Sediment and Water Quality in HEC-RAS

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The HEC-RAS Modeling System

- 1D River Hydraulics
- Graphical User Interface
- Steady & Unsteady Flow
- Bridges, Culverts, Dams, weirs, gates, etc…
- Data storage/management
- Graphics, Tabular Output & Reporting
- GeoRas – ArcGIS

History of HEC-RAS Development

- 1D Steady Flow Analysis
  - FY 1992 - 1999
  - Produced Steady flow versions of HEC-RAS (Beta 1&2, Versions 1.0 - 1.2, 2.0 – 2.2)
- 1D Unsteady Modeling for River Analysis
  - FY 2000 – 2005
  - Versions 3.0 – 3.1.3
- 1D Sediment Transport for River Analysis
  - FY 2004 – 2007
- 1D Water Quality Modeling
  - FY 2004 – 2007

Features added to recent versions of HEC-RAS

- Mixed Flow Regime for Unsteady Flow
- Dam Break Analysis
- Levee Breaching
- Pump Stations
- Navigation Dams
- Stable Channel Design and Analysis
- Sediment Transport Potential

New HEC-RAS Developments (that we will be talking about today)

- Sediment Transport (Mobile Bed Hydraulics)
- Water Quality

Mobile Bed Sediment Transport

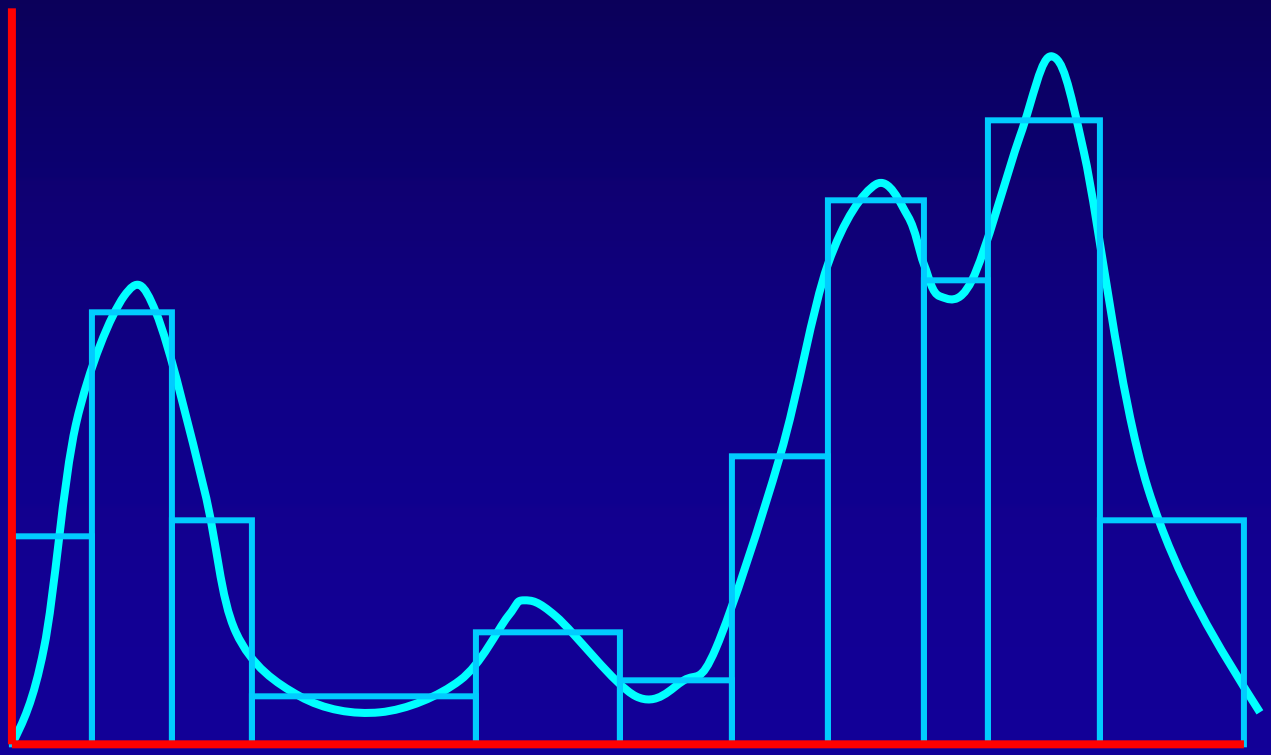
- Goals of adding sediment routing into HEC-RAS
- Quasi-Steady Hydrodynamics
- Transport Capacity
- Sediment continuity
- Sorting and Armoring
- Erosion and Deposition
- User Interface Design
- Preliminary Results
- Additional Capabilities Planned

Goals of adding Mobile Bed Capabilities into HEC-RAS

- Replicate the capabilities of HEC-6
  - Re-coding general capabilities in RAS
  - Differences exist in hydraulic computations
- Add new capabilities beyond current HEC-6 Features
- Improve the capabilities where we have known deficiencies

