
- Both steady & unsteady flow analysis
- GIS tools aid engineering analysis
  - Automated calculation of functions (Energy Equation)
  - Structural validation of hydraulic control features
  - Voluminous data on World Wide Web
- Makes data into visual event – easier for human brain to process!

Overall Drawbacks

- Time required to learn several software packages
- Non-availability of TIN or high resolution data
- Estimation of Manning's Coefficient
  - Few LU/LC files have this as attribute data
- Velocity distribution data may not be calculated
  - HEC-RAS export file without velocity data means no velocity TIN or grid

HEC-HMS

HEC-HMS simulates rainfall-runoff for the watershed



(Source: ftp://ftp.crwr.utexas.edu)

HEC-HMS Background

Purpose of HEC-HMS

- Improved User Interface, Graphics, and Reporting
- Improved Hydrologic Computations
- Integration of Related Hydrologic Capabilities

Importance of HEC-HMS

- Foundation for Future Hydrologic Software
- Replacement for HEC-1

Improvements over HEC-1

Ease of Use

- projects divided into three components
- user can run projects with different parameters instead of creating new projects
- hydrologic data stored as DSS files
- capable of handling NEXRAD-rainfall data and gridded precipitation

Converts HEC-1 files into HMS files

HEC-1
EXERCISE PROBLEM

A small undeveloped watershed has the parameters listed in the following tables. A unit hydrograph and Muskingum routing coefficients are known for subbasin 3, shown in Fig.1(a). *TC* and *R* values for subbasins 1 and 2 and associated SCS curve numbers (CN) are provided as shown. A 5-hr rainfall hyetograph in in./hr is shown in Fig.1(b) for a storm event that occurred on July 26, 2011. Assume that the rain fell uniformly over the watershed. Use the information given to develop a HEC-1 input data set to model this storm. Run the model to determine the predicted outflow at point *B*.

SUBBASIN NUMBER	*TC* (hr)	*R* (hr)	SCS CURVE NUMBER	% IMPERVIOUS (%)	AREA (mi^2)
1	2.5	5.5	66	0	2.5
2	2.8	7.5	58	0	2.7
3	--	--	58	0	3.3

UH FOR SUBBASIN 3:	TIME (hr)	0	1	2	3	4	5	6	7
	U (cfs)	0	200	400	600	450	300	150	0

(Bedient et al., 2008)

Example Problem Contd…

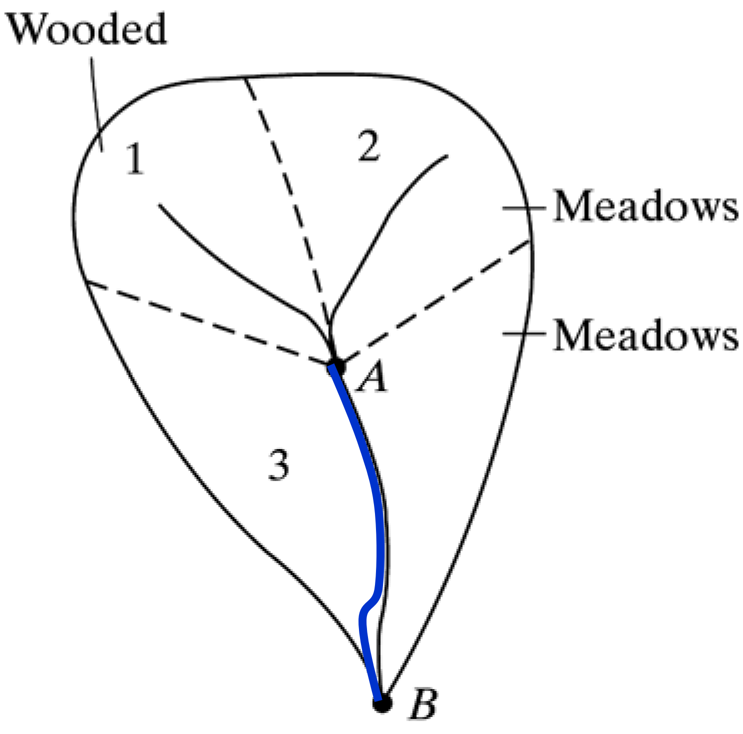


Fig.1(a)

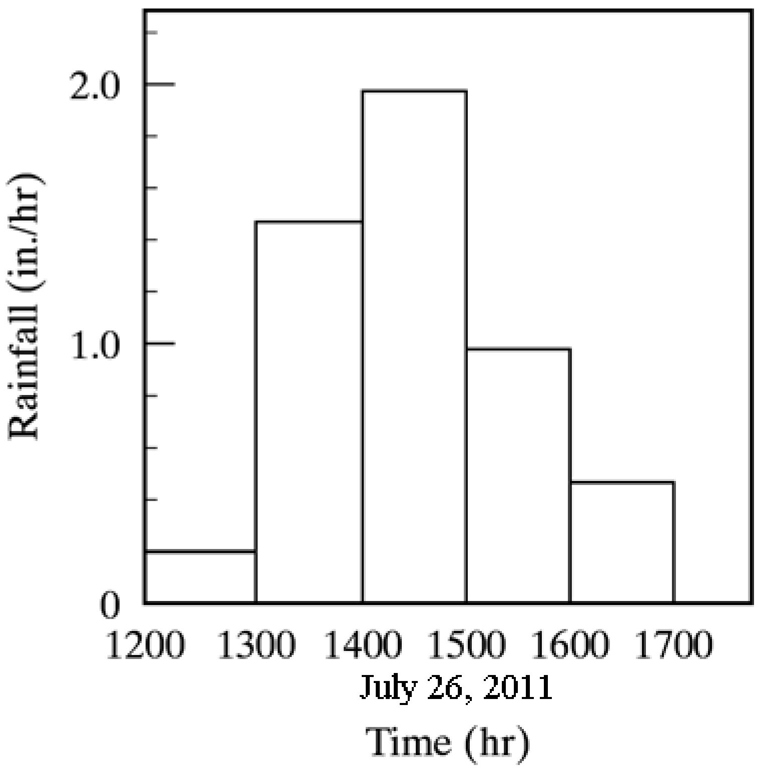


Fig.1(b)

Muskingum coefficients: x = 0.15, K = 3 hr, Area = 3.3 sq mi

Solution : The input data set is as follows:

