Aug 06 S.R. Geomorphology Data Review

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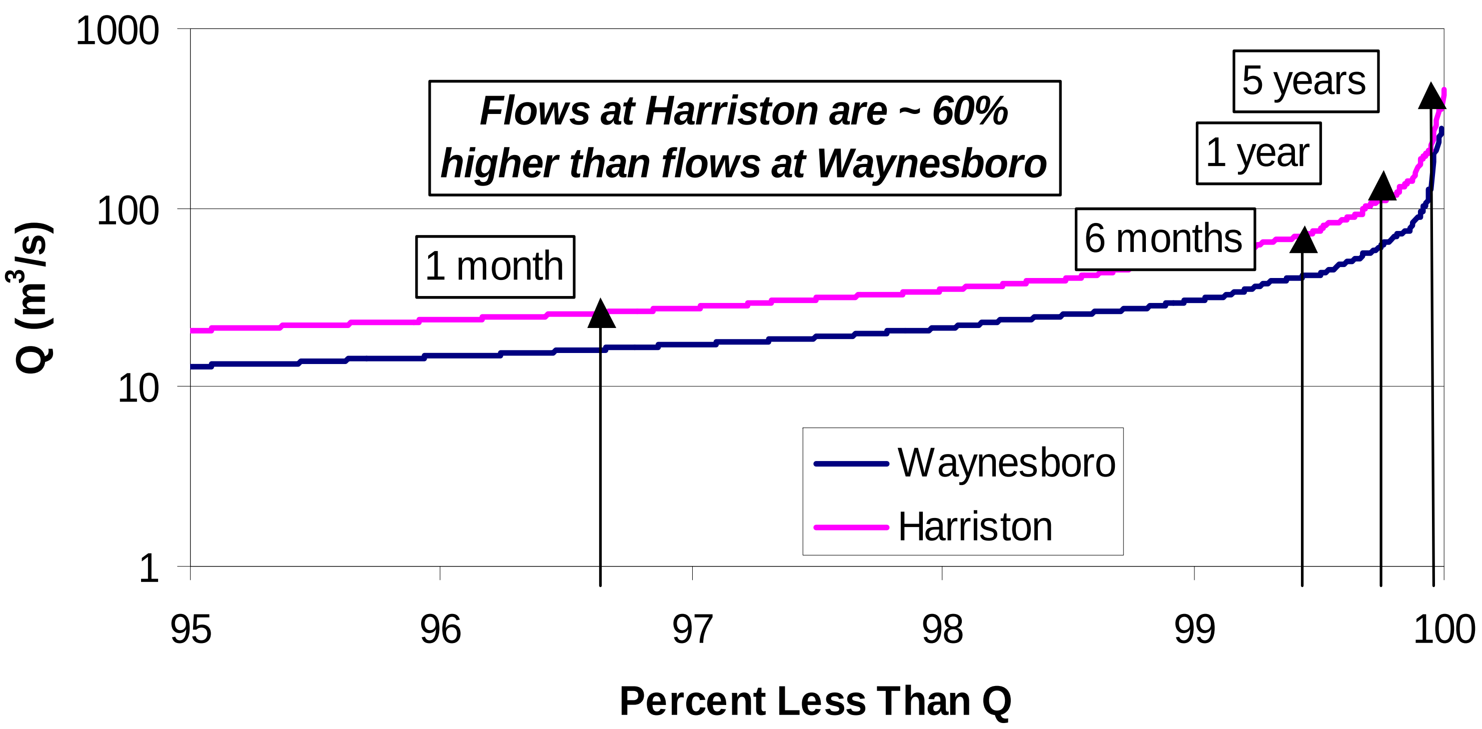
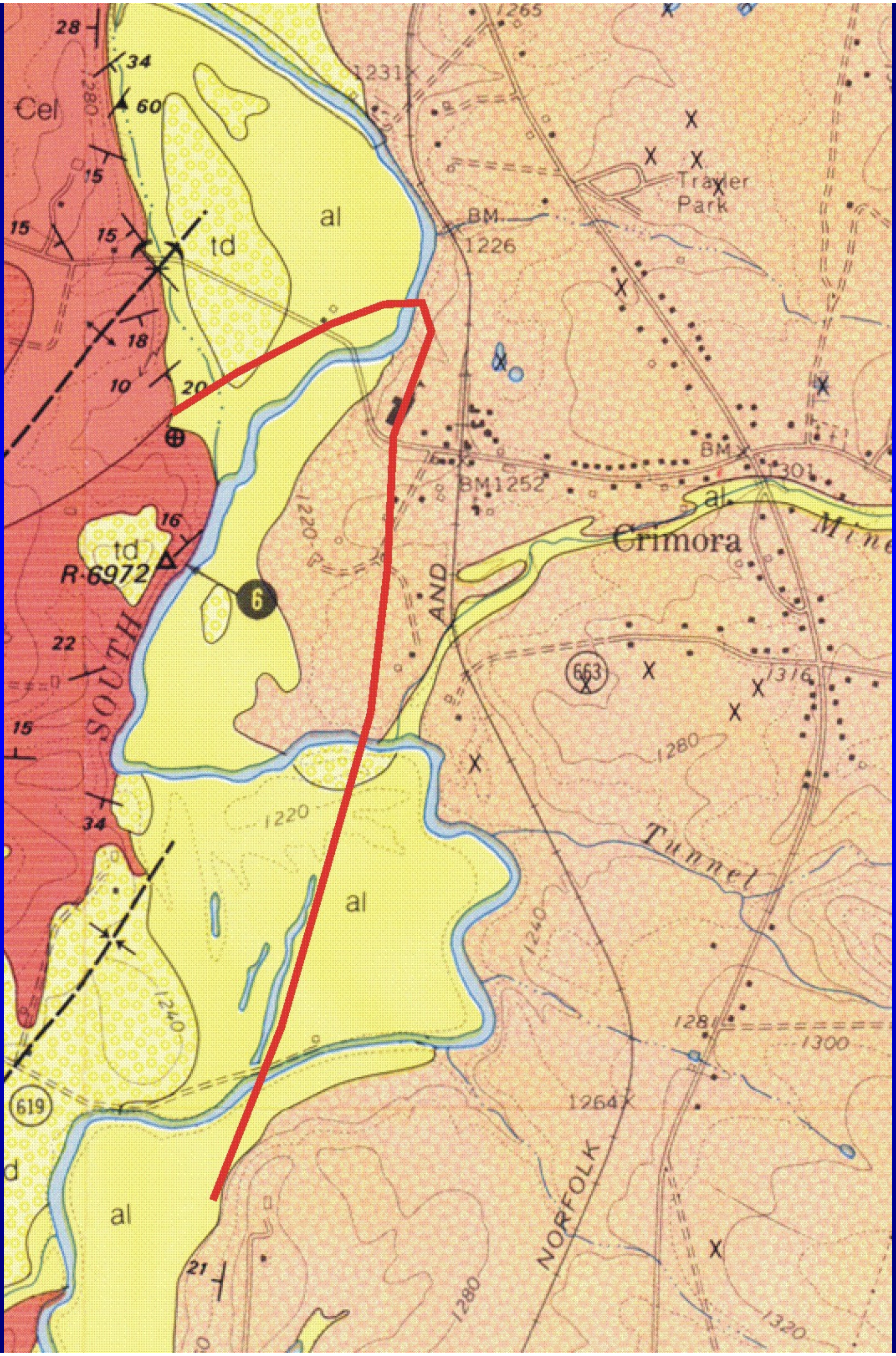
Summary of the Geomorphology of South River, Waynesboro too Port Republic

High Flows Increase ~ 60% from Waynesboro to Harriston (not strongly related to flow recurrence interval)



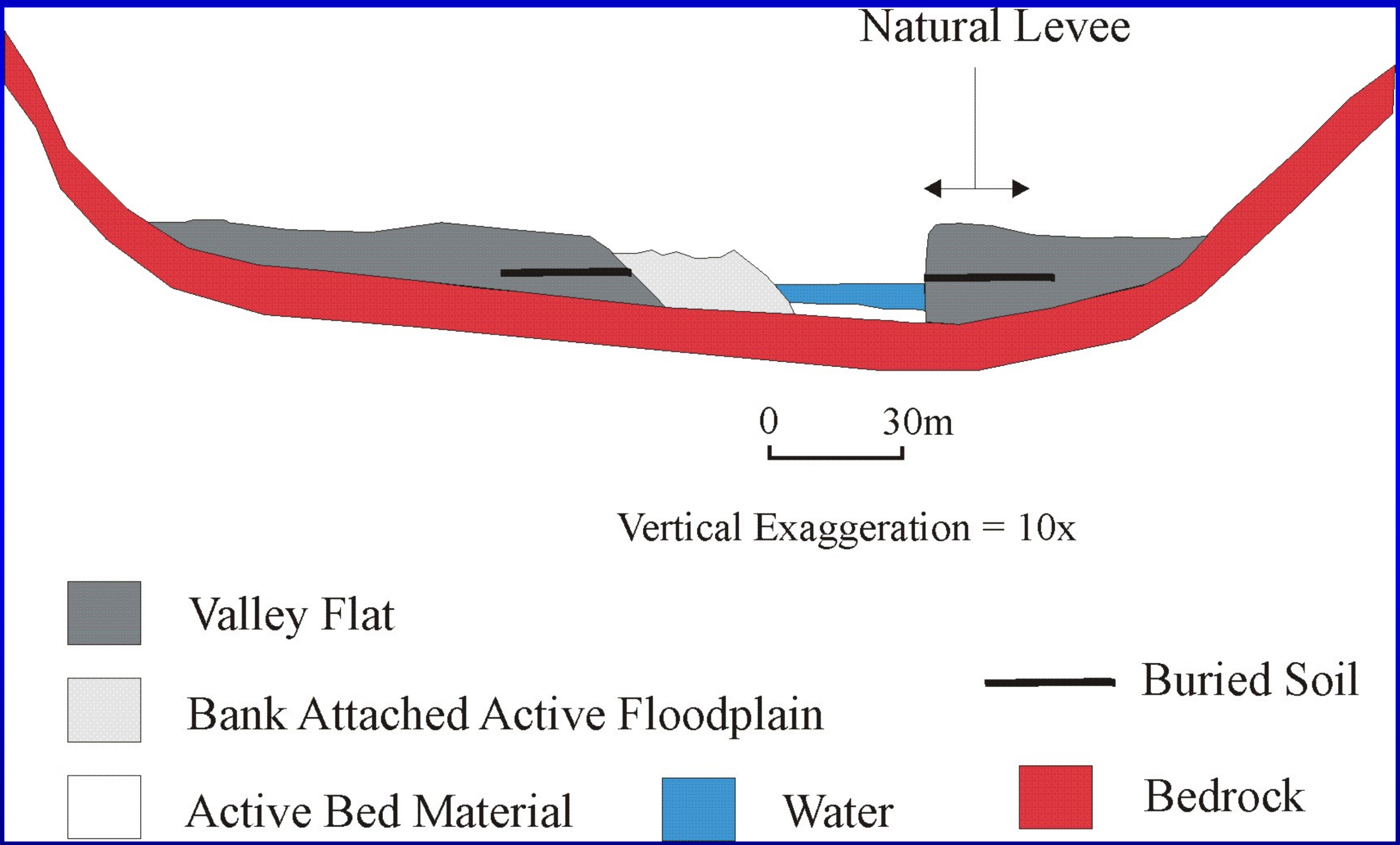
Geologic Setting

- Deposits bordering the channel consist of:
  - Bedrock
  - Modern alluvium
  - “older”Alluvial fan deposits
  - Terrace deposits
- (from GIS rectified published geologic mapping)