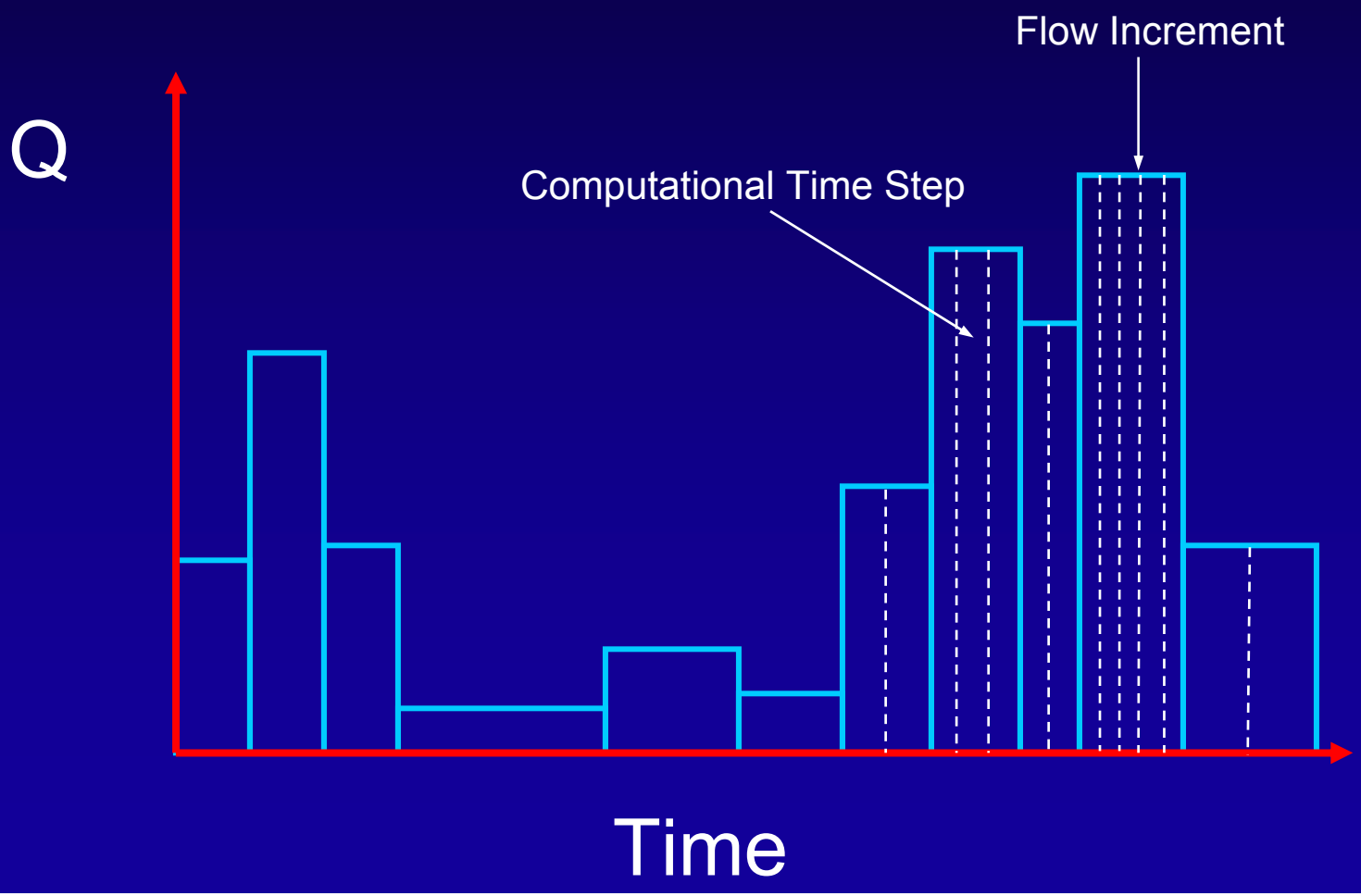
Quasi-Steady Flow

- Flow Hydrograph represented by a series of steady flows associated with durations.



- Requires a new way of handling flows in HEC RAS

Computational Time Steps



Transport Potential Functions

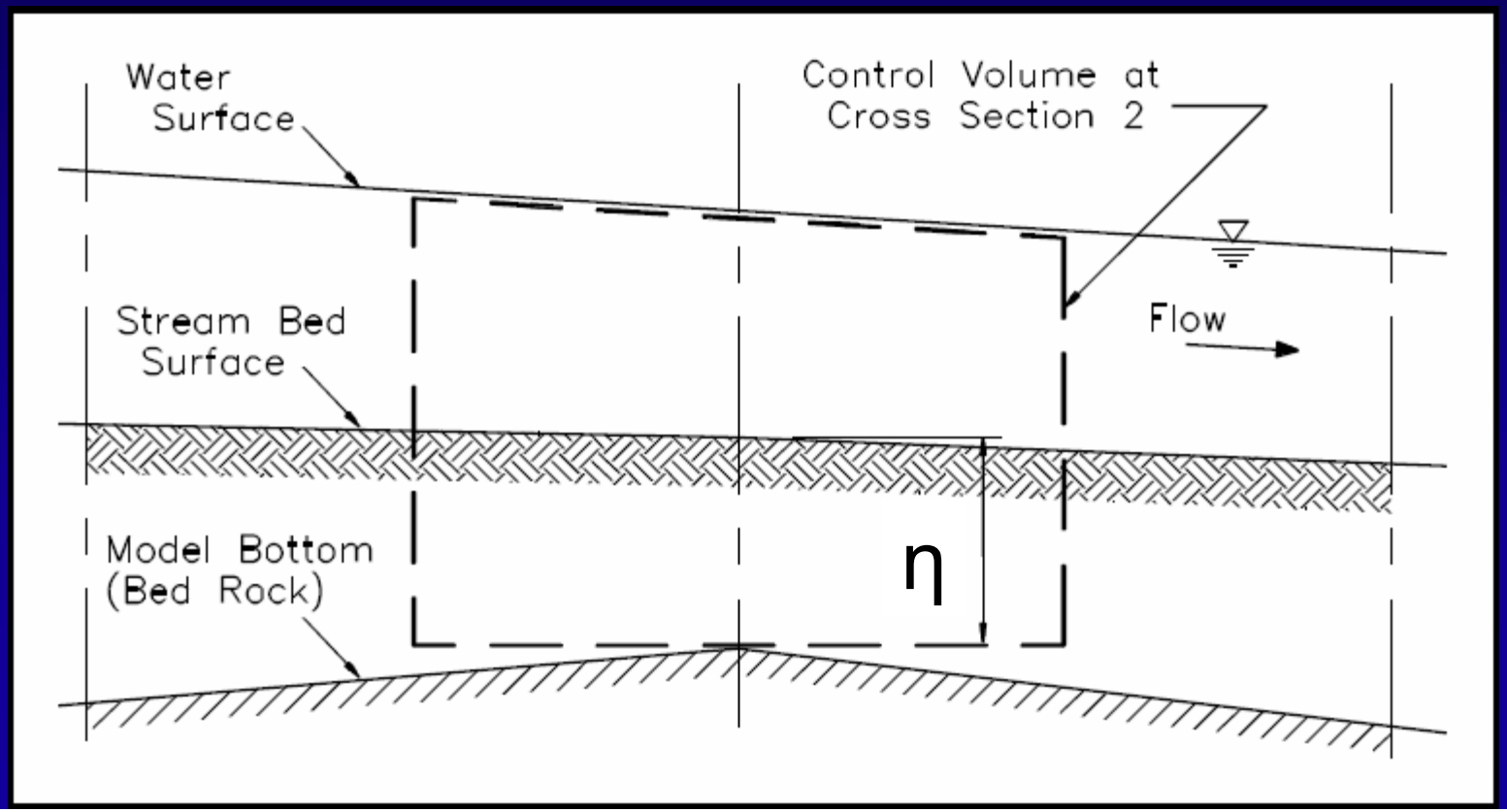
- Ackers-White
- Englund-Hansen
- Laursen (Copeland)
- Myer-Peter-Meuler
- Toffaleti
- Yang (Sand and Gravel)

Transport Capacity

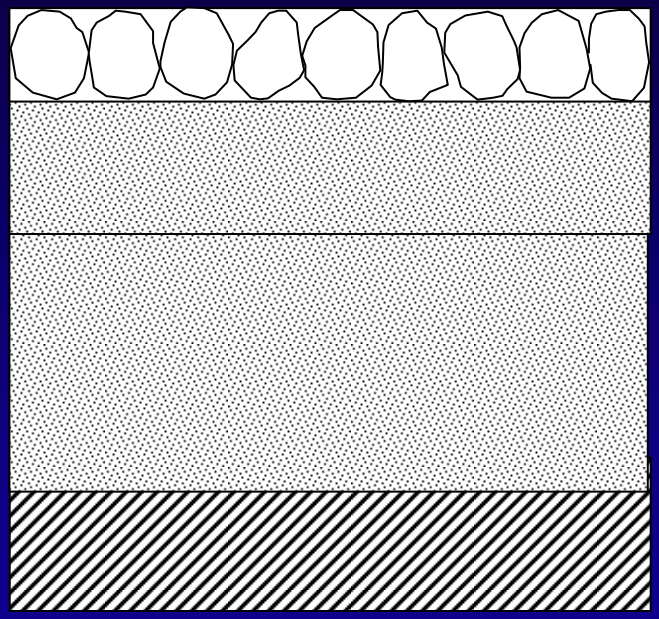
- Bed Material and Inflowing Load divided into separate grain classes (up to 20)
- Transport potential is calculated for each grain size
- Transport Capacity = (Transport Potential for each grain size) X (fraction of that material in active layer of bed)

Sediment Continuity: Exner Equation

$$(1-\lambda_p)B\frac{\partial \eta}{\partial t} = -\frac{\partial Q_s}{\partial x}$$