ID	****	EXAMPLE PROBLEM					
ID	****						
ID	****	HEC-1 INPUT DATA SET					
ID	****						
IT	60	60	25-Jul-07	1200	100		
IO	4						
KK	SUB1						
KM		RUNOFF FROM SUBBASIN 1					
PI	0.2	1.5	2	1	0.5		
BA	2.5						
LS		66	0				
UC	2.5	5.5					
KK	SUB2						
KM		RUNOFF FROM SUBBASIN 2					
BA	2.7						
LS		58	0				
UC	2.8	7.5					
KK	A						
KM		COMBINE RUNOFF FROM SUB 1 WITH RUNOFF FROM SUB 2 AT A					
HC	2						
KKA TO B							
KM		MUSKINGUM ROUTING FROM A TO B					
RM	1	3	0.15				
KK	SUB3						
KM		RUNOFF FROM SUBBASIN 3					
BA	3.3						
LS		58	0				
UI	0	200	400	600	450	300	150

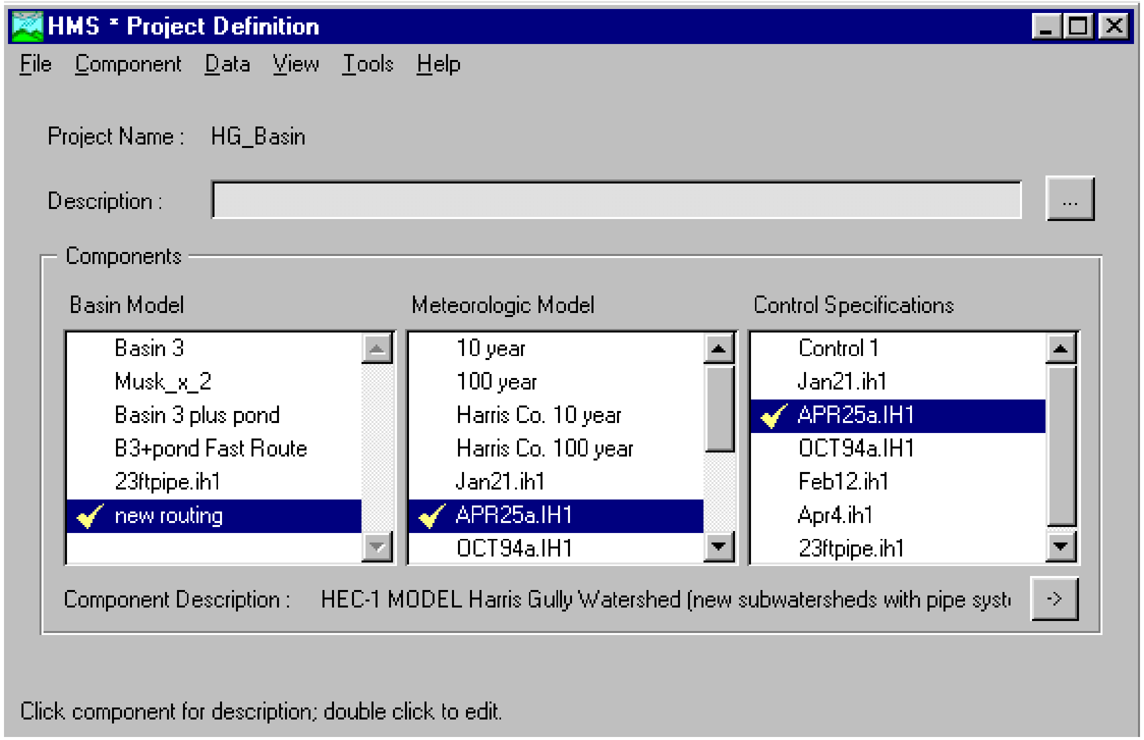
Using HEC-HMS **Contd…**

Three components

- ***Basin model*** - contains the elements of the basin, their connectivity, and runoff parameters **(It will be discussed in detail later)**
- ***Meteorologic Model*** - contains the rainfall and evapotranspiration data
- ***Control Specifications*** - contains the start/stop timing and calculation intervals for the run

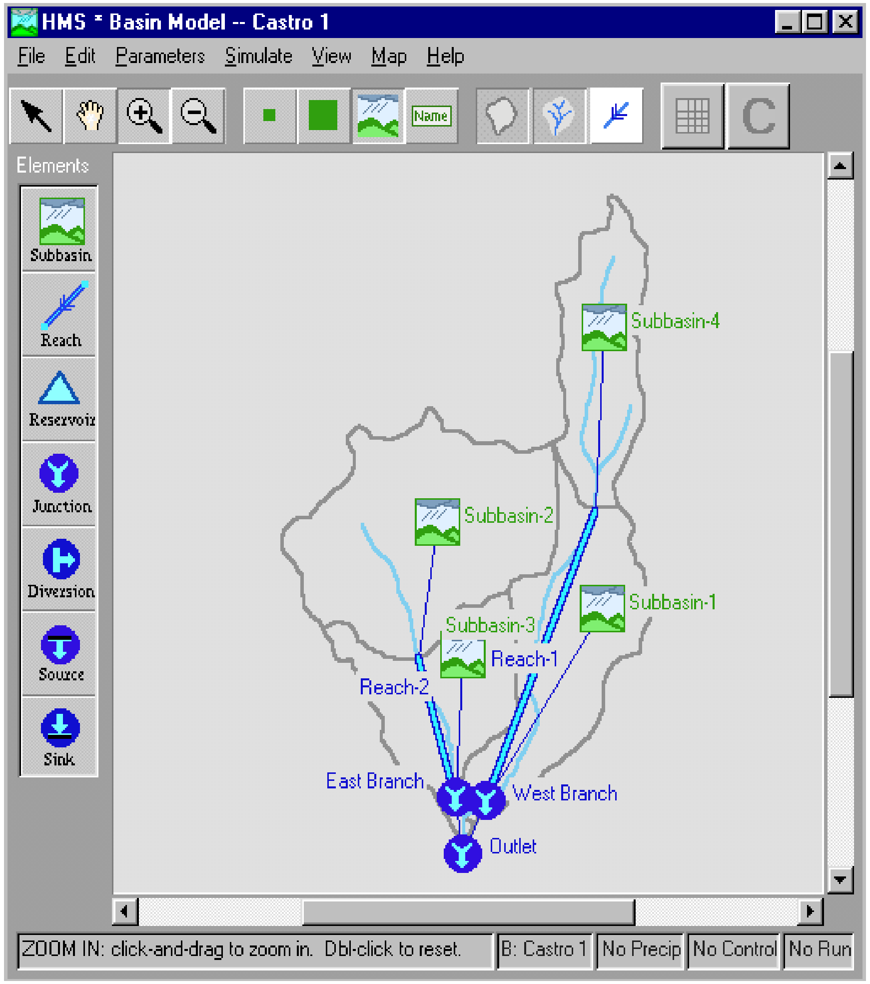
Project Definition

- It may contain several basin models, meteorological models, and control specifications
- It is possible to select a variety of combinations of the three models in order to see the effects of changing parameters on one sub-basin