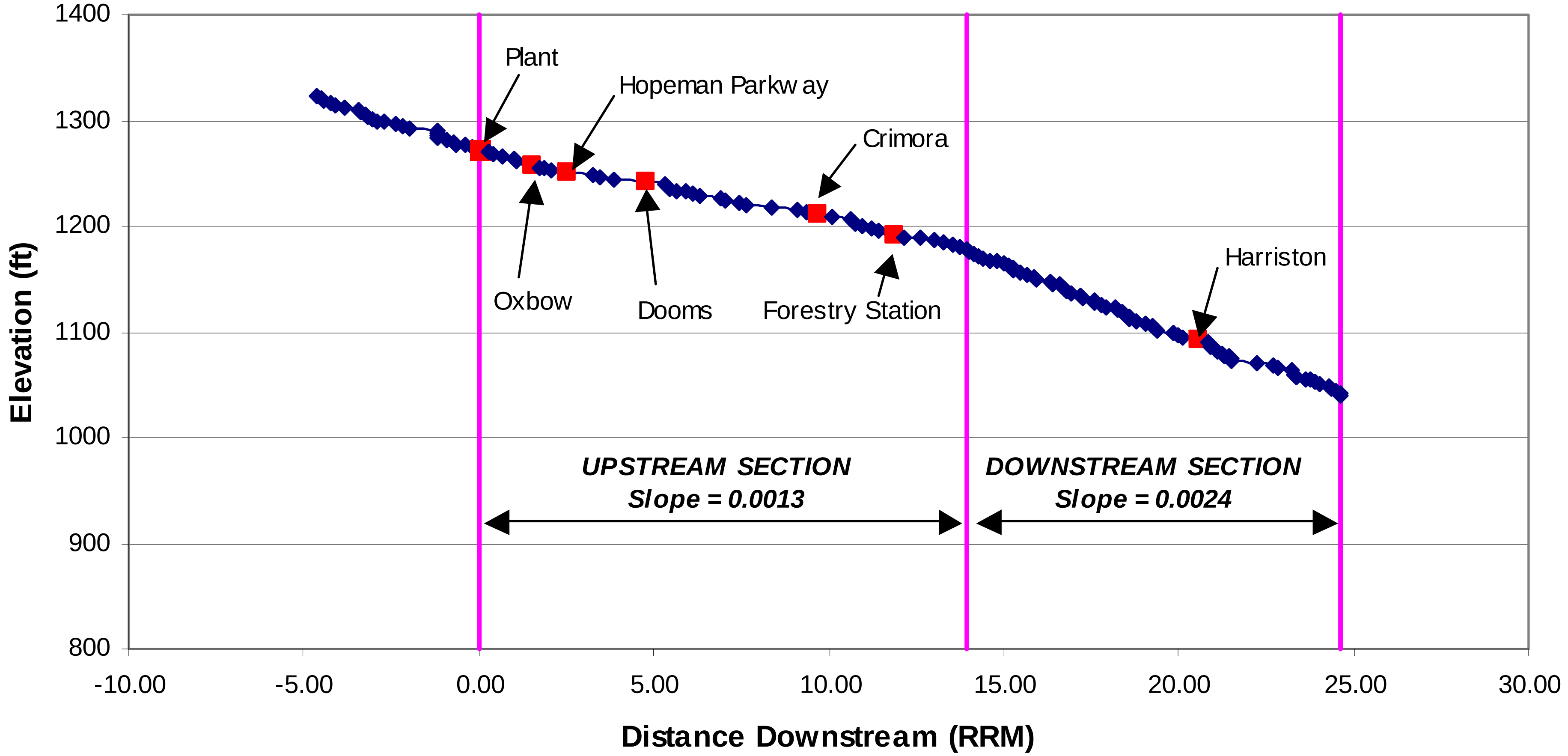
Classification of "Modern" Alluvial Deposits

(mostly applicable to upstream ½ of study area)



Example
“Bank
Attached
Active
Floodplain”

Upstream vs Downstream Reaches



Other Differences Between Upstream and Downstream Reaches

Characteristic	Upstream Value	Downstream Value
Slope	Averages 0.0013	Averages 0.0024
Frequency of islands	1/mile	4/mile
“Modern” alluvial deposits	“wide”	“narrow”
“Currently” eroding banks	25% of banks eroding	17% of banks eroding
Bank erosion 1937-2005	low	high (island formation!)
Silt-clay deposits in channel	46 cubic meters per mile	28 cubic meters per mile
Bed material grain size	Modal size – cobble	Modal size – boulders
“Apparent” natural levees	More abundant	Less abundant

Occurrence of Long Pools

- These are unusual features of gravel-bed rivers
- Some appear to be caused by bedrock exposures
- Others likely occur as a result of gravel inputs from tributaries that “dam” the river

Database of 9 Historic Dams (likely more before 1937)

Informal Name	River Mile	Years Imaged on Aerial Photograp	Comments
Waynesboro Plant	0	1937 , 1949 , 1951	gone in '57
North Park	1.05	1937 , 1949 , 1951	gone in '63
Dooms	4.9	1937 , 1951 , 1976	"out 78" according to 76 photo
Above Crimora	9.62	1937 , 1951	partially out in 76'
Forestry Station	11.62	1937 , 1951	gone in 76, (map says "out 60s")
Above Grand Caverns	19.3	1937 , 1951 ,76	Jersey Lilly Mill ? (from 76 photo)
Below Grand Caverns	20.2	1937 , 1951	gone in 76
Below Grottoes	22.86	1937	gone in 76
Port Republic	23.55	1937 , 1951	Appears breached in 1951 , gone in 76

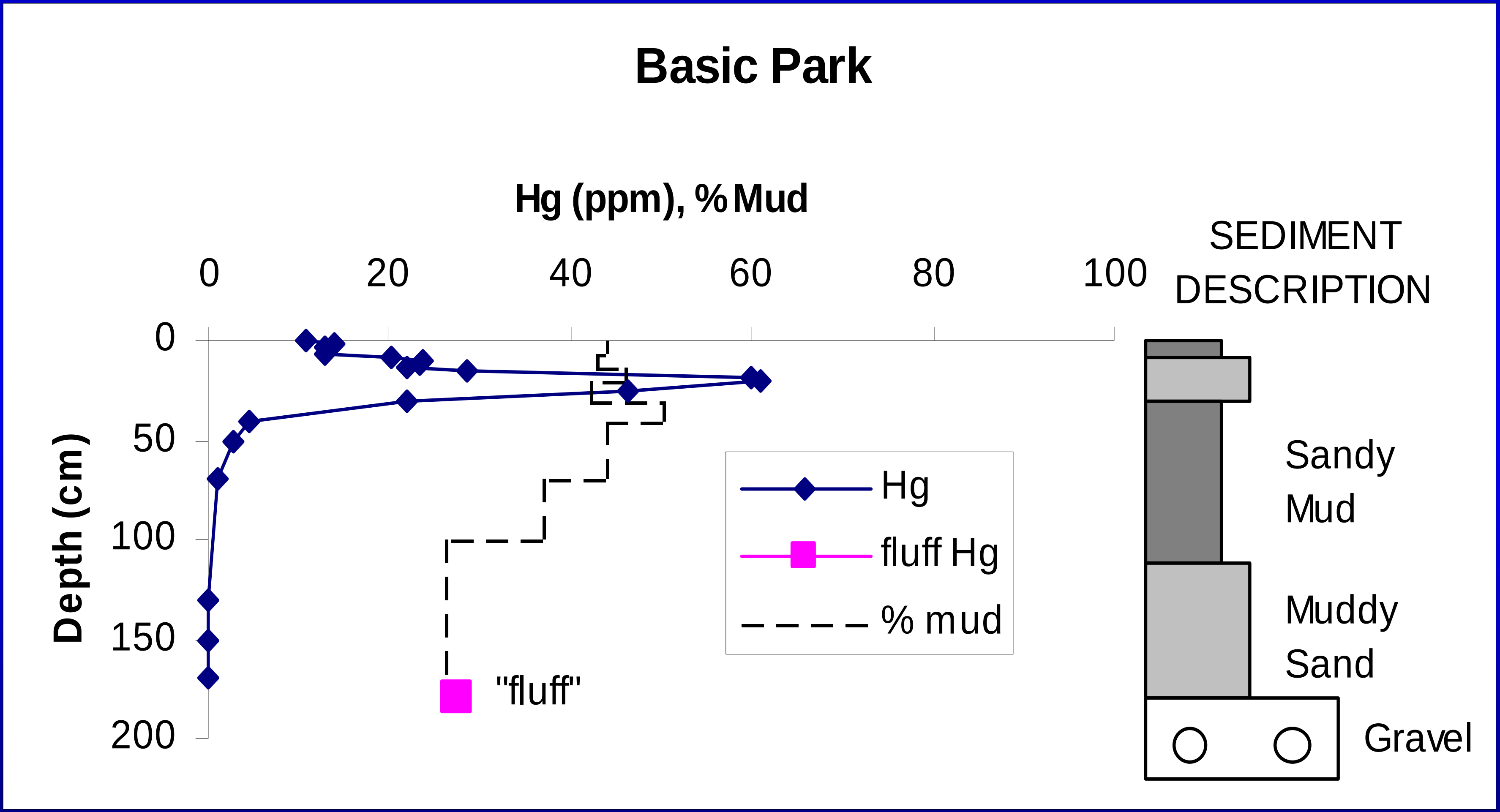
Geomorphic Classifications of South River