Sorting and Armoring



Diagramed and Conceptualized HEC 6 Code

3 Methods in HEC-6T

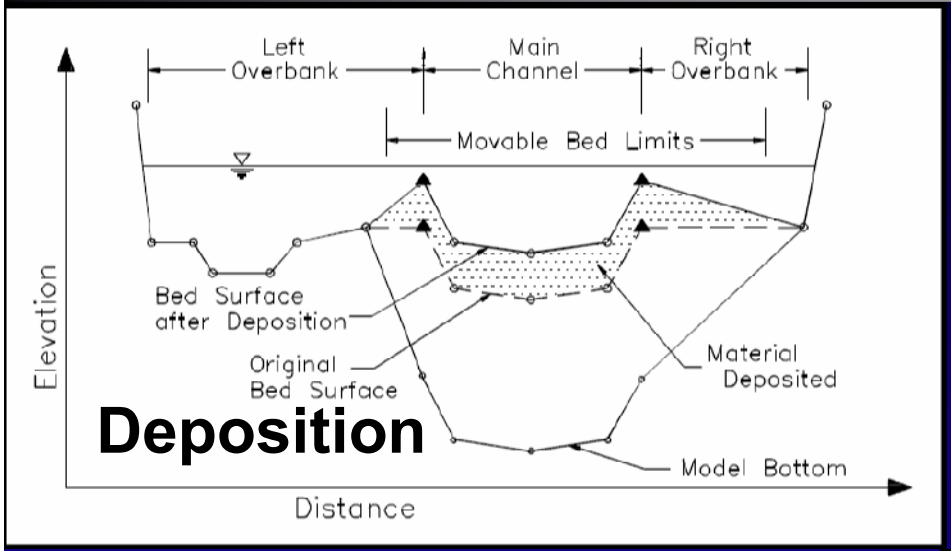
Exner 5 implemented Currently in RAS

Temporal Constraints on Eroding and Depositing

- Erosion and deposition does not occur instantaneously.
- Deposition is based on settling velocity:
  - Deposition efficiency coefficient = $\frac{V_s(i) \cdot \Delta t}{D_e(i)}$
- Erosion is based on "Characteristic Flow Length"
  - Erosion = (Gs – Qs) x C_e Entrainment Coefficient
  - Where:

$$C_e = 1.368 - e^{\frac{L}{30 \cdot D}}$$

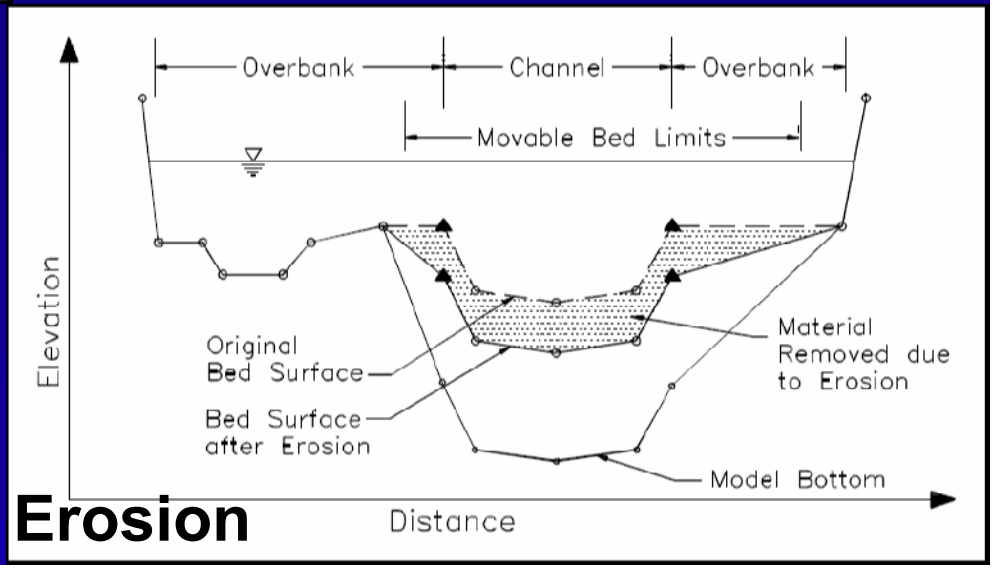
Erosion and Deposition to RAS Cross Sections



Deposition

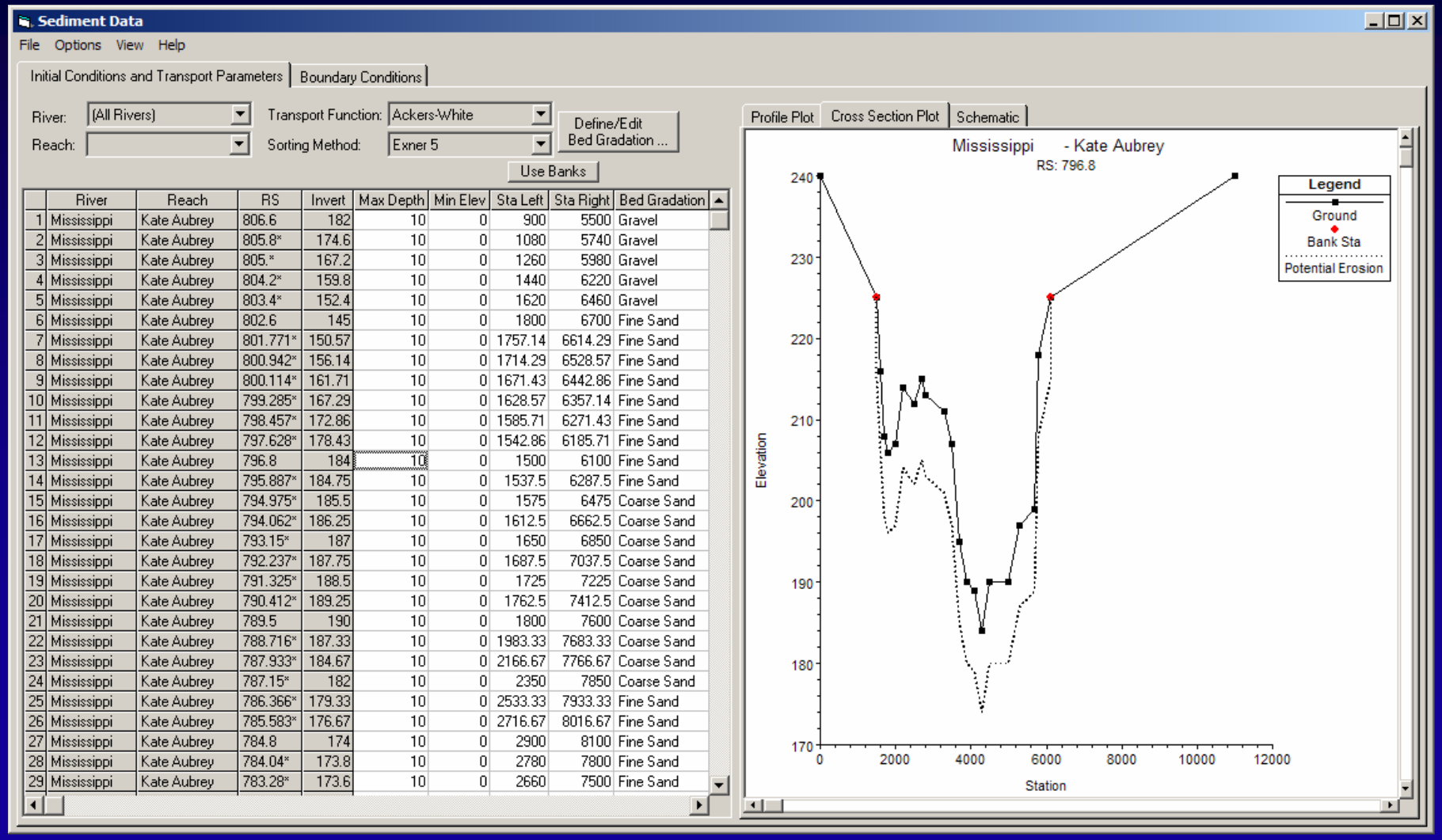
RAS computations modified to compute bed changes and modify cross sections before each time step

