Rapid Geomorphic Assessment of Erosion Volumes for SWAT Calibration in Large Watersheds

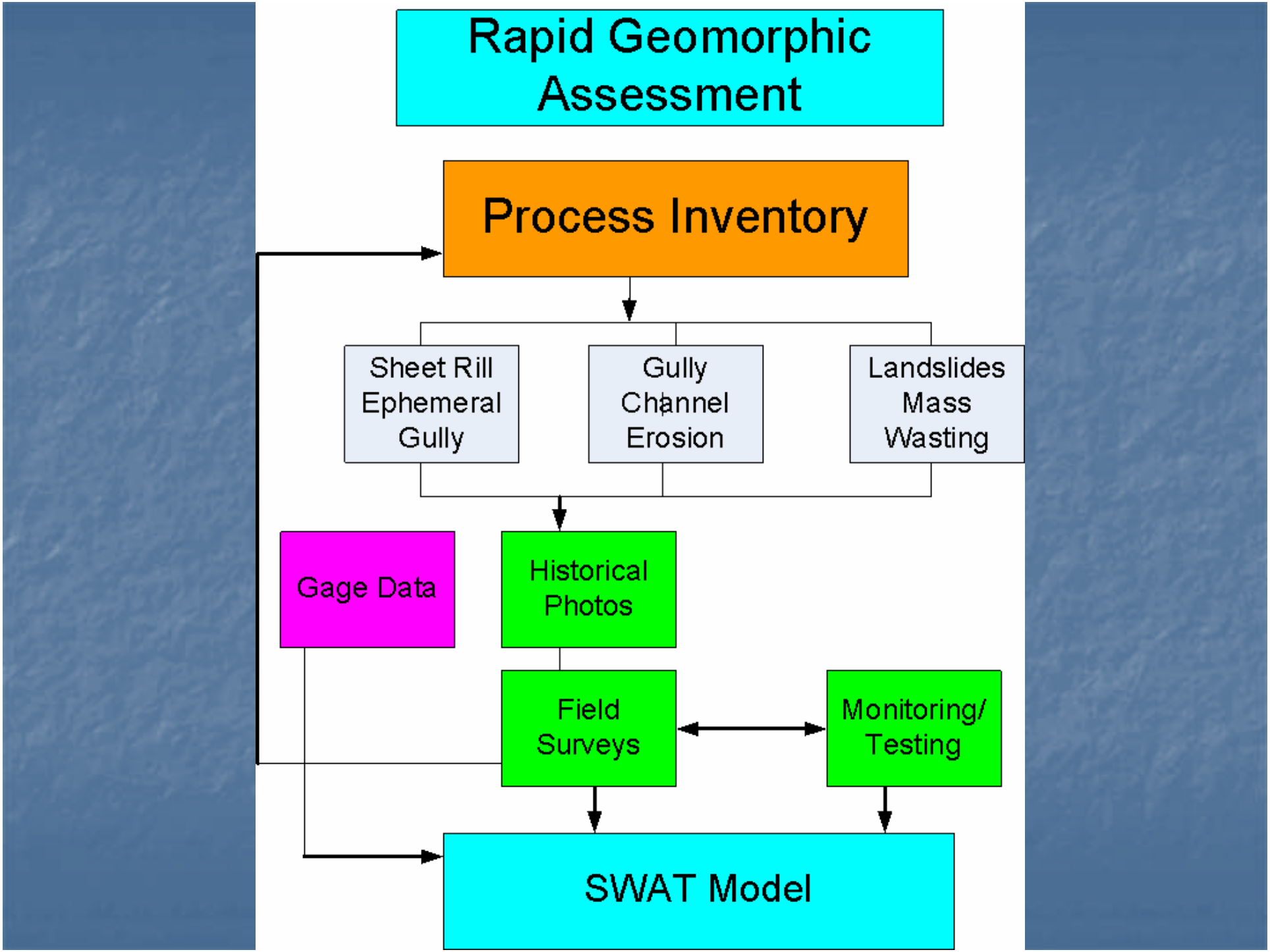
P.M. Allen, B. Narasimhan

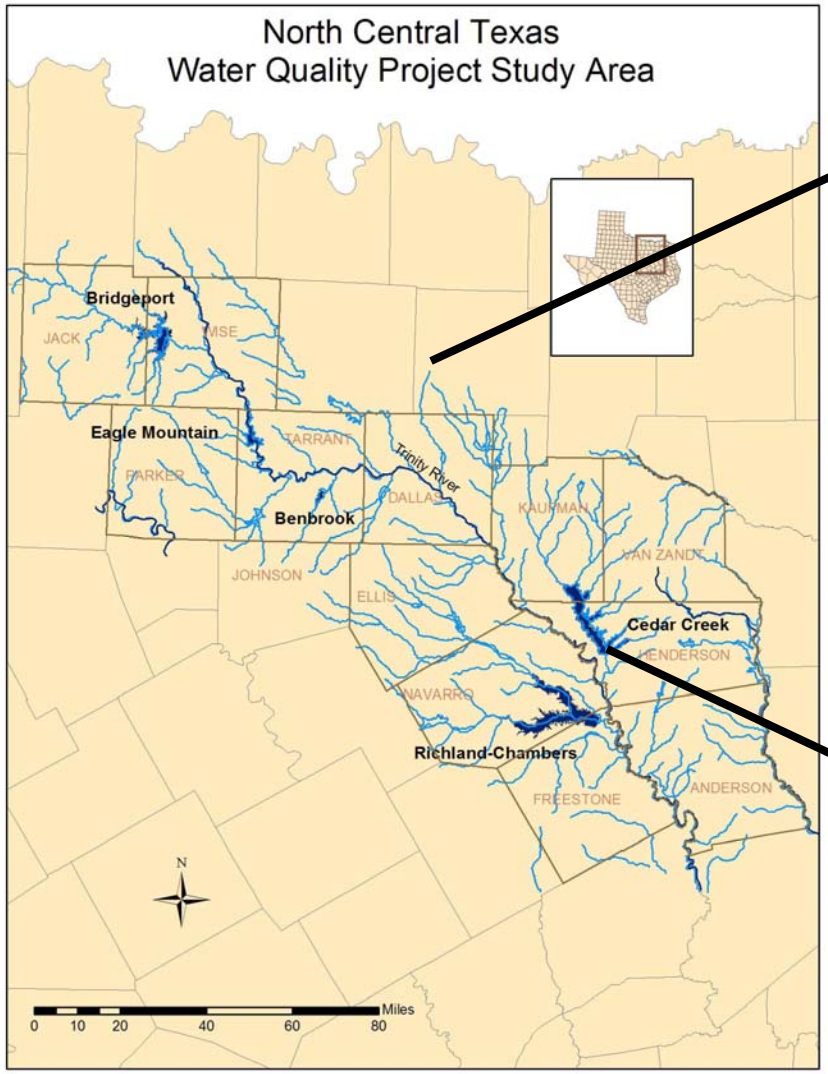
J. Dunbar, S. Prochnow, S. Capello

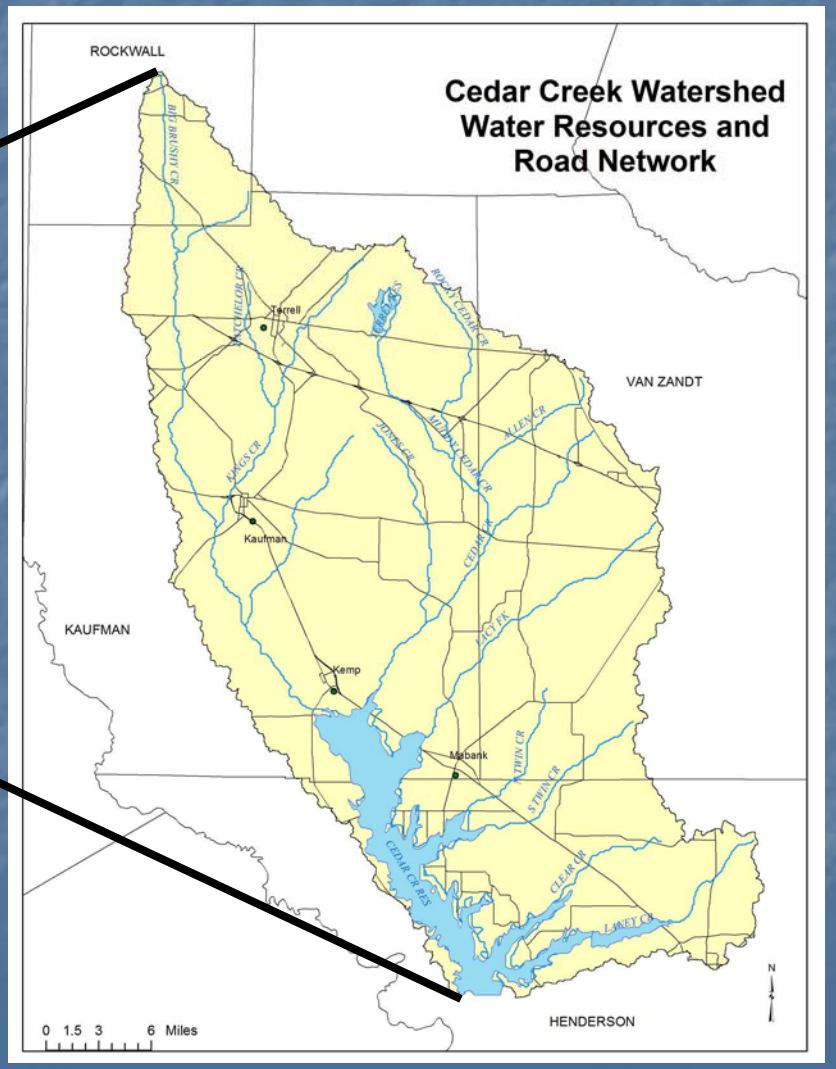
R. Srinivasan

When in trouble modeling, say nothing and try to look inconspicuous

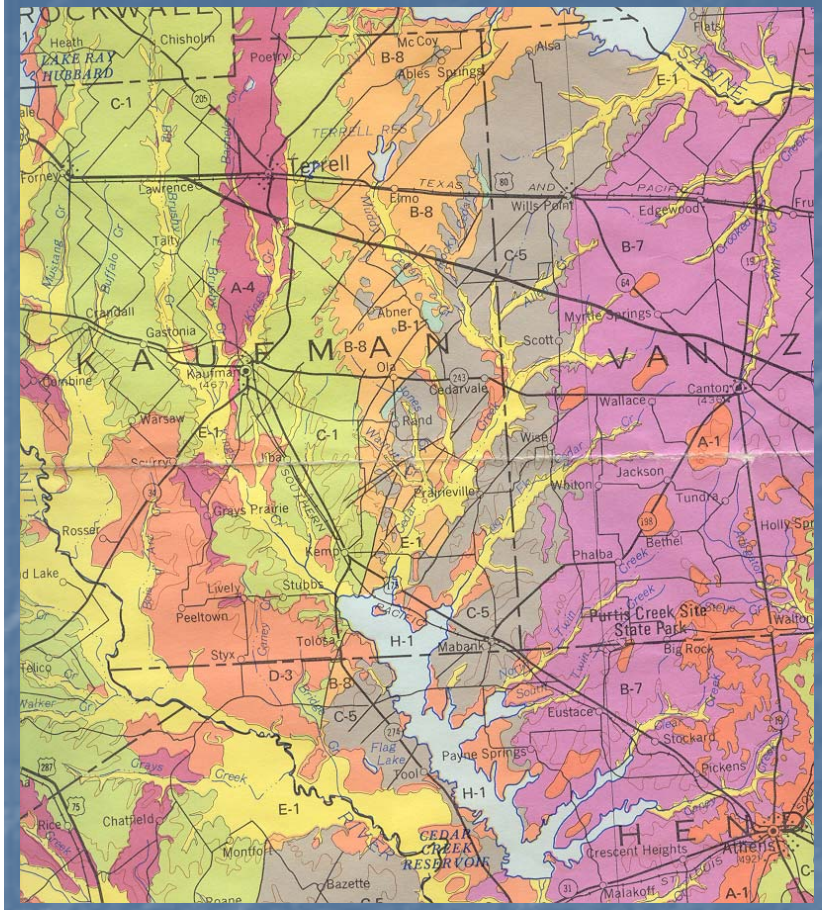
Cedar Creek Project: Rapid Basin Assessment for SWAT Calibration

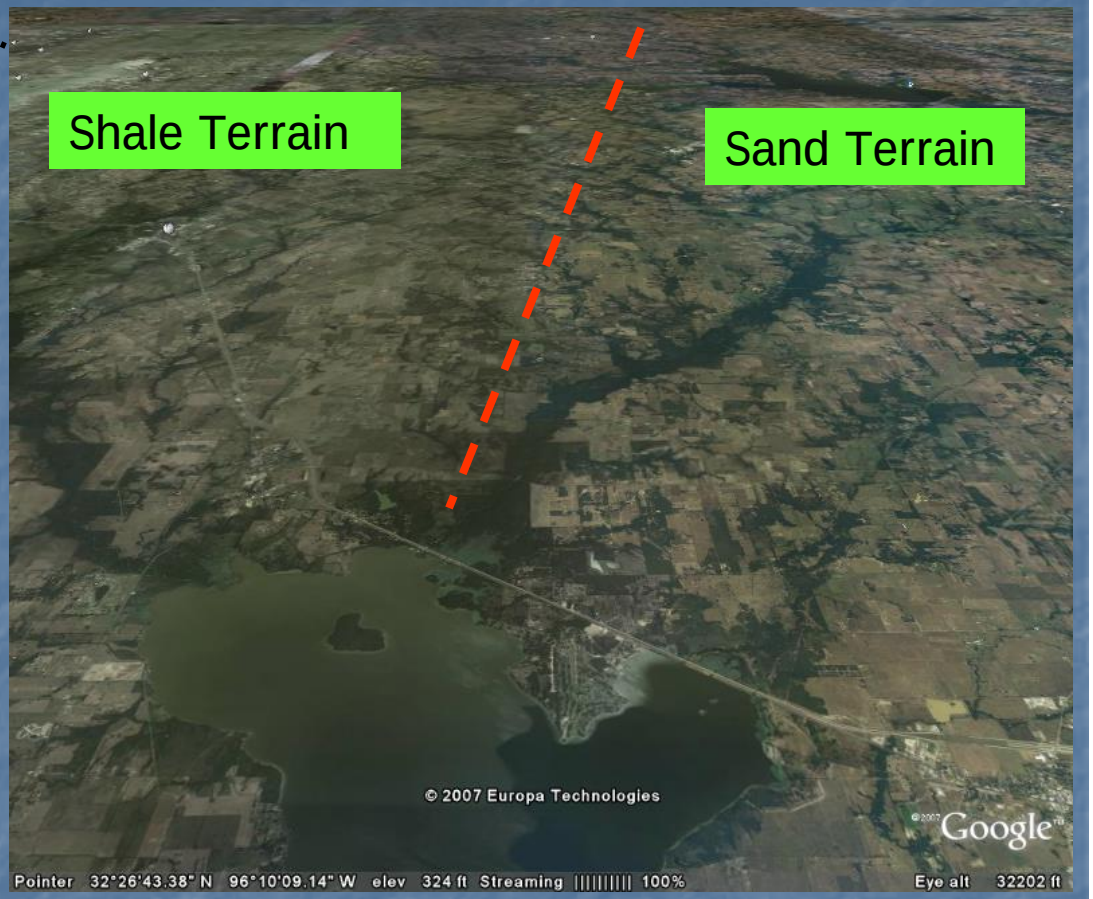

Rapid Geomorphic Assessment
Process Inventory
Sheet Rill Ephemeral Gully
Gully Channel Erosion
Landslides Mass Wasting
Gage Data
Historical Photos
Field Surveys
Monitoring/ Testing
SWAT Model


North Central Texas
Water Quality Project Study Area
Bridgeport
Eagle Mountain
Benbrook
Cedar Creek
Richland-Chambers
Trinity River
JACK
WISE
PARKER
TARRANT
DALLAS
KAUFMAN
VAN ZANDT
JOHNSON
ELLIS
HENDERSON
NAVARRO
FREESTONE
ANDERSON
N
0 10 20 40 60 80 Miles

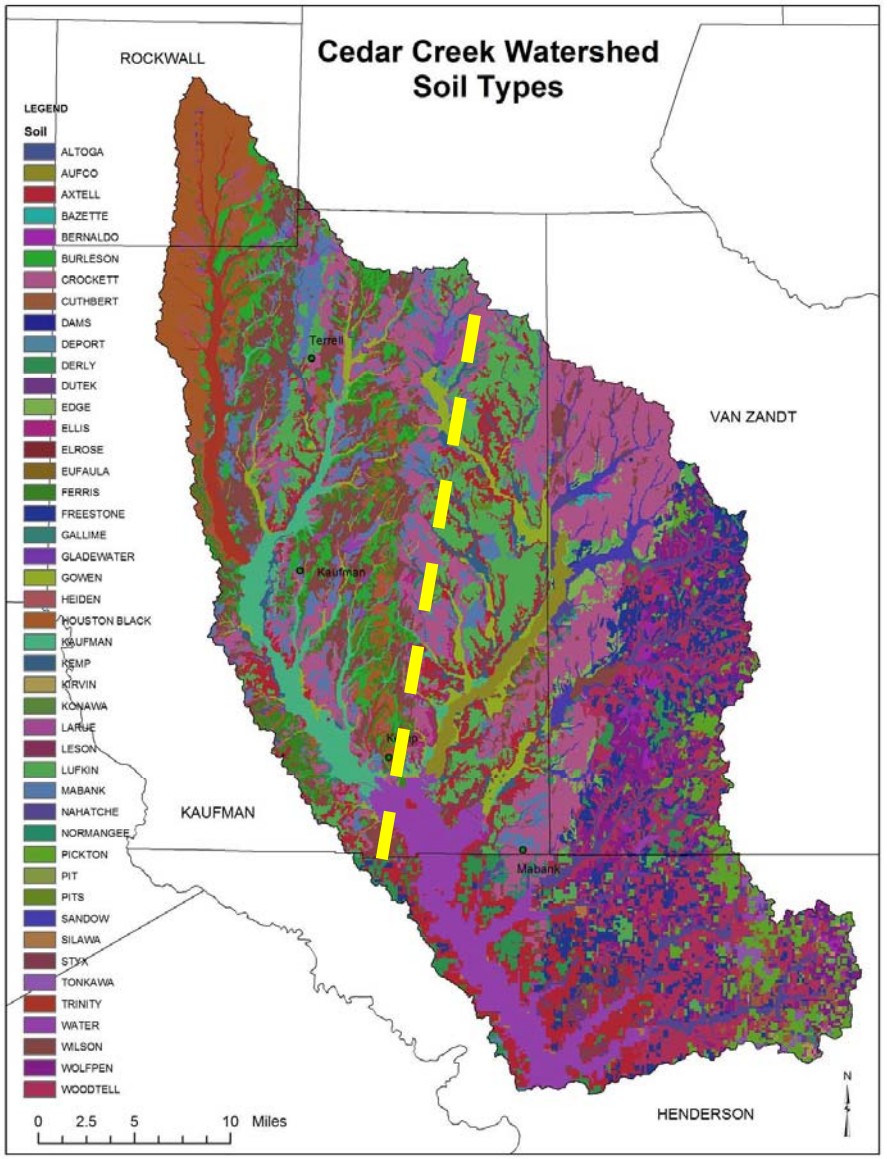

Cedar Creek Watershed
Water Resources and
Road Network
ROCKWALL
VAN ZANDT
KAUFMAN
HENDERSON
Terrell
Kaufman
Kemp
Mabank
0 1.5 3 6 Miles
N