Classification	Classification of S. R.	Comments
Bed material	Gravel-bed	Implies that significant movement of the bed material occurs only a few times per year
Plan Form	Sinuous	Not meandering, braided, or anastomosing; implies lateral stability
Type of load	Mixed load	Both bedload and suspended load transport are important
Source of sediment supply, extent of external control	Bedrock-Alluvial	Bedrock lowers potential rates of change during storm discharges and other perturbations
Size of sediment supply	Low	Suggests that sediment yield and sediment fluxes are relatively low

Organization of Geomorphology Results

- **Eroding banks**
  - Characterization (Hg, grain size, LOI, etc)
  - Mapping current bank erosion
  - Mapping historic bank erosion 1937-2005
  - Lidar surveys
- **Silt-Clay storage in the channel**
  - Channel bed
  - Fine-Grained Channel Margin deposits
- **Floodplain processes**
  - Deposition on valley flat, including natural levees
  - Evolution of bank-attached active floodplains
  - Long term floodplain evolution
- **Suspended sediment transport**
- **Annual Silt and Clay budget, Waynesboro-Harriston**
- **"particle-related" Hg budget, Waynesboro-Harriston**
- **Conceptual model of silt-clay and Hg-related transport at different discharges**

Characterization of 5 Eroding Banks

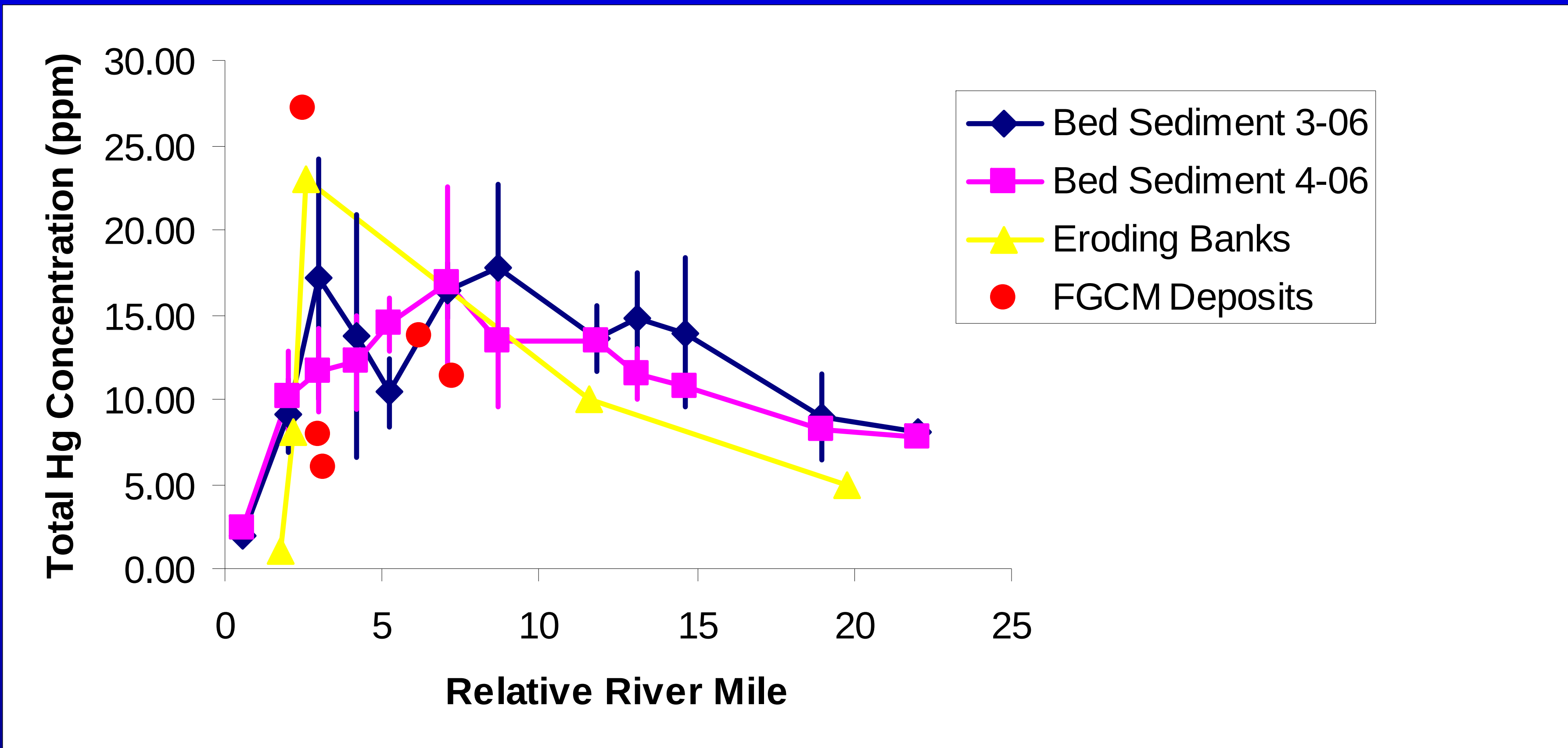


Characterization of "Eroding" Banks

Name	RRM	Date Sampled	Average Hg Concentration (ppm)	Average % Mud	Loss On Ignition (%)(mean, range)	Comments
Allied Ready Mix	1.78	8-10-2005	1	34	3,1-7	
Basic Park	2.18	8-10-2005	8	37	4,2-7	
Hopeman Parkway	2.6	October, 2004	23	NA (not sampled for grain size)	NA (not measured)	Sampled by Ralph Turner and Richard Jensen
Forestry Station	11.58	8-11-2005	10	64	5,3-10	Likely reservoir deposits sampled in bank
Grand Caverns	19.84	7-14-2005	5	14	2,1-3	Sampling site ~ 20 m from bank in floodplain

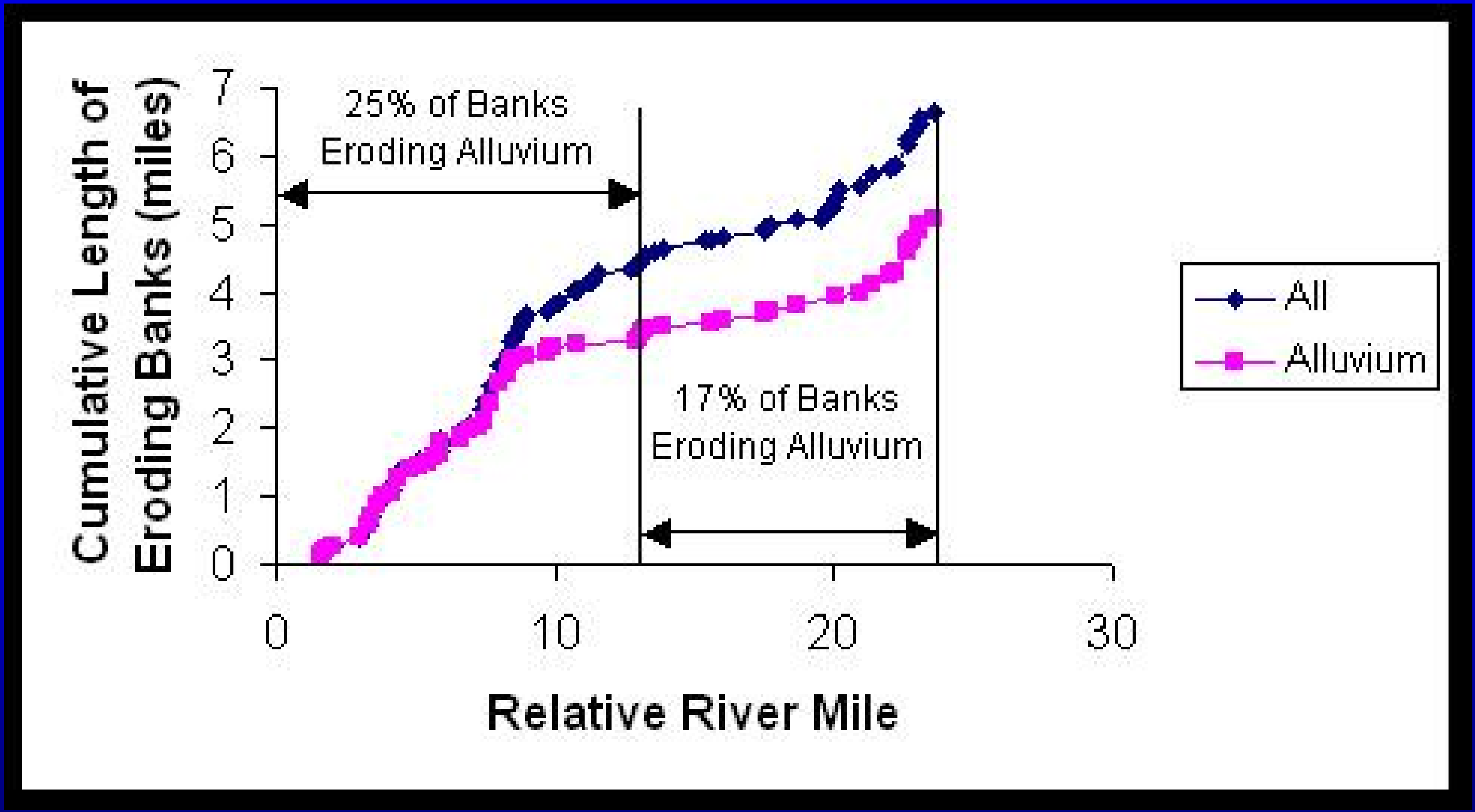
Mean Eroding Bank Hg Similar to Mean Hg in Mud Sampled on Bed, FGCM Deposits

