LECTURE #12

INSTREAM WATER QUALITY – TEMPERATURE, SEDIMENT, & GENERAL CONSTITUENT

RCHRES STRUCTURE CHART

RCHRES
Simulate a reach or mixed reservoir

HYDR
Simulate hydraulic behavior

ADCALC
Estimate advective behavior of constituents

CONS
Simulate conservative constituents

HTRCH
Simulate heat exchange & water temperature

SEDTRN
Simulate inorganic sediment

GQUAL
Simulate generalized quality constituents

RQUAL
Simulate constituents involved in biochemical transformations

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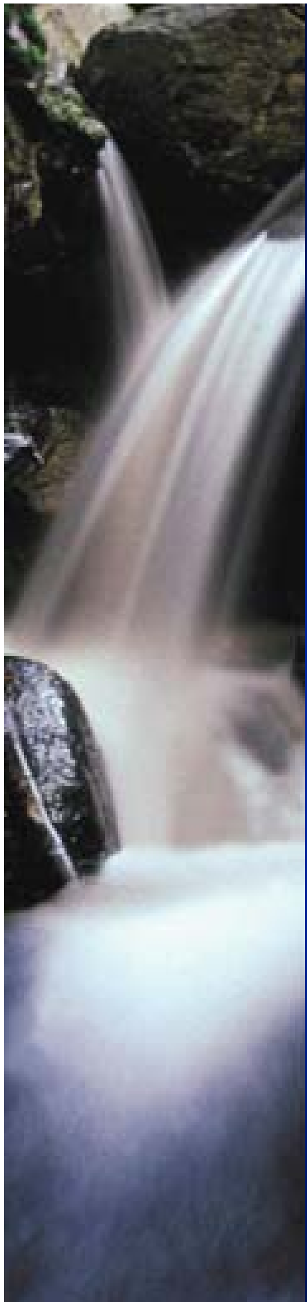
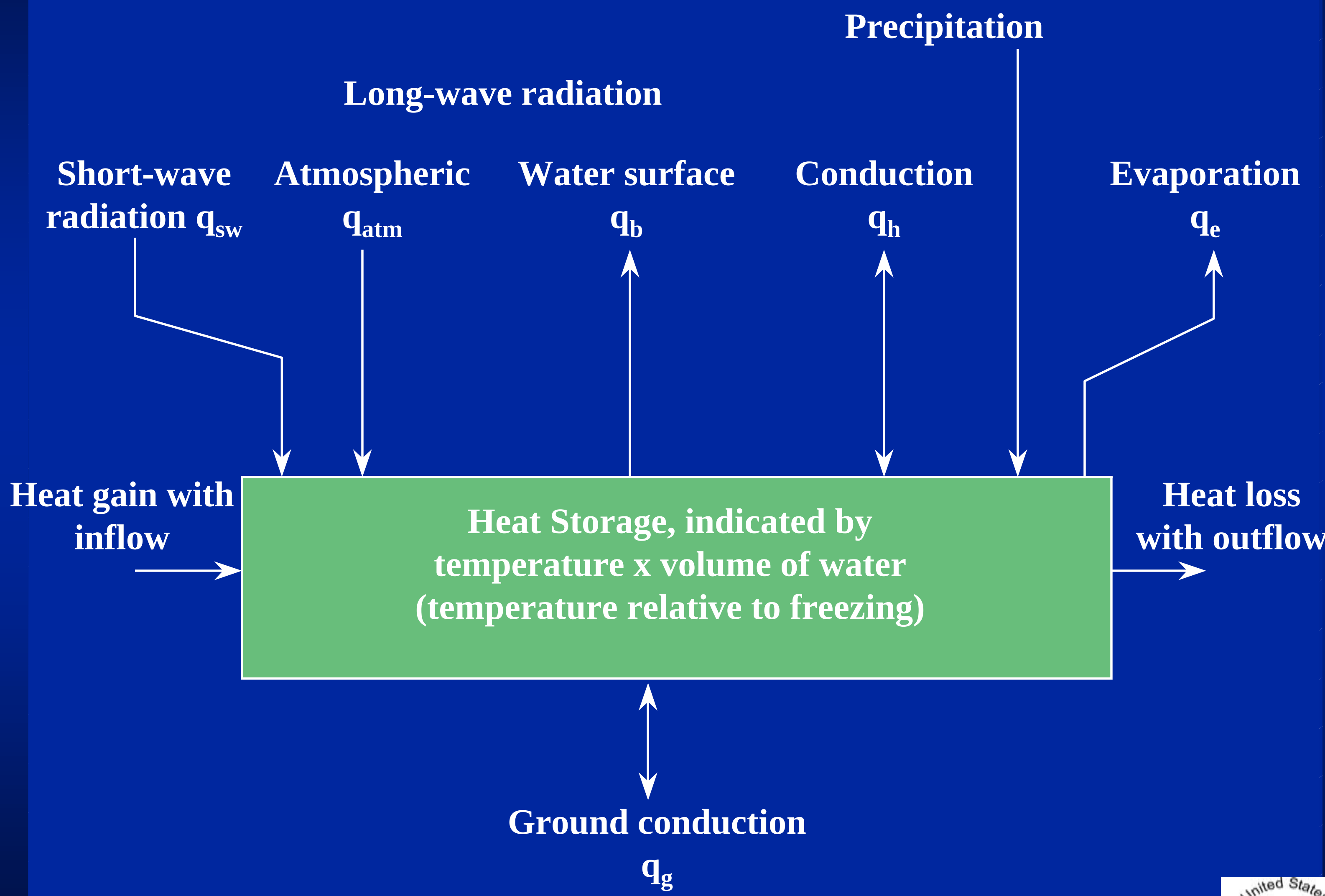
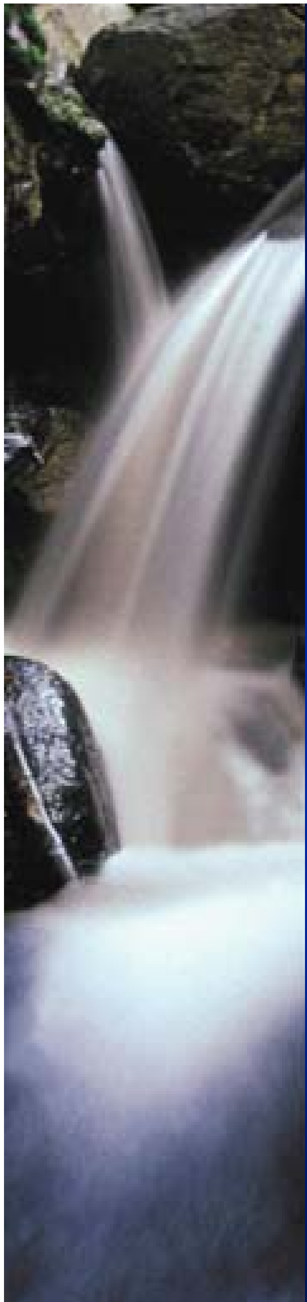
WATER TEMPERATURE (HTRCH)

- Temperature is a critical habitat characteristic for fish and other organisms
- Temperature affects rates of other water quality processes
- Dissolved oxygen concentrations are dependent on temperature



HEAT EXCHANGE PROCESSES





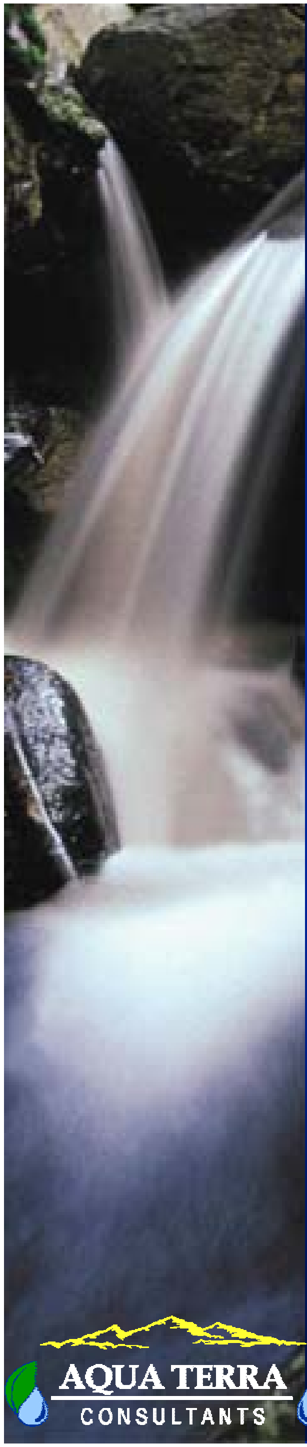
WATER TEMPERATURE - ENERGY BALANCE

$$q_{total} = q_{sw} + q_{atm} + q_b + q_h + q_e + q_g$$

	Component	Key parameters and inputs
q_{sw}	Short-wave radiation	Solar radiation*, shading factor
q_{atm}	Long-wave radiation (atmospheric)	Cloud cover*, air temperature,* LW radiation coefficient
q_b	Long-wave radiation (back)	
q_h	Conduction/convection	Air temperature*, wind speed*, Heat transport coefficient
q_e	Evaporation	Dewpoint*, air temperature*, wind speed*, evaporation coefficient
q_g	Ground conduction (optional)	Ground temperature, conduction coefficients

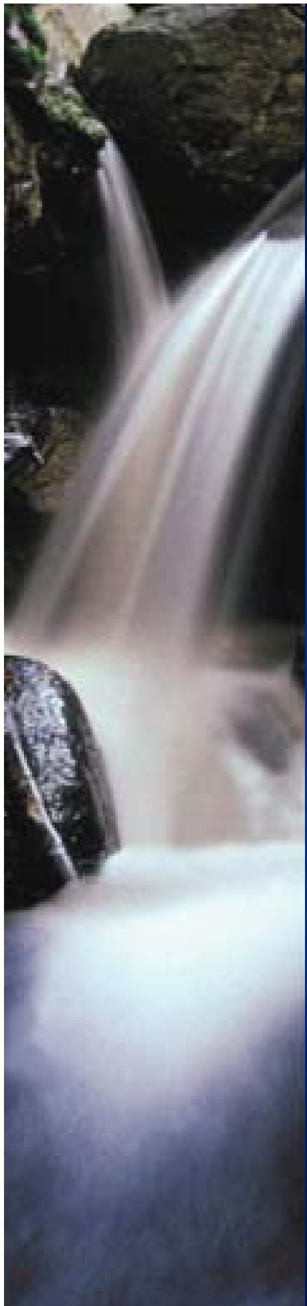
Note: Air temperature is corrected for elevation

*Time series input



DATA REQUIRED FOR WATER TEMPERATURE

- Meteorologic data
  - solar radiation
  - air temperature
  - wind speed
  - cloud cover
  - dewpoint temperature
- Surface area of water exposed to radiation (shade)
- Boundary conditions – inflow/outflow rates and temperatures
- Measured water temperatures for model calibration