Basin Model

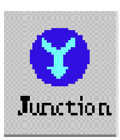
- GUI supported
- Click on elements from left and drag into basin area
- Works well with GIS imported files
- Actual locations of elements do not matter, just connectivity and runoff parameters



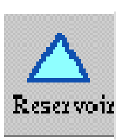
1. Basin Model Elements

- **subbasins**- contains data for subbasins (losses, UH transform, and baseflow)

- **reaches**- connects elements together and contains flood routing data



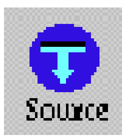
- **junctions**- connection point between elements



- **reservoirs**- stores runoff and releases runoff at a specified rate (storage-discharge relation)

1. Basin Model Elements Contd…

- **sinks**- has an inflow but no outflow



- **sources**- has an outflow but no inflow

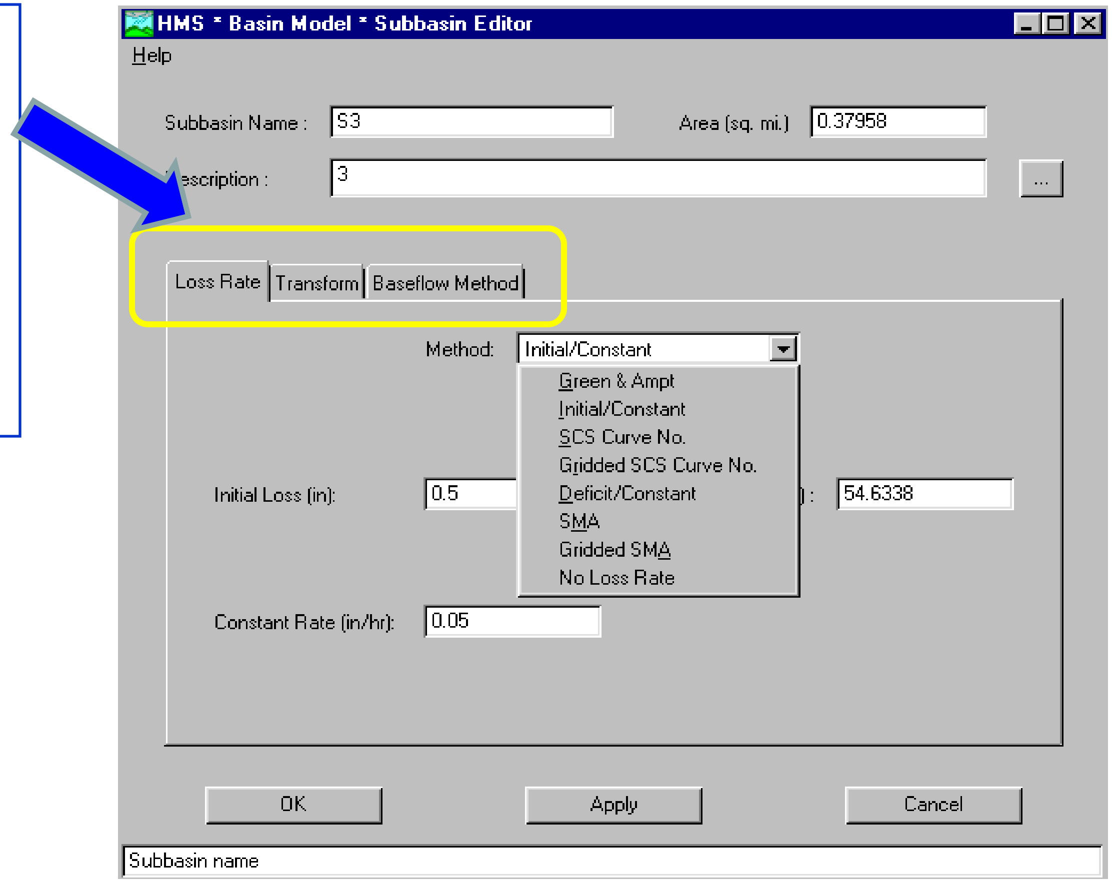
- **diversions**- diverts a specified amount of runoff to an element based on a rating curve - used for detention storage elements or overflows

2. Basin Model Parameters

a) Loss rate

b) Transform

c) Baseflow methods



2. Basin Model Parameters

Contd…

2a) Abstractions (Losses)

1. Interception Storage
2. Depression Storage
3. Surface Storage
4. Evaporation
5. Infiltration
6. Interflow
7. Groundwater and Base Flow

2b) Transformation

1. Unit Hydrograph
2. Distributed Runoff
3. Grid-Based Transformation

Methods:

a. Clark
b. Snyder
c. SCS
d. Input Ordinates
e. ModClark
f. Kinematic Wave

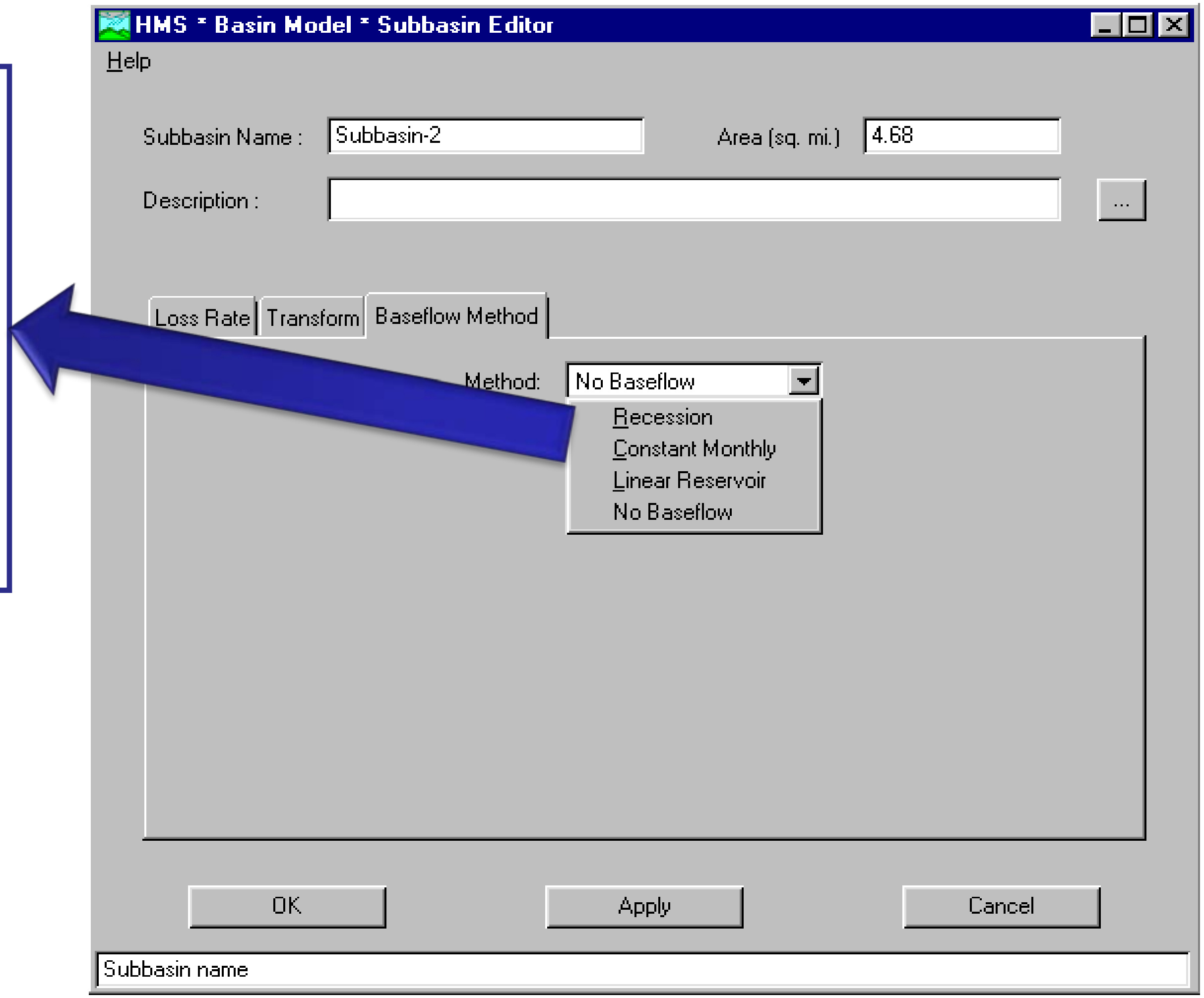
2c) Baseflow Options

a. recession

b. constant monthly

c. linear reservoir

d. no base flow



Stream Flow Routing

- Simulates Movement of Flood Wave Through Stream Reach
- Accounts for Storage and Flow Resistance
- Allows modeling of a watershed with sub-basins

Reach Routing

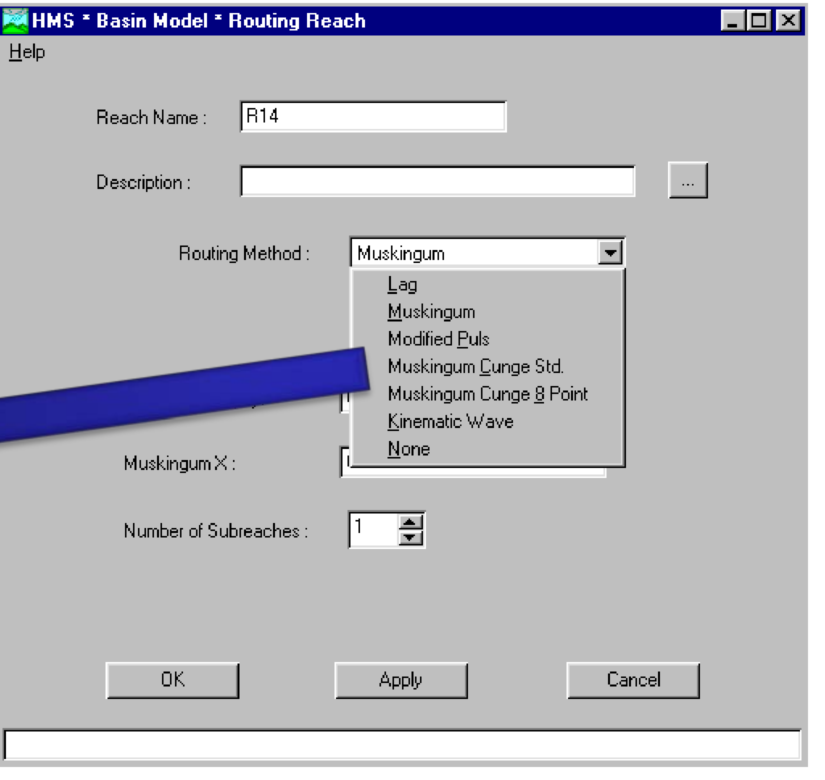
a) Simple Lag

b) Modified Puls

c) Muskingum

d) Muskingum Cunge

e) Kinematic Wave



Methods for Stream Flow Routing

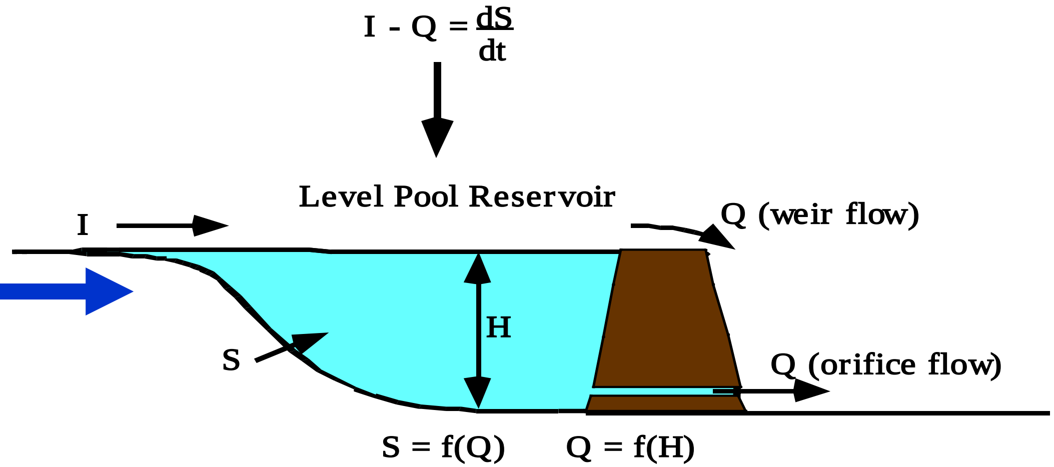
- Hydraulic Methods - Uses partial form of St Venant Equations
  - Kinematic Wave Method
  - Muskingum-Cunge Method
- Hydrologic Methods
  - Muskingum Method
  - Storage Method (Modified Puls)
  - Lag Method