NO DILUTION FROM UPSTREAM SEDIMENT SOURCES



Mapping Currently Eroding Banks

(note – *41% of banks are eroding between RRM 21-24*)



Historic Bank Erosion, 1937-2005

5 “Styles” of Bank Erosion

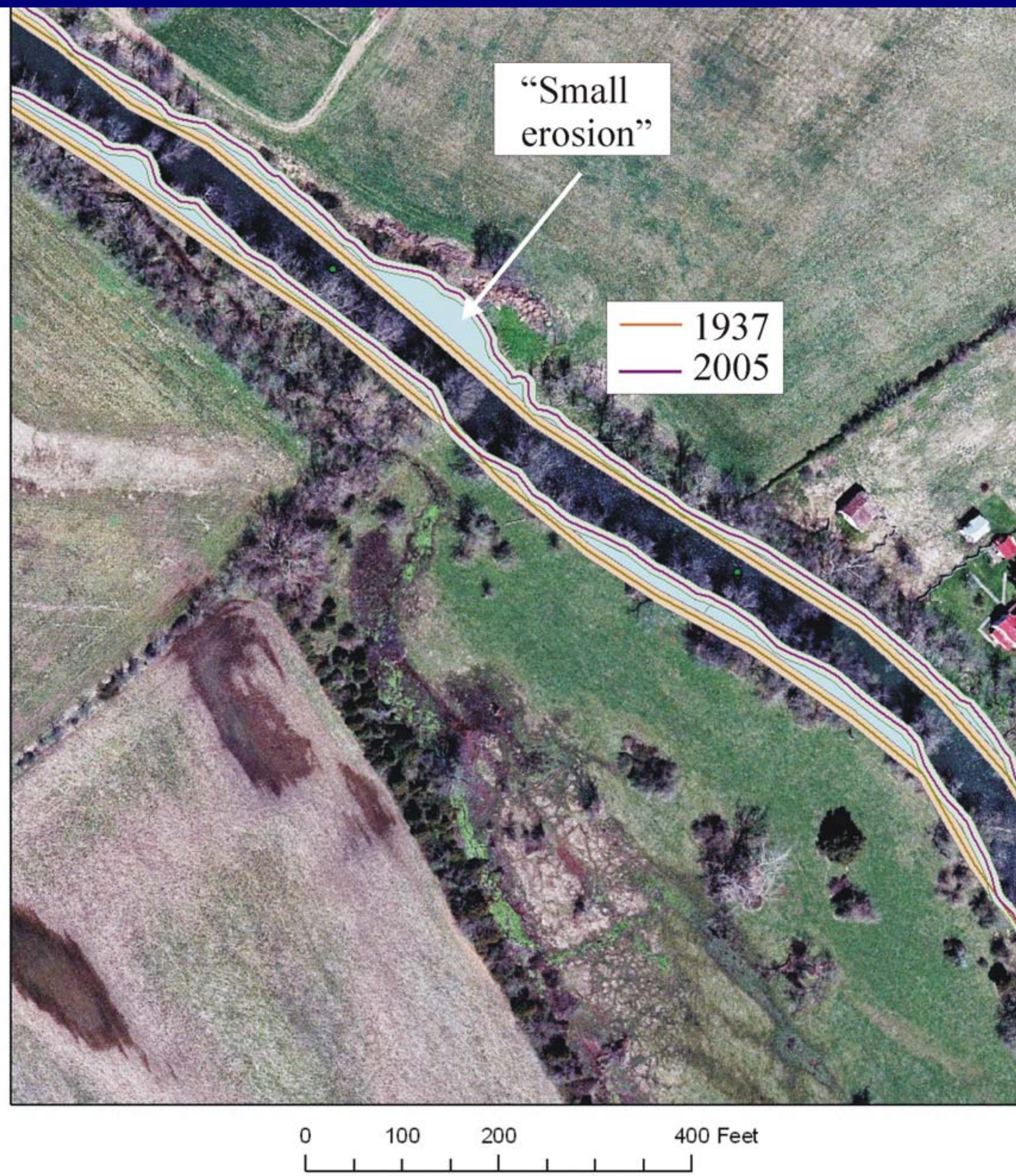
1. No resolvable erosion
2. Small areas of erosion (caused by ??)
3. Classic bend migration
4. Erosion related to tributaries from Blue Ridge
5. Island development

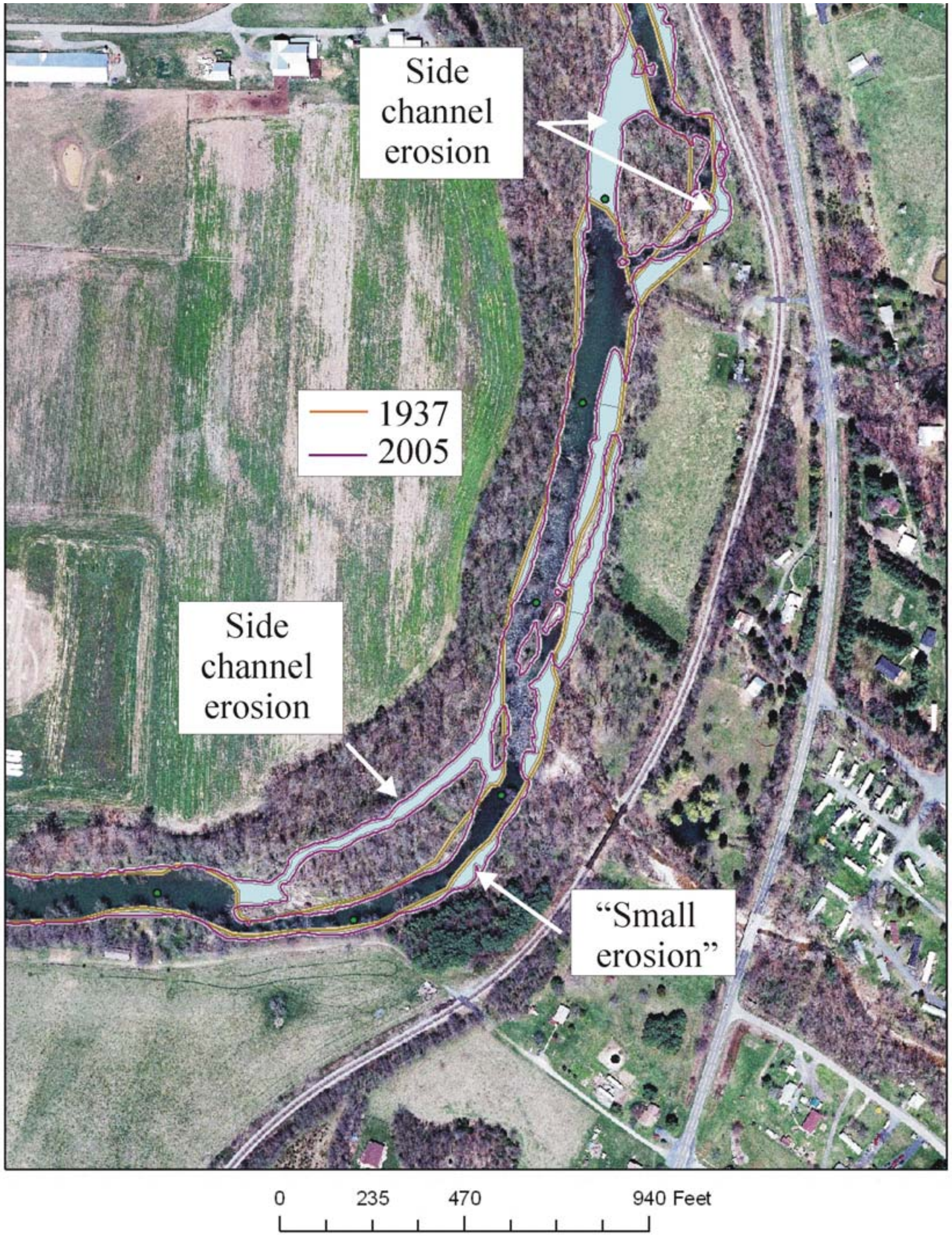
Several Examples….