WATER TEMPERATURE CALIBRATION

- Calibration parameters:
  - **CFSAEX** - fraction of water surface exposed to solar radiation
  - **KATRAD** - atmospheric long-wave radiation coefficient (~ 9)
  - **KCOND** - conduction coefficient (1 – 20)
  - **KEVAP** - evaporation coefficient (1 – 5)
  - **KMUD** - water-bed sediment heat conduction coefficient
  - **KGRND** - ground-bed sediment heat conduction coefficient in two-interface method
  - **MUDDEP** – depth of mud/bed sediment in two-interface method
  - **TGRND** – ground temperature
    - inflow temperature (heat loading from land)

- Inspect hourly simulation results to verify that diurnal variation is reasonable and stable

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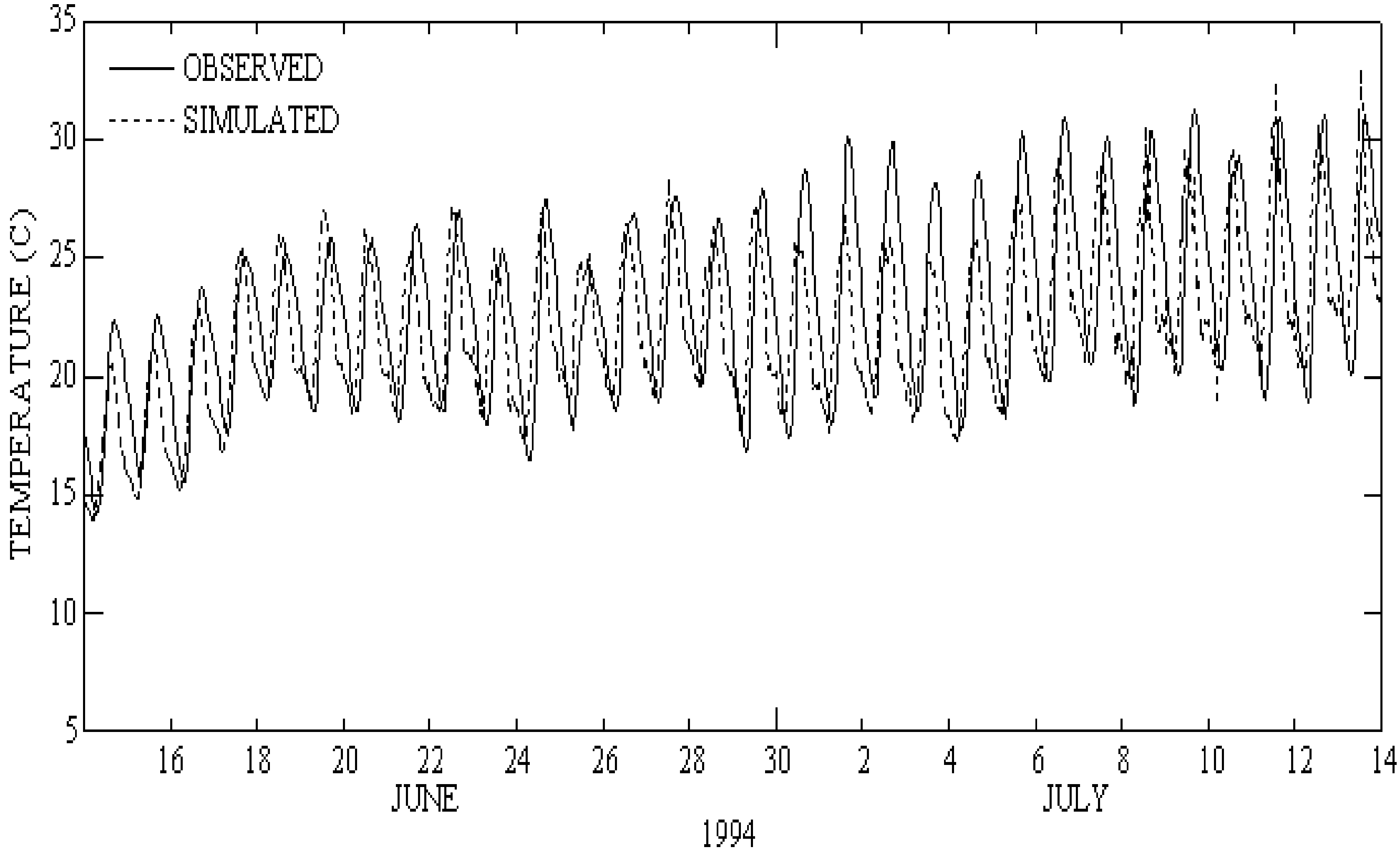
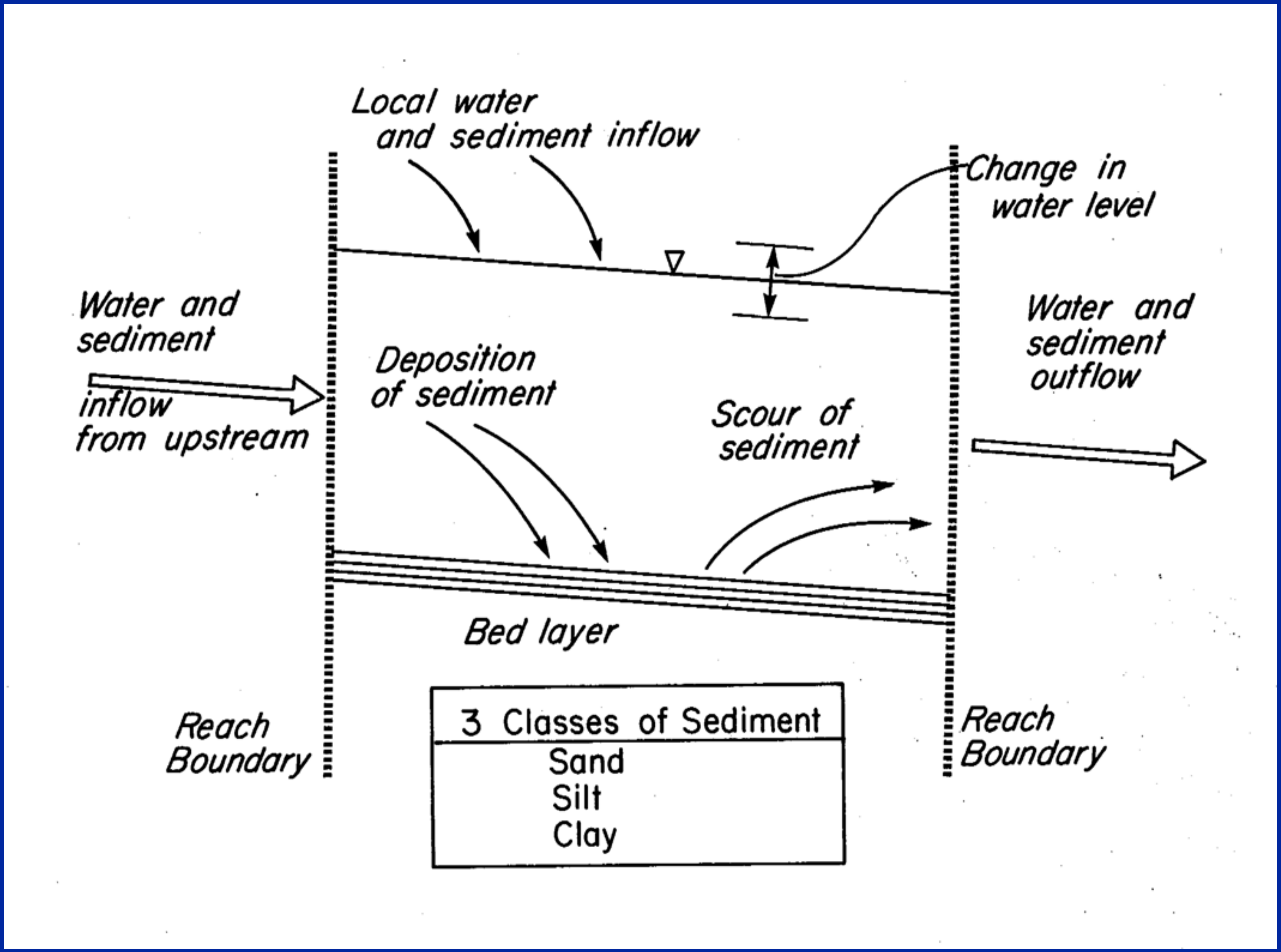
TRUCKEE RIVER – WATER TEMPERATURE



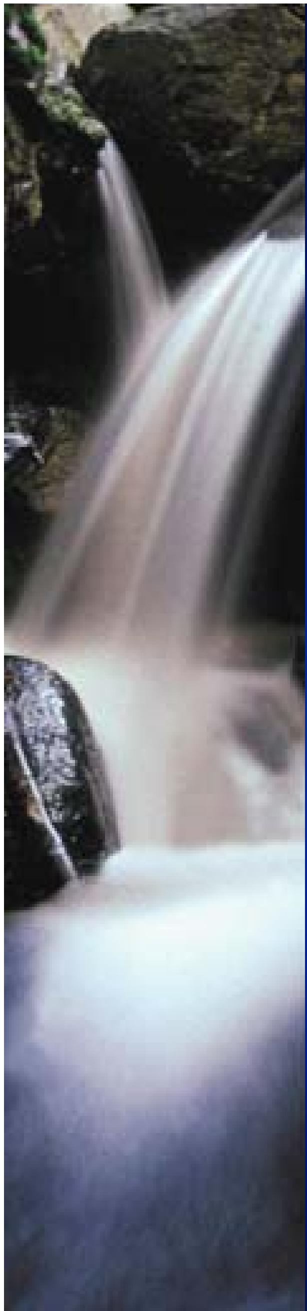
TRUCKEE RIVER WATER TEMPERATURE

SEDIMENT PROCESSES IN WATERBODIES



SEDIMENT TRANSPORT SIMULATION

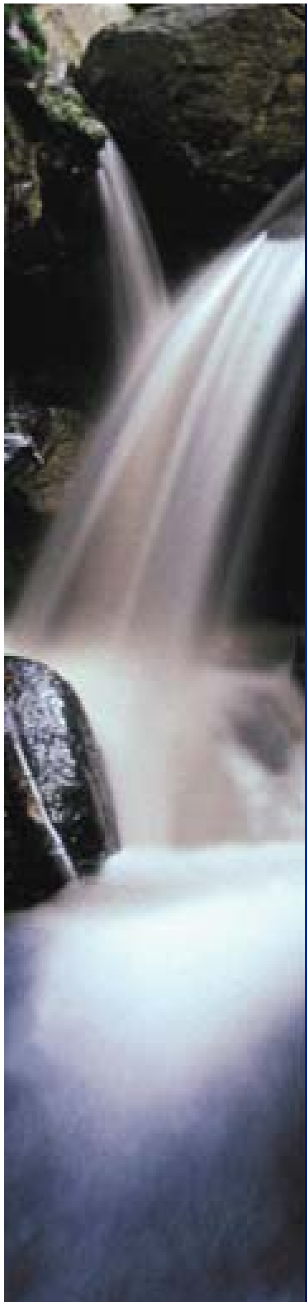
- **Sand, silt and clay fractions**
- **Advection, deposition and scour**
- **Completely-mixed (CSTR) water column and bed compartments**
- **Sand transport - three options**
  - **Toffaleti method**
  - **Colby method**
  - **Power function**
- **Cohesive (silt, clay) deposition and scour based on shear stress calculations (Krone and Partheniades)**
- **Scour and deposition does not affect hydraulic properties**
- **Reach-dependent parameters**
- **No lateral movement of bed materials between reaches**
- **Sediment inflows from land surface are divided into (constant) sand, silt and clay fractions**