Reservoir Routing

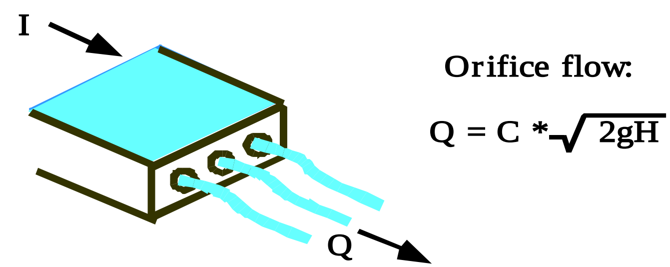
- **Developed Outside HEC-HMS**
- **Storage Specification Alternatives:**
  - Storage versus Discharge
  - Storage versus Elevation
  - Surface Area versus Elevation
- **Discharge Specification Alternatives:**
  - Spillways, Low-Level Outlets, Pumps
  - Dam Safety: Embankment Overflow, Dam Breach

Reservoirs

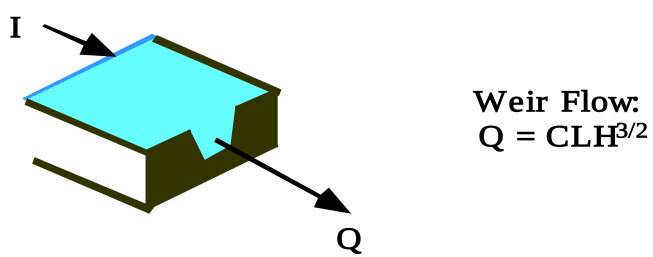
- ❑Pond storage with outflow pipe



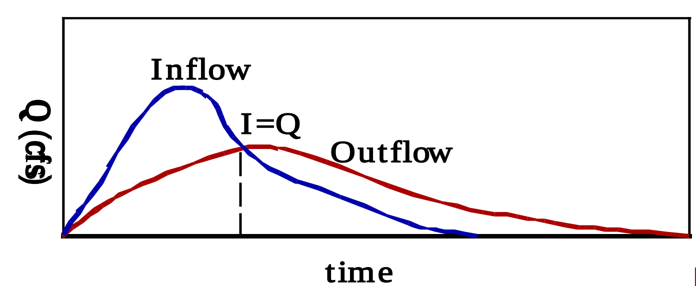
- ❑Orifice flow



- ❑Weir flows