- **Cross Sections**
- **Bridges**



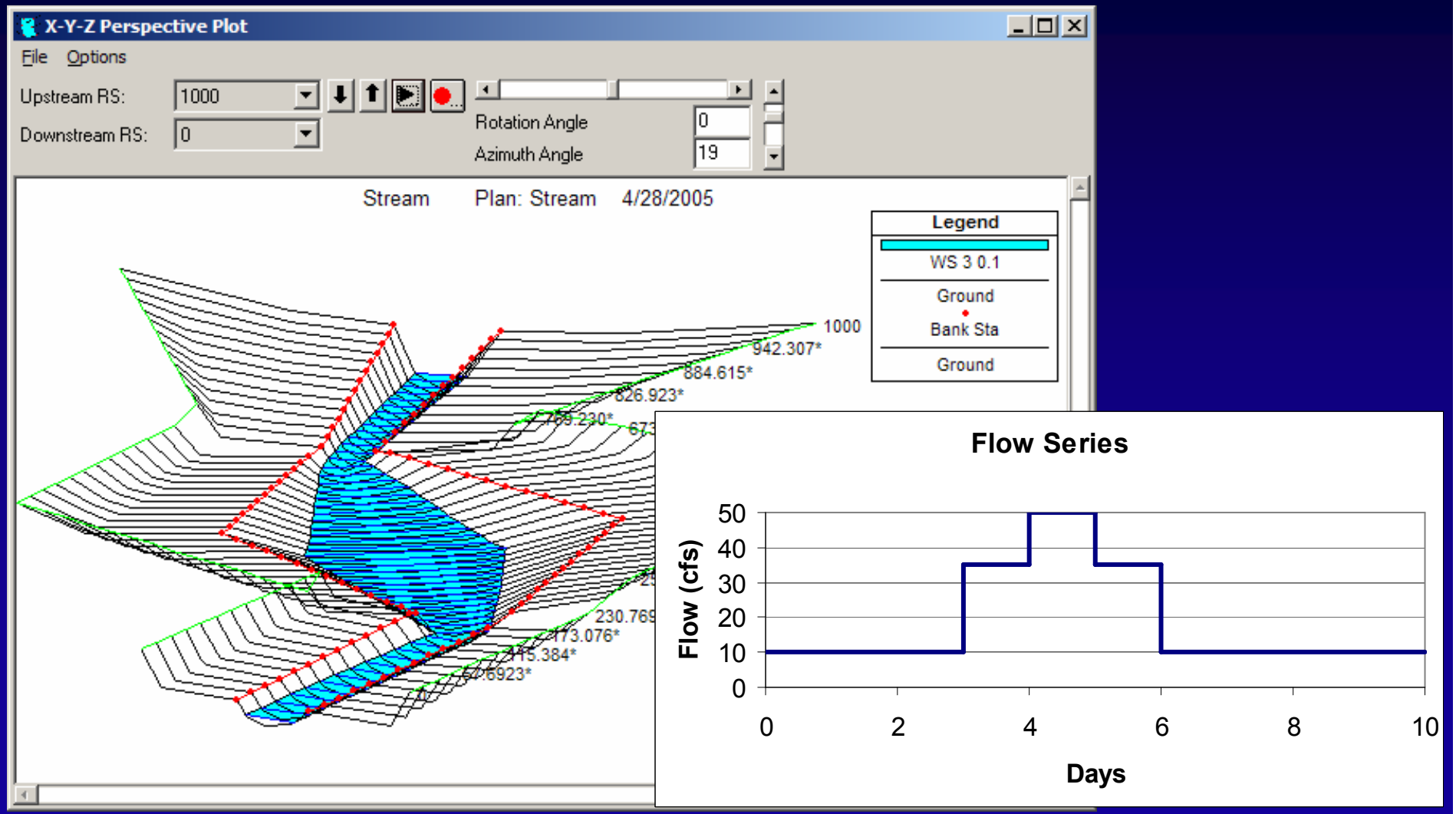
Erosion

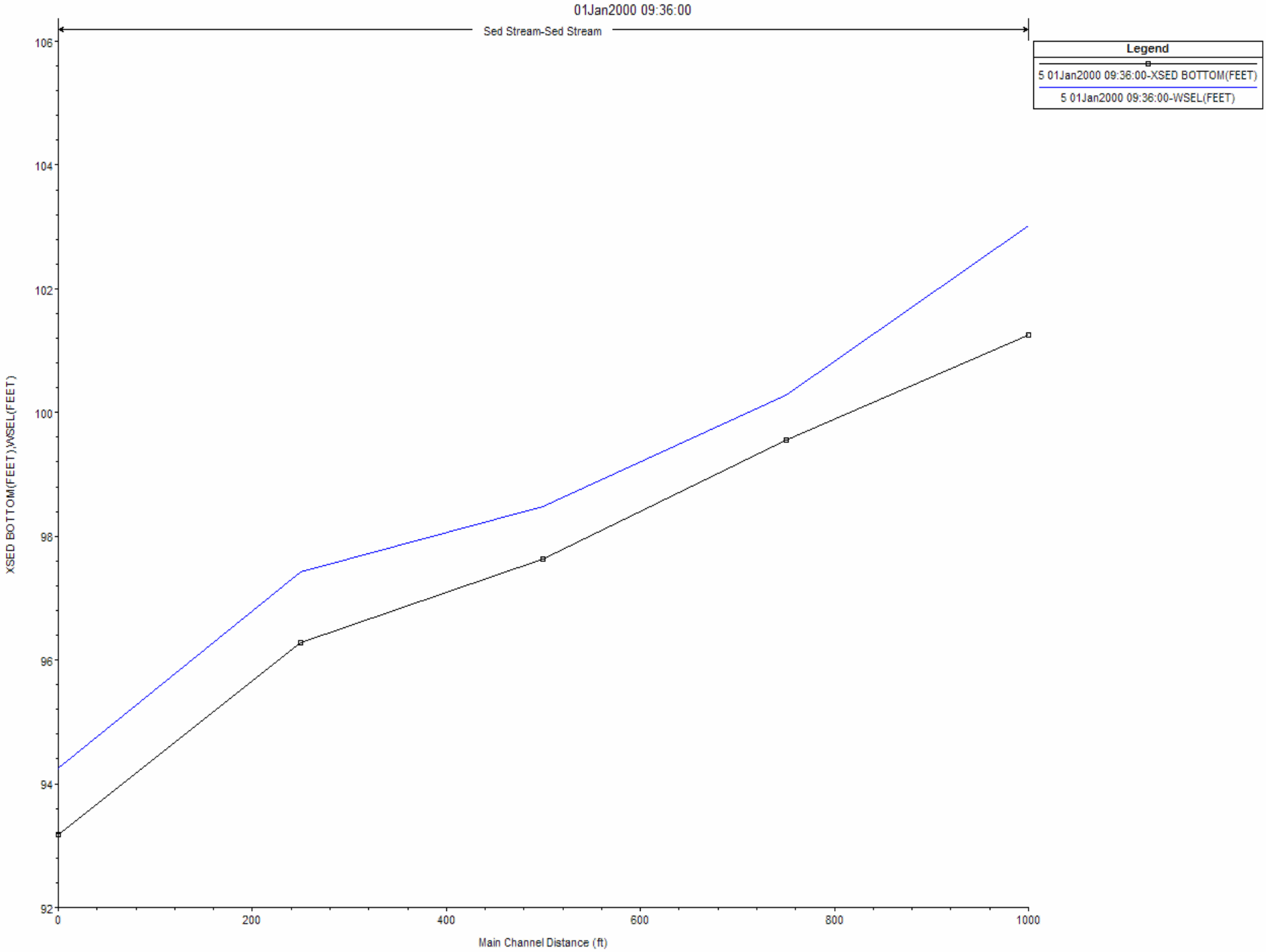
Sediment User Interface



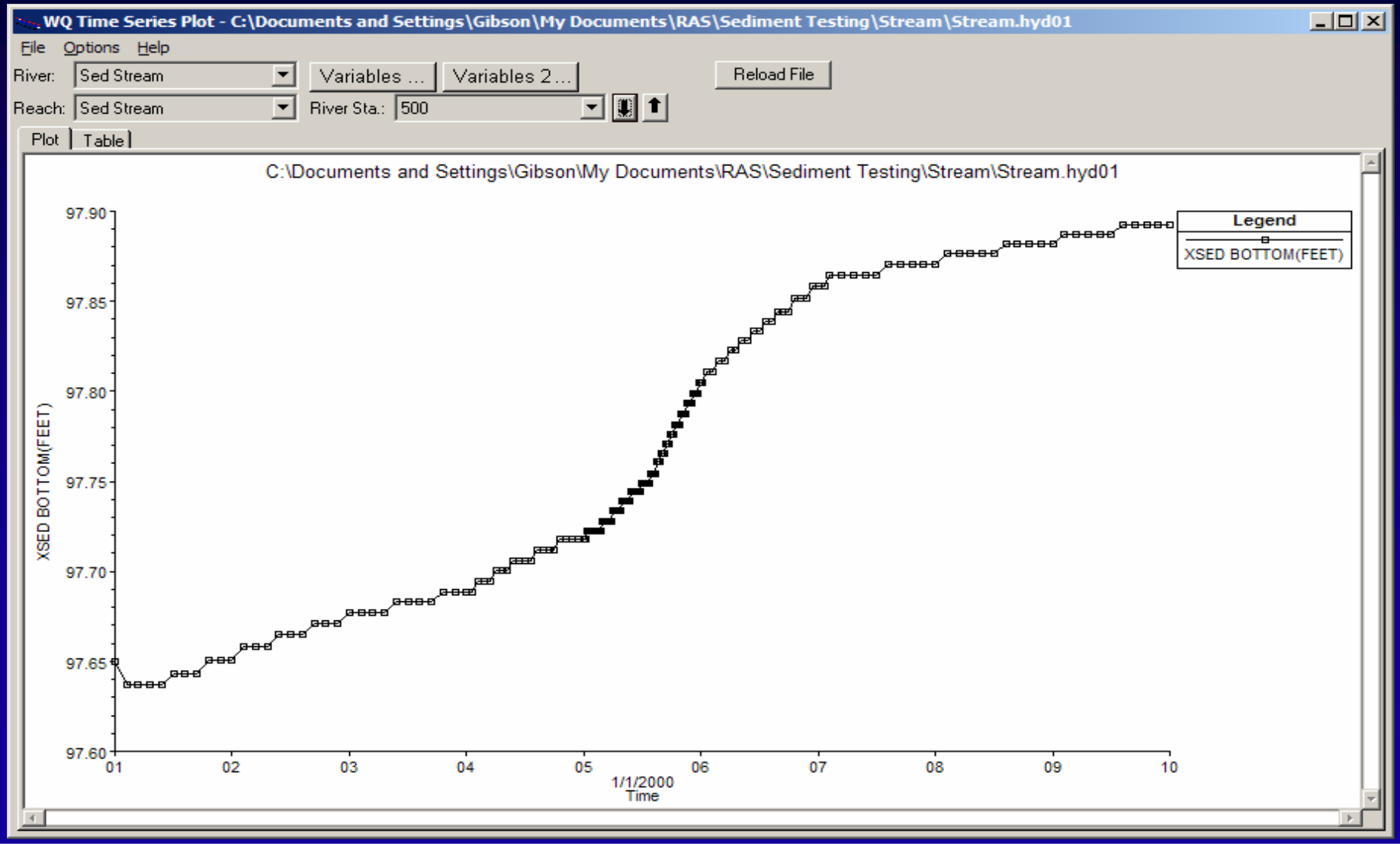
	River	Reach	RS	Invert	Max Depth	Min Elev	Sta Left	Sta Right	Bed Gradation
1	Mississippi	Kate Aubrey	806.6	182	10	0	900	5500	Gravel
2	Mississippi	Kate Aubrey	805.8*	174.6	10	0	1080	5740	Gravel
3	Mississippi	Kate Aubrey	805.*	167.2	10	0	1260	5980	Gravel
4	Mississippi	Kate Aubrey	804.2*	159.8	10	0	1440	6220	Gravel
5	Mississippi	Kate Aubrey	803.4*	152.4	10	0	1620	6460	Gravel
6	Mississippi	Kate Aubrey	802.6	145	10	0	1800	6700	Fine Sand
7	Mississippi	Kate Aubrey	801.771*	150.57	10	0	1757.14	6614.29	Fine Sand
8	Mississippi	Kate Aubrey	800.942*	156.14	10	0	1714.29	6528.57	Fine Sand
9	Mississippi	Kate Aubrey	800.114*	161.71	10	0	1671.43	6442.86	Fine Sand
10	Mississippi	Kate Aubrey	799.285*	167.29	10	0	1628.57	6357.14	Fine Sand
11	Mississippi	Kate Aubrey	798.457*	172.86	10	0	1585.71	6271.43	Fine Sand
12	Mississippi	Kate Aubrey	797.628*	178.43	10	0	1542.86	6185.71	Fine Sand
13	Mississippi	Kate Aubrey	796.8	184	10	0	1500	6100	Fine Sand