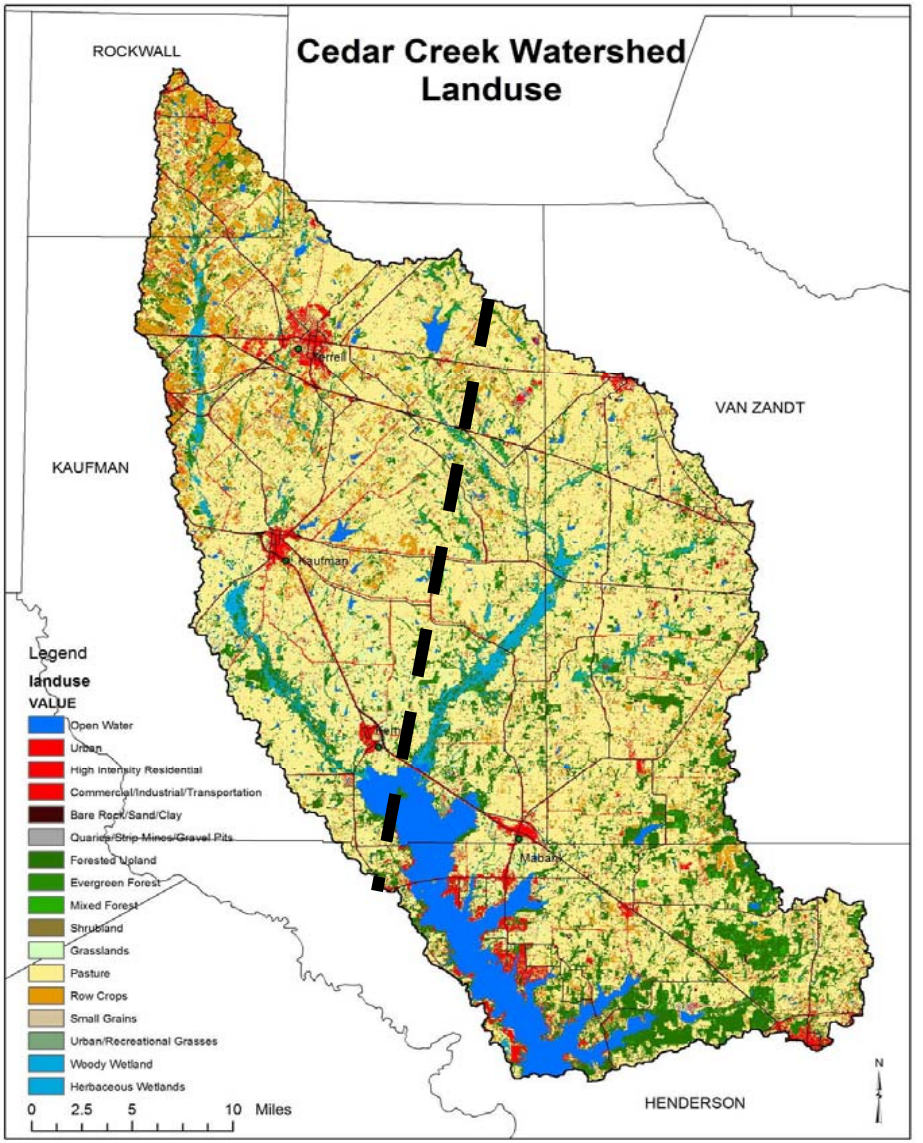
Erosion and Geology





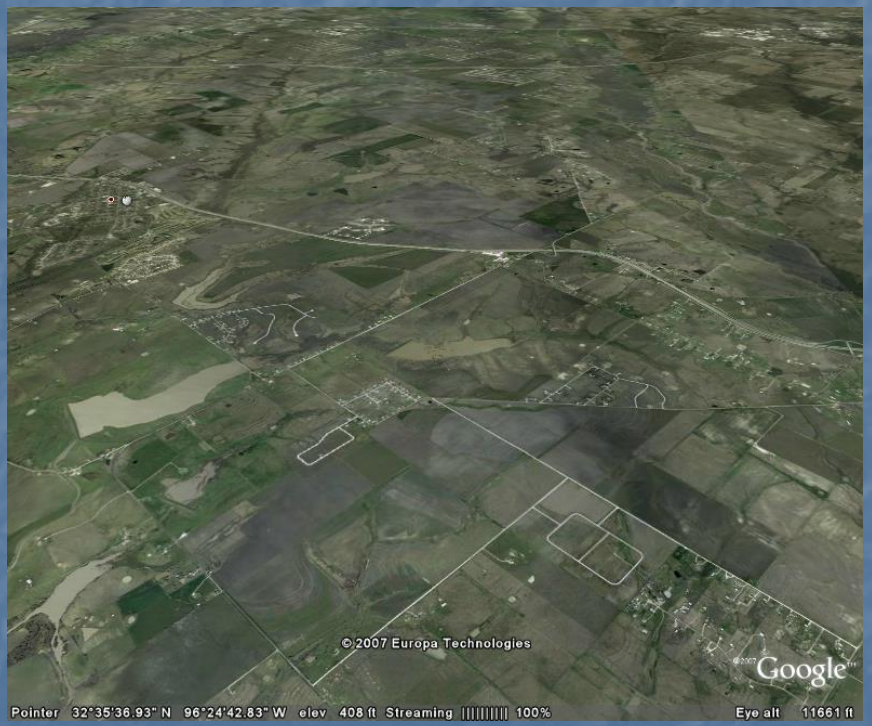
Soils and Land Use





Soils and Land-use

More Cultivation/Urbanizing

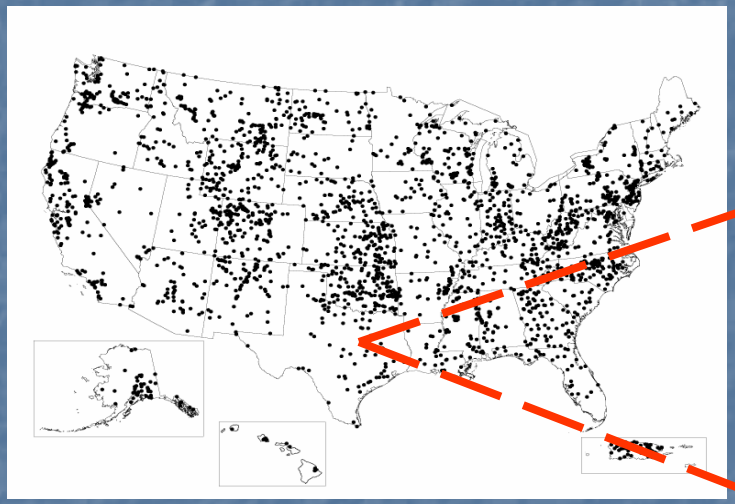


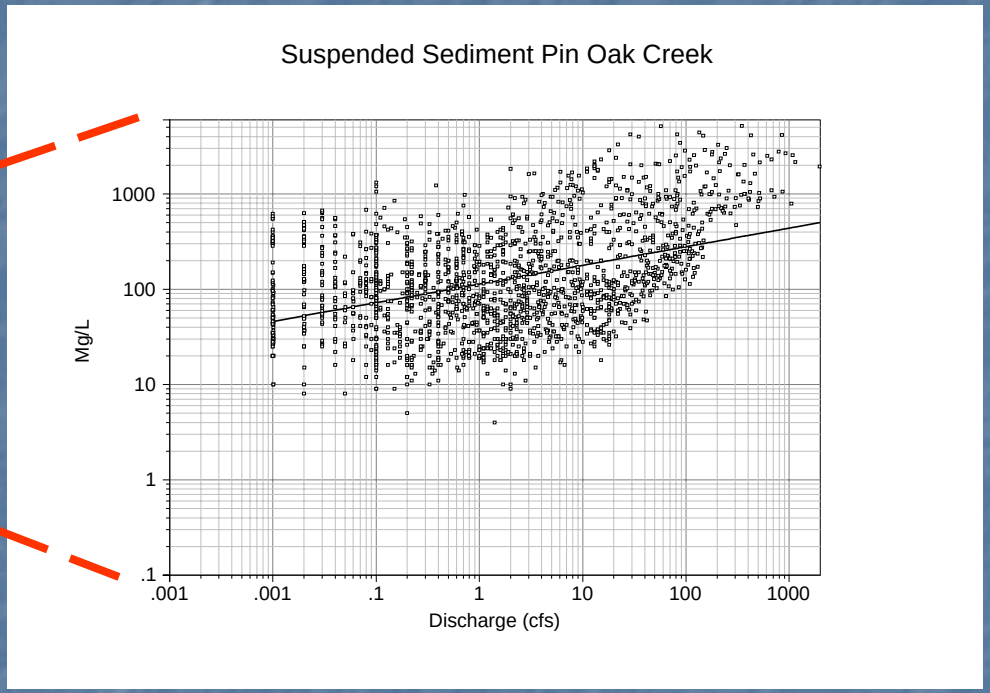
More Forested/Less Cultivation

DATA for RGA & Sediment Budgets

- Monitoring Suspended Sediment and Bed Material and Gage Data
- Reservoir Surveys/Resurveys
- Inferential: Historical Air Photographs and Field Surveys
- Models

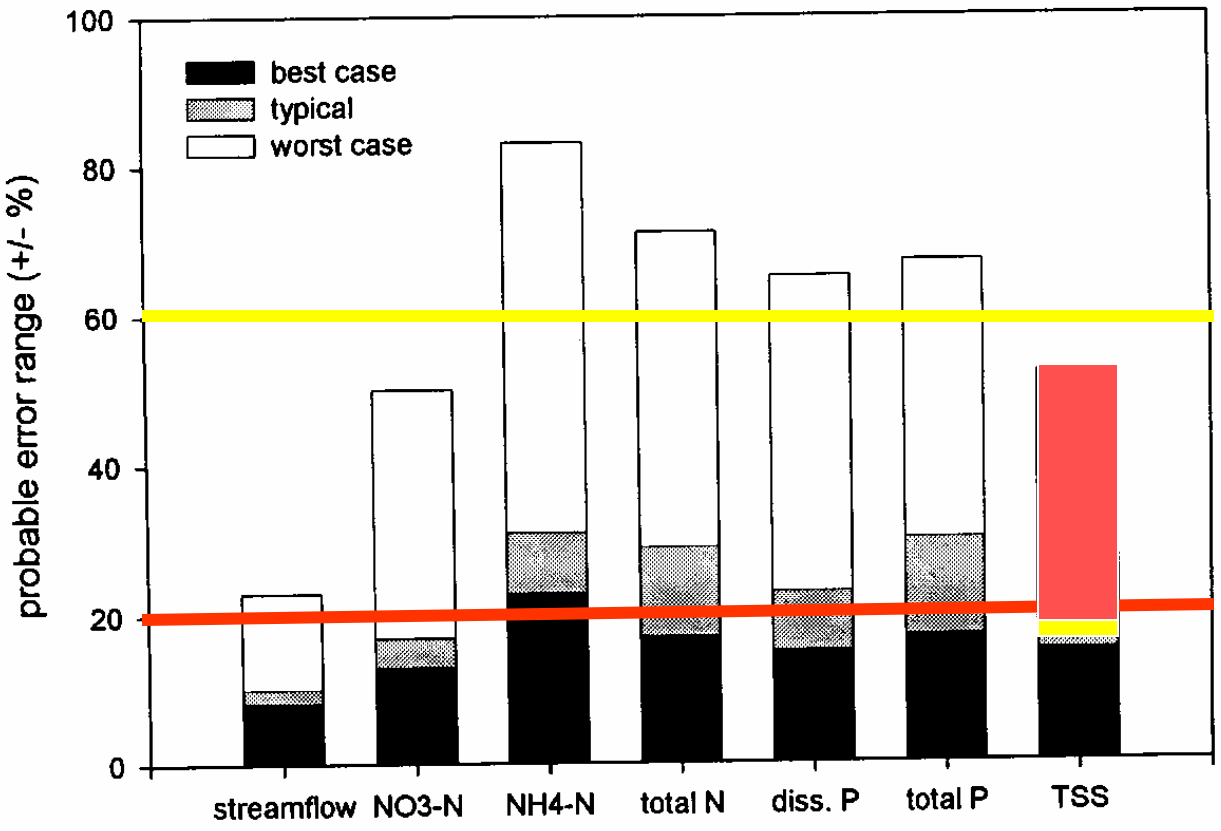
USGS Suspended Sediment Stations





About 21 Active Stations in Texas; 6 in the Blackland Prairie; most larger rivers