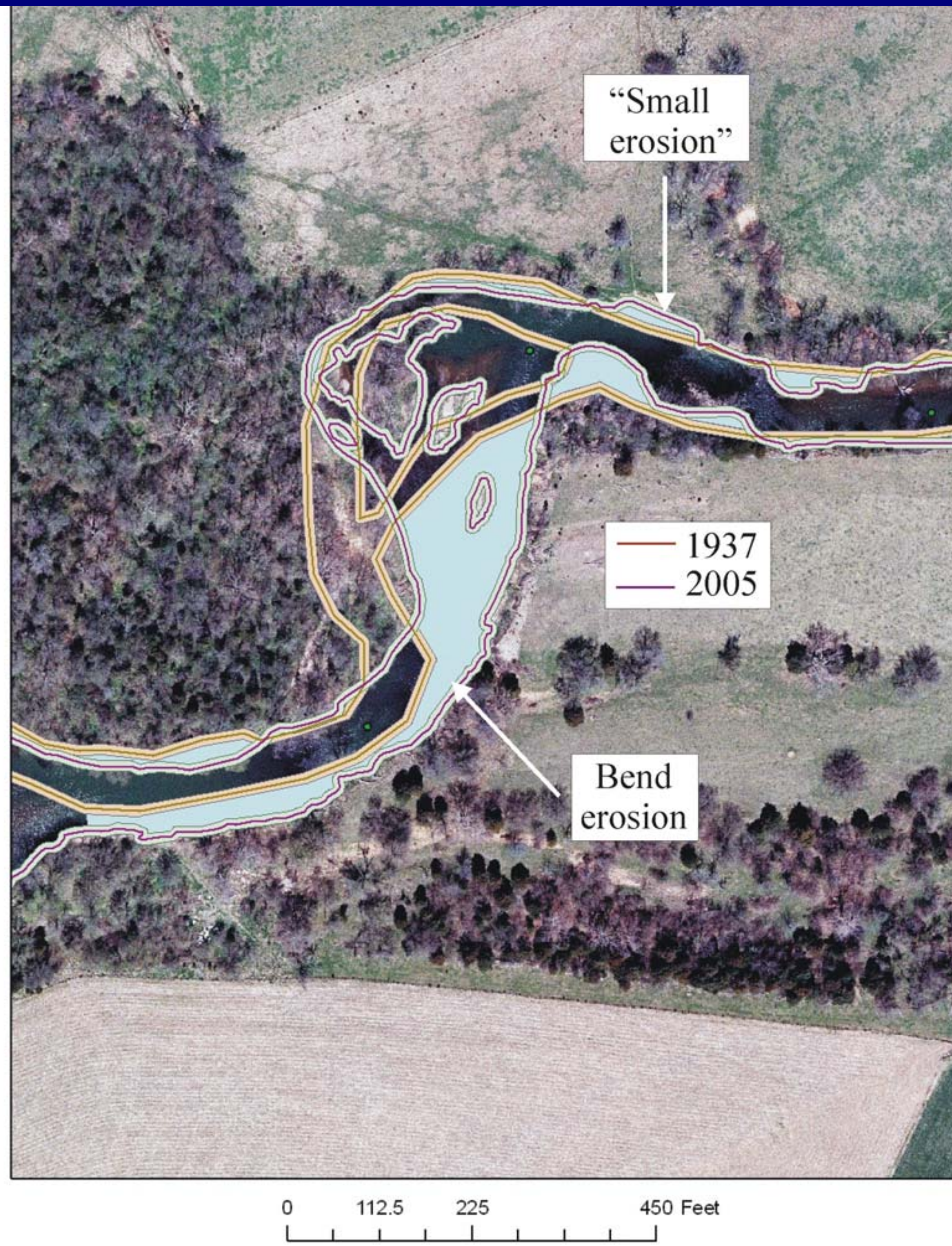
RRM	Figure	Type	Area (m^2)	Length (m)	Nominal Bank Erosion Rate (cm/yr)	
2.15	6.8	"small"	92	97	3	
9.25	6.9	related to dam removal	1151	318	11	
9.4	6.9	bend	1387	433	9	
9.5	6.9	bend or related to bridge	1158	324	10	
10.45	6.10	"small"	397	194	6	
15.68	6.11	"small"	321	188	5	
15.68	6.11	side channel	2104	696	NA	
16.0	6.11	side channel	2620	329	NA	
16.0	6.11	side channel	510	303	NA	
22.5	6.12	bend	3082	604	15	
22.62	6.12	"small"	71	61	3	


1937
2005
"Small
erosion"
0
60
120
240 Feet

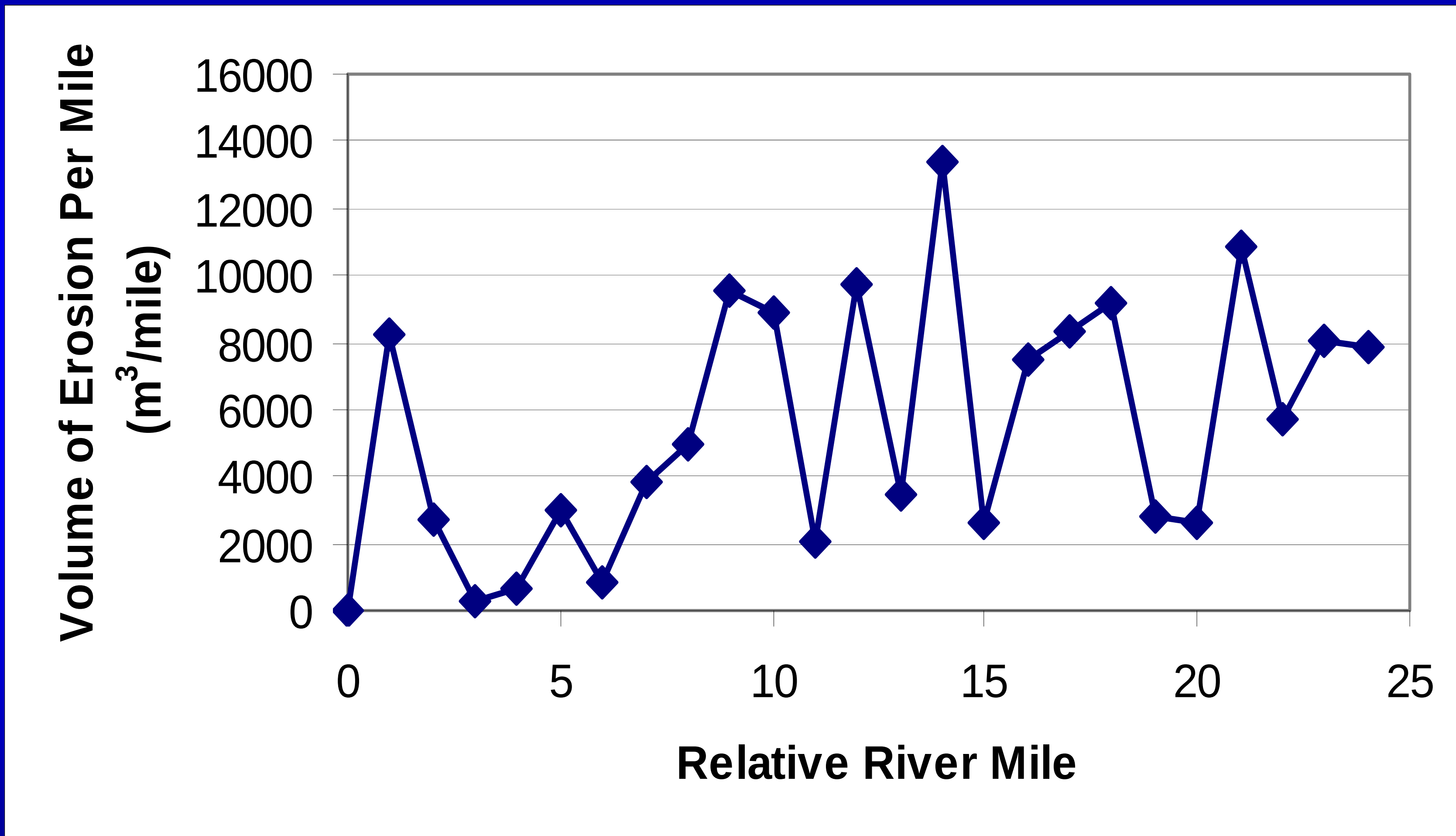

Bend erosion
1937
2005
Erosion related to dam removal
0
205
410
820 Feet


"Small erosion"
1937
2005
0
100
200
400 Feet


Side channel erosion
1937
2005
Side channel erosion
"Small erosion"
0
235
470
940 Feet