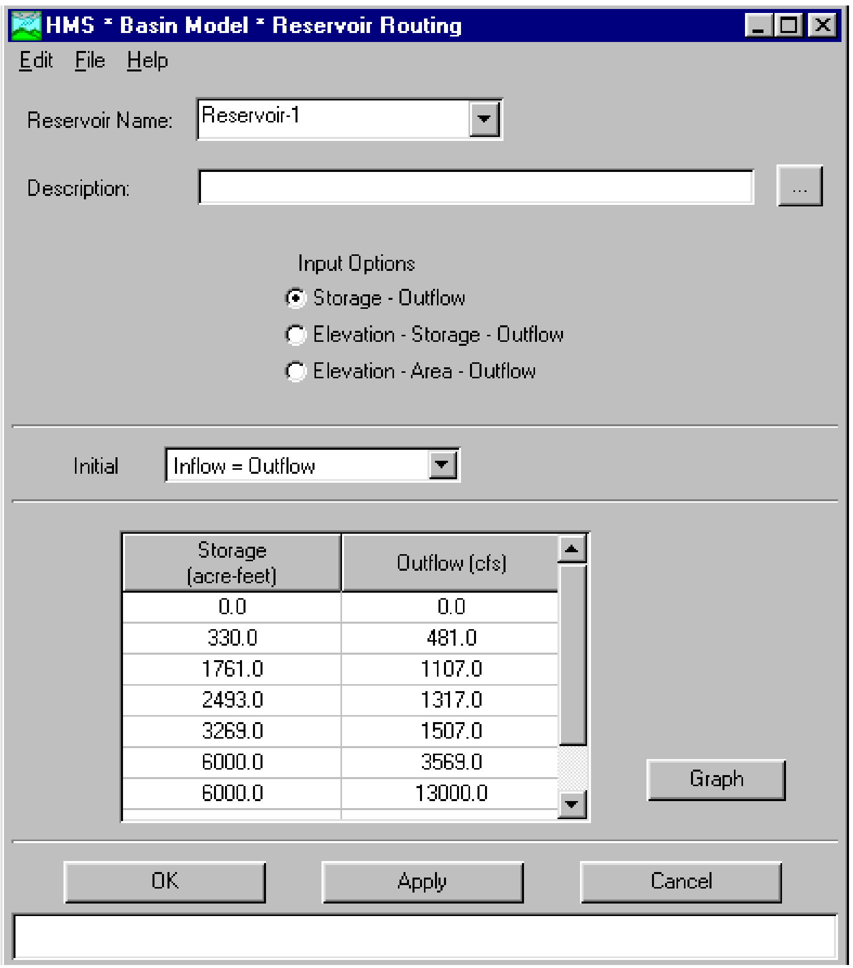
- ❑Inflow and Outflow

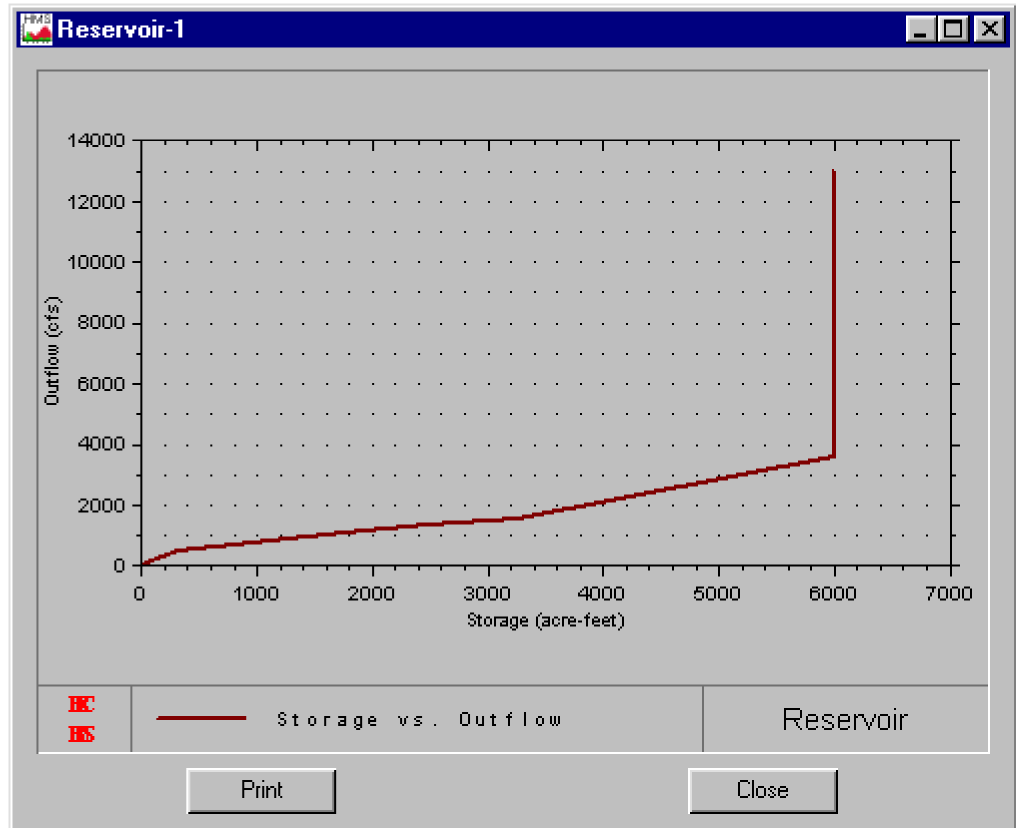


Reservoir Data Input

- Initial Conditions to be considered
  - Inflow = Outflow
  - Initial Storage Values
  - Initial Outflow
  - Initial Elevation
- Elevation Data relates to both Storage/Area and Discharge
- HEC-1 Routing routines with initial conditions and elevation data can be imported as Reservoir Elements

Reservoir Data Input Window

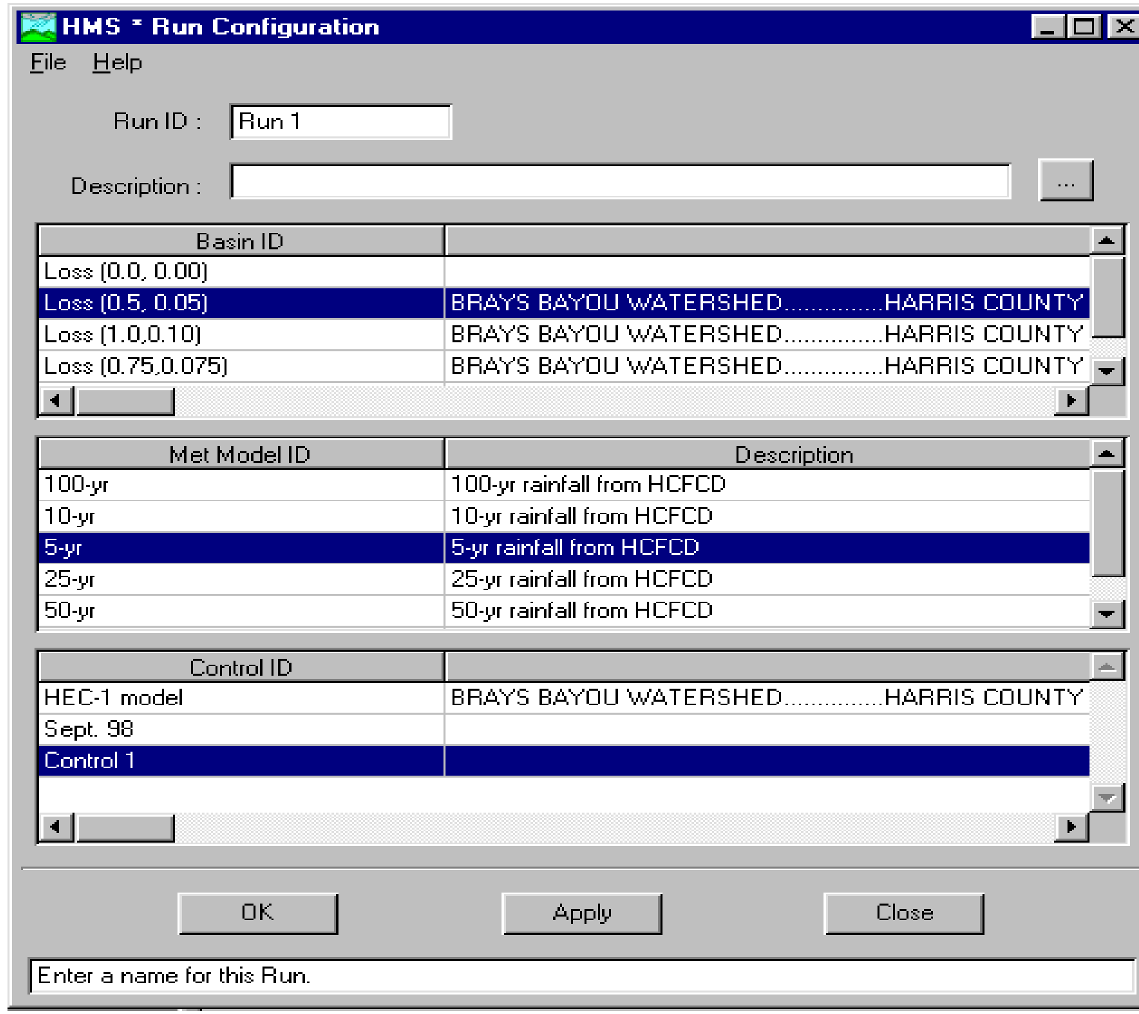




Running a project

User selects:

1. Basin model
2. Meteorologic model
3. Control ID for the HMS run

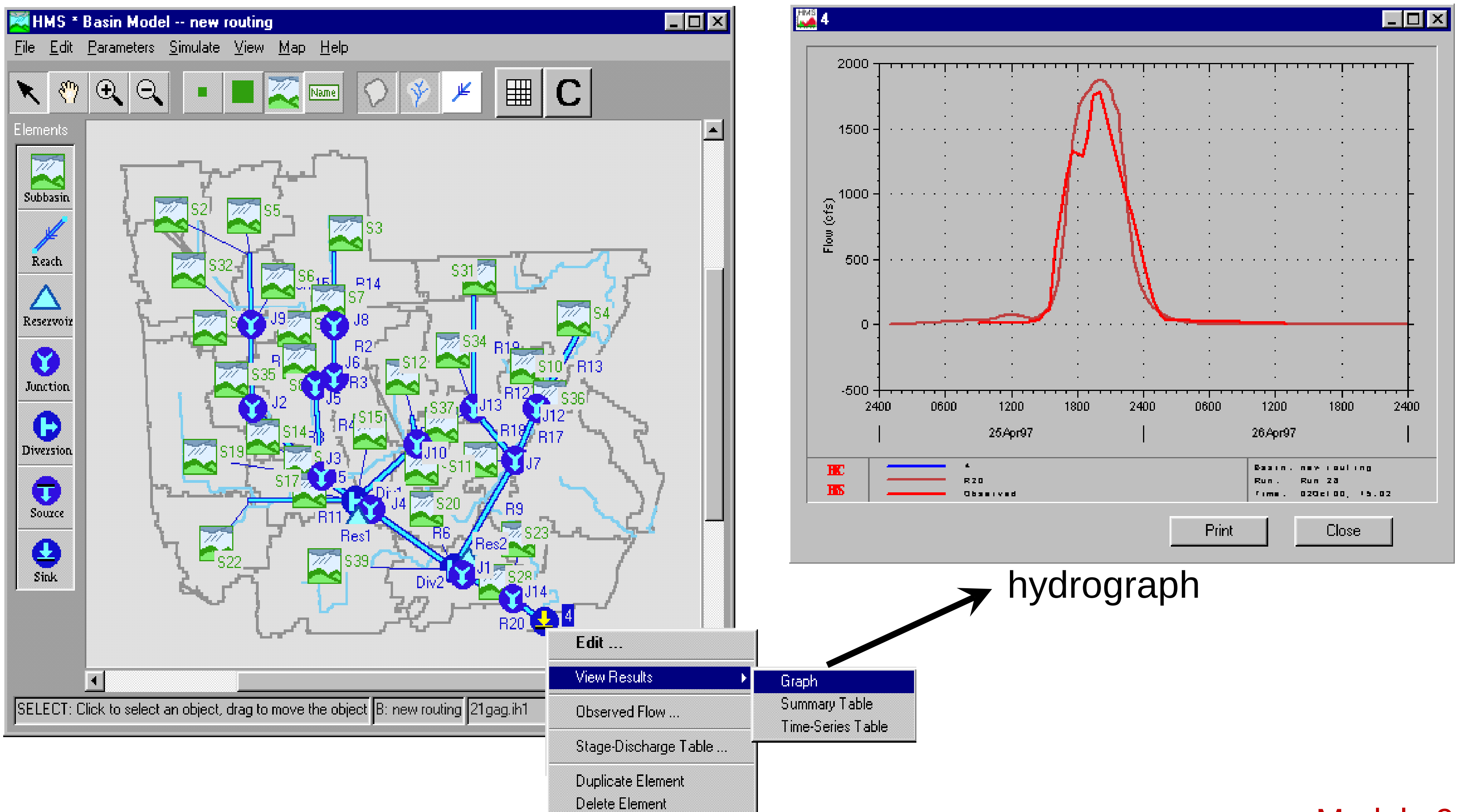


Viewing Results

- **To view the results:**
  - right-click on any basin element, results will be for that point
- **Display of results:**
  - hydrograph- graphs outflow vs. time
  - summary table- gives the peak flow and time of peak
  - time-series table- tabular form of outflow vs. time
- **Comparing computed and actual results:**
  - plot observed data on the same hydrograph to by selecting a discharge gage for an element