SAND TRANSPORT SIMULATION: TOFFALETI METHOD

Toffalleti method (SANDFG = 1)

- Four depth zones
- Velocity and relative concentration profiles assumed
- Temperature correction
- Sand transport capacity calculated for each zone; scour occurs if sand concentration is less than capacity; otherwise deposition occurs
- Inputs/parameters: water temperature, particle diameter, settling velocity, slope

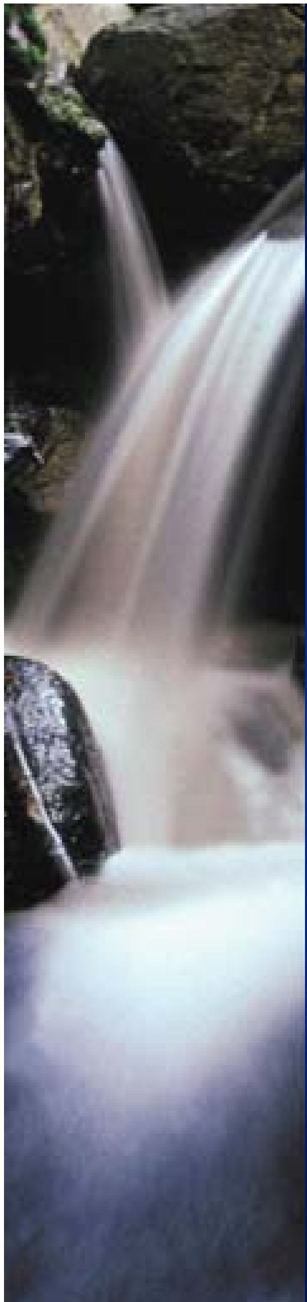


SAND TRANSPORT SIMULATION: COLBY METHOD

Colby method (SANDFG = 2)

- Empirical relationships
- Sand transport capacity estimated from nomograph as a function of hydraulic radius, flow velocity, and sediment diameter
- Transport corrected for water temperature and fine sediment concentration
- Acceptable parameter ranges:

Median bed sediment diameter	0.1 - 0.8 mm.
Hydraulic radius	0.1 - 100 ft.
Mean stream velocity	1.0 - 10.0 ft/sec



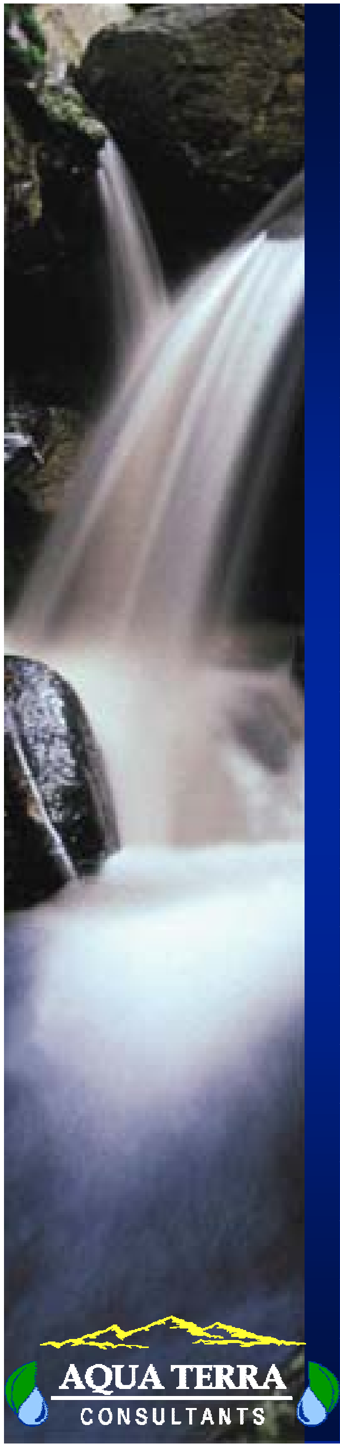
SAND TRANSPORT SIMULATION: POWER FUNCTION METHOD

Power function equation (SANDFG = 3)

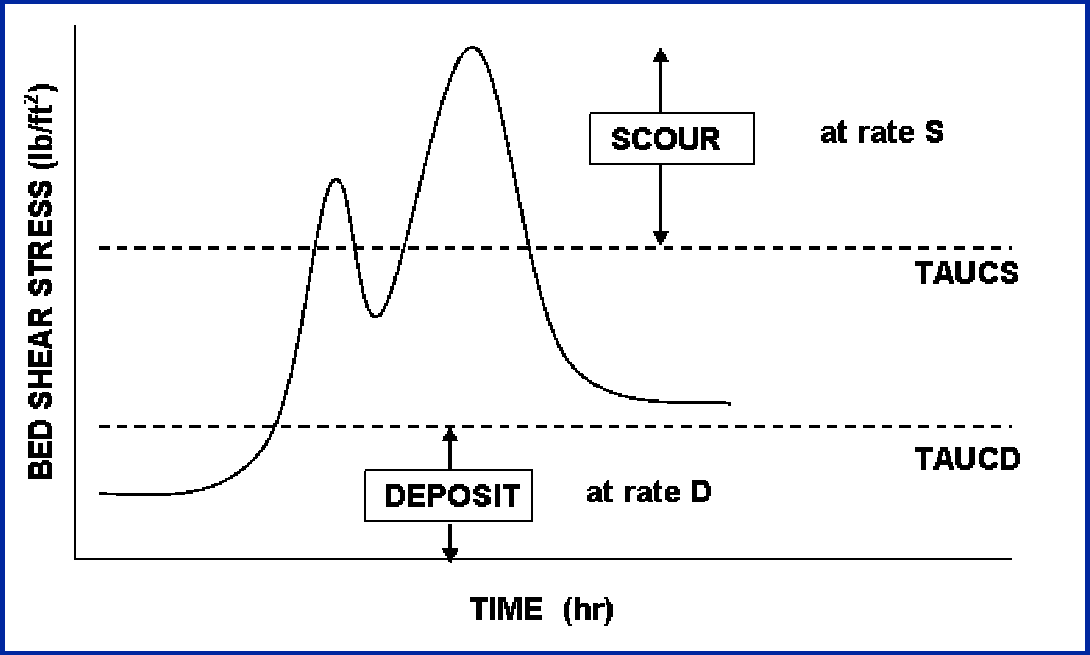
$$PSAND = (KSAND)*(AVVEL)^{EXPSND}$$

Where:

- **PSAND** = potential sand concentration
- **KSAND** = coefficient (input parameter)
- **AVVEL** = average stream velocity
- **EXPSND** = exponent (input parameter)



SCOUR/DEPOSITION FOR COHESIVE SEDIMENTS (SILT & CLAY)



Scour rate: S = **M** * (TAU/**TAUCS** – 1.0)

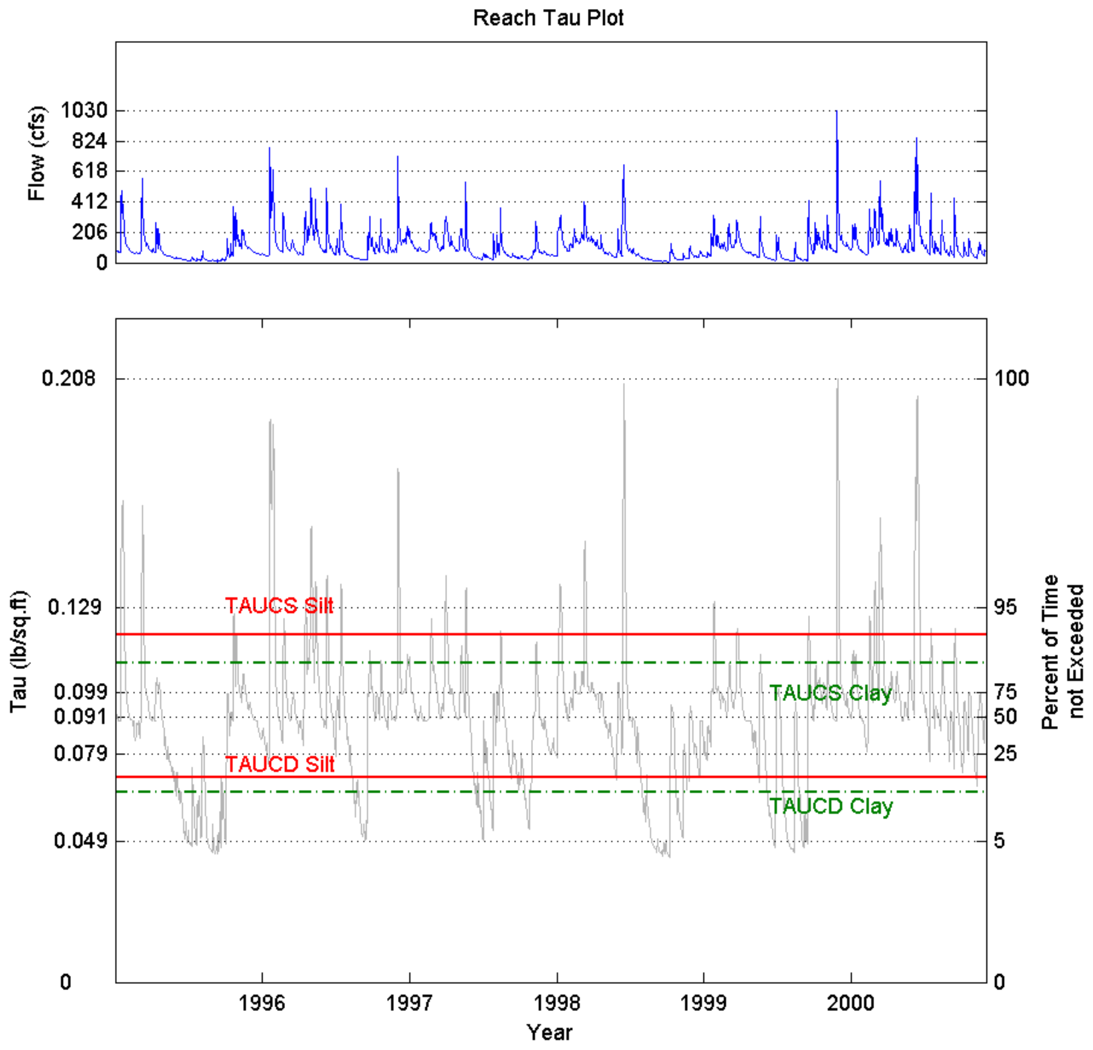
Deposition rate: D = **W** * CONC * (1.0 – TAU/**TAUCD**)