Uncertainty in Measured Data

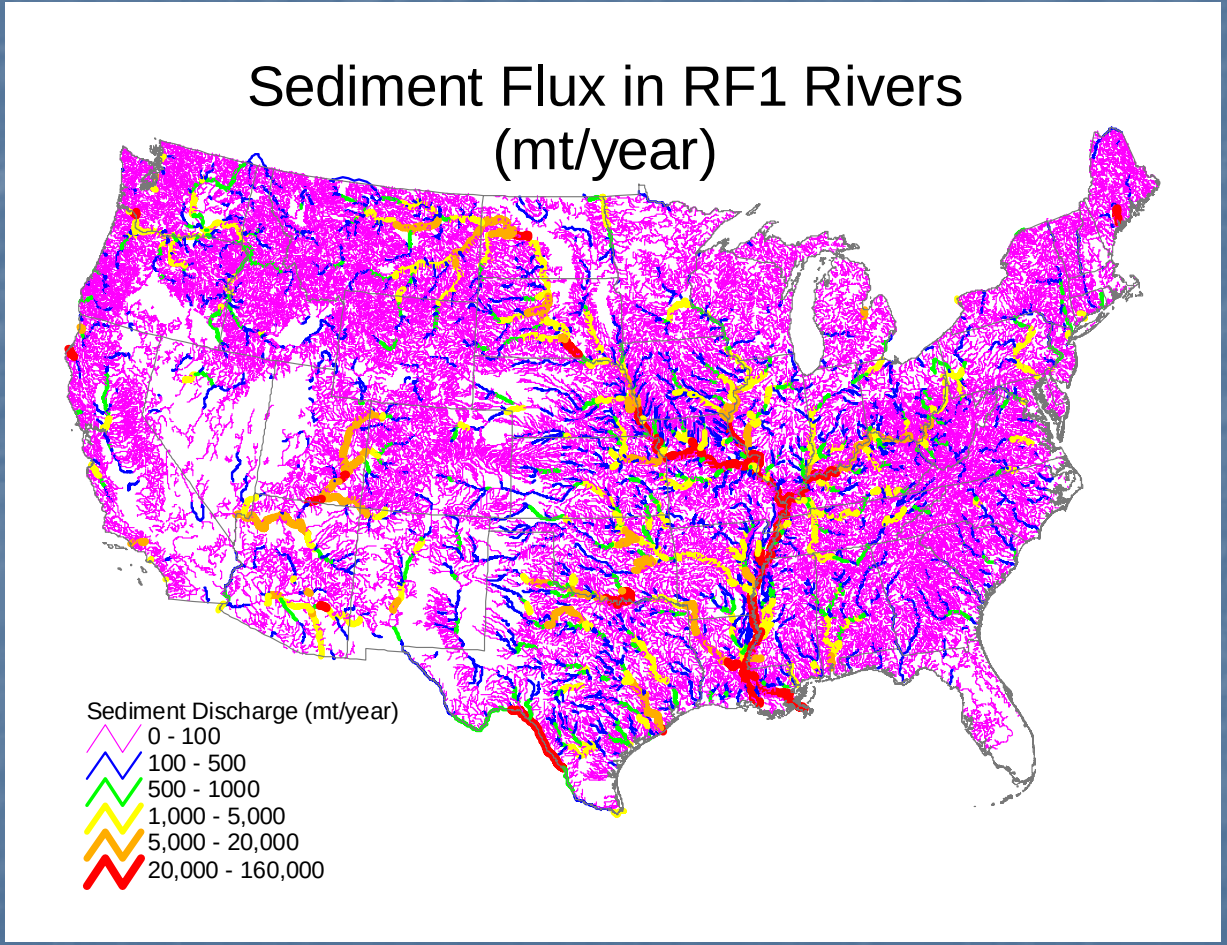


Harmon, D. 2006 ARS USDA

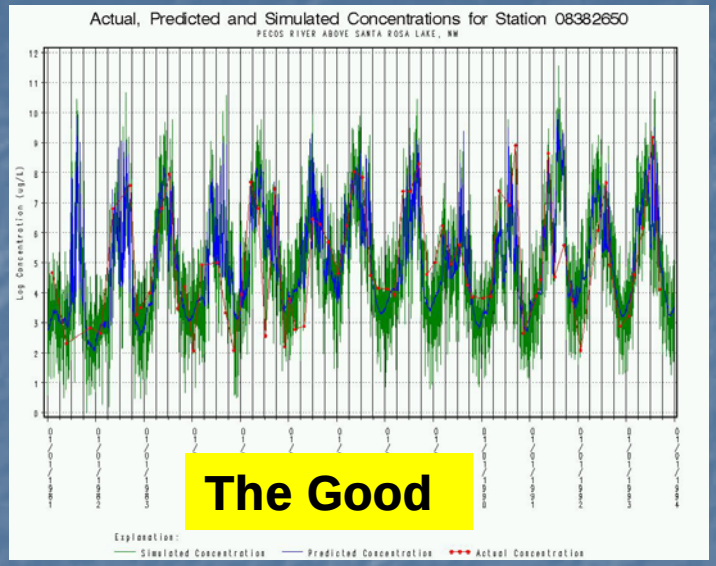
SPARROW: USGS

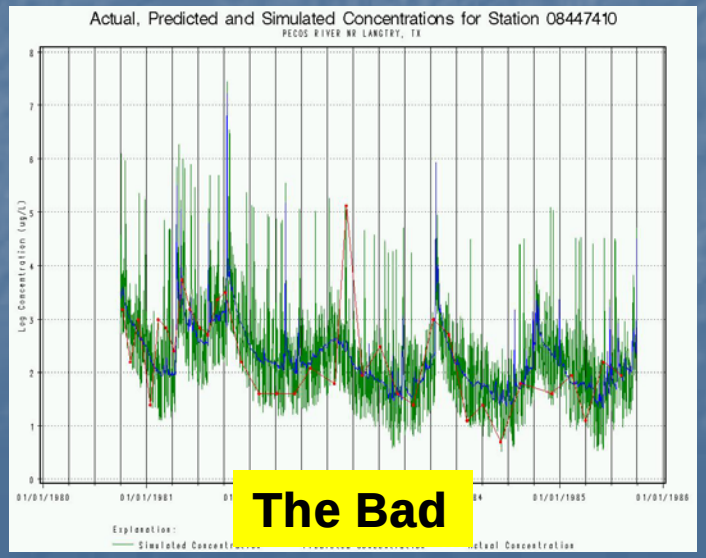
A Regional Statistical

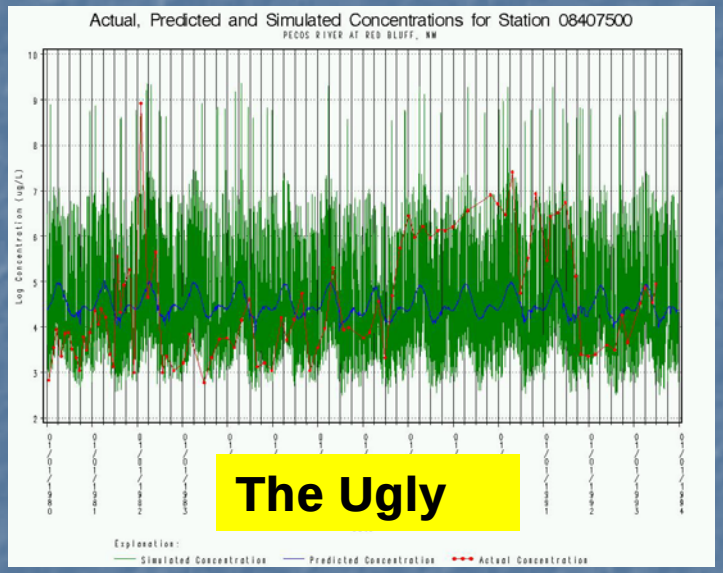
Model of Gaged Data



Load Estimates







Cedar Creek Sediment: Gage Data Estimates

Tons/yr.	Minimum	25th%	50th%	75th%	Maximum
Without Upstream Control	9519 (104,711)	266,538 (266,538)	1,875,282 (428,364)	3,931,430 (1,589,706)	8,557,761 (3,588,738)
With Upstream Control	3836 (42,340)	107,415 (107,310)	755,739 (172,645)	1,584,366 (640,575)	3,448,778 (1,446,130)

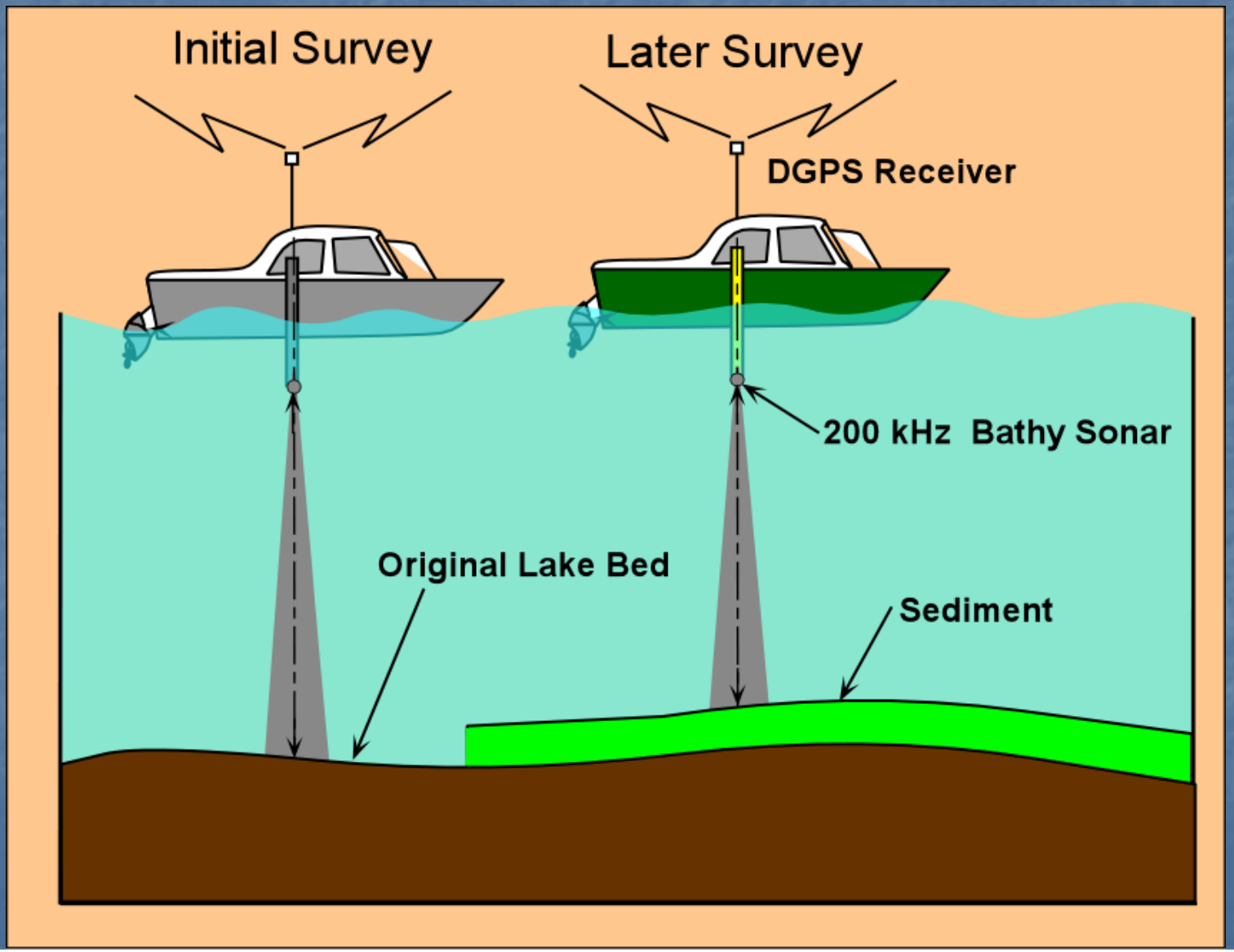
Simon et. al. 2004

Results for Watershed: Weighted by Province Average = 665,480 tons/year

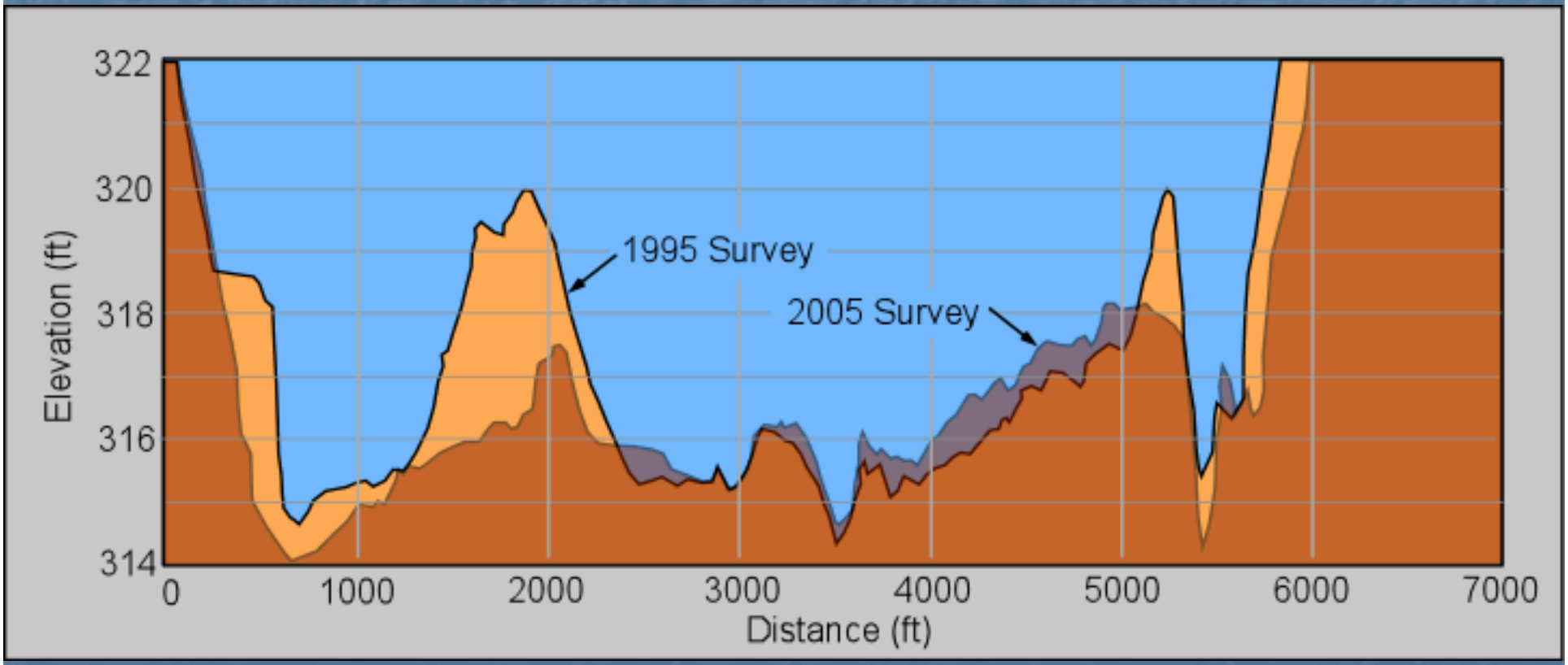
Sediment Yield/Budgets

- Monitoring Suspended Sediment and Bed Material and Gage Data
- Reservoir Surveys/Resurveys
- Inferential: Historical Air Photographs and Field Surveys
- Models

Sediment Volume by "Old" Differential Bathymetry



Problem: No Precision for Sediment Volume Estimates

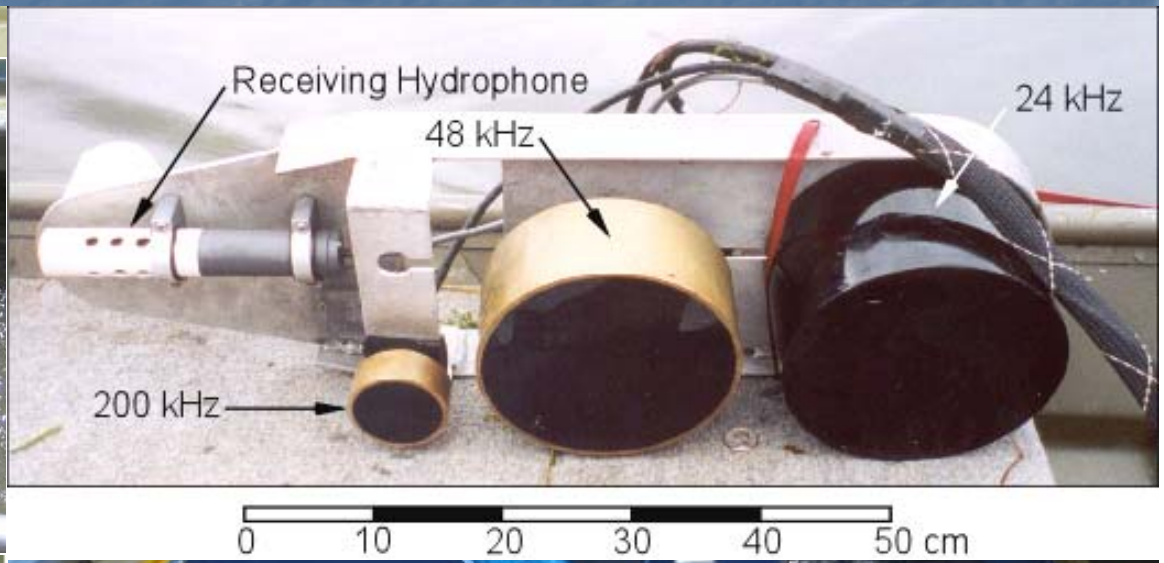


After TWDB, 2005

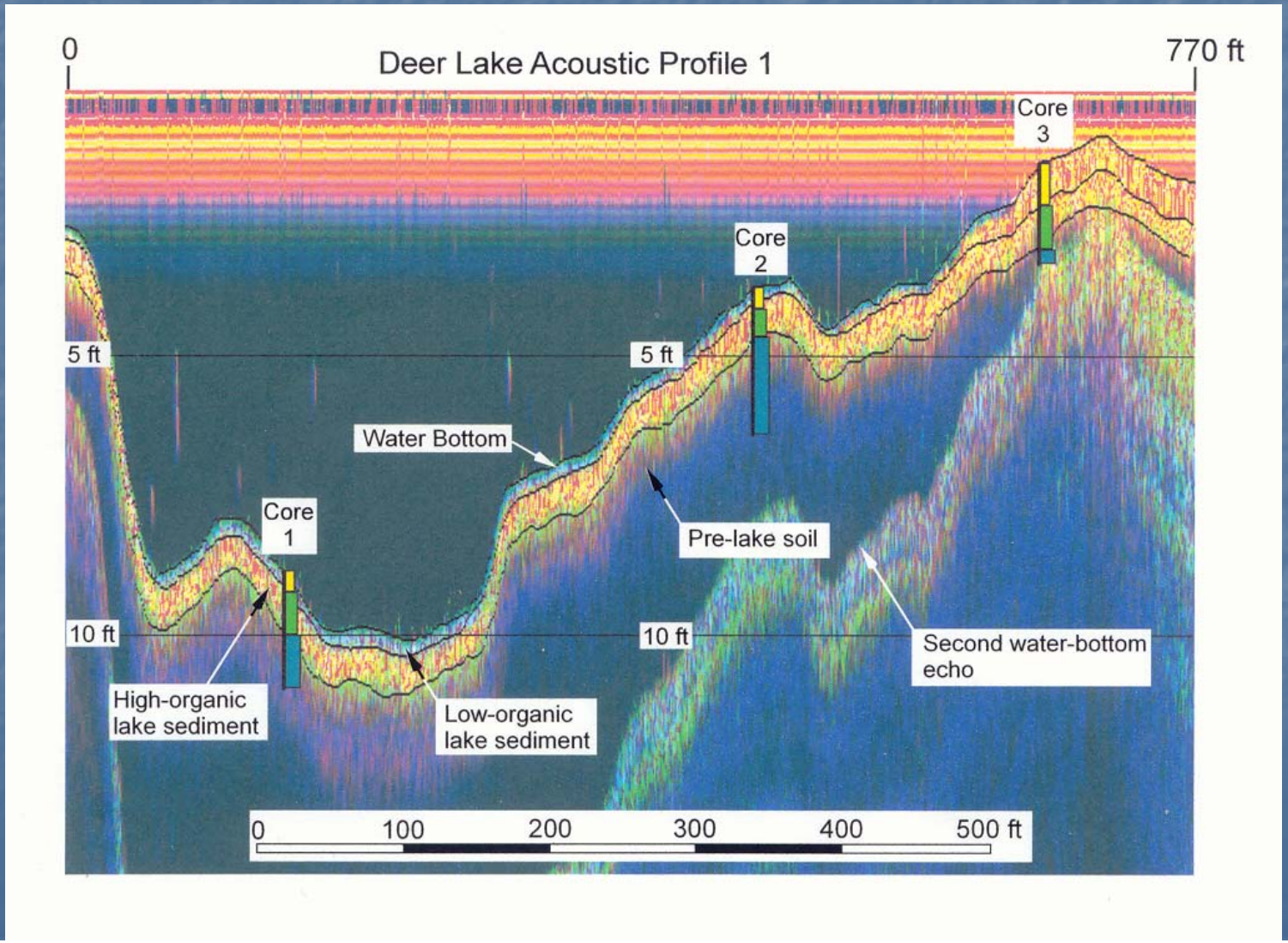
Cedar Creek Results: Bathymetric Resurvey Method

- Volumetric Change = 41,276 ac/ft.
- Density Assumptions @ 35 lbs/cuft
- Yield = 790,000 tons year