Viewing Results

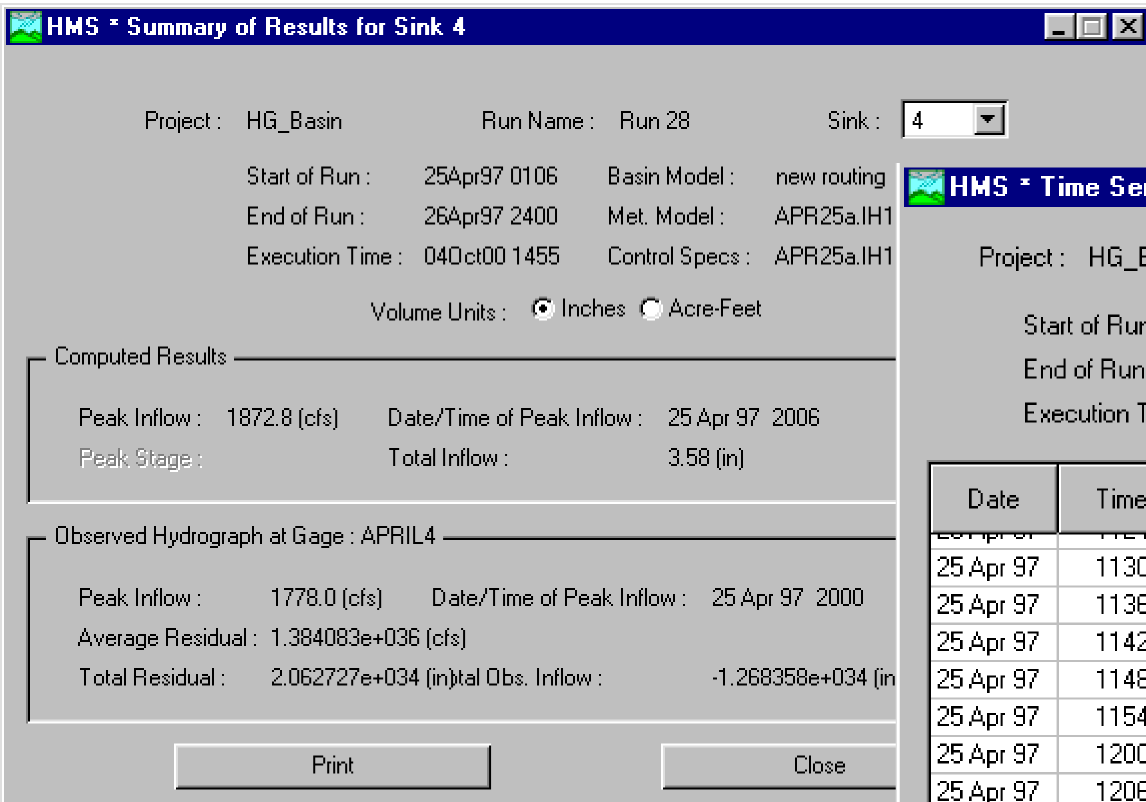
Contd…



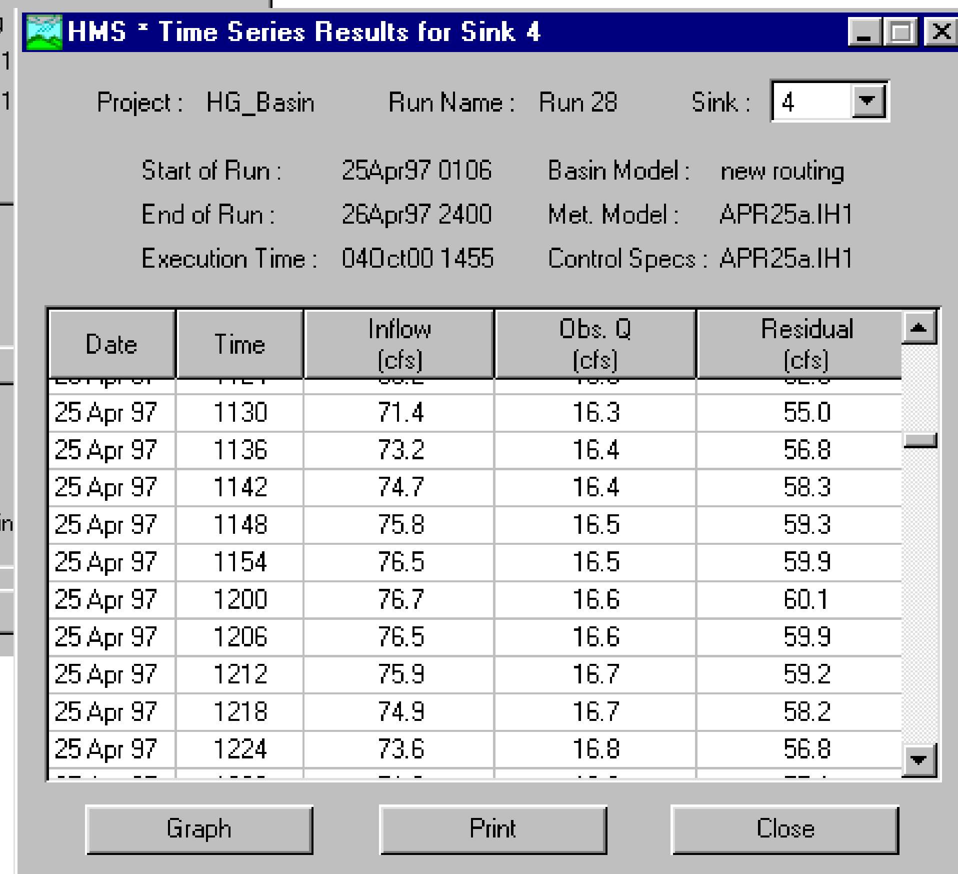
HEC-HMS Output

1. Tables
   - Summary
   - Detailed (Time Series)
2. Hyetograph Plots
3. Sub-Basin Hydrograph Plots
4. Routed Hydrograph Plots
5. Combined Hydrograph Plots
6. Recorded Hydrographs - comparison

Viewing Results



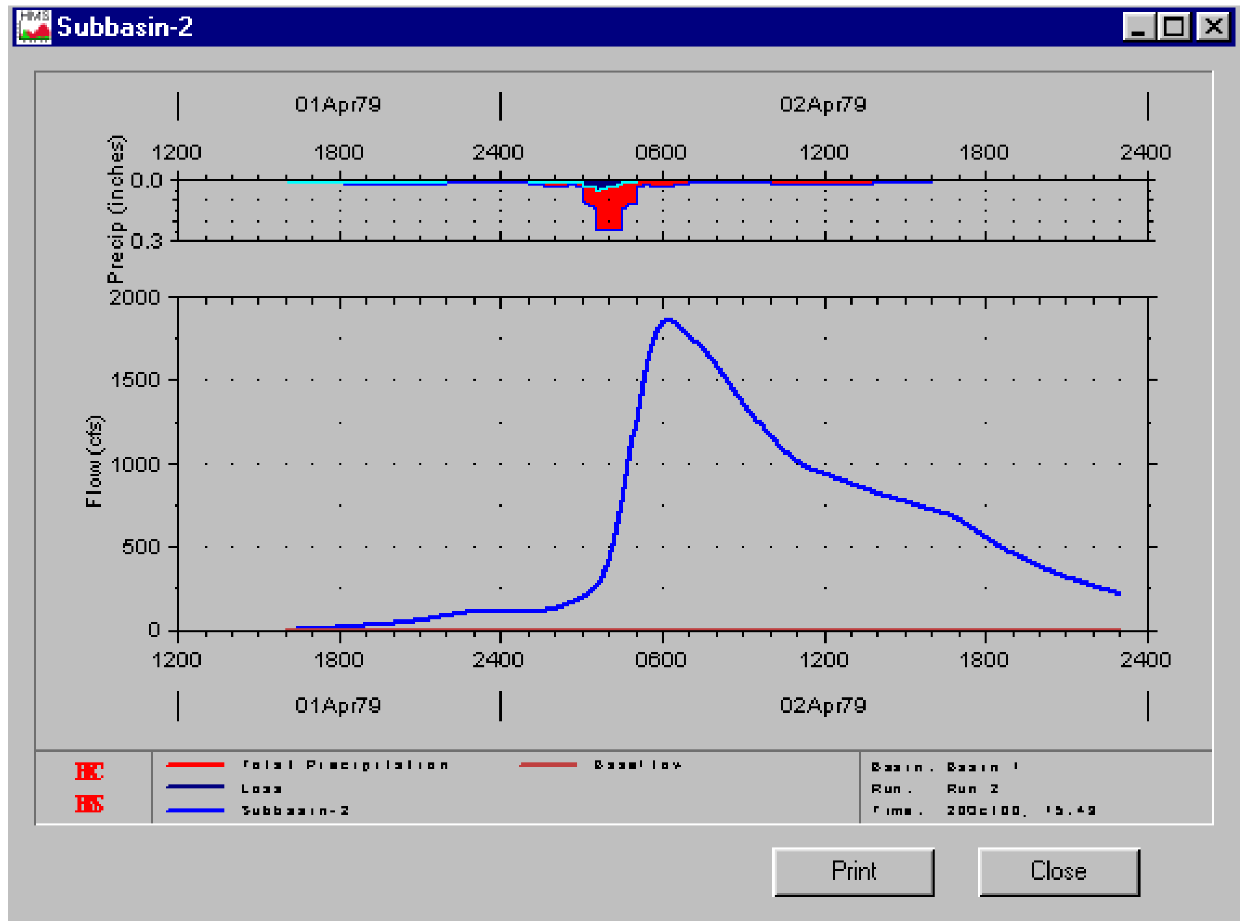
Summary table



Time series table

Sub-Basin Plots

- Runoff Hydrograph
- Hyetograph
- Abstractions
- Base Flow



Junction Plots

a. Tributary Hydrographs

b. Combined Hydrograph

c. Recorded Hydrograph