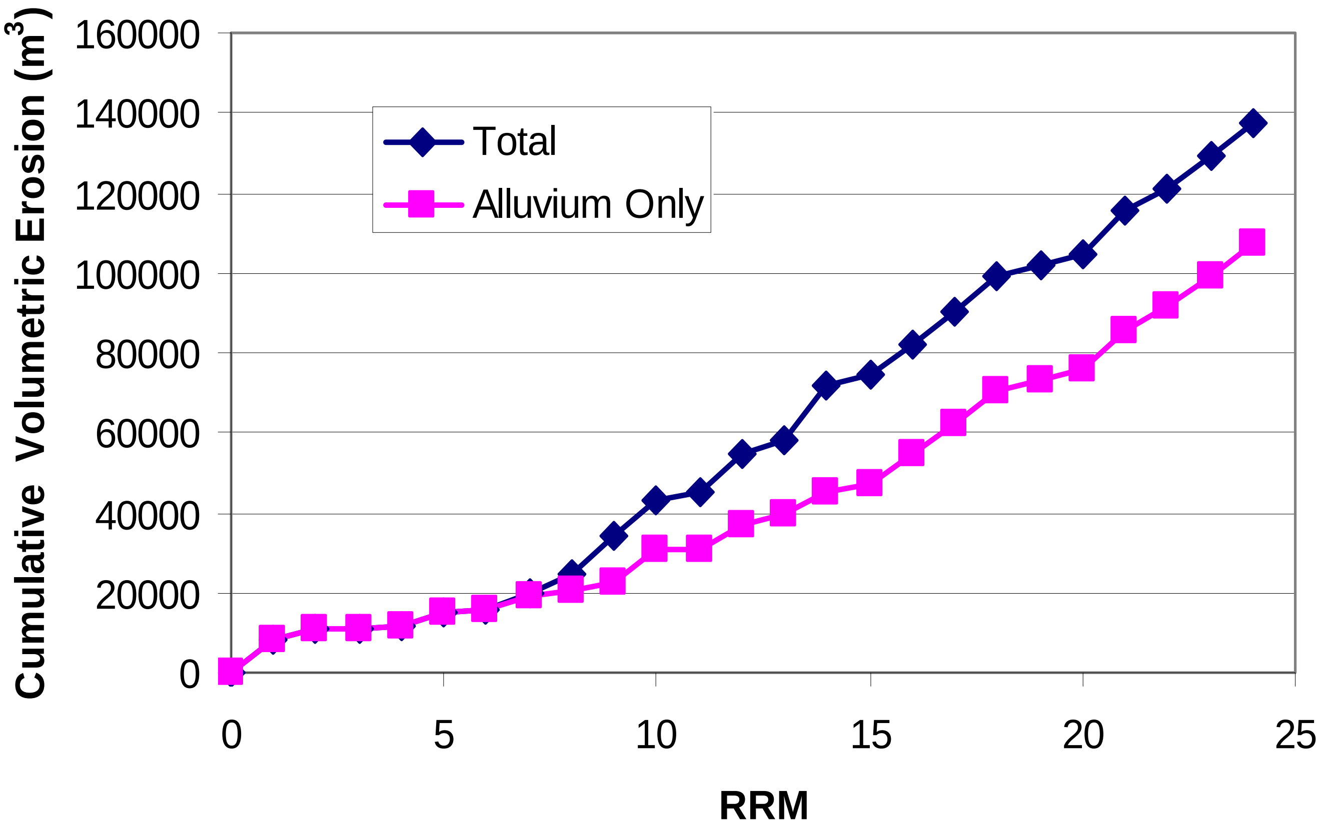

"Small erosion"
1937
2005
Bend erosion
0
112.5
225
450 Feet

Volume of Bank Erosion Per Mile

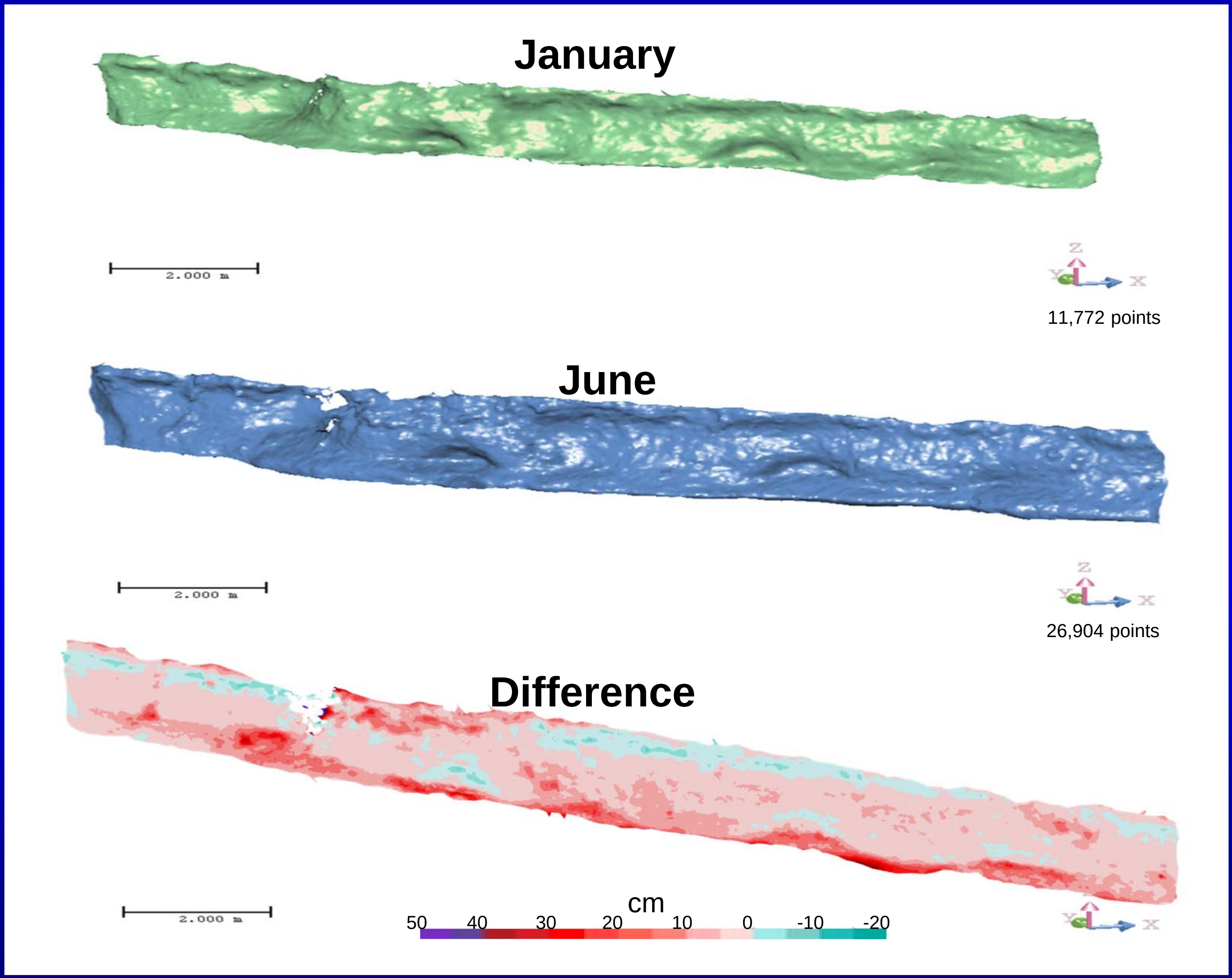


Cumulative Bank Erosion vs RRM

Note – more erosion downstream – likely caused by influxes of gravel from tributaries via confluence bar and island development



Bank Erosion From Lidar Surveys, Jan-June 2006 @ Allied Ready Mix Site



Take Home Points – Bank Erosion Studies

- Eroding banks have significant Hg concentrations
  - Vertically averaged total Hg concentrations are similar to those of sediments sampled in the channel
- Bank erosion rates along South River are typically very low, often < 10 cm/yr
  - Effects of riparian trees, bedrock, cohesive bank sediments
  - More rapid rates occur when channel is forced to "digest" gravel inputs from tributaries
- Short term erosion could favor the upper parts of banks with high Hg concentrations

Silt-Clay Storage In the Bed

Estimates based on data from the Ecological Study

Relative River Mile	Silt/Clay Volume (L)		Mass/bed area (kg/m^2)	
	March, 2006	April, 2006	March, 2006	April, 2006
0.6	4	0.5	0.100	0.013
2	4	1.5	0.100	0.038
3	4	2.5	0.100	0.063
4.2	3	1.4	0.075	0.035
5.2	2.5	2	0.063	0.050
7.1	4.5	1.5	0.113	0.038
8.7	1.8	1.0	0.044	0.025
11.8	6	4	0.150	0.100
13.1	1	1.1	0.025	0.028
14.6	1	0.7	0.025	0.018
19	1.8	1.7	0.045	0.043
22.4	1.3	0.8	0.031	0.019
		Mean for March and April		0.050

Silt-Clay Storage in the Bed

"Approximately 39,000 kg of silt and clay are stored in the streambed of the entire study area from Waynesboro-Port Republic. This value is 3 orders of magnitude less than the annual suspended sediment load of the South River, and is volumetrically insignificant" (from Geomorphology Report, Chapter 10)

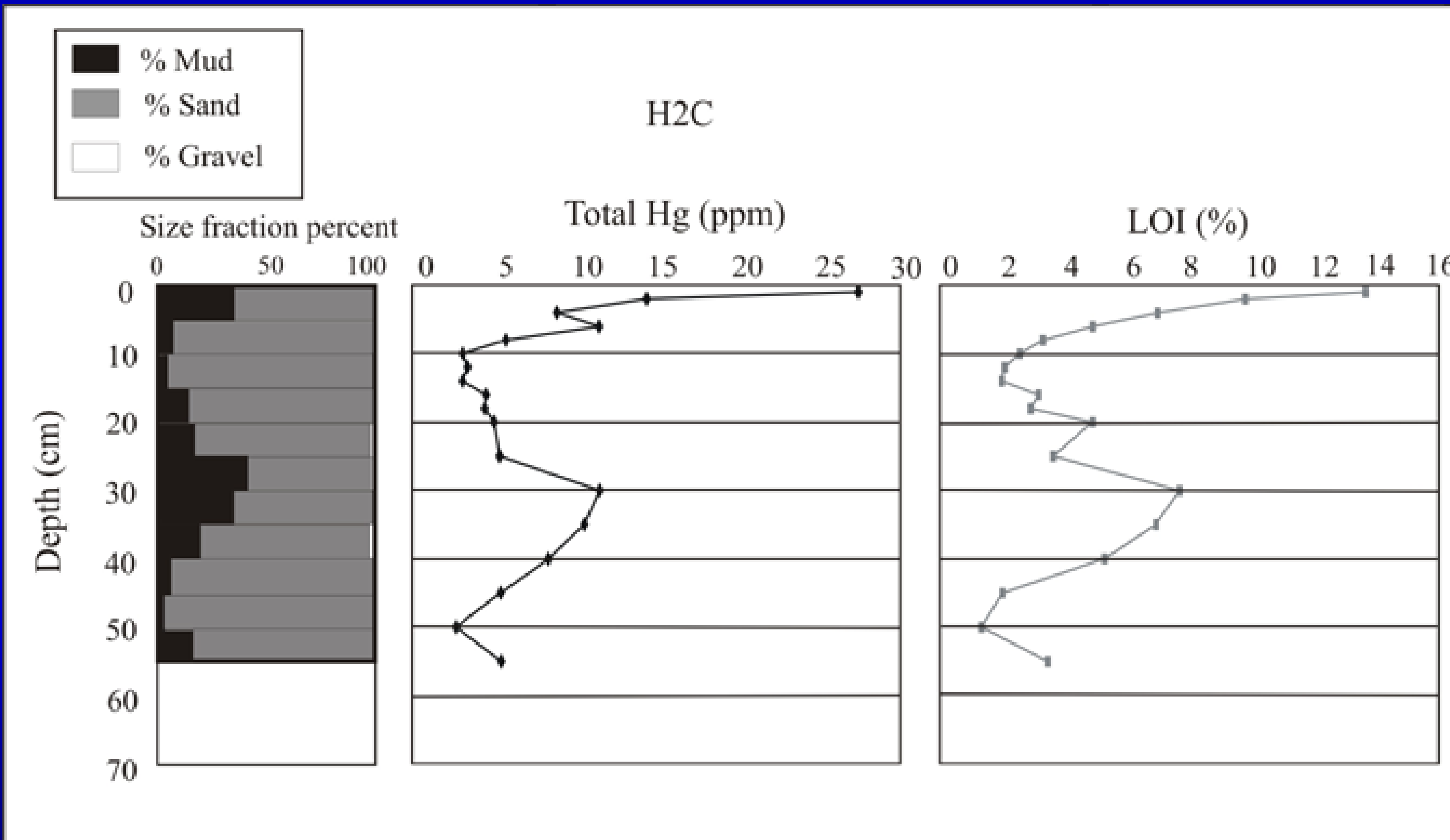
Sediment Storage in Fine-Grained Channel Margin Deposits

- Summary of Analytical Results
- Occurrence
  - Geomorphic settings
  - Slope control
  - Distribution, Waynesboro – Port Republic
- Age and residence times
- Model of FGCM evolution
- Sediment, Hg budget implications