14	Mississippi	Kate Aubrey	795.887*	184.75	10	0	1537.5	6287.5	Fine Sand
15	Mississippi	Kate Aubrey	794.975*	185.5	10	0	1575	6475	Coarse Sand
16	Mississippi	Kate Aubrey	794.062*	186.25	10	0	1612.5	6662.5	Coarse Sand
17	Mississippi	Kate Aubrey	793.15*	187	10	0	1650	6850	Coarse Sand
18	Mississippi	Kate Aubrey	792.237*	187.75	10	0	1687.5	7037.5	Coarse Sand
19	Mississippi	Kate Aubrey	791.325*	188.5	10	0	1725	7225	Coarse Sand
20	Mississippi	Kate Aubrey	790.412*	189.25	10	0	1762.5	7412.5	Coarse Sand
21	Mississippi	Kate Aubrey	789.5	190	10	0	1800	7600	Coarse Sand
22	Mississippi	Kate Aubrey	788.716*	187.33	10	0	1983.33	7683.33	Coarse Sand
23	Mississippi	Kate Aubrey	787.933*	184.67	10	0	2166.67	7766.67	Coarse Sand
24	Mississippi	Kate Aubrey	787.15*	182	10	0	2350	7850	Coarse Sand
25	Mississippi	Kate Aubrey	786.366*	179.33	10	0	2533.33	7933.33	Fine Sand
26	Mississippi	Kate Aubrey	785.583*	176.67	10	0	2716.67	8016.67	Fine Sand
27	Mississippi	Kate Aubrey	784.8	174	10	0	2900	8100	Fine Sand
28	Mississippi	Kate Aubrey	784.04*	173.8	10	0	2780	7800	Fine Sand
29	Mississippi	Kate Aubrey	783.28*	173.6	10	0	2660	7500	Fine Sand