New Method: Multi-frequency Acoustic Survey System

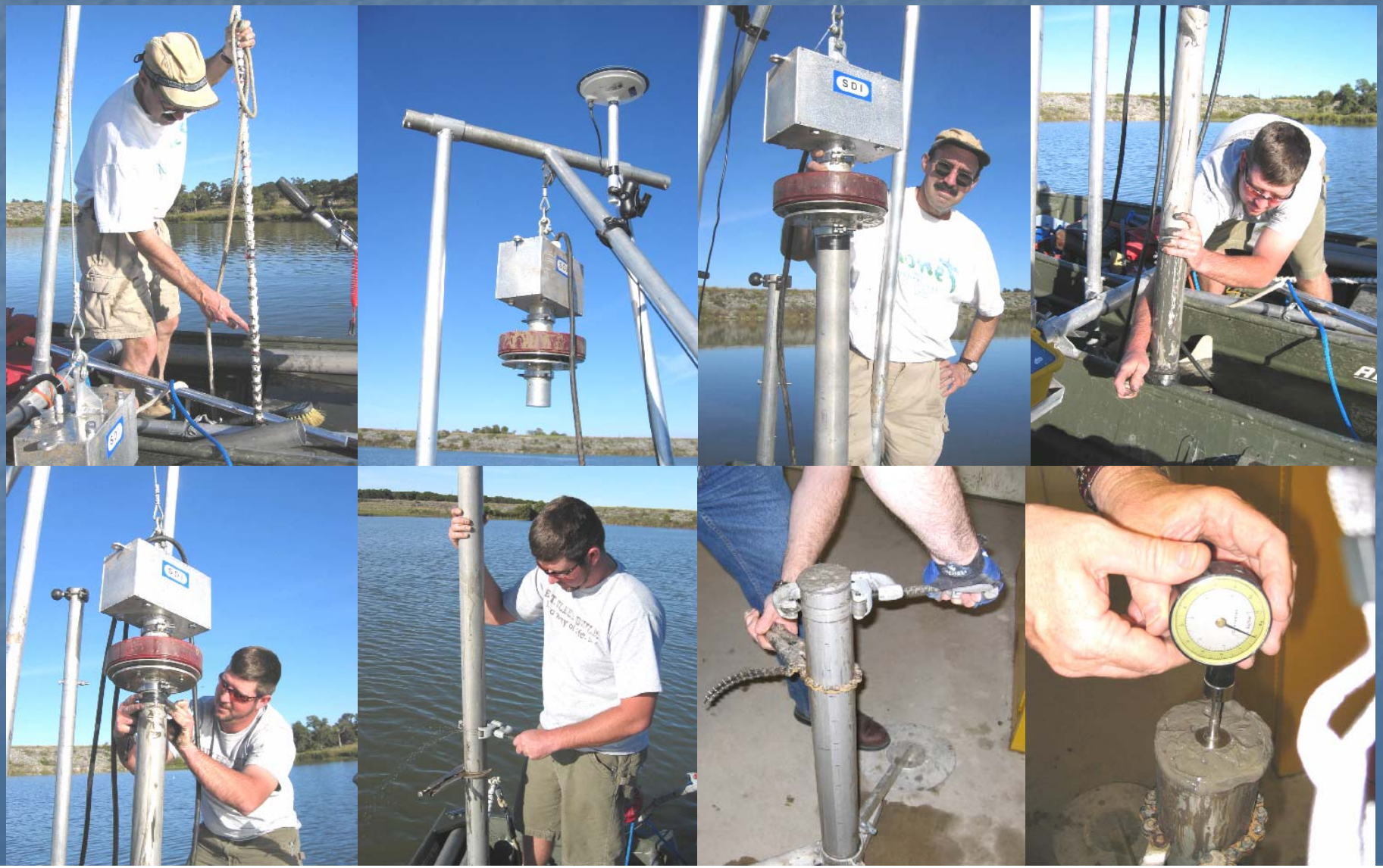


Results: Sub-bottom Acoustics

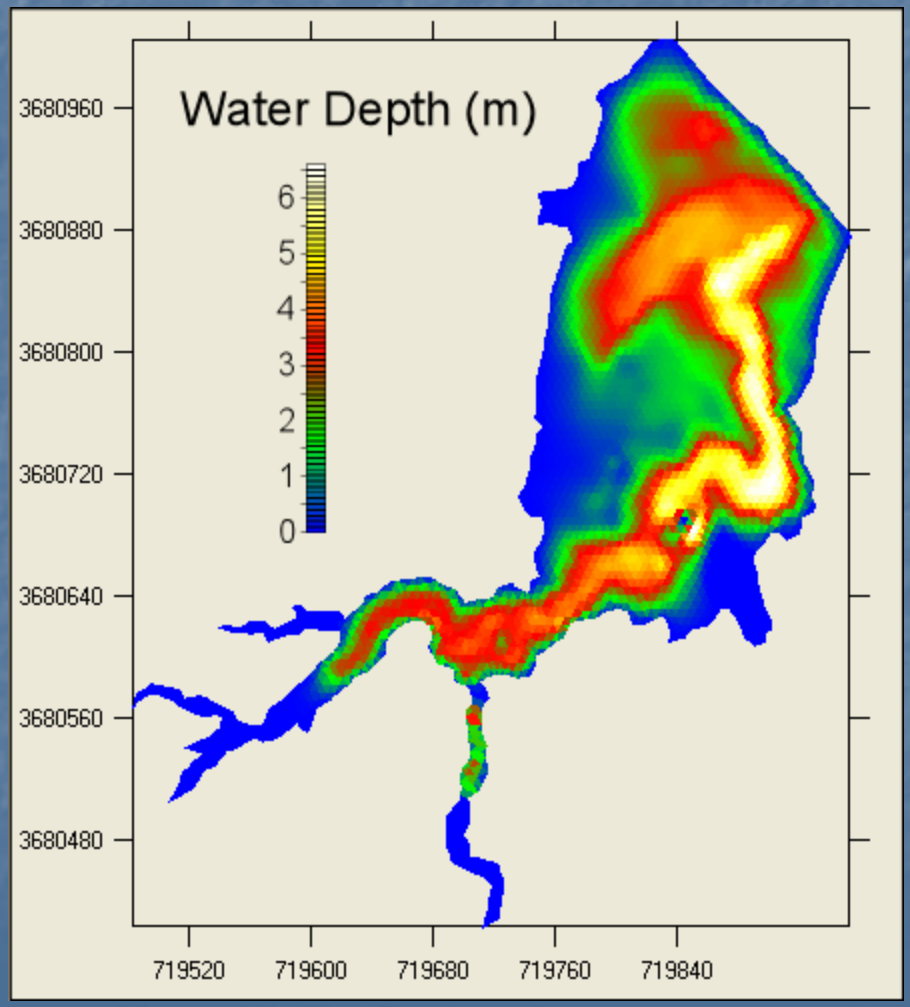


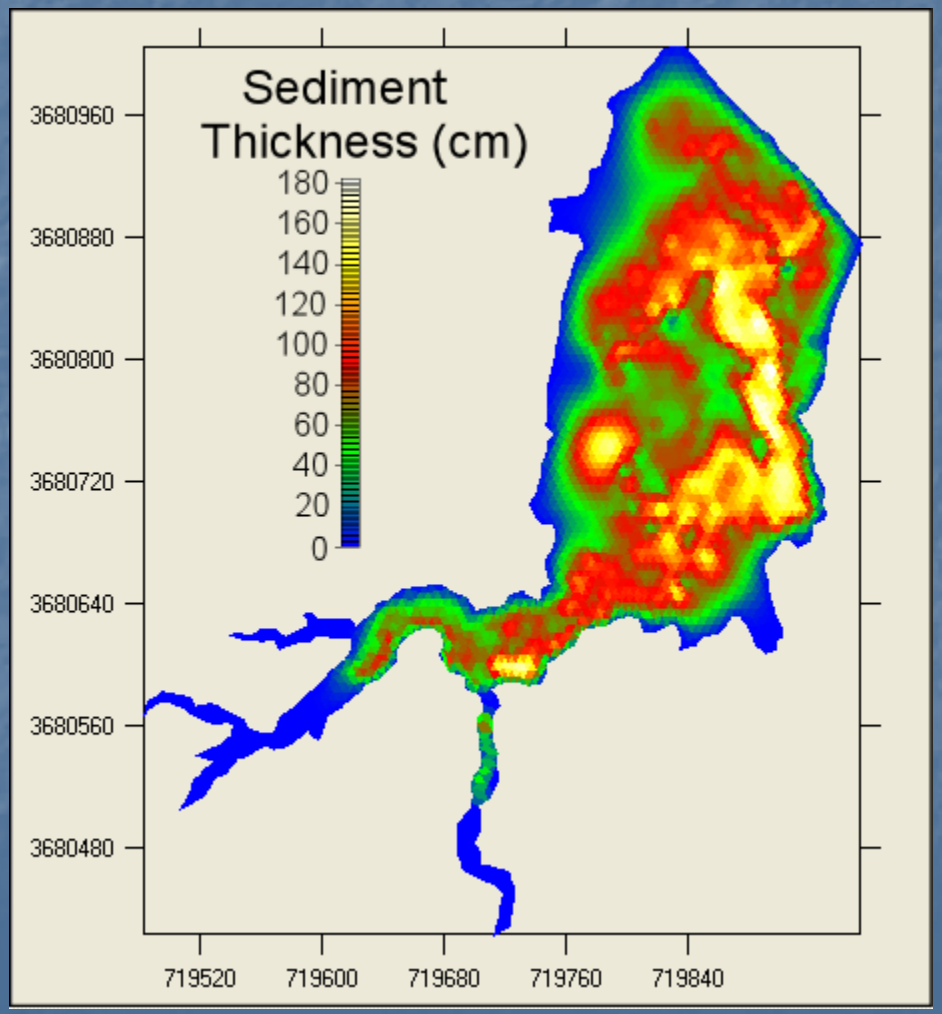
New Method: Survey Vessel

Vibracoring in Flood Control Reservoirs

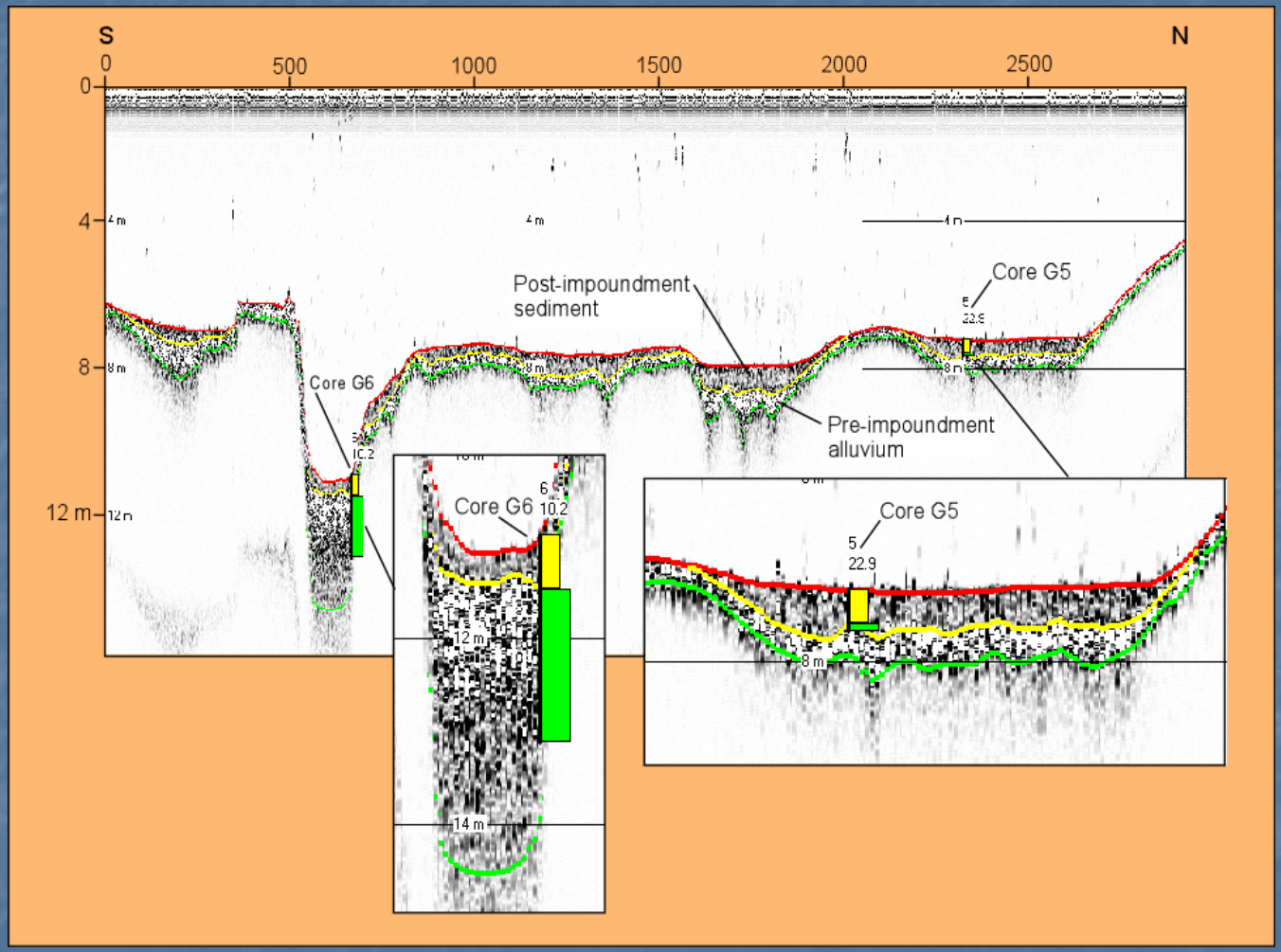


Water Depth and Sediment Thickness in a Flood Control Reservoir



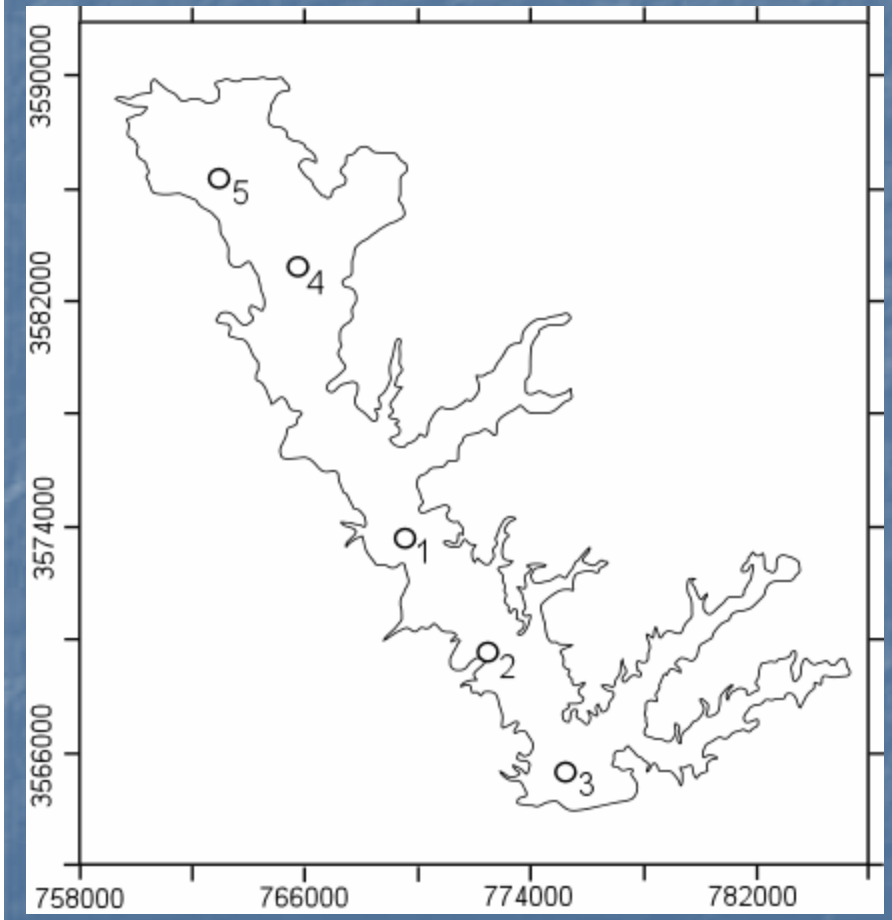


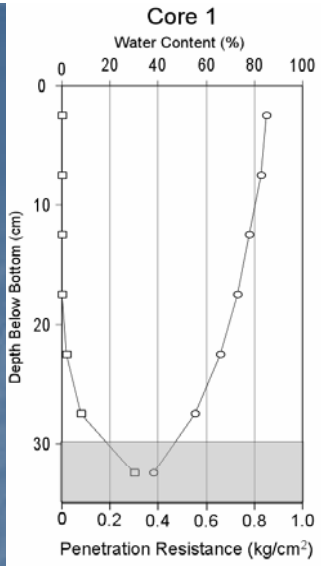
Cedar Creek Results:

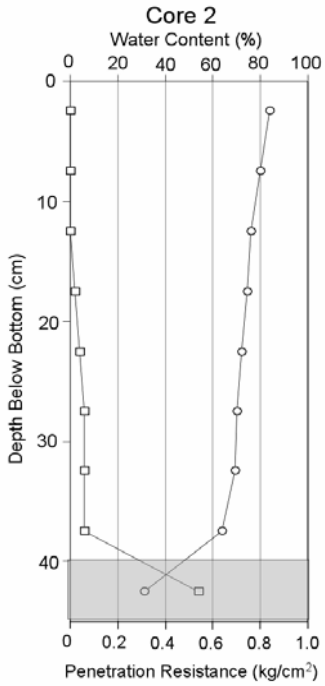


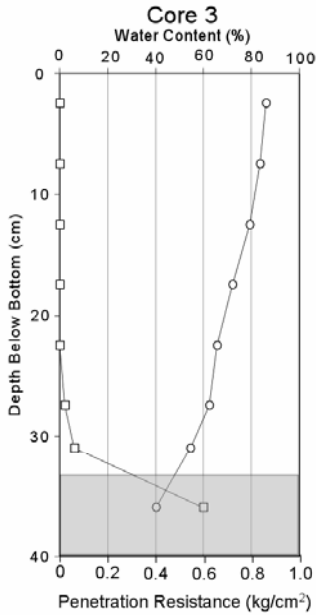
Uniform thickness 1-2ft.