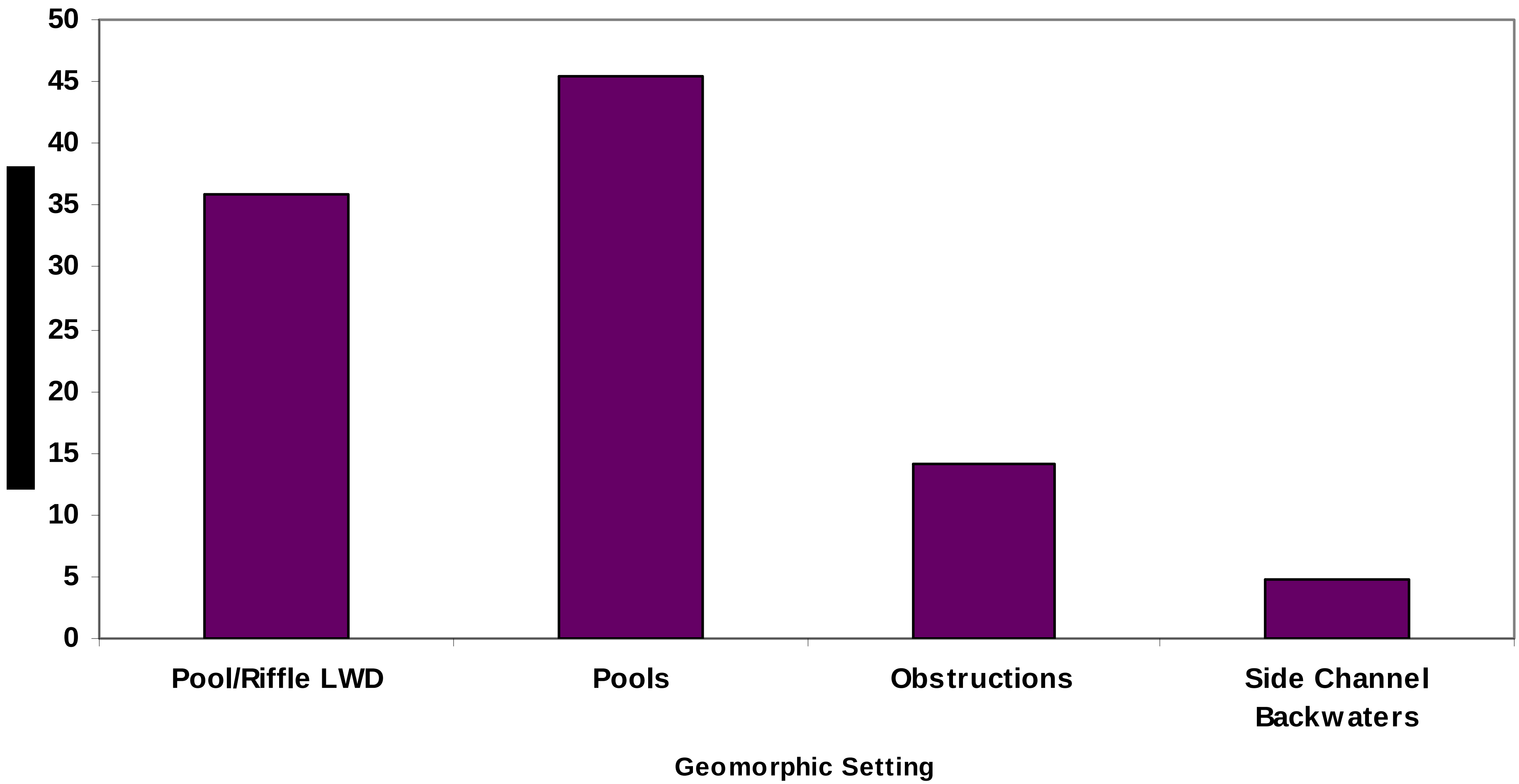
Average THg

Name	Total Hg		Hg (ppm)
	as rec'd	dry	
	ng g^{-1}		
H1A	15209.92	27128.93	**27.13**
H2A	3876.68	5962.64	**5.96**
H2C	4061.24	7848.73	**7.85**
D5A	6836.17	13726.25	**13.73**
D7A	4834.39	11410.96	**11.41**
Core 1	73538.49	133576.06	**133.58**
Core 3	12923.08	20972.40	**20.97**

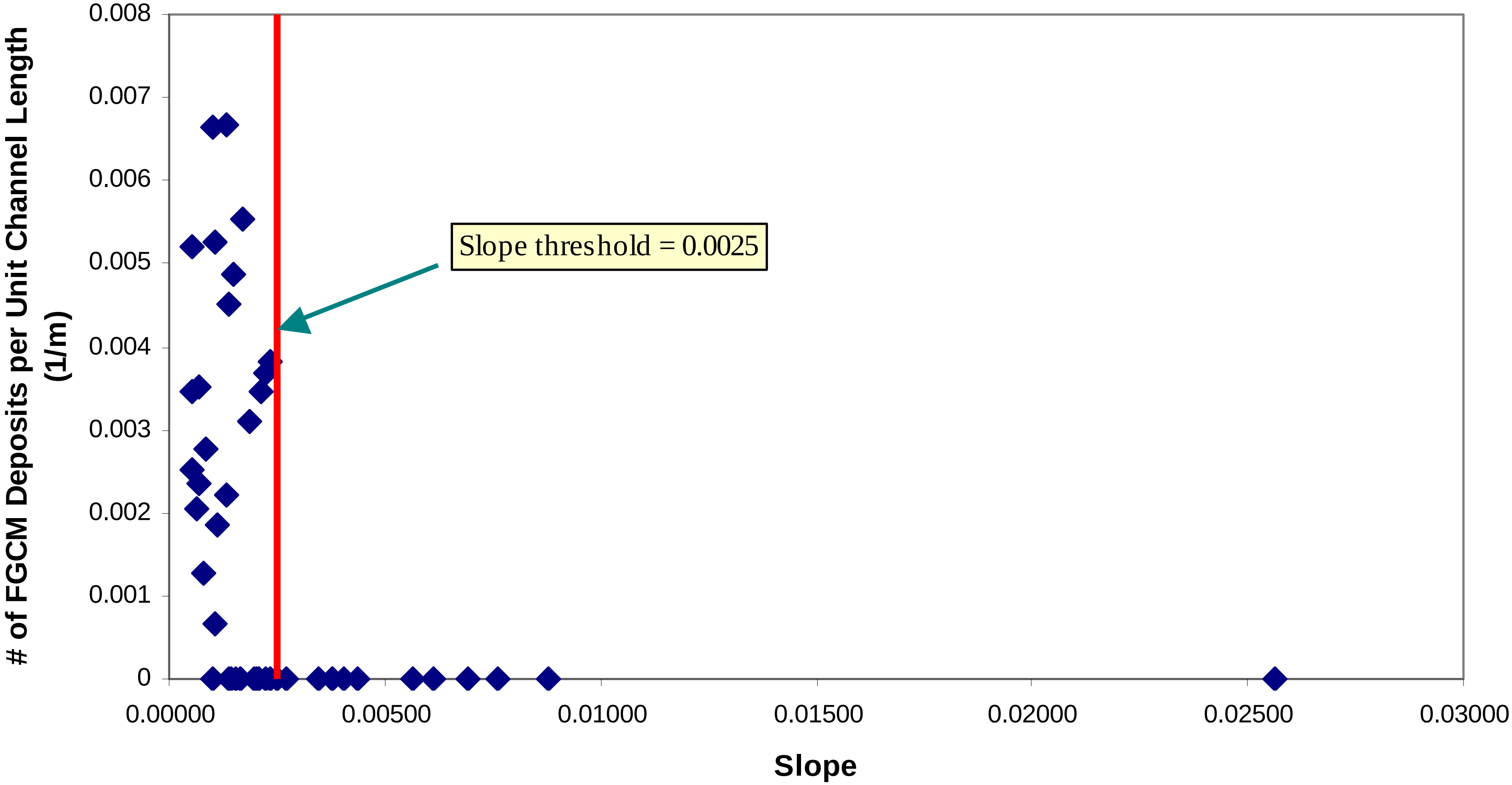
Example Results – Core H2C RRM 3.12



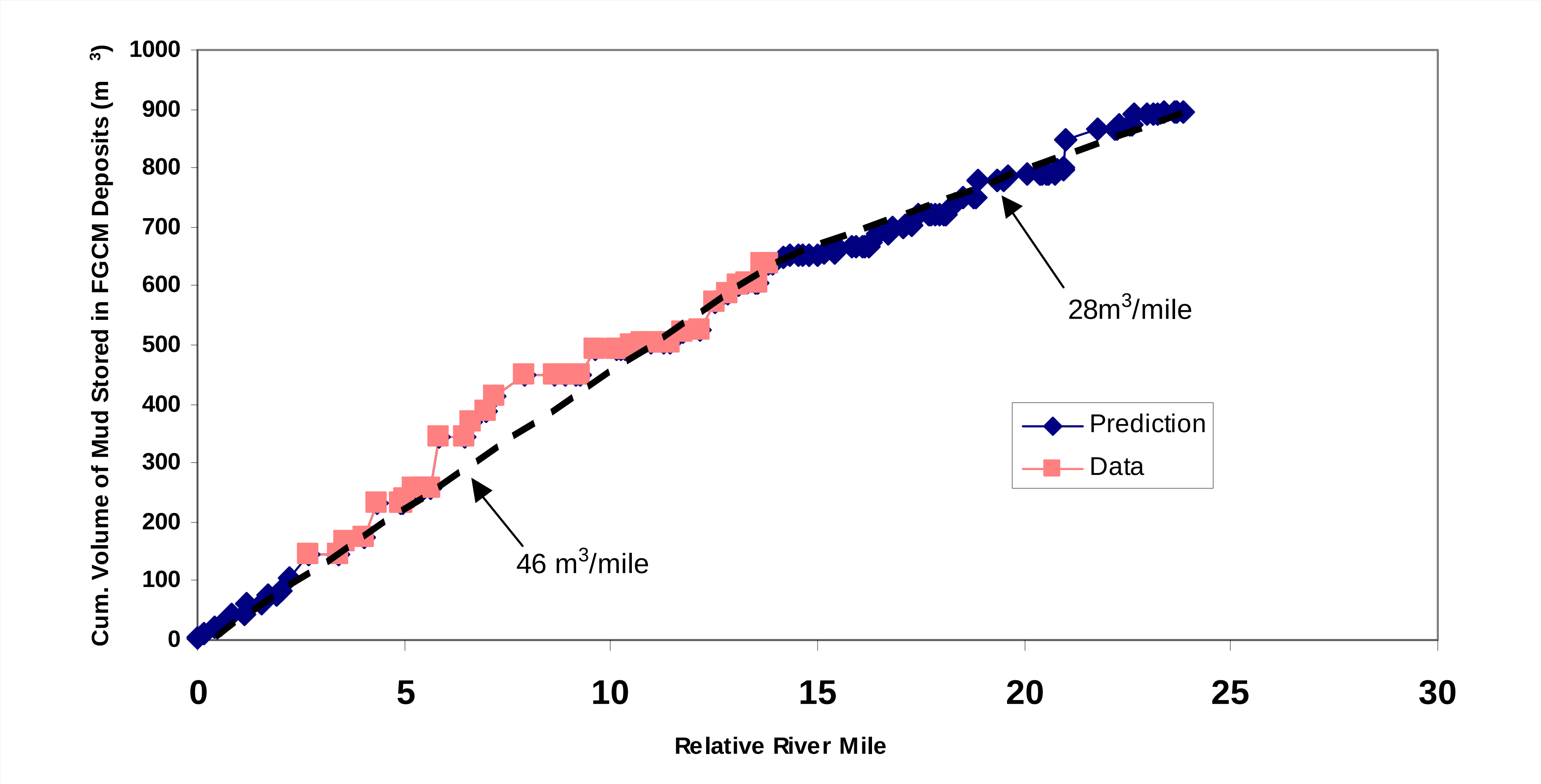
Occurrence – 4 Different Geomorphic Settings