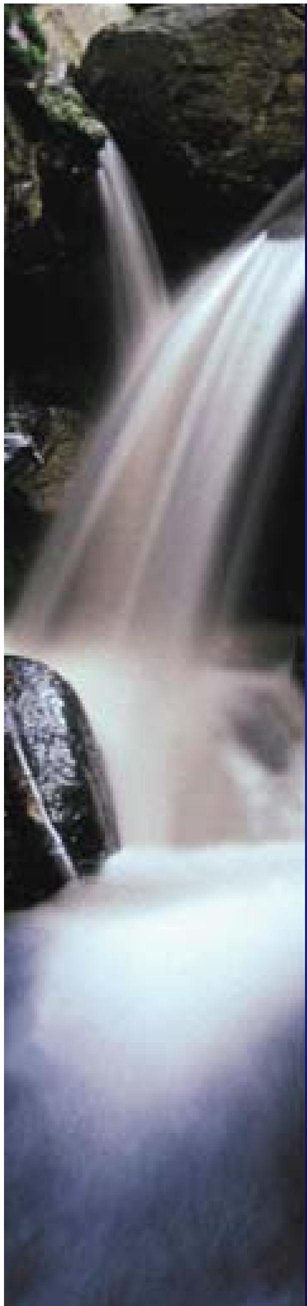
Shear stress: TAU = SLOPE * GAM * HRAD

Where

- **M** = erodibility coefficient ($lb/ft^2/hr$)
- **W** = particle fall velocity in still water (ft/hr)
- **TAUCS** = critical shear stress for scour (lb/ft^2)
- **TAUCD** = critical shear stress for deposition (lb/ft^2)
- CONC = concentration of sediment (lb/ft^3)
- GAM = density of water (lb/ft^3)
- HRAD = hydraulic radius (ft)

TAU PLOT


Reach Tau Plot
Flow (cfs)
1030
824
618
412
206
0
0.208
0.129
0.099
0.091
0.079
0.049
0
Tau (lb/sq.ft)
100
95
75
50
25
5
0
Percent of Time not Exceeded
TAUCS Silt
TAUCS Clay
TAUCD Silt
TAUCD Clay
1996
1997
1998
1999
2000
Year



SEDIMENT TRANSPORT PARAMETERS

General and hydraulic information

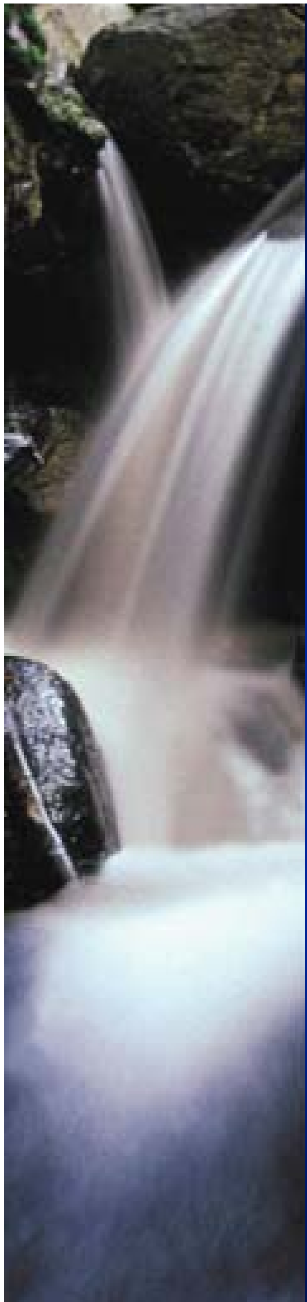
BEDWID - Width of stream cross-section where deposition occurs
BEDWRN - When bed depth exceeds this value, a warning message is printed
POR - Bed porosity – used for calculating bed depth
LEN - Length of reach
DELTH - Drop in water surface elevation over reach length
DB50 - Median diameter of bed sediment

Sand parameters

D - Effective particle diameter
W - Particle fall velocity
RHO - Particle density
KSAND - Coefficient in sand transport power function equation
EXPSND - Exponent in sand transport power function equation

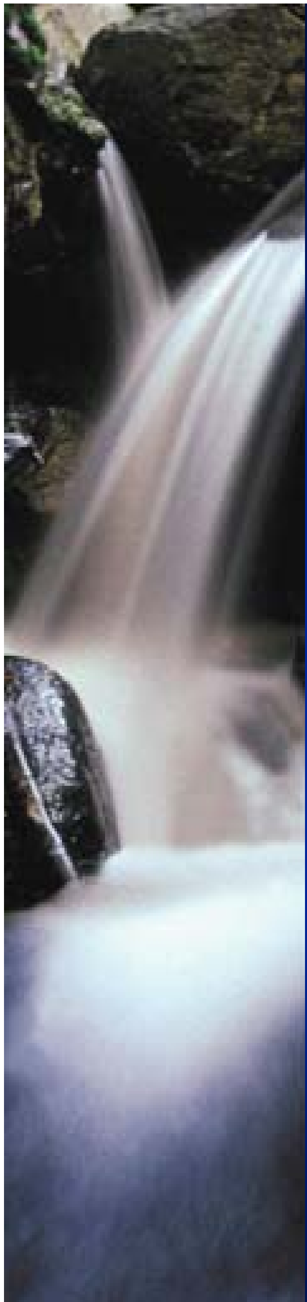
Silt & Clay parameters

D - Effective particle diameter
W - Particle fall velocity
RHO - Particle density
TAUCD - Critical bed shear stress for deposition
TAUCS - Critical bed shear stress for scour
M - Scour/erodibility coefficient

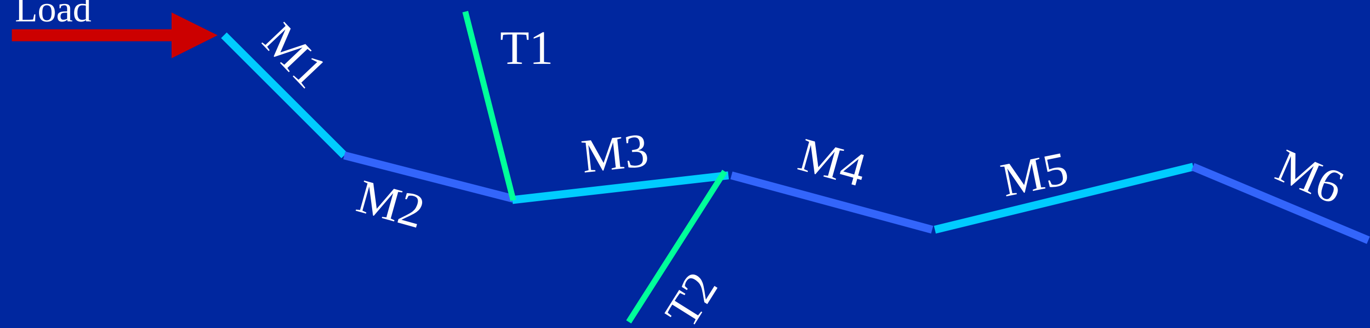


SEDIMENT TRANSPORT CALIBRATION

- **Estimate initial parameter values for cohesive (silt, clay) and sand sediment fractions**
- **Make calibration run and output shear stress (TAU) values (max and min daily) for each reach**
- **Perform sediment mass balance to determine land surface versus stream channel contributions**
- **Evaluate sediment load simulation for both mass outflow and composition compared to available data**
- **Adjust TAUCS and TAUCD to cause scour and deposition of cohesive sediments at appropriate times**
- **Adjust erodibility (M) to improve calibration of cohesive sediments for storms with good flow simulation**
- **Adjust sand parameters based on bed and load composition compared to available data**
- **Re-do calibration run and output analyses**



TABULATION OF STREAM SEDIMENT FLUXES AND BEHAVIOR FOR REVIEW



Reach Segment	Nonpoint (tons)	Point Source (tons)	Upstream In (tons)	Total Inflow (tons)	Outflow (tons)	Deposit (+) Scour (-) (tons)	Cumulative Point/NonPt (tons)	Cumulative Trapping Efficiency (%)	Reach Trapping Efficiency (%)
Mainstem 1	212.5	107.4	6,453.7	6,785.3	6,186.3	599.7	10,566.9	41.5	8.8
Mainstem 2	68.8	0.0	6,186.3	6,255.0	5,384.8	870.6	10,635.7	49.4	13.9
Tributary 1	102.4	0.0	0.0	102.2	125.0	-22.7	102.2	-22.0	-22.0
Mainstem 3	5.8	0.0	5,509.8	5,515.6	4,916.3	599.9	10,744.0	54.2	10.9
Tributary 2	281.1	0.0	0.0	280.5	352.6	-72.1	280.5	-25.5	-25.5
Mainstem 4	215.4	0.0	5,268.9	5,483.9	4,269.8	1,215.1	11,240.4	62.0	22.1
Mainstem 5	54.1	0.0	4,269.8	4,323.8	3,507.1	826.2	11,294.5	68.9	18.9
Mainstem 6	93.9	0.0	3,507.1	3,600.8	2,190.8	1,421.3	11,388.4	80.8	39.2