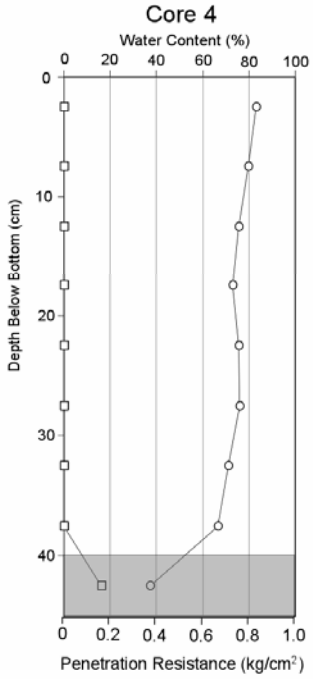
Reservoir Cores and Sediment Survey

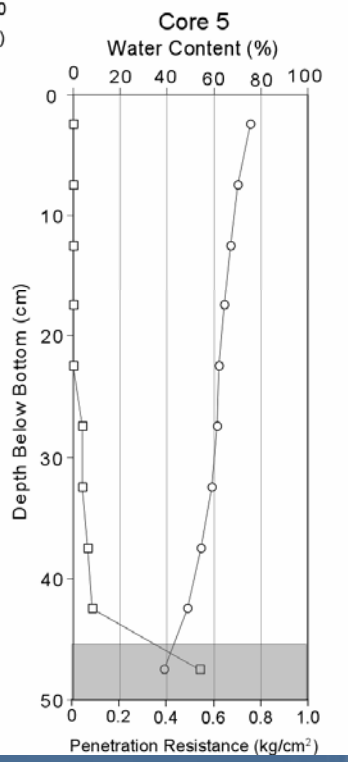












Compute Average Density

Cedar Creek: Results Sub-Bottom System Survey

- Sediment was uniform thickness from 1-2 feet from Sub-bottom acoustics; resurvey volumetric values reasonable for 40 year time period
- Sediment densities were 21.5 lbs/cuft. from core analysis
- Density x Volume= 492,247 tons/yr. total sediment
- REM: 790,000 Bathymetric; 665,480 Gage

Sediment Yeild/Budgets

- Monitoring Suspended Sediment and Bed Material and Gage Data
- Reservoir Surveys/Resurveys
- Inferential: Historical Air Photographs and Field Surveys
- Models

Field Assessment

Laser, Digital Camera, GPS

Survey Form Stream Assessment

Date: / /2006

Location: _____ GPS _____

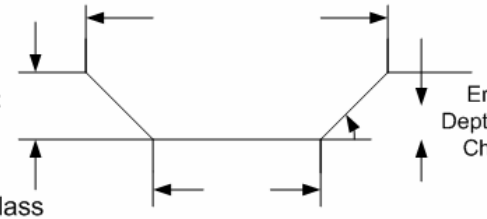
Channel Slope USGS 7.5 _____ Drainage Area Acres _____ Photos _____

1 Channel, Gully, Other If Gully Note: headcut height?___

2 Riparian Vegetation: Note on bank

3 Texture: gravel, sand, silt, clay silty clay, loam

4 Reach Length Visible_____ft.



Erosion Class
5 Slight_____
Moderate____
Severe_____

6 Bed Material Size (est.)
_____

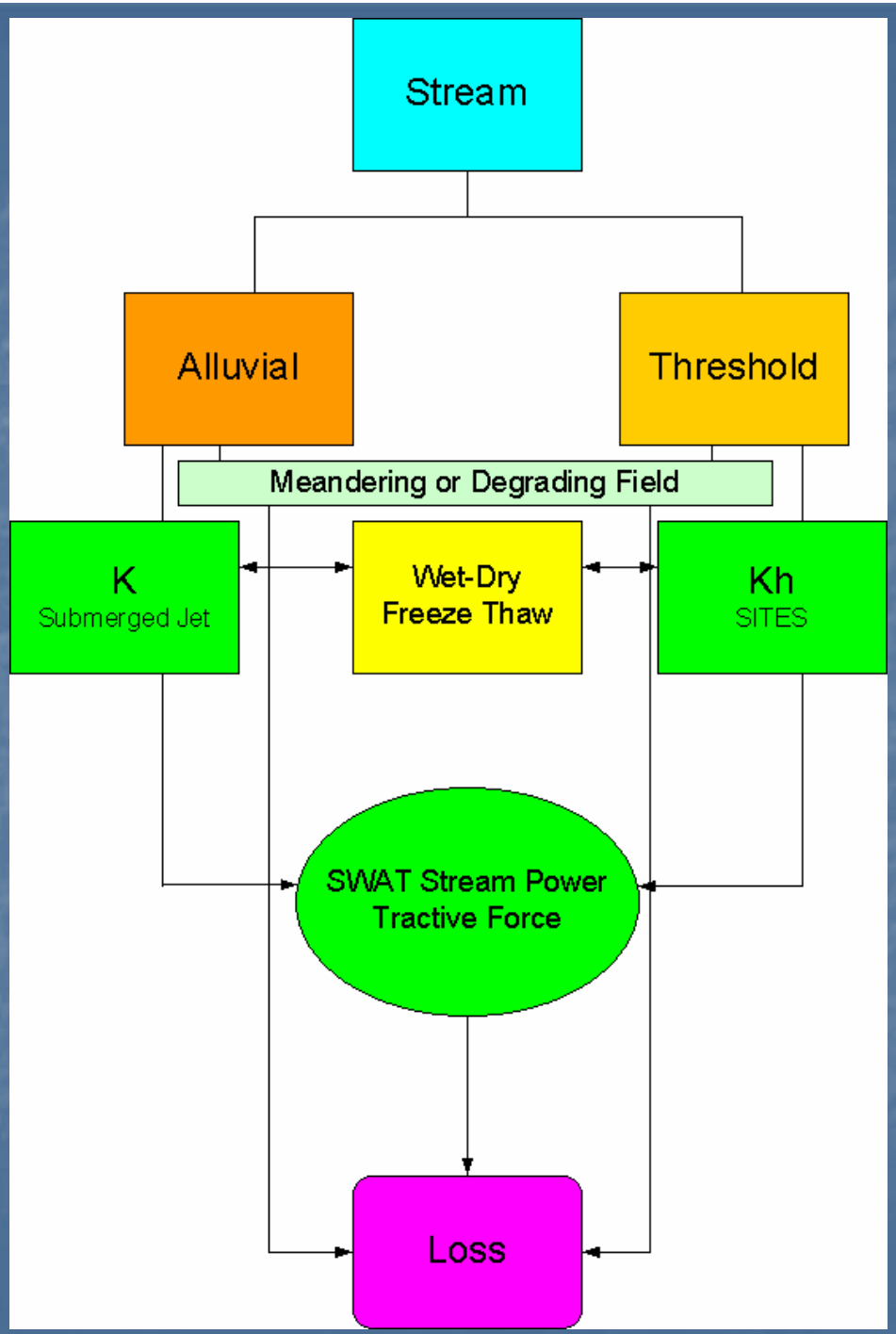
Erosion Class
Slight_____
Moderate____
Severe_____

7 Bank Processes
Slumps__
Wedge__
Infinite Slope__

Bank Processes
Slumps__
Wedge__
Infinite Slope__

8 CEM Model Phase
I Stable
II Degrading
III Degrading and Widening
IV Aggrading

PMA


Stream
Alluvial
Threshold
Meandering or Degrading Field
K
Submerged Jet
Wet-Dry
Freeze Thaw
Kh
SITES
SWAT Stream Power
Tractive Force
Loss

1. Stream Types: Will it Erode?

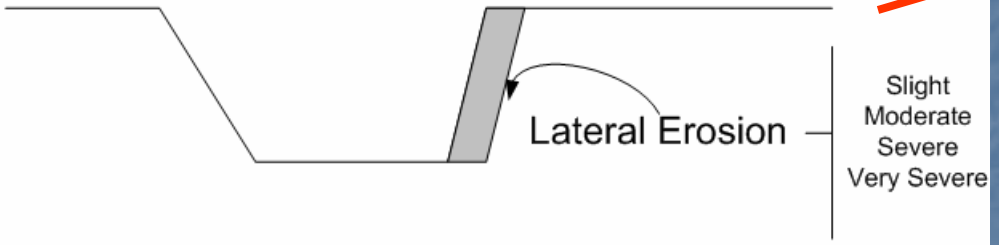
Alluvial

Threshold

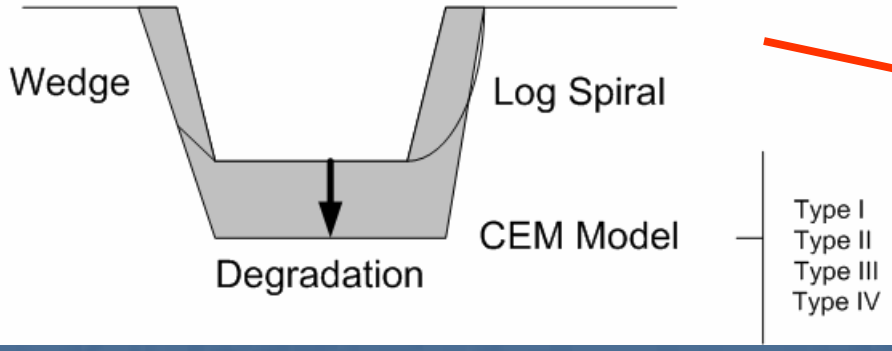
2. Erosion: Implications

Channel Erosion Meandering/Degrading

Meandering Channel System



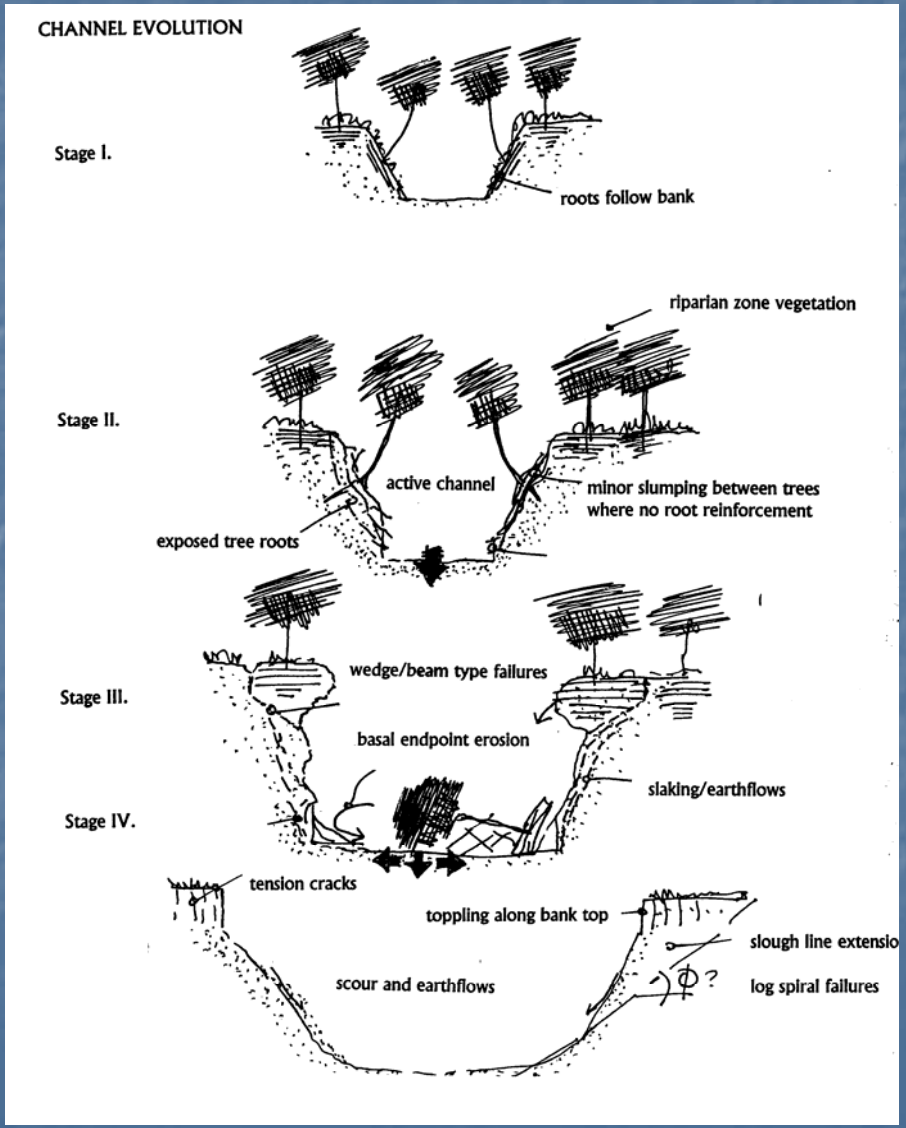
Degrading Channel System

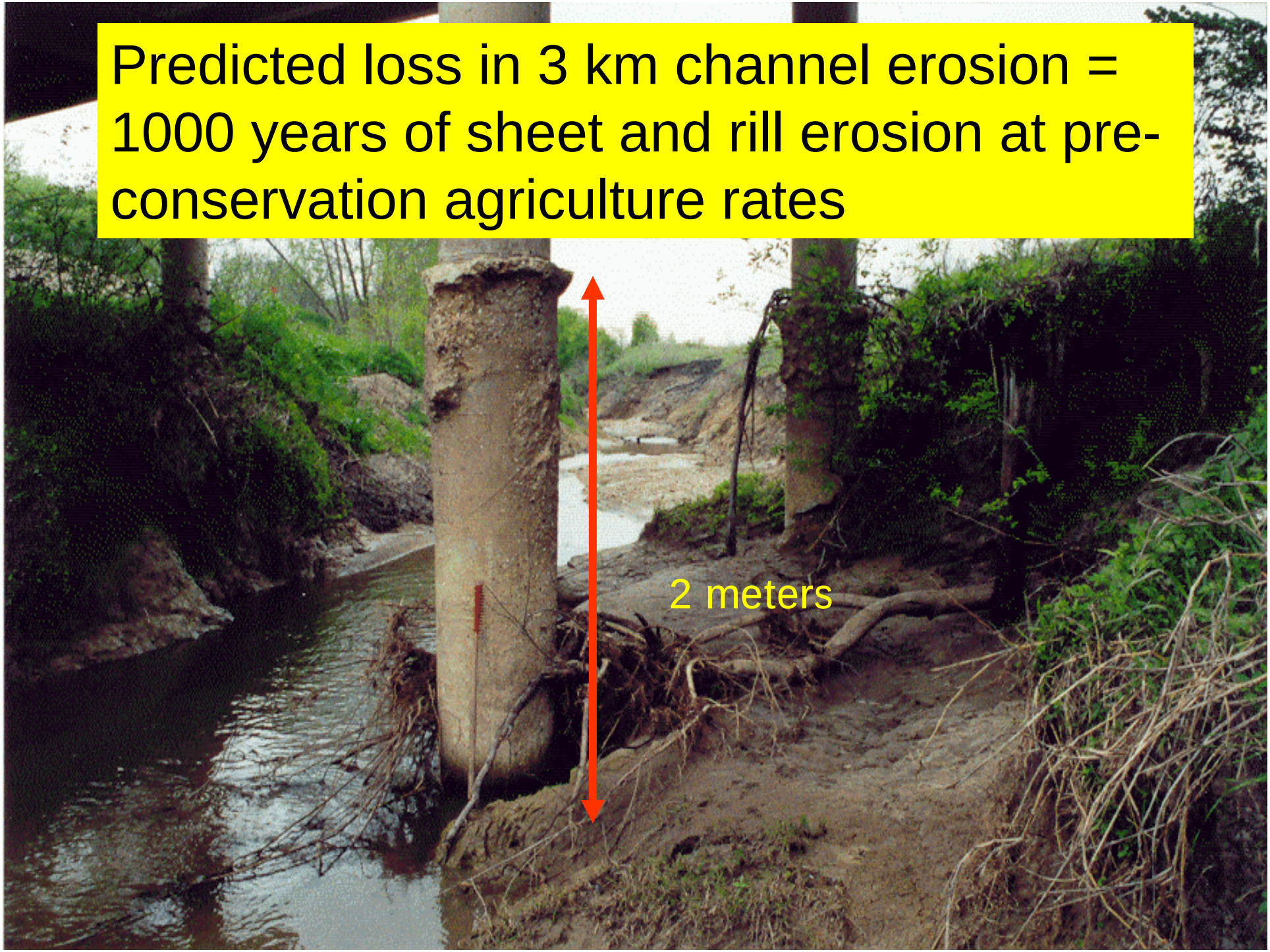


Downcut =3X Greater Erosion

Channel Evolution Model:

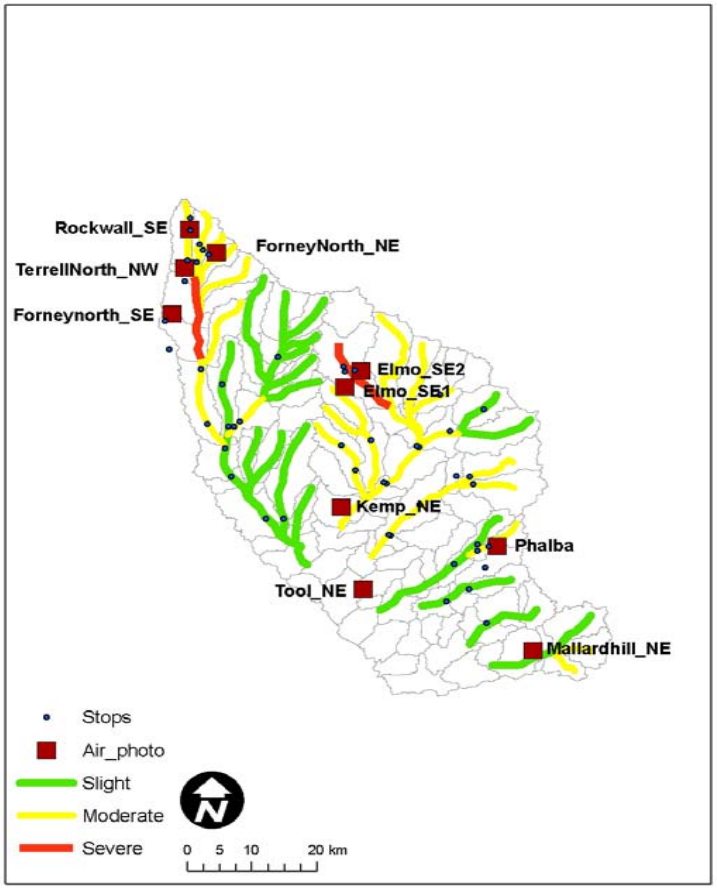
Degrading System



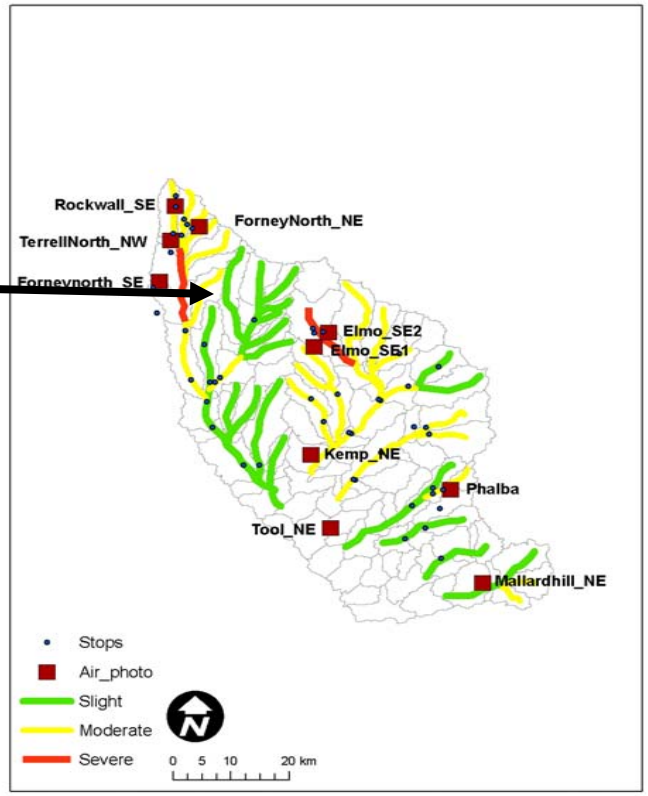

Predicted loss in 3 km channel erosion = 1000 years of sheet and rill erosion at pre-conservation agriculture rates
2 meters

Cedar Creek: Field + Airphotos = Reach Classification

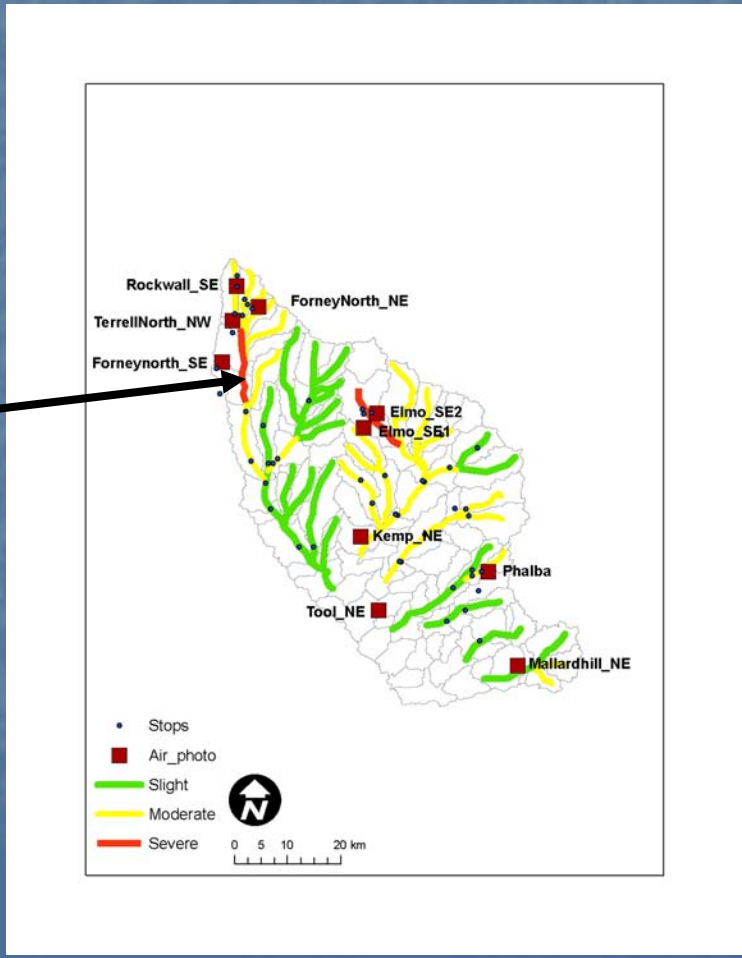
Visited 29 Locations;
Analyzed 10 Historic Photos



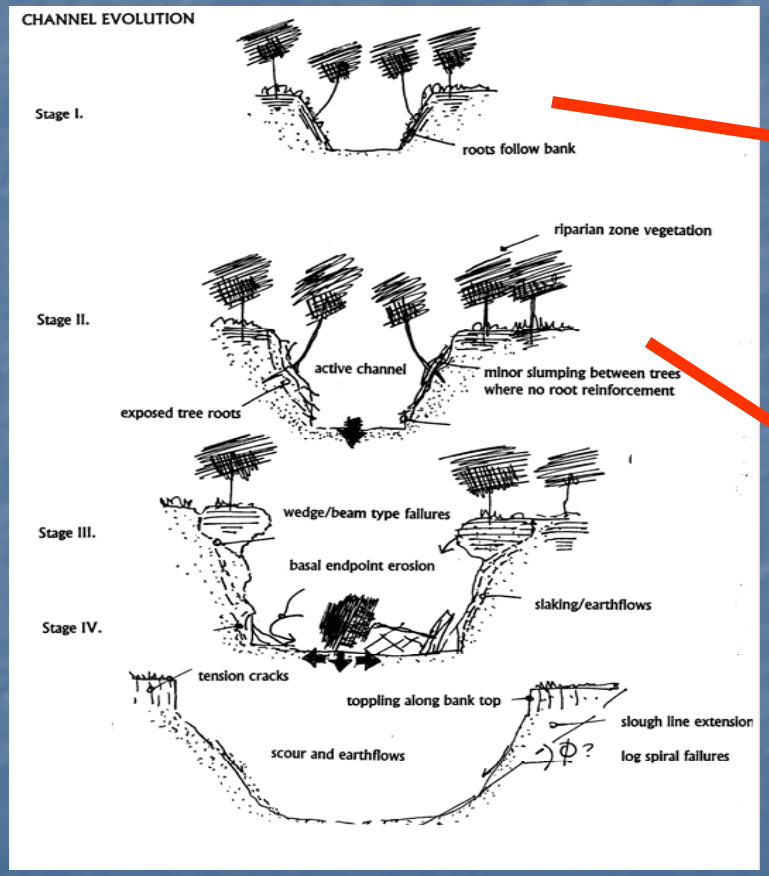
Cedar Creek: Lateral Erosion Most Prominent 90% Channels



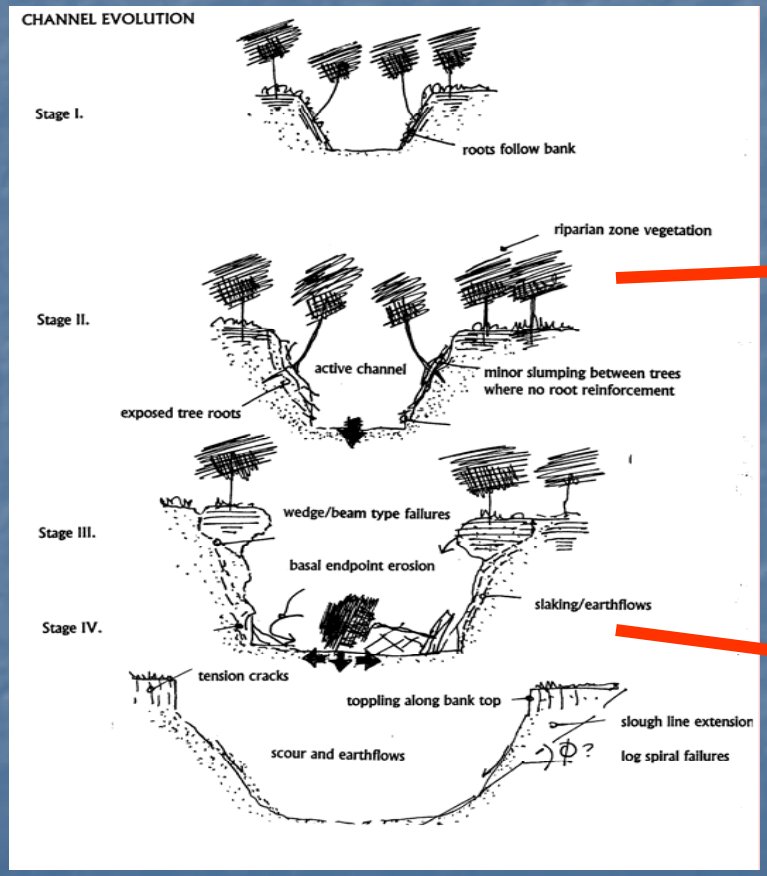
Cedar Creek: Degrading Channels About 10%



Cedar Creek: Degrading Channels
CEM: I-II



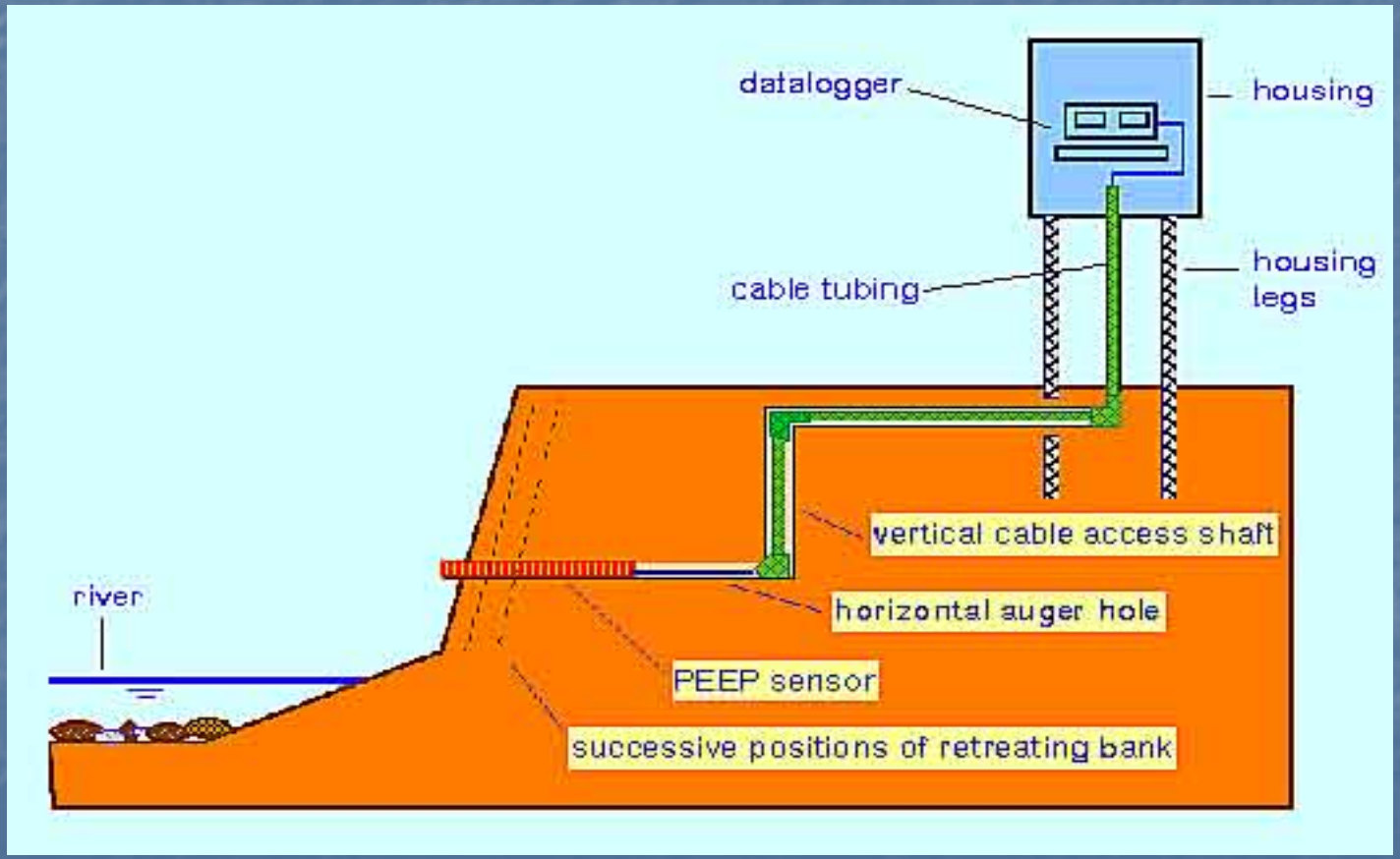
Cedar Creek:CEM: II-III



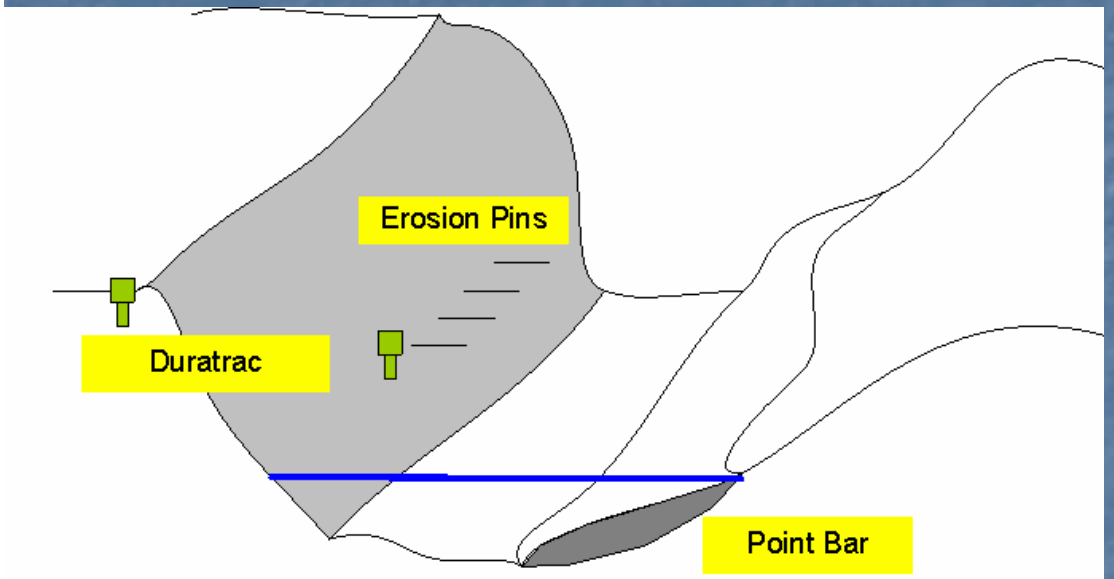
Erosion Rates?

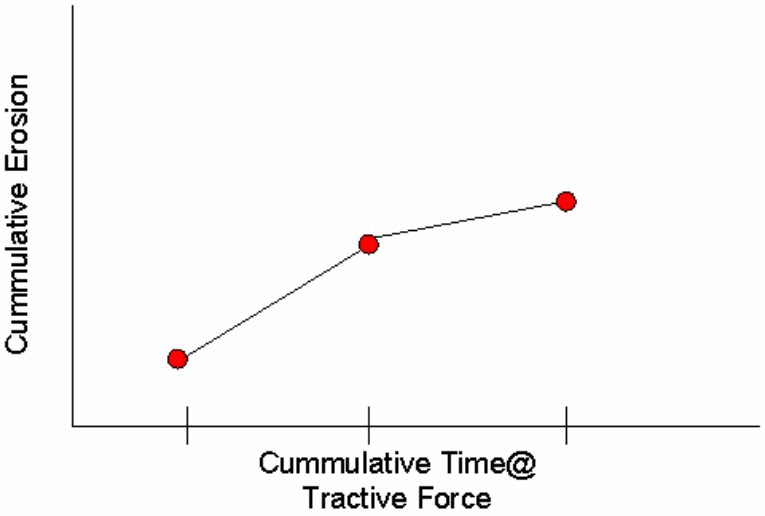
- Monitor: Best data but time consuming and costly
- Field Assessment of Erosion Coefficients: Submerged Jet Test (Hanson, 1990)
- Other Empirical Methods

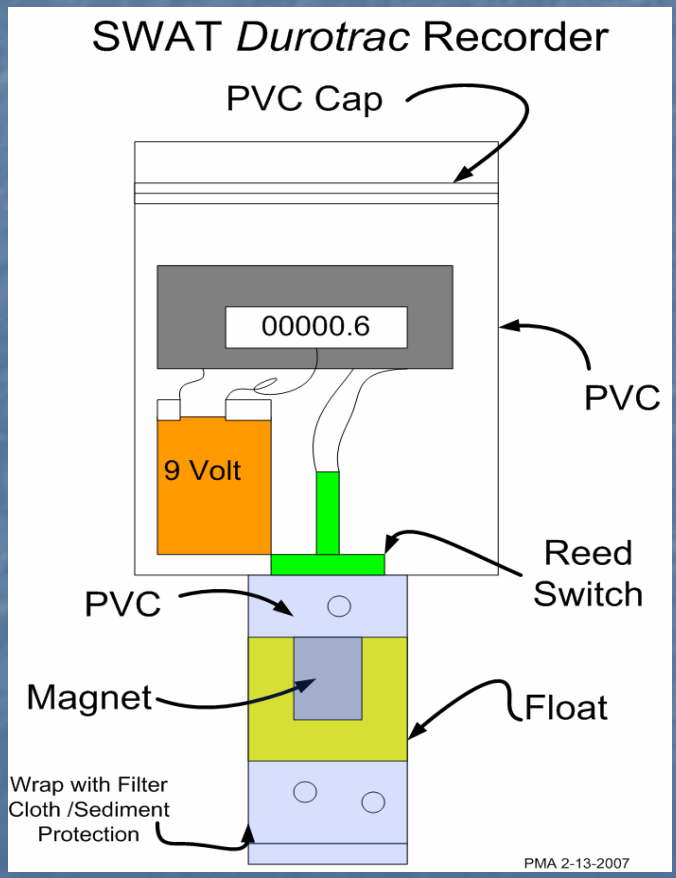
Monitoring Erosion: Pins or Peeps



Erosion Pins and Duratrac







Erosion Rates?