FGCM Deposition Favored at Lower Slopes



Distribution of Mud Stored in FGCM Deposits, Waynesboro-Crimora



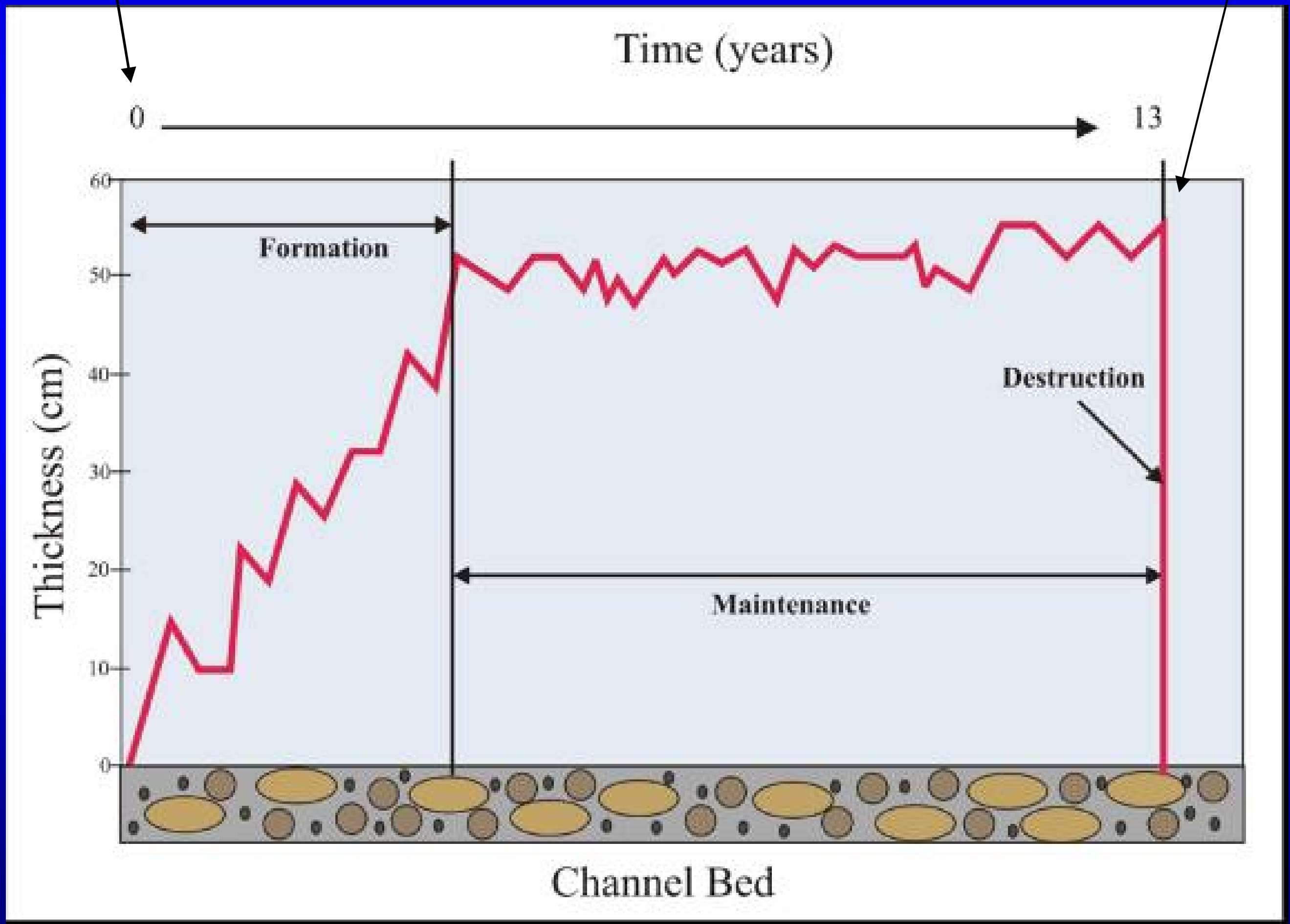
Maximum ages of FGCM Deposits From ^{14}C Dating

Core	Age at Base (years)
Core 1	> 55
H1A	19
H2A	14
H2C	13
D5A	10
D7A	11

“Life Cycle” of A Representative FGCM Deposit

Deposition begins after LWD trapped on channel margins

Destruction during whopping flood



Summary: FGCM Deposits

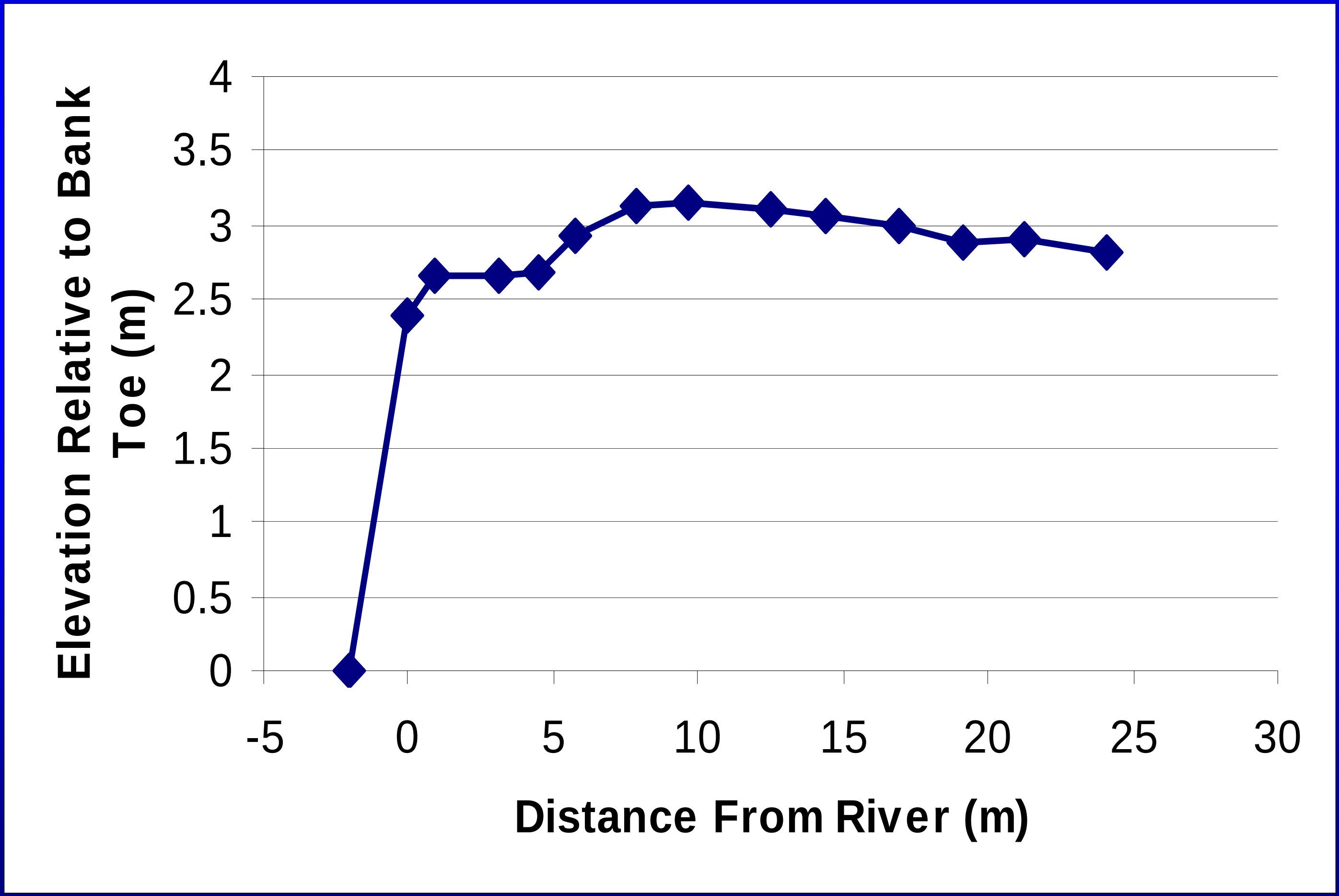
- Volume of mud stored equivalent to 16% of annual suspended sediment load
- FGCM deposits average about 70% sand and 30ppm total Hg
- FGCM deposits have a typical lifespan of 10-20 years
  - Probably do not contribute significantly to an annual sediment budget

Floodplain Sedimentary Processes and History