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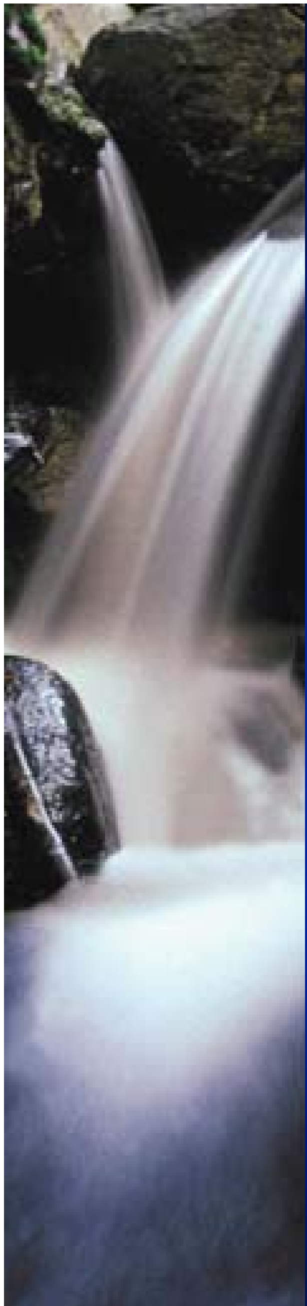
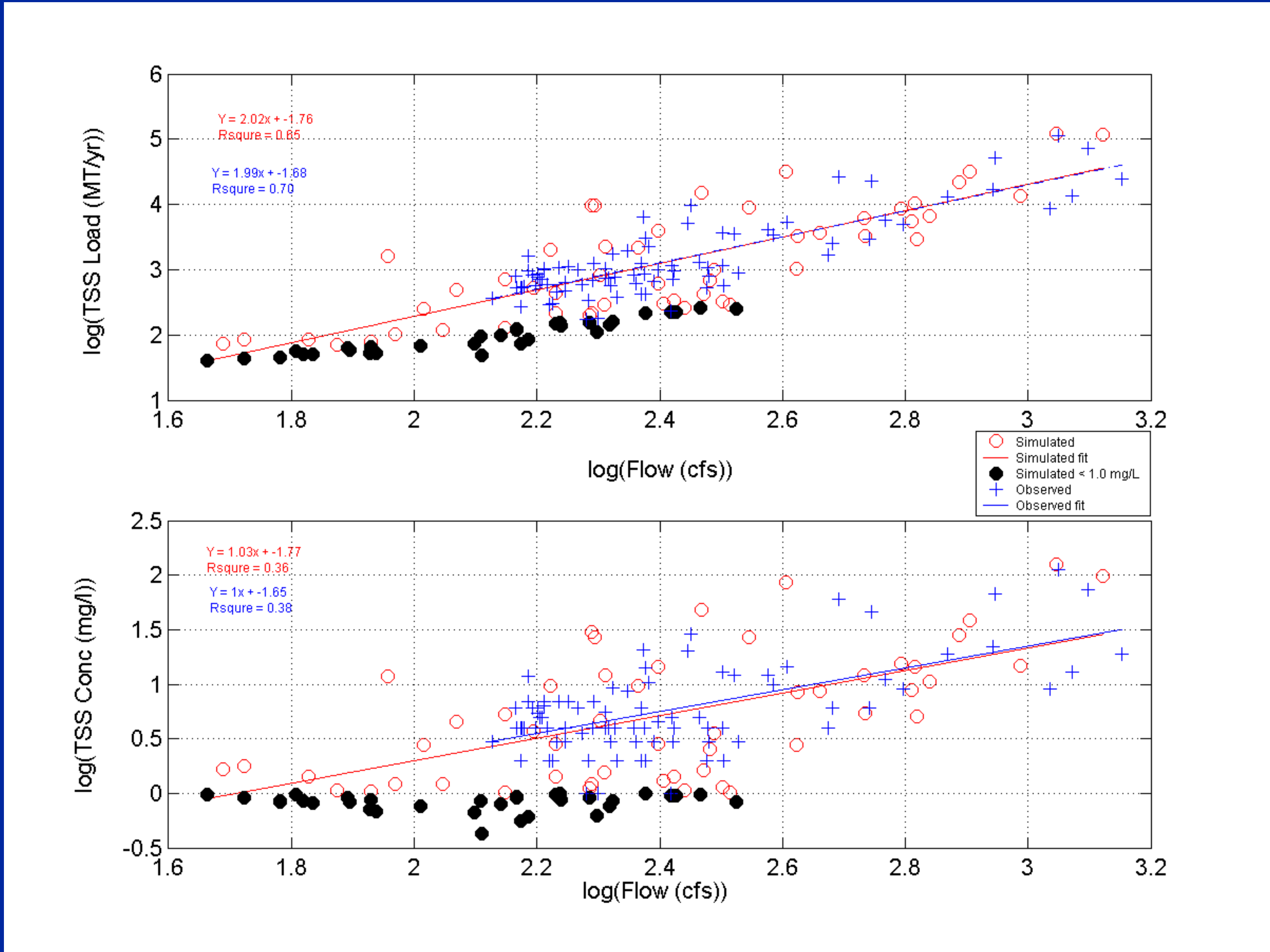
OBSERVED AND SIMULATED RATING CURVES





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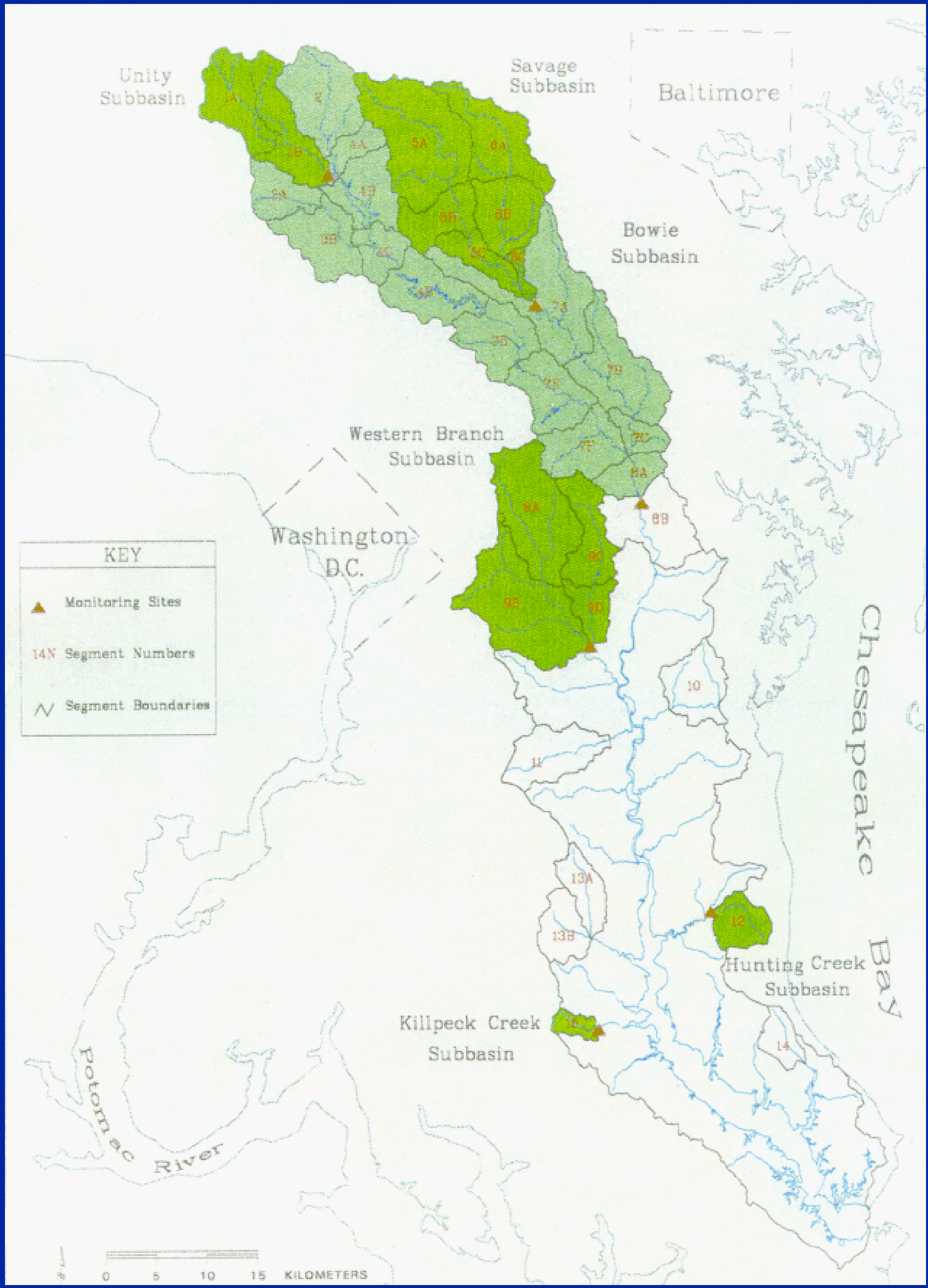
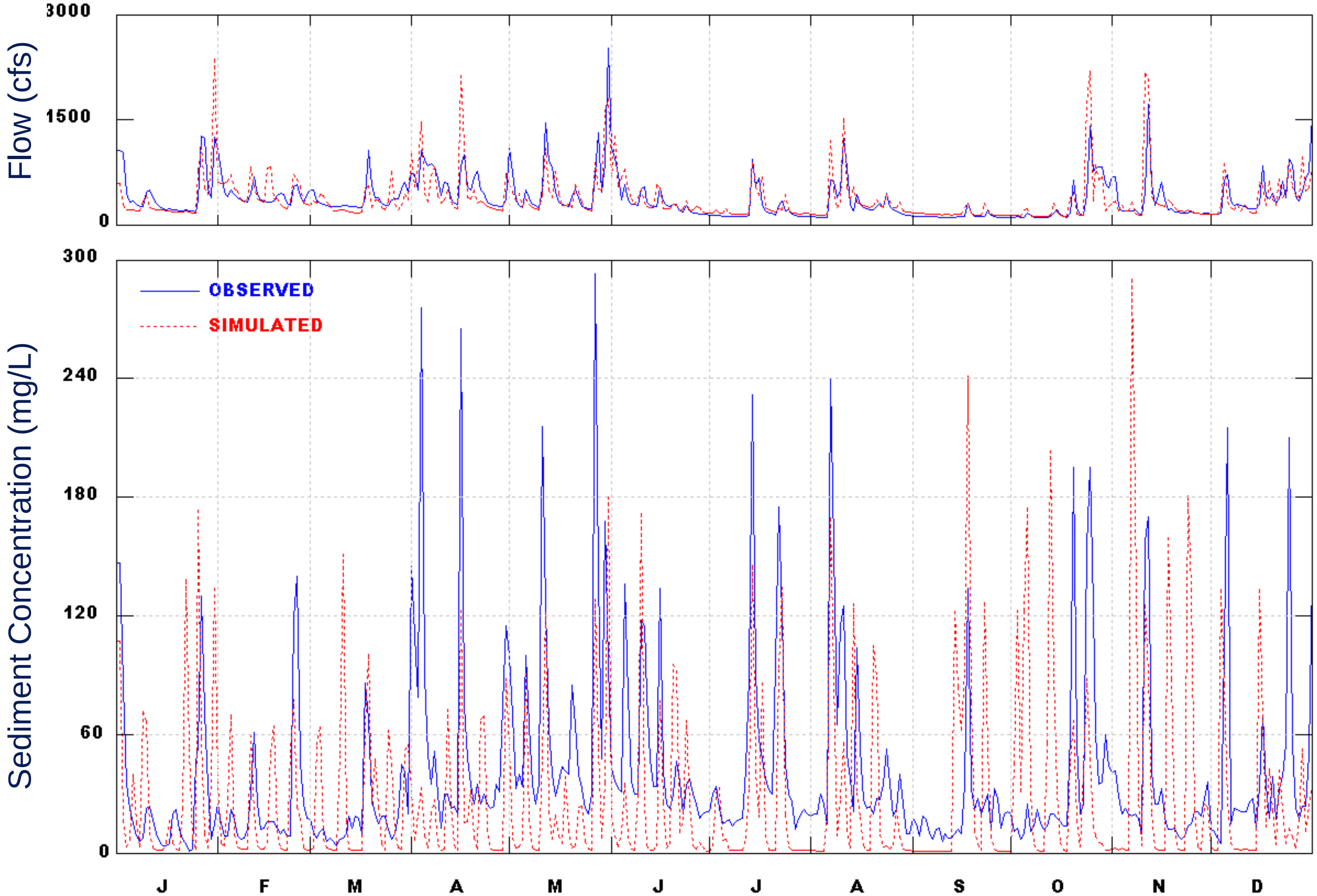
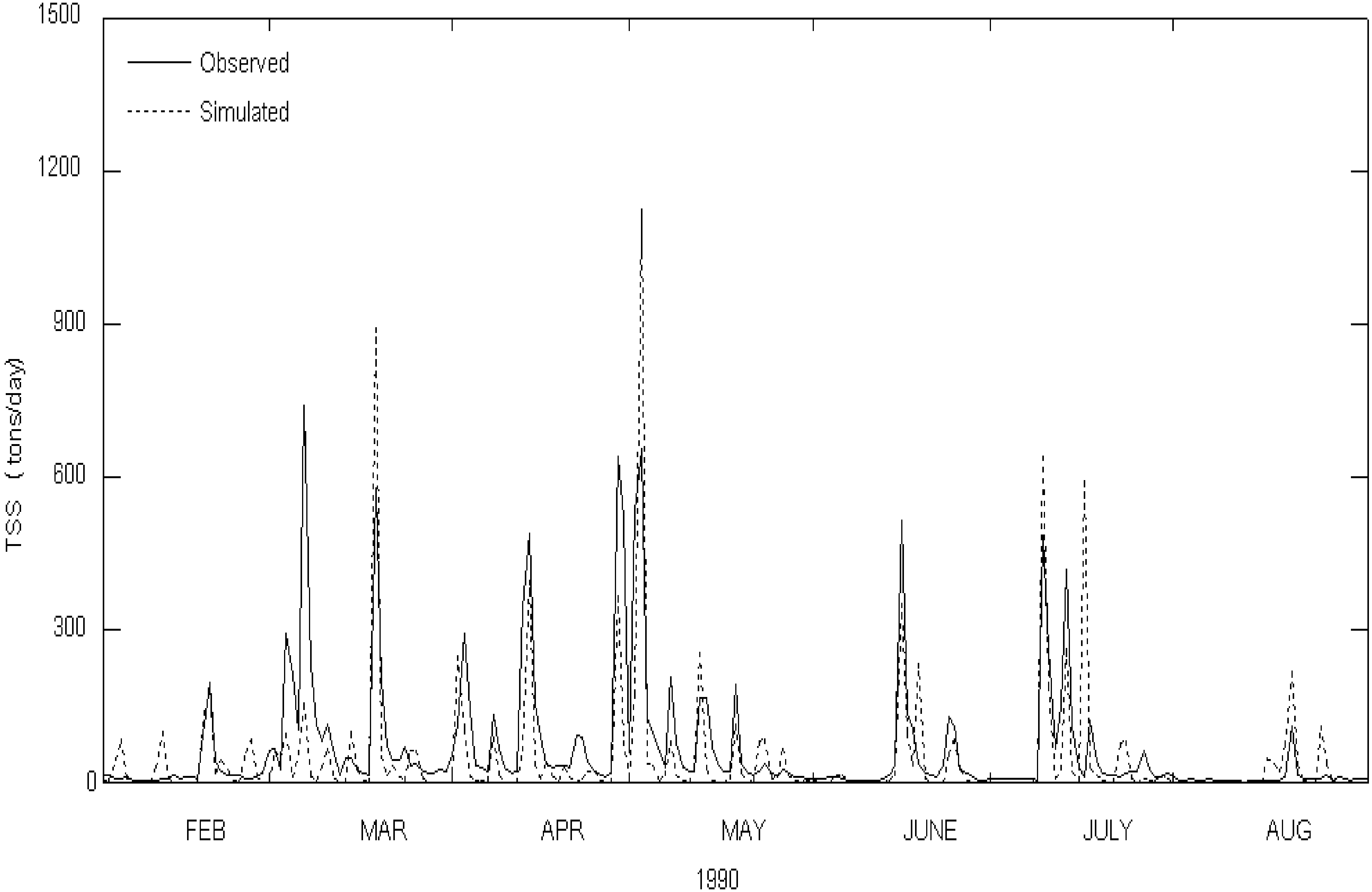
PATUXENT RIVER BASIN (MD)