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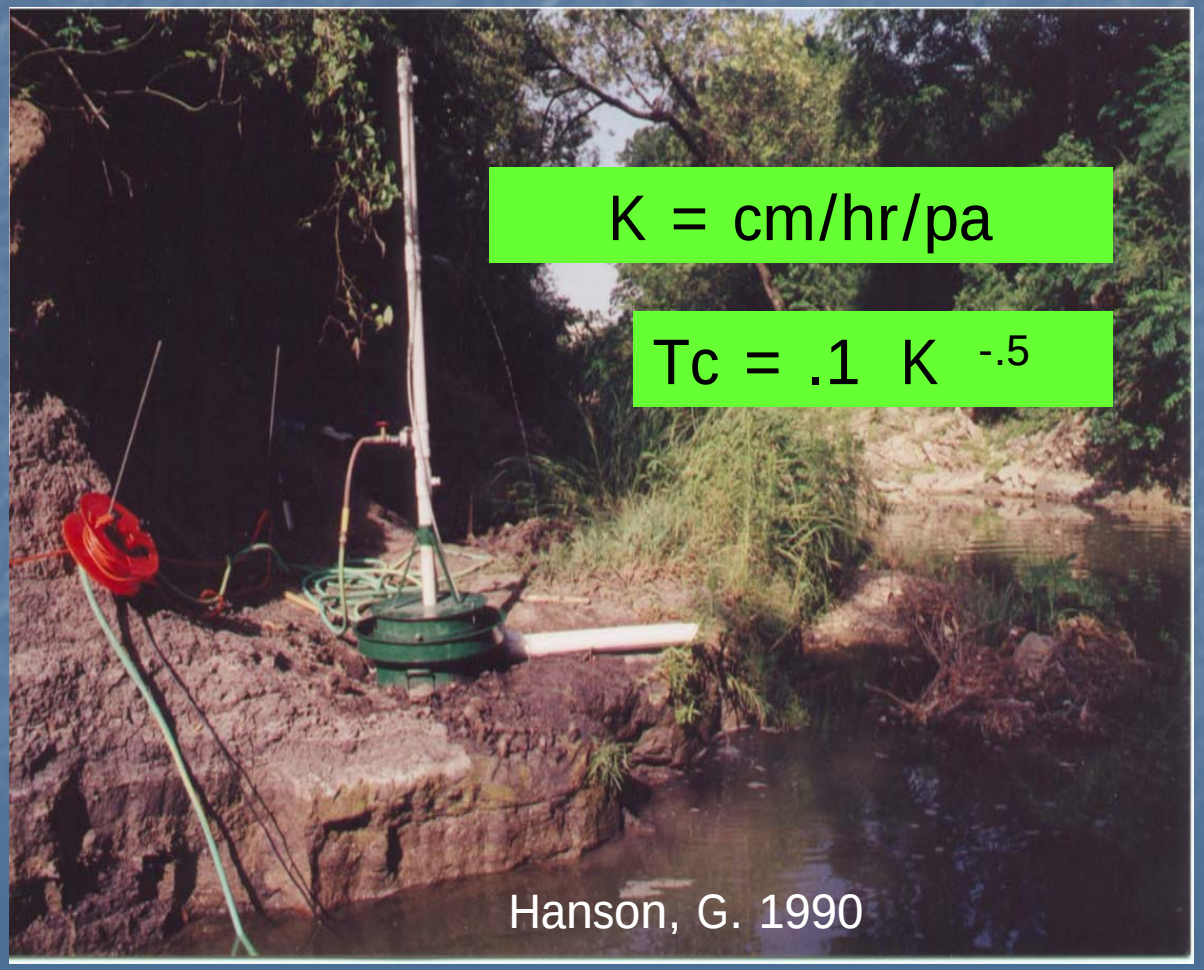
- Field Assessment of Erosion Coefficients: Submerged Jet Test (Hanson, 1990)
- Other Empirical Methods

Cedar Creek: Submerged Jet Test

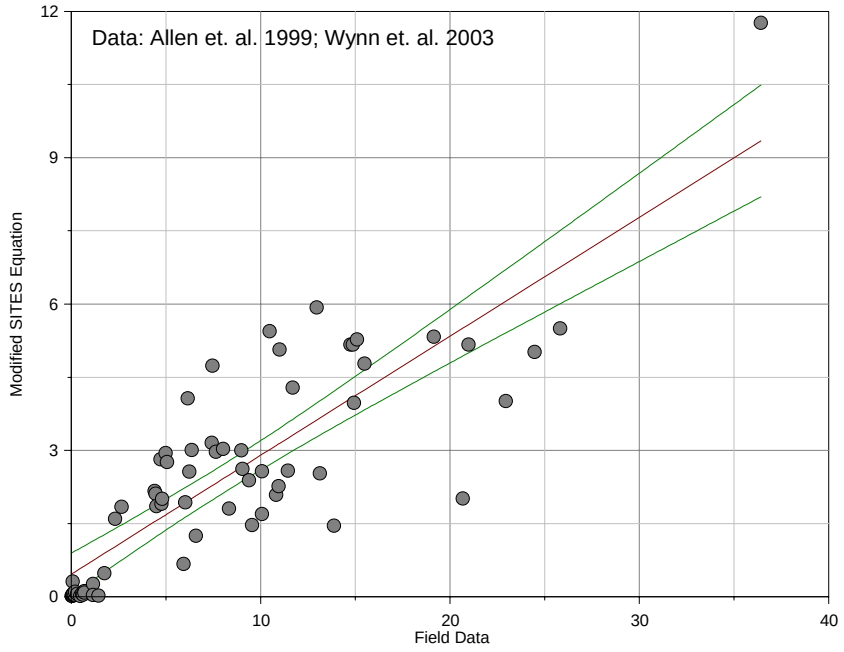
- Hanson
- Wynn
- Allen
- Simon



DETACHMENT RATE EQUATION

$$k_d = \frac{5.66\gamma_w}{\gamma_d} \exp[\,-0.121(c\%)^{0.41}\left(\frac{\gamma_d}{\gamma_w}\right)^{3.10}]$$

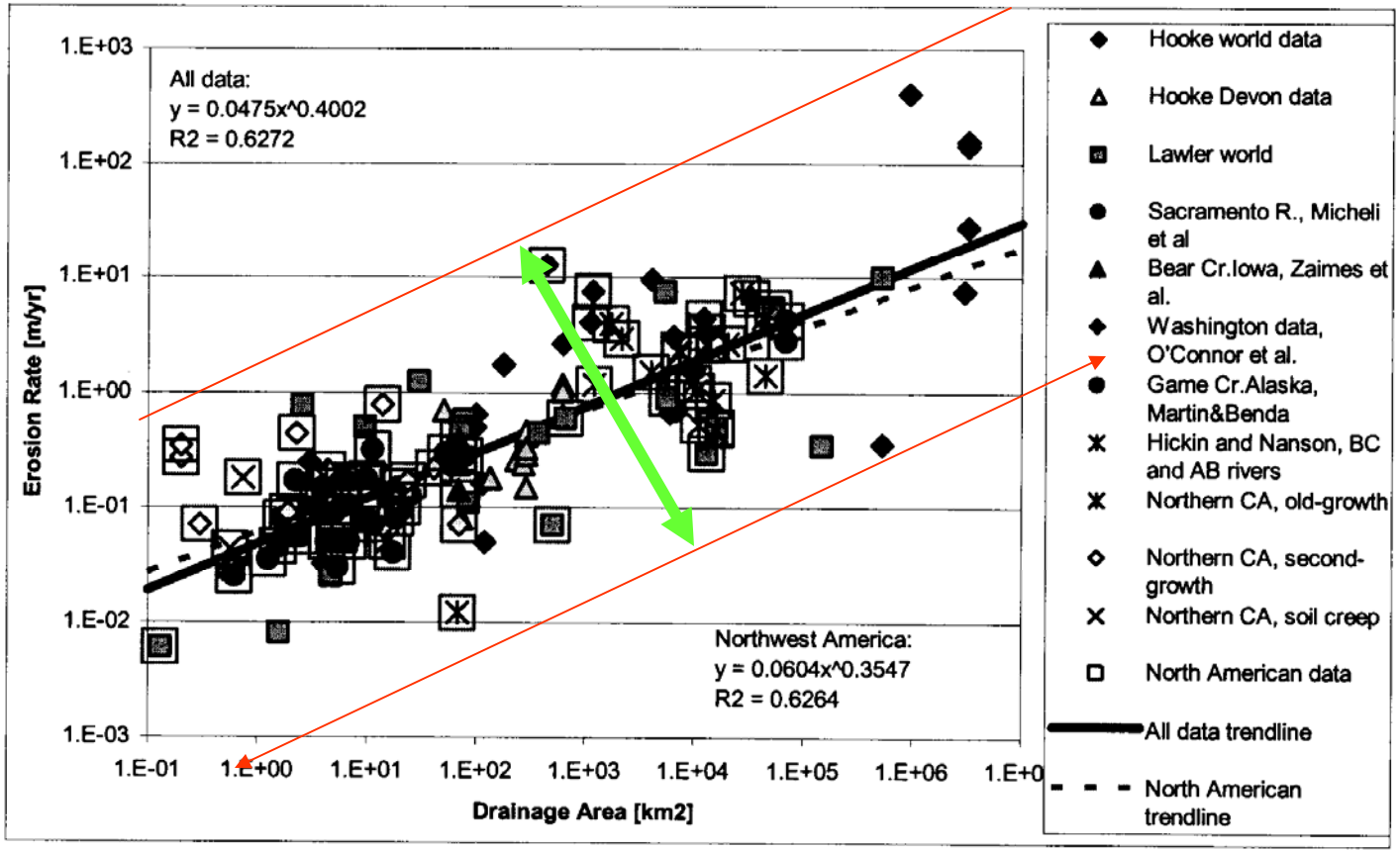
K~ Unit Dry Weight; % Silt Clay; Wet/Dry; Freeze Thaw



Erosion Rates?

- Monitor: Best data but time consuming and costly
- Field Assessment of Erosion Coefficients: Submerged Jet Test (Hanson, 1990)
- Other Empirical Methods

Results Monitoring: Worldwide Channel Erosion



Volume Erosion Channel: Methods

Griener Method (1982)	**Channel/Gully Rate*Delivery Ratio**
Wilkinson Method	**0.5 Length *Height*Er*Density**
Integration Method	**Same above except allow for change width with length**
SEDNET Method	**.0001pgQS Stream Power**
Gaged Data Method	**Estimates Based on Simon's Sediment Yield Eq. and % channel erosion**

Rate Erosion: Field Loss Rates

Lateral Recession Rate (ft/yr.)	Average (ft./year)	Category	Description
0.01-0.12	.0675	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang. No exposed tree roots.
0.2-0.8	.5	Moderate	Bank is predominantly bare with some rills and vegetative overhang. Some exposed tree roots. No slumps.
0.5-1.4	.94	Severe	Bank is bare with very noticeable vegetative overhang. Many tree roots exposed and some fallen trees. Slumping or rotational failures are present. Some changes in cultural features such as missing fence posts and realignment of roads.

Quantify with Duratrac/Pin data

Sediment Density Values

Soil Textural Class	Dry Density For Design (tons/cubic foot)
Organic matter	0.011
Gravel	0.05
Sand	0.055
Silt	0.0425
Clay	0.035

Cedar Creek: Channel Erosion All Methods

Method	Modeled Channel Erosion (tons/year)
Model Calibrated Original Data	471,052 (Spatial Sciences Lab)
Griener Method (1982)	129,357 (adjusted for upstream reservoirs)
Wilkinson Method	168,182 (SWAT channel lengths)
Integration Method	151,359 (Drainage Area/Length)
SEDNET Method	197,684 (bare channel condition)
Gaged Data Method	225,922 (Assume Blackland 1/3 basin)
Mean (All Methods)	165,504

Field Data Taken at One Time: Past Land Use Changes?

- Historical Air Photographs
- 10 year Intervals

1940

1956

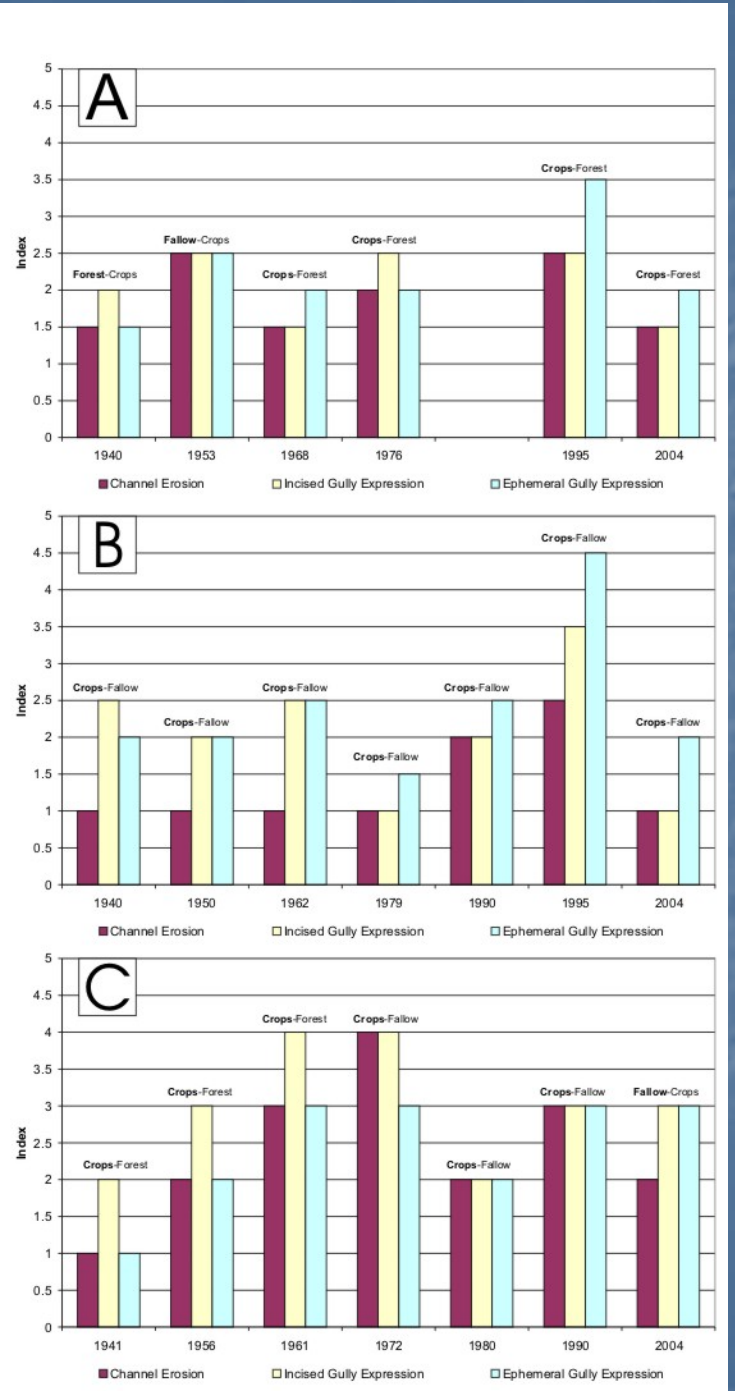
1961

1979

1995

2004

Time Series Air Photographic Analysis Indicates Fairly Stable Land-use over the Basin Since the Reservoir Built