Simple Transport Example




01Jan2000 09:36:00
Sed Stream-Sed Stream
Legend
5 01Jan2000 09:36:00-XSED BOTTOM(FEET)
5 01Jan2000 09:36:00-WSEL(FEET)
XSED BOTTOM(FEET),WSEL(FEET)
106
104
102
100
98
96
94
92
0
200
400
600
800
1000
Main Channel Distance (ft)

Time Series of Bed Elevation at a Single XS

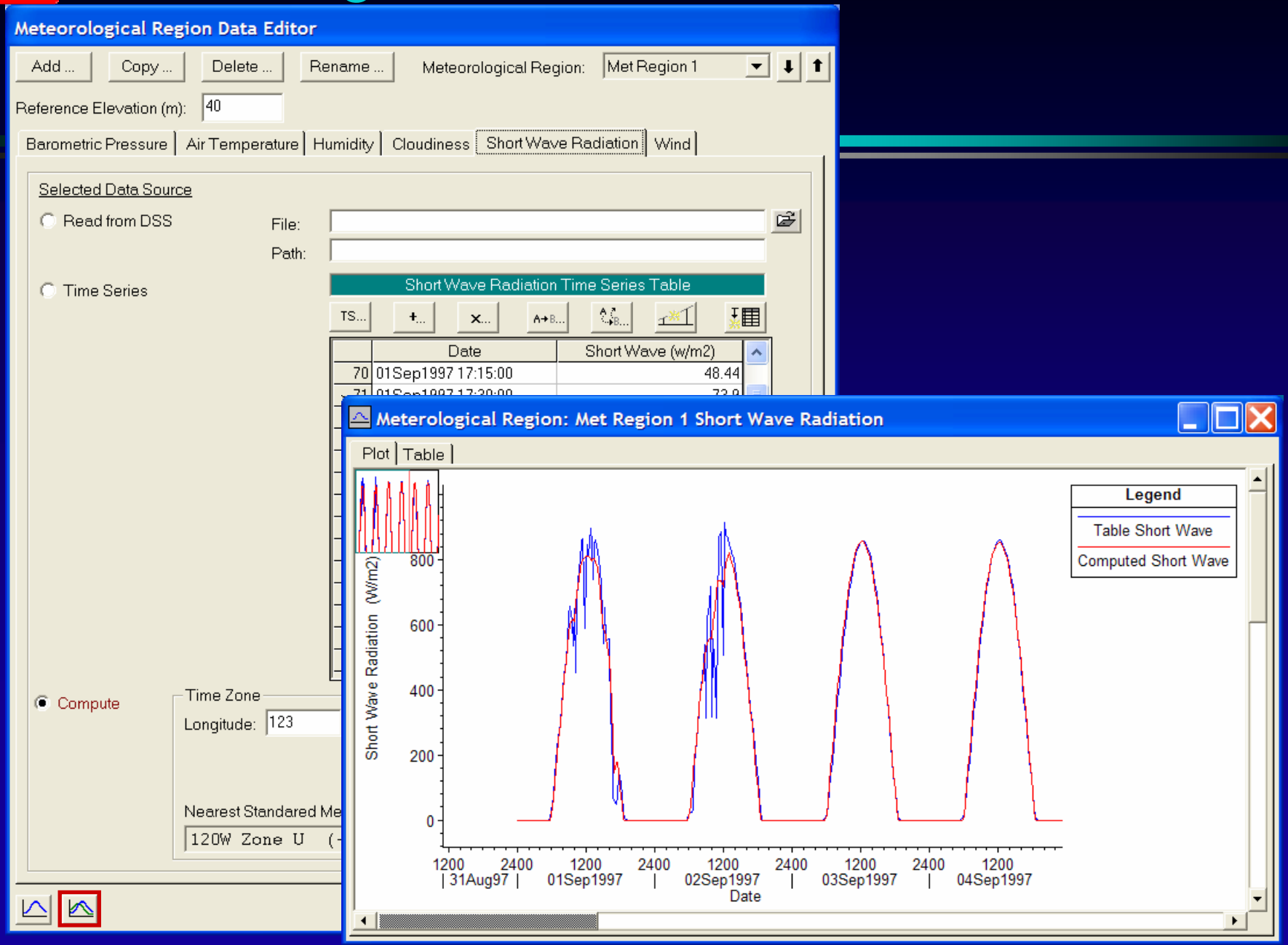


Water Quality

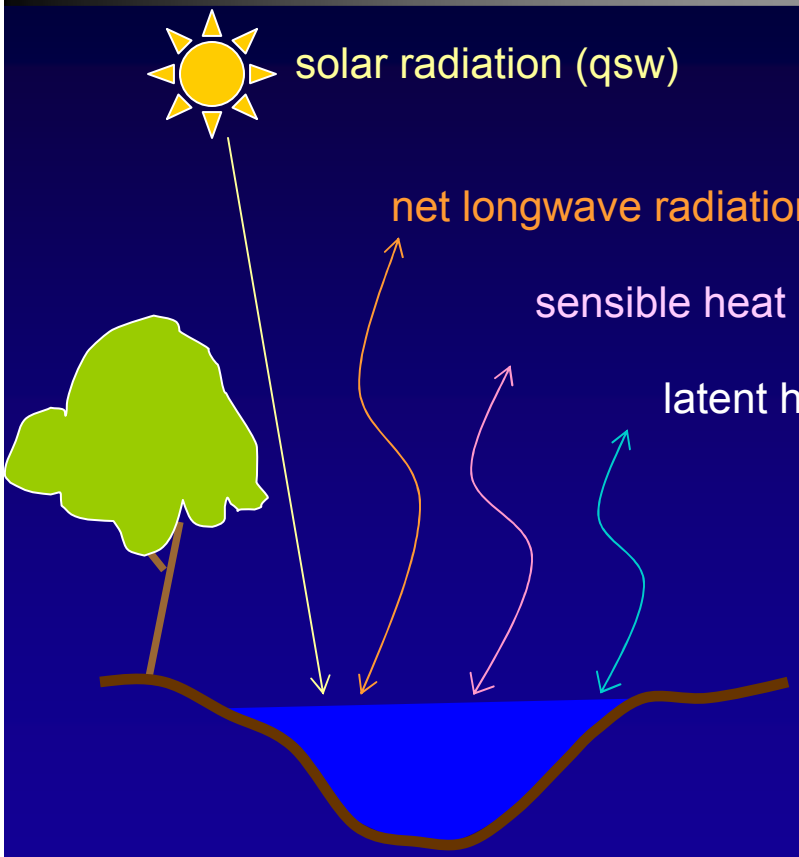
Water Quality (Temperature) Model

- Based on unreleased version of CE-QUAL-RIV1
- QUICKEST-ULTIMATE numerical scheme
  - Finite Volume
  - Variable grid size
  - Automatic time step selection
- Full energy budget for Temperature
- Working with ERDC to use a common Nutrient Model

Meteorological Data Editor – Solar Radiation



Source/Sink Term for Temperature (Energy Budget)



solar radiation (qsw) — f (site location, time of day, day of year, atmospheric turbidity, cloud cover)

net longwave radiation (qlw) — f (air temperature, water temperature)

sensible heat (qh) — f (temperature gradient, wind, a&b)