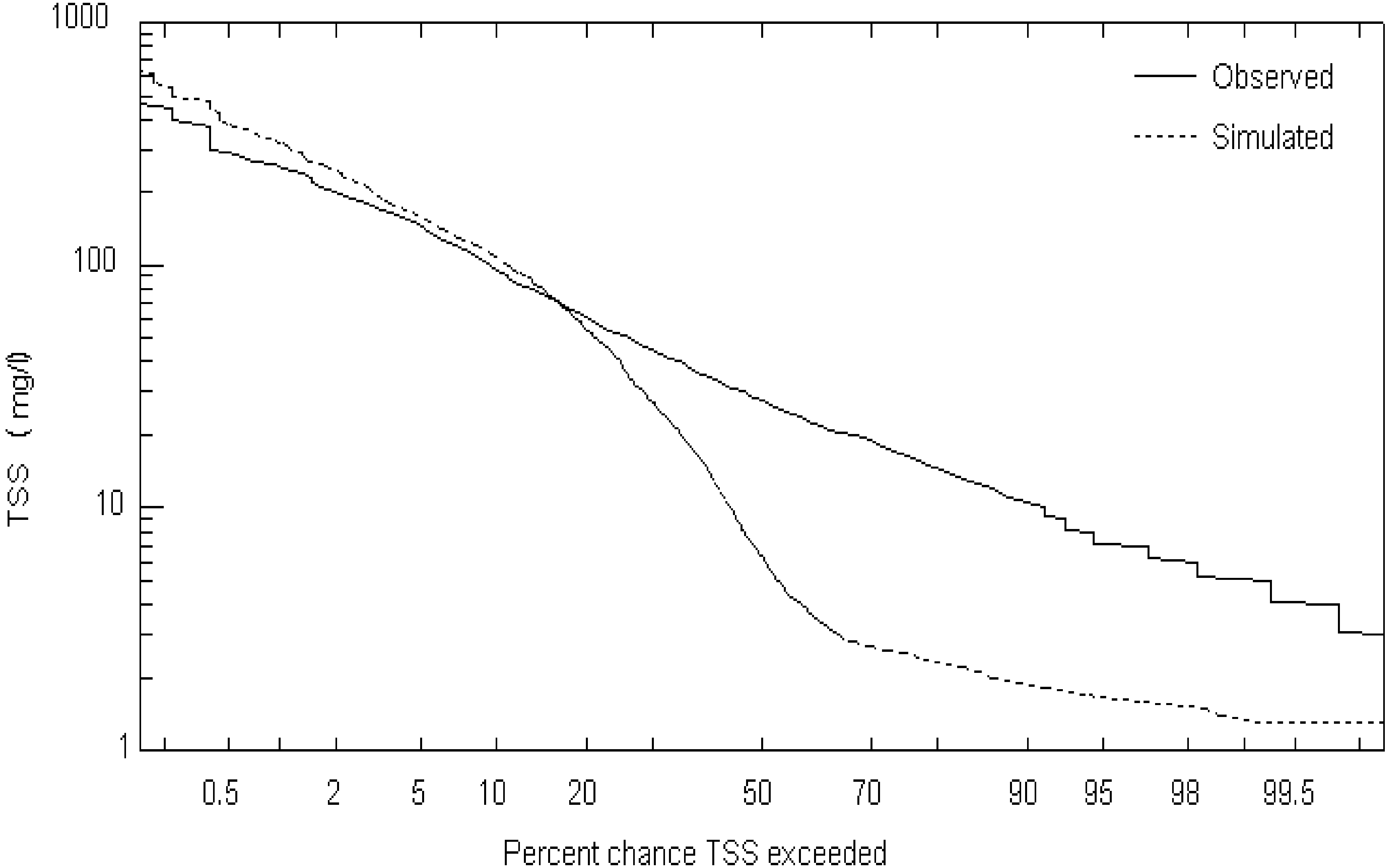
ANNUAL TIMESERIES PLOT



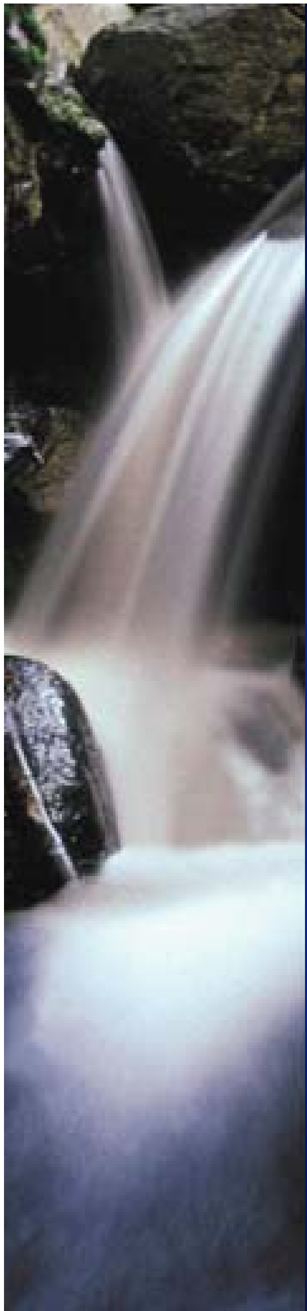
Patuxent River at Bowie, MD



Patuxent River at Bowie, MD
Sediment Load



Patuxent River at Bowie, MD
Sediment Concentration (1986-1990)



PATUXENT RIVER - SOIL EROSION TARGETS & ANNUAL SEDIMENT LOADS

Soil Erosion Targets For Patuxent Model (tons/acre/year)

Low Density Residential	0.09
Med Density Residential	0.27
Commercial	0.67
Forest	0.009 – 0.017
Pasture	0.05 – 0.09
Hay	0.11 – 0.21
High-till crops	0.38 – 1.93
Low-till crops	0.27 – 0.91

Simulated and Observed Annual Sediment Loads at Bowie (tons)

YEAR	SIMULATED	OBSERVED
1986	20,000	20,200
1987	21,000	18,900
1988	13,100	18,700
1989	46,400	36,000
1990	18,200	23,500
MEAN	23,700	23,500

PATUXENT RIVER – SEDIMENT PARAMETERS

	SAND	SILT	CLAY
D (in)	0.005	0.0004	0.0001
W (in/sec)	0.10	0.0003	0.00001
RHO (g/cm^3)	2.50	2.20	2.00
KSAND	0.05 – 0.10		
EXPSND	1.7 – 5.5		
TAUCD (lbs/ft^2)		0.08 – 0.12	0.10 – 0.14
TAUCS (lbs/ft^2)		0.10 – 0.32	0.10 – 0.40
M ($lbs/ft^2/day$)		0.01 – 0.90	0.01 – 0.90