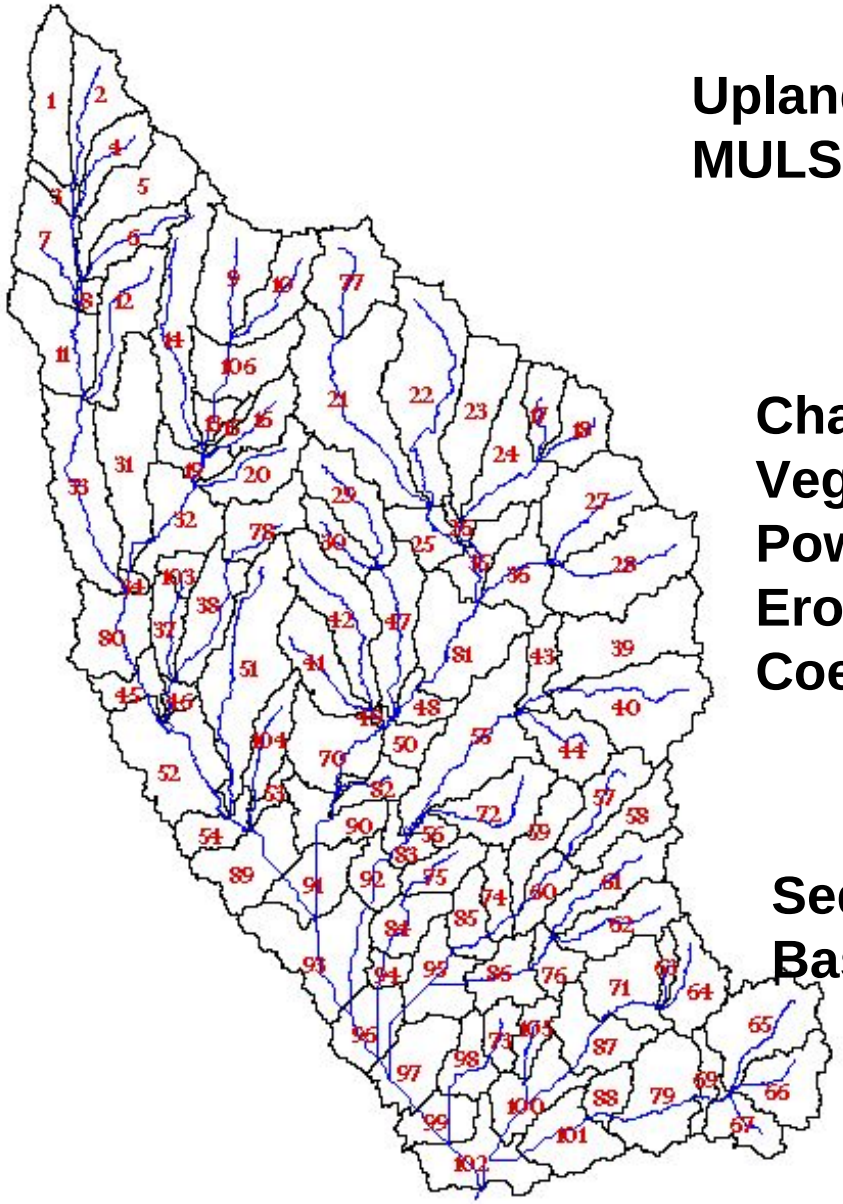
Sediment Yield/Budgets

- Monitoring Suspended Sediment and Bed Material and Gage Data
- Reservoir Surveys/Resurveys
- Inferential: Historical Air Photographs and Field Surveys
- Models

SWAT

Soil and Water Assessment Tool

Jeff Arnold
USDA-ARS, Temple, TX

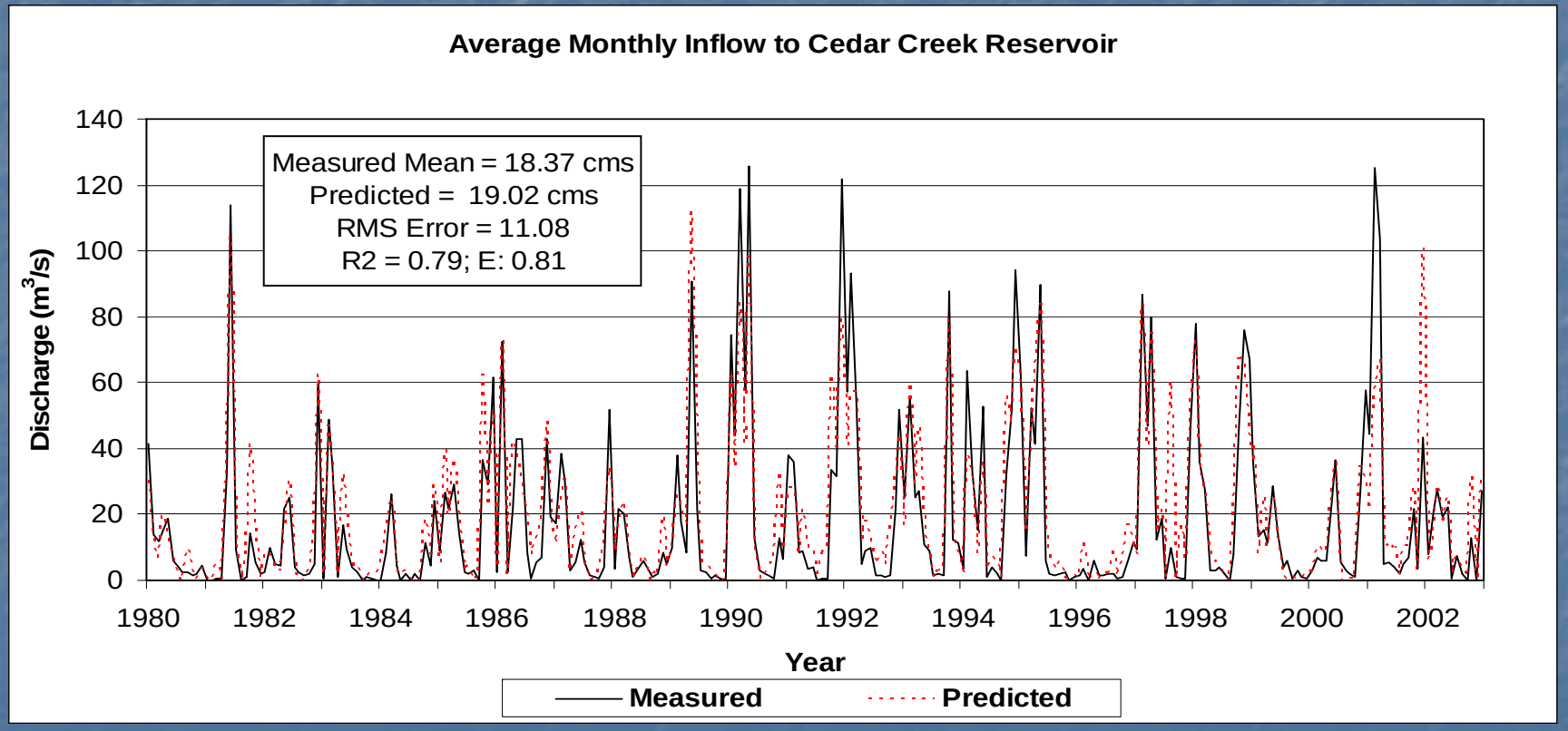


Uplands modelled MULSE

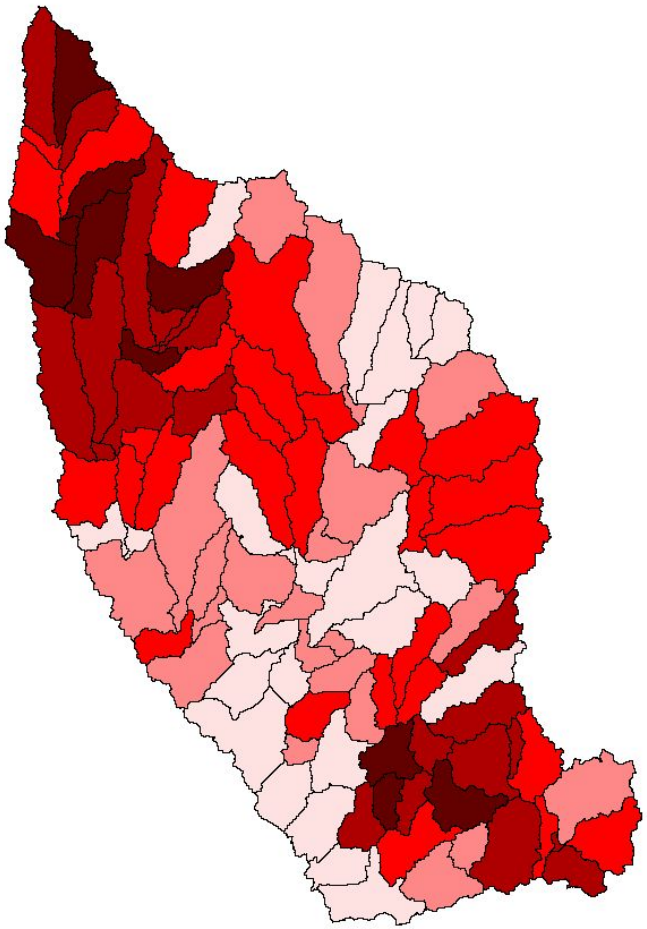
Channel Erosion: Vegetation, Stream Power and Erodibility Coefficient

Sediment Routed to Basin Outlet

Cedar Creek: Discharge



Overland Erosion

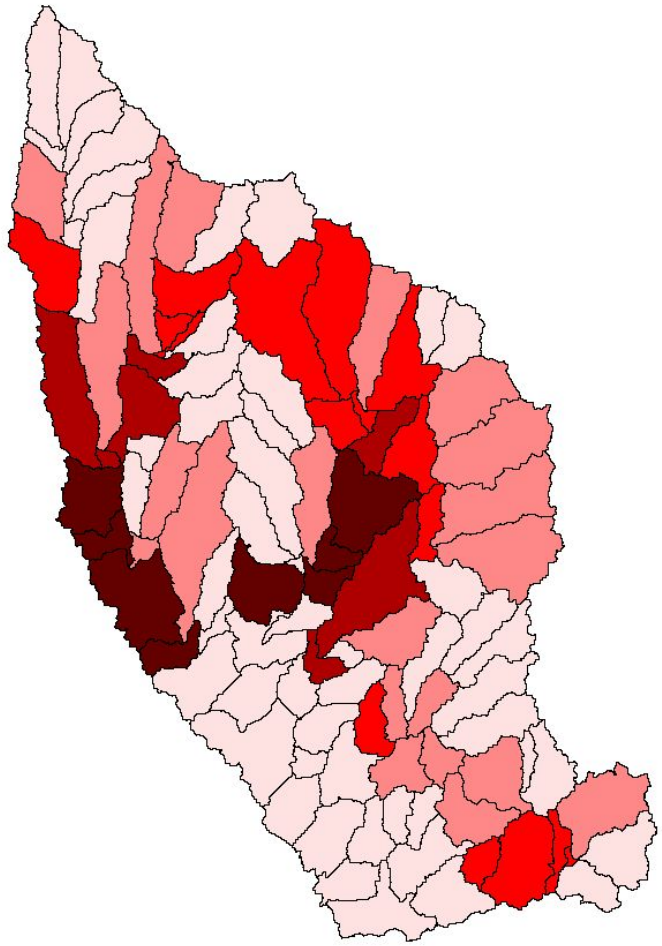


Overland Erosion (t/ha/year)
- 0.328 - 1.087
- 1.087 - 1.779
- 1.779 - 2.887
- 2.887 - 4.151
- 4.151 - 5.933

N
W E
S

10 0 10 20 Miles

Channel Erosion



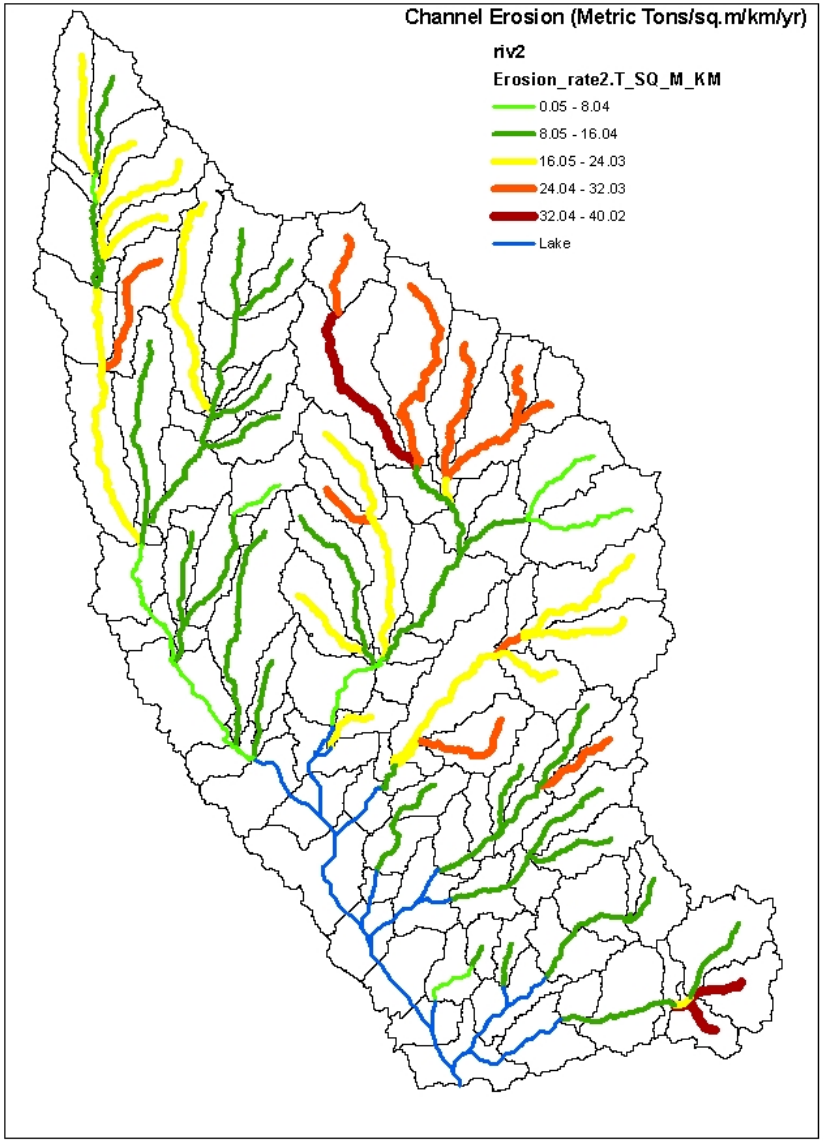
Channel Erosion (kg/m/year)
0 - 6.652
6.652 - 15.157
15.157 - 25.923
25.923 - 50.595
50.595 - 102.387

N
W
E
S

10 0 10 20 Miles

SWAT Modeled Erosion

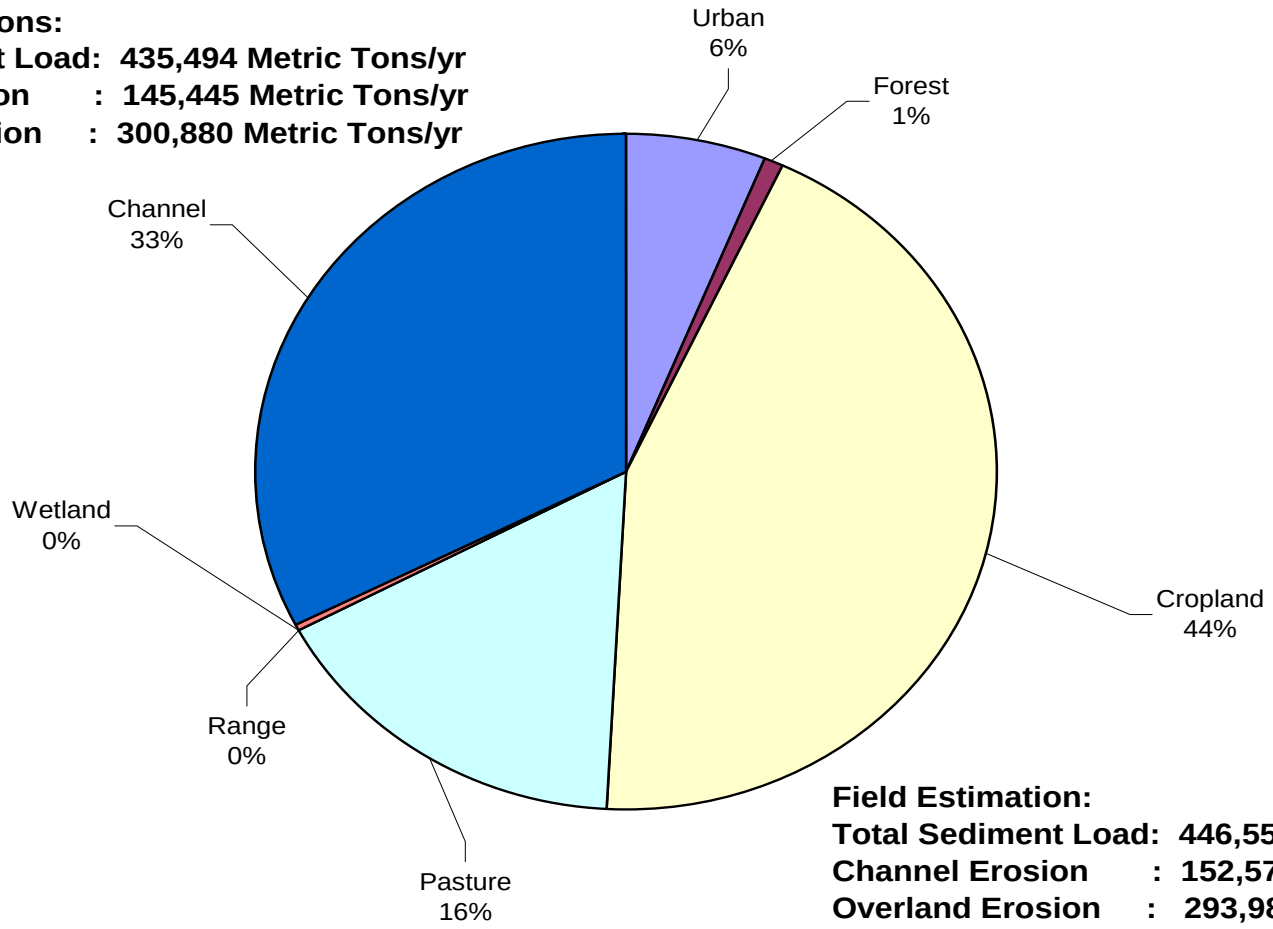
Adjust to Field Data



Cedar Creek: SWAT/FIELD

Cedar Creek (Sediment)

SWAT Predictions:
Total Sediment Load: 435,494 Metric Tons/yr
Channel Erosion : 145,445 Metric Tons/yr
Overland Erosion : 300,880 Metric Tons/yr



Field Estimation:
Total Sediment Load: 446,558 Metric Tons/yr
Channel Erosion : 152,572 Metric Tons/yr
Overland Erosion : 293,986 Metric Tons/yr

Conclusions

- Sub-bottom Reservoir Survey Techniques with core should be considered the gold standard for assessing sedimentation rates (Cesium for older structures)
- RGA: by land use/physiographic province should be done
- Stream Monitoring: should be started; Pins,Peeps and Submerged Jet
- SWAT integral for prediction future changes under future Land Use, BMP, Climate etc. Field Data gives the past only.