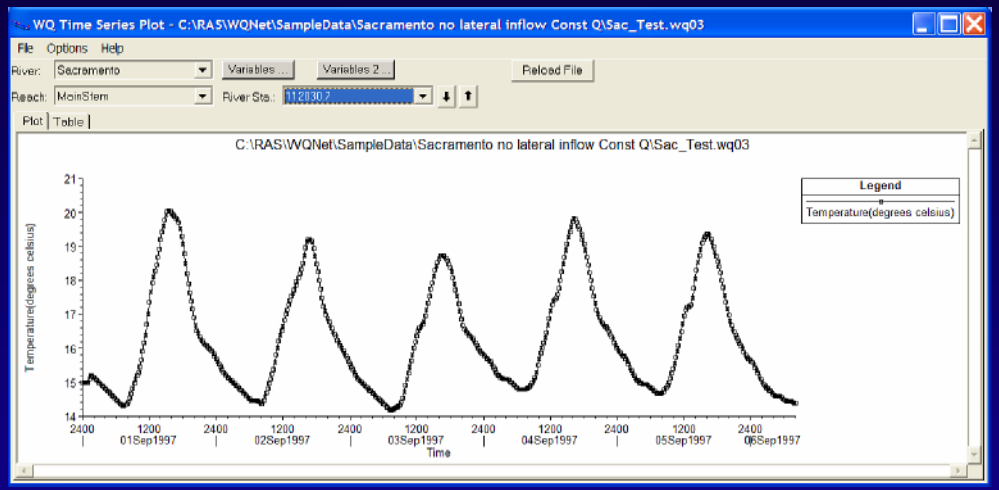
latent heat (qe) — f (vapor pressure gradient, wind, a&b)

$$q_{net} = q_{sw} + q_{lwn} + q_h + q_e$$

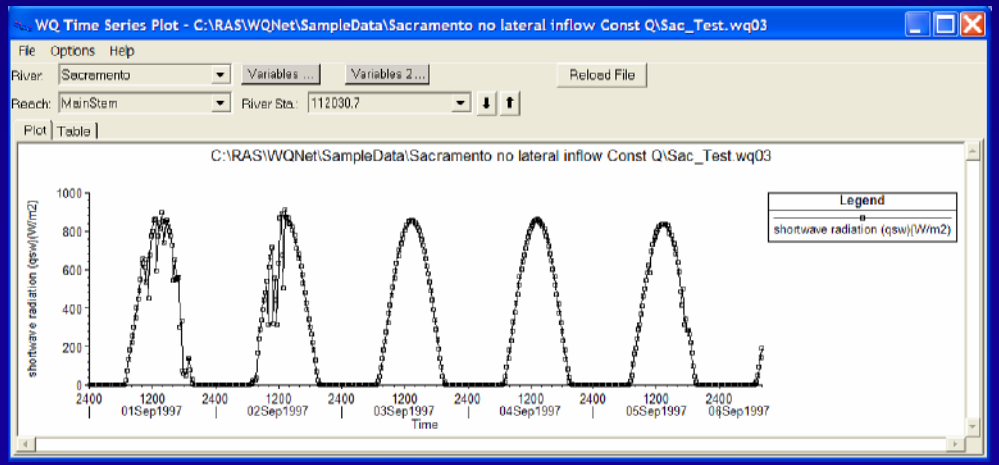
Planned:

- ground heat conduction
- shading (topographic, riparian)