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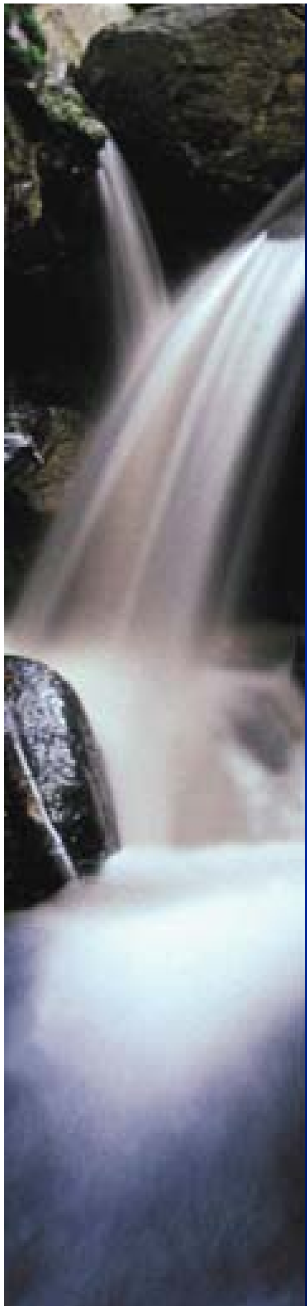

HSPF SEDTRN PARAMETERS AND TYPICAL/POSSIBLE RANGES (#1)

			RANGE OF VALUES					
NAME	DEFINITION	UNITS	TYPICAL		POSSIBLE		FUNCTION OF ...	COMMENT
			MIN	MAX	MIN	MAX		
SANDFG								
SDFG	Indicates Method Used for Sandload Simulation	none	1	3	1	3	Type of stream; user experience.	1 - Toffaleti, 2 - Colby, 3 - Power Function
SED-GENPARM								
BEDWID	Width of cross-section over which HSPF will assume bed sediment is deposited	ft	10	500	5	1000	Reach \ Waterbody morphology	Constant regardless of stage, top-width, etc
BEDWRN	Bed depth which, if exceeded (i.e., through deposition) will cause a warning message to be printed	ft	0.5	10	0.5	20	Reach \ Waterbody morphology, User Needs	Only affects when warning messages will be printed about high bed depth/deposition. Lakes/reservoirs will have higher values.
POR	Porosity of the bed (volume voids/total volume)	none	0.3	0.6	0.25	0.9	Reach \ Sediment Bed Characteristics	Only affects bed depth calculation. Can set to 0.5 if no data are available.
SED-HYDPARM								
LEN	Length of the RCHRES	miles	0.1	1.0	0.01	100	Topography, stream morphology	If very large lengths are calculated, reach should be subdivided.
DELTH	Drop in water elevation from upstream to downstream extremities of the RCHRES	ft	5	50	0.1	100	Topography, stream morphology	If large drops are calculated, the reach should be subdivided into multiple separate reaches.
DB50	Median diameter of bed sediment (assumed constant)	in	0.01	0.02	0.001	1.0	Channel bed properties	Only used for lake shear stress and Toffaleti/Colby methods

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HSPF SEDTRN PARAMETERS AND TYPICAL/POSSIBLE RANGES (#2)

NAME	DEFINITION	UNITS	RANGE OF VALUES TYPICAL MIN	TYPICAL MAX	POSSIBLE MIN	POSSIBLE MAX	FUNCTION OF ...	COMMENT
SAND-PM								
D	Effective diameter of the transported sand particles	in	.002	0.08	.0005	0.2	Sediment properties	Not used in calculations. Set to 0.01 in.
W	Fall velocity of transported sand particles in still water	in/sec	0.2	4.	0.1	10.	Particle diameter and density	Used for Toffaleti method.
RHO	Density of sand particles	g/cm^3	2.2	2.7	1.5	3.0	Sediment properties	Used for calculating bed depth.
KSAND	Coefficient in sandload power function formula	complex	0.01	0.5	0.001	10.	Sand properties and hydraulics	**Calibration**. Affects sand concentration.
EXPSND	Exponent in sandload power function formula	complex	1.5	3.5	1.0	6.0	Sand properties and hydraulics	**Calibration**. Affects sand scour. Usually start with 2.0
SILT-CLAY-PM								
D	Effective diameter of silt, or clay particles	in	.0002 .00001	.0025 .00015	.0001 .000005	.004 .00025	Sediment properties	Used for calculating bed depth.
W	Fall velocity of transported silt or clay particles in still water	in/sec	.0001	0.01	0.0	0.1	Particle diameter and density	Affects concentration during low flow.
RHO	Density of silt or clay particles	g/cm^3	1.8	2.7	1.5	3.0	Sediment properties	Used for calculating bed depth.
TAUCD*	Critical bed shear stress for deposition	lb/ft^2	0.01	0.3	0.001	1.0	Silt/clay properties and hydraulics	**Calibration**. Affects timing & magnitude of deposition. Initial values based on computed shear stress.
TAUCS*	Critical bed shear stress for scour	lb/ft^2	0.05	0.5	0.01	3.0	Silt/clay properties and hydraulics	**Calibration**. Affects timing & magnitude of scour. Initial values based on computed shear stress.
M*	Erodibility coefficient	$lb/ft^2.d$	0.01	2.	0.001	5.0	Silt/clay properties and hydraulics	**Calibration**. Affects magnitude of scour.

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GENERAL QUALITY CONSTITUENTS – GQUAL

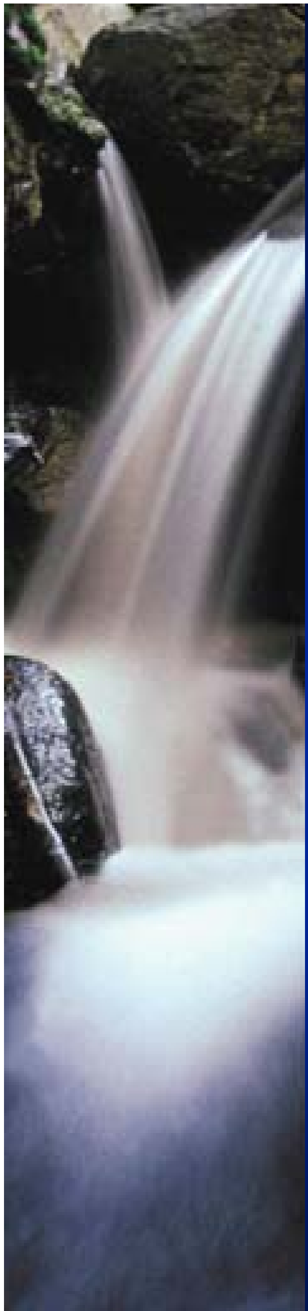
ORGANICS/PESTICIDES
BACTERIA
METALS

1. **Can simulate up to five independent constituents**

2. **Constituent can be a "daughter" product of another constituent**

3. **Optional decay mechanisms**

4. **Sediment association (adsorption/desorption)**



GENERAL QUALITY CONSTITUENTS – GQUAL

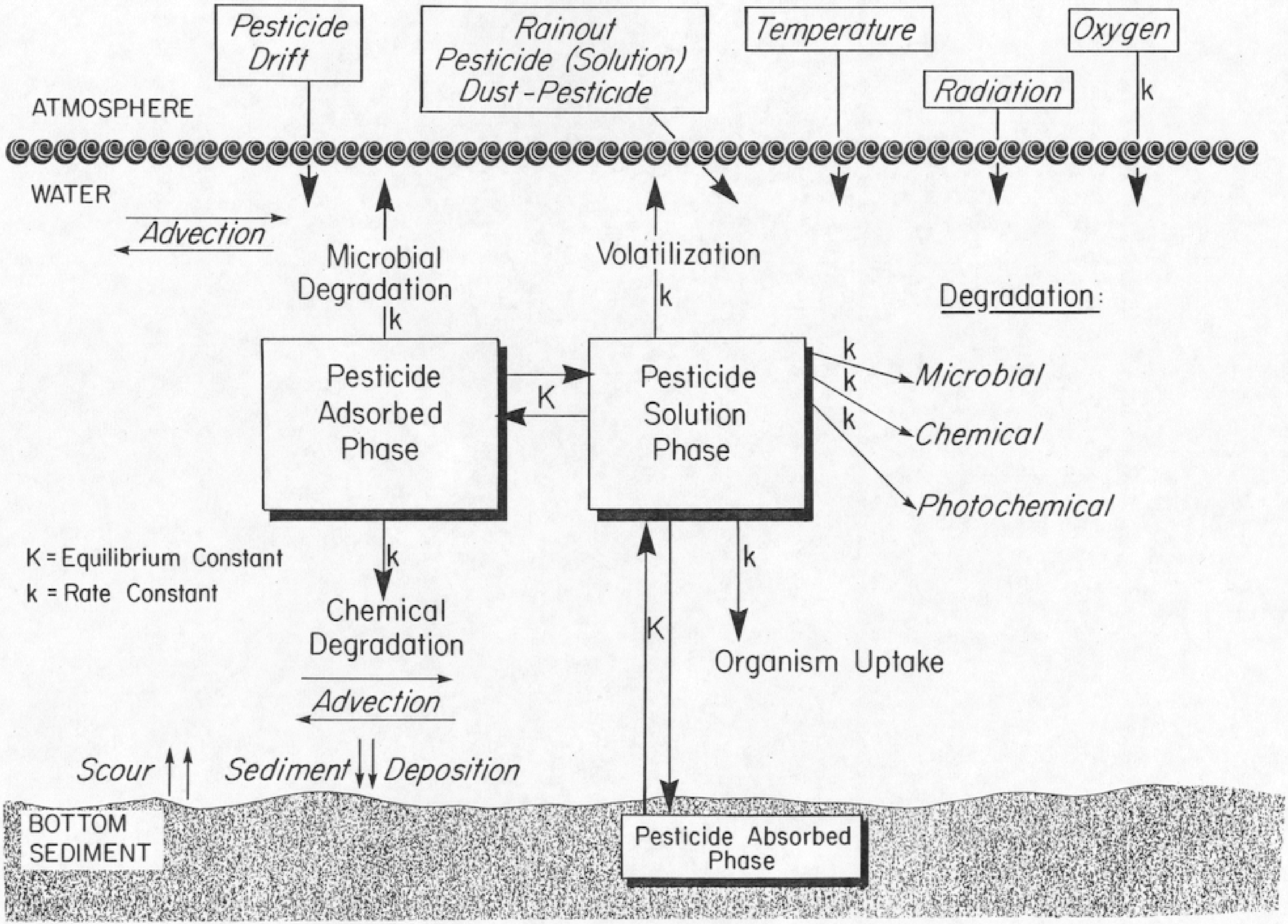
Instream Transport & Fate Processes

- **Advection**
- **Decay/Die-Off**
- **Adsorption/Desorption**
- **Sedimentation & Scour**

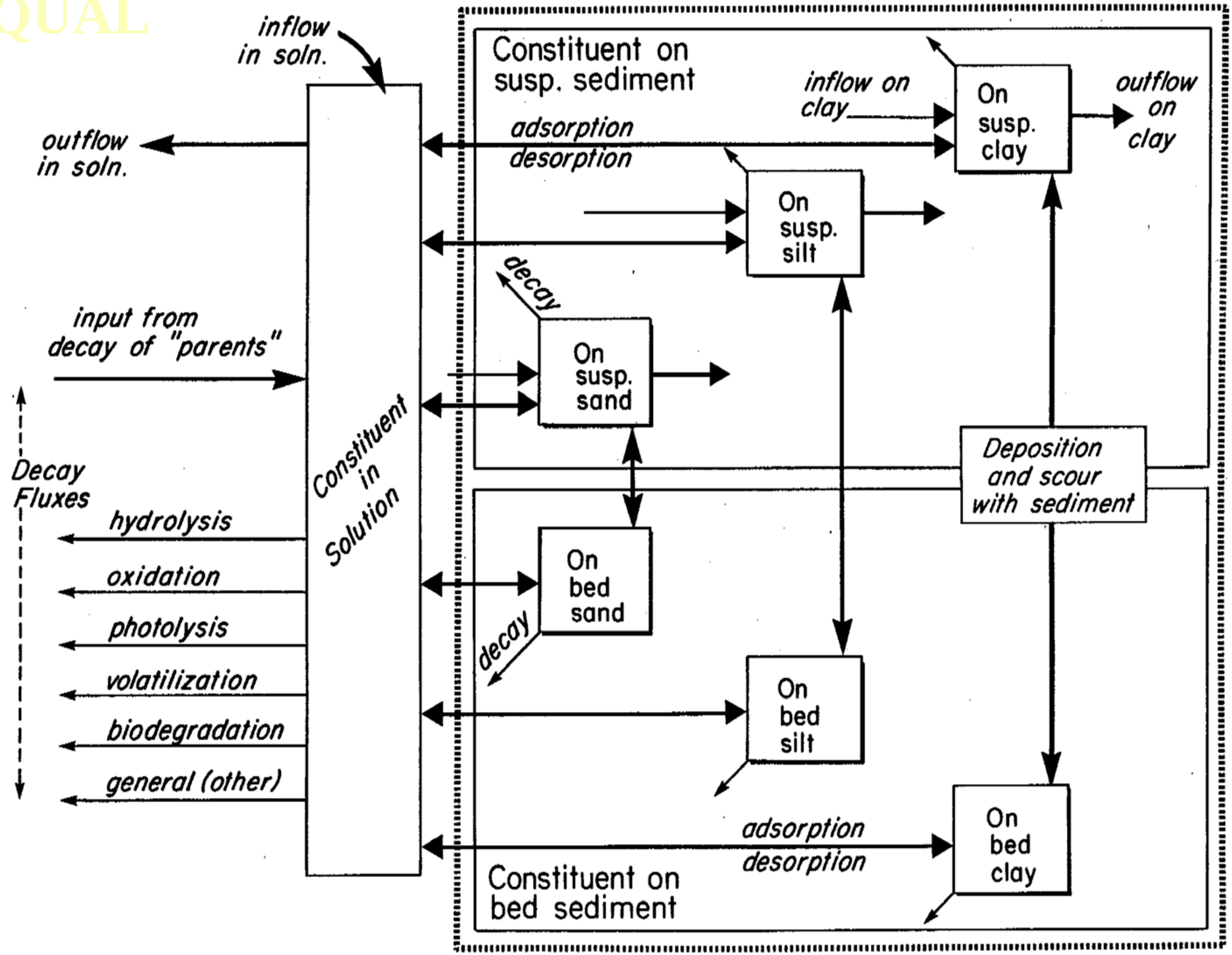
Pollutant Sources

- **Nonpoint Source**
  - **- PQUAL/IQUAL or PEST**
  - **- potency factor or accumulation/washoff method**
- **Point Source**
  - **- characterize flow and pollutant load**

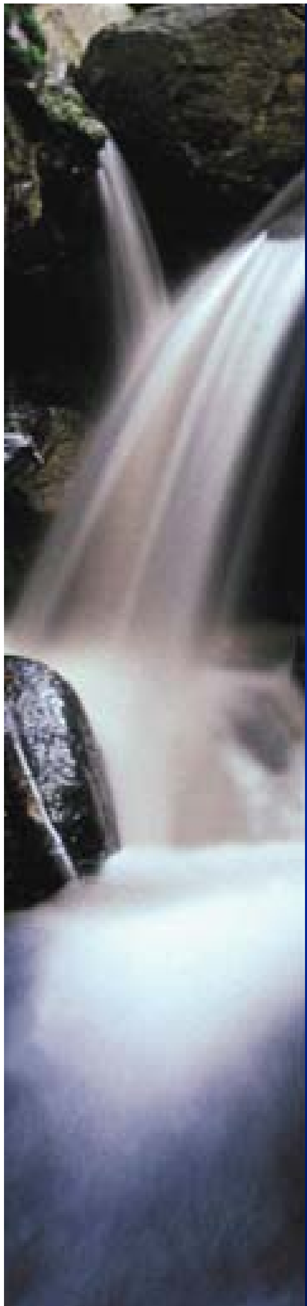
PESTICIDE PROCESSES IN STREAMS



GQUAL



inflow in soln.
outflow in soln.
input from decay of "parents"
Decay Fluxes
hydrolysis
oxidation
photolysis
volatilization
biodegradation
general (other)
Constituent in Solution
Constituent on susp. sediment
adsorption desorption
inflow on clay
On susp. clay
outflow on clay
On susp. silt
decay
On susp. sand
Deposition and scour with sediment
On bed sand
decay
On bed silt
adsorption desorption
On bed clay
Constituent on bed sediment



GQUAL PARAMETERS – DISSOLVED PHASE

General First Order Decay
- rate **(FSTDEC)**
- temperature correction coefficient **(THFST)**

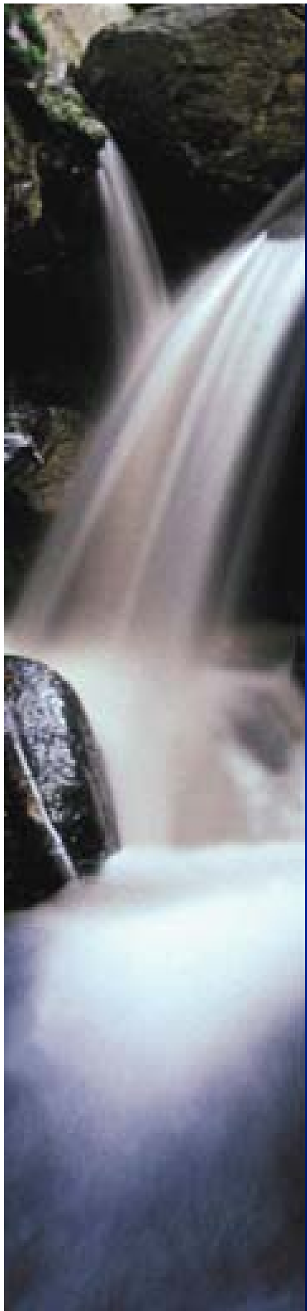
Hydrolysis
- rates **(KA**, **KB**, **KN)**
- temperature correction coefficient **(THHYD)**

Oxidation by Free Radical Oxygen
- rate **(KOX)**
- temperature correction coefficient **(THOX)**

Volatilization
- ratio of volatilization rate to reaeration rate (**CFGAS)**

Biodegradation
- rate **(BIOCON)**
- temperature correction coefficient **(THBIO)**

Photolysis
- chemical absorption coefficients, quantum yield, temperature correction coefficient, absorption coefficients (base, sediment, plankton), extinction efficiency of clouds, fraction of surface exposed to radiation



GQUAL PARAMETERS – ADSORBED PHASE

Decay rates of adsorbed chemical*

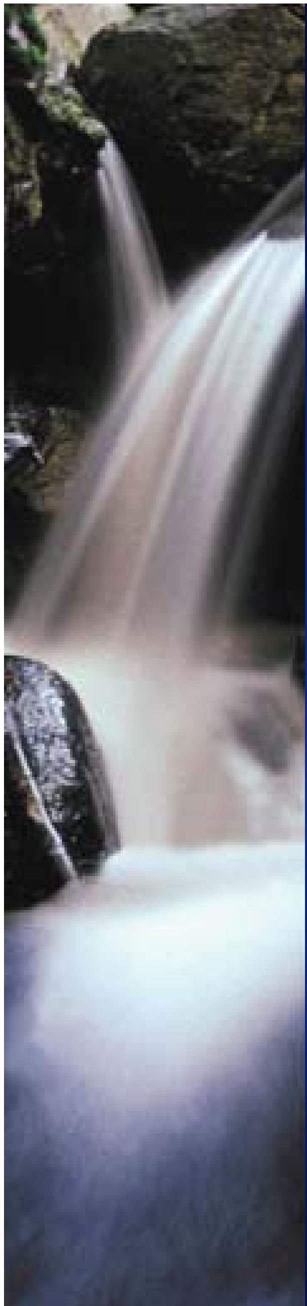
Temperature correction coefficients of adsorbed decay*

Adorption/desorption partition coefficients*

Adsorption/desorption transfer rates*

Adsorption/desorption transfer temperature correction coefficients*

* Six (6) values are input: suspended sand, silt, clay, and bed sand, silt, clay.



GQUAL - UNITS CONVERSION FACTOR

CONV

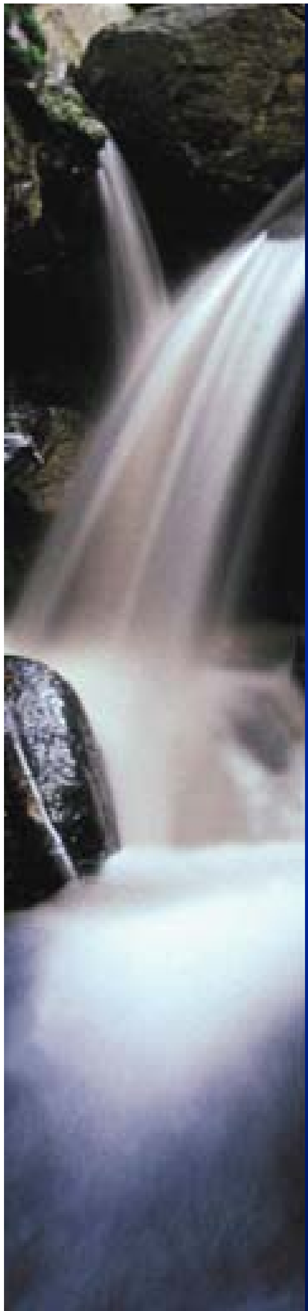
CONCentration = **CONV** * (**QTYID**/VOLume)

where

- **CONC**entration = dissolved concentration units (e.g., µg/L, mg/L, #organisms/L)
- **CONV** = conversion factor
- **QTYID** = mass units (e.g., lbs, kg, or #organisms)
- VOLume = volume of water (ft^3 if **EMFG**=1; m^3 if **EMFG**=2)

Examples:

	CONC units	QTYID	EMFG	CONV
Metal/Pest/Organic	µg/L	lbs	1	1.602E+07
Metal/Pest/Organic	µg/L	kg	1	3.532E+07
Bacteria	#organisms/L	#organisms	1	0.03532
Bacteria	#organisms/L	#organisms	2	0.001



GQUAL CALIBRATION

Key Parameters:

- **Decay/transformation rates**
- **Adsorption/desorption (partition) coefficients**
- **Adsorption/desorption transfer rates**

CALABAZAS CREEK (CA) - COPPER