Time Series Plots

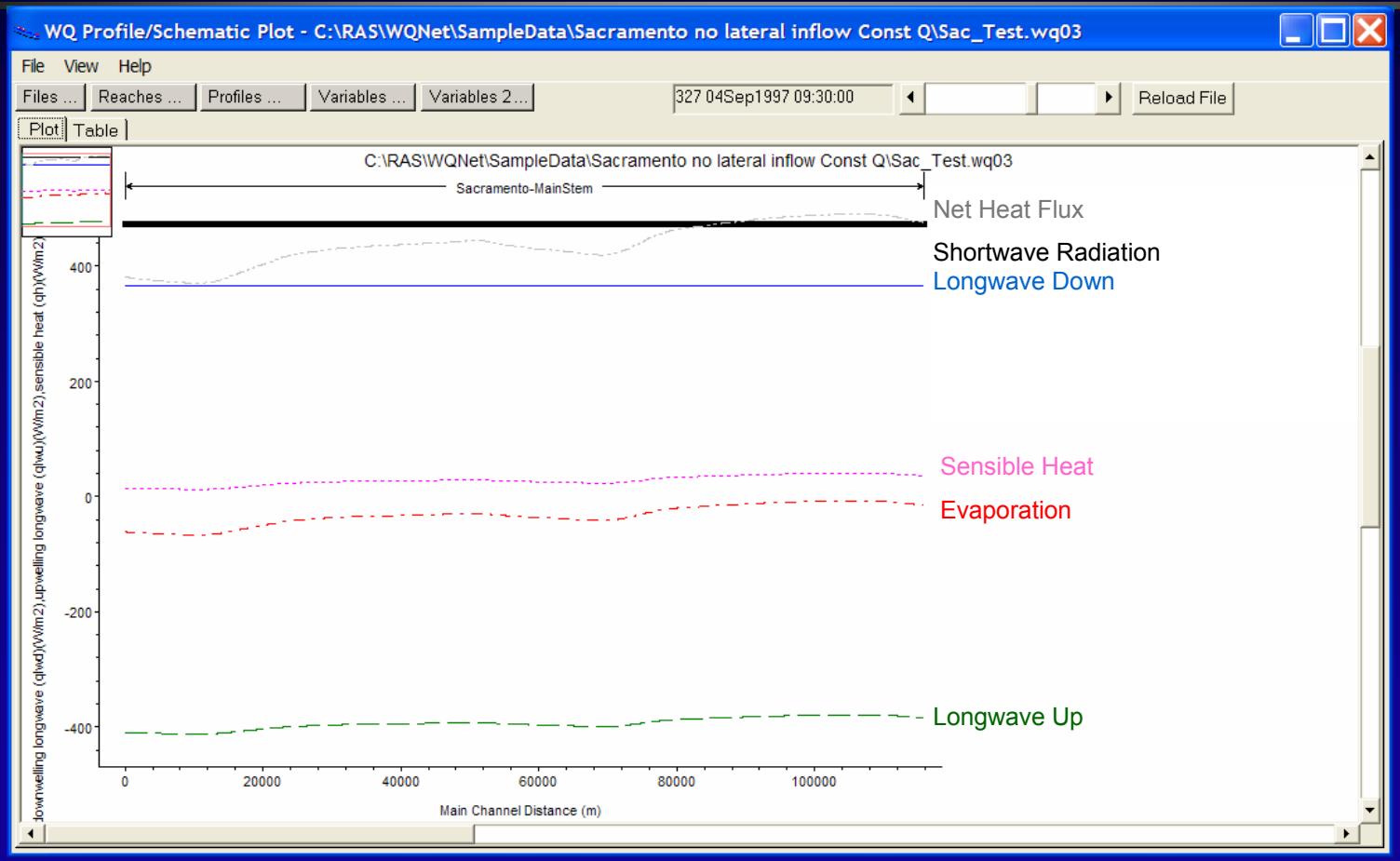


Water temperature



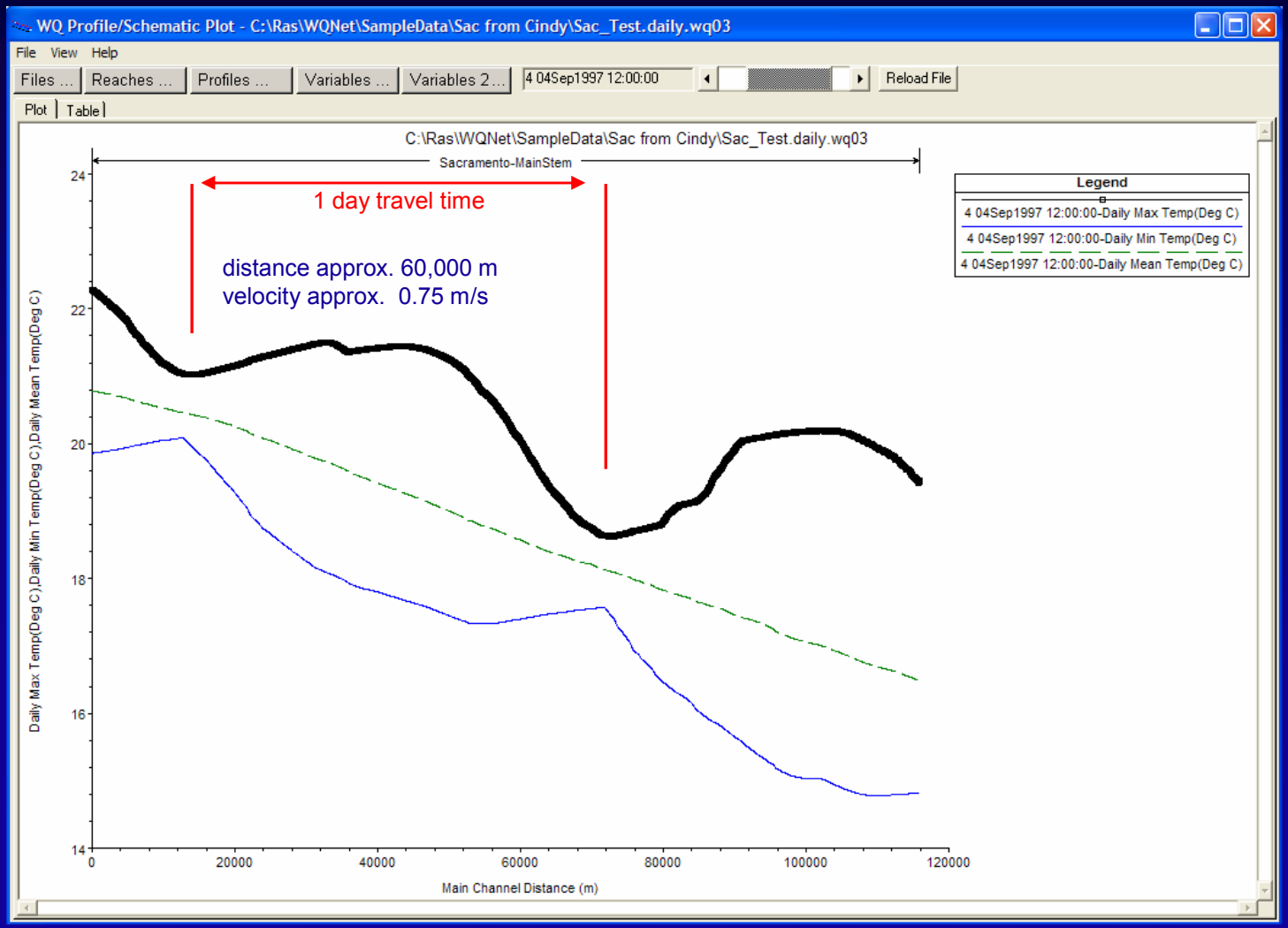
Solar Radiation

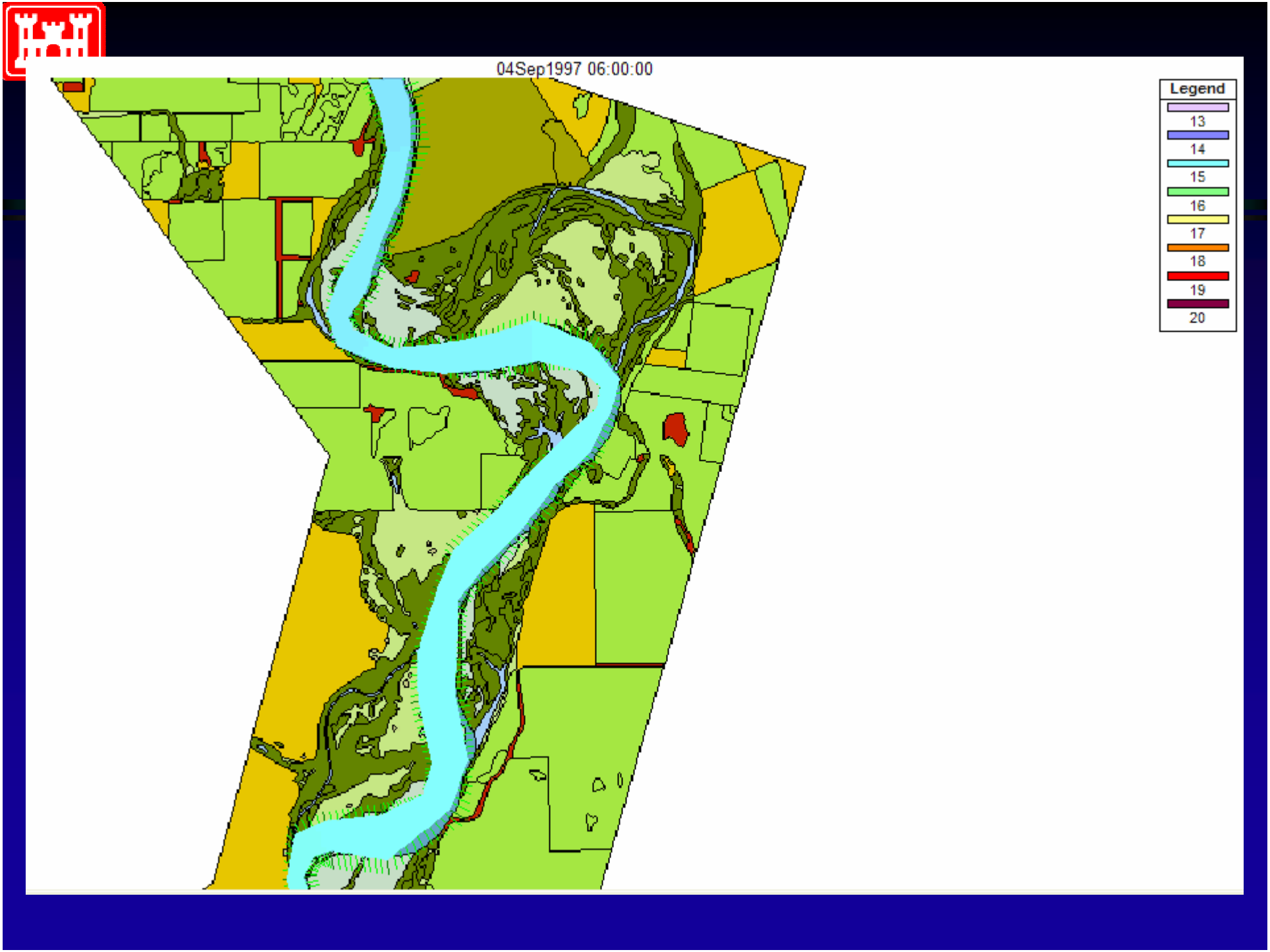
Plot of Energy Budget Terms



Component Outputs can be Viewed Separately

Profile Plot of Temperature




04Sep1997 06:00:00
Legend
13
14
15
16
17
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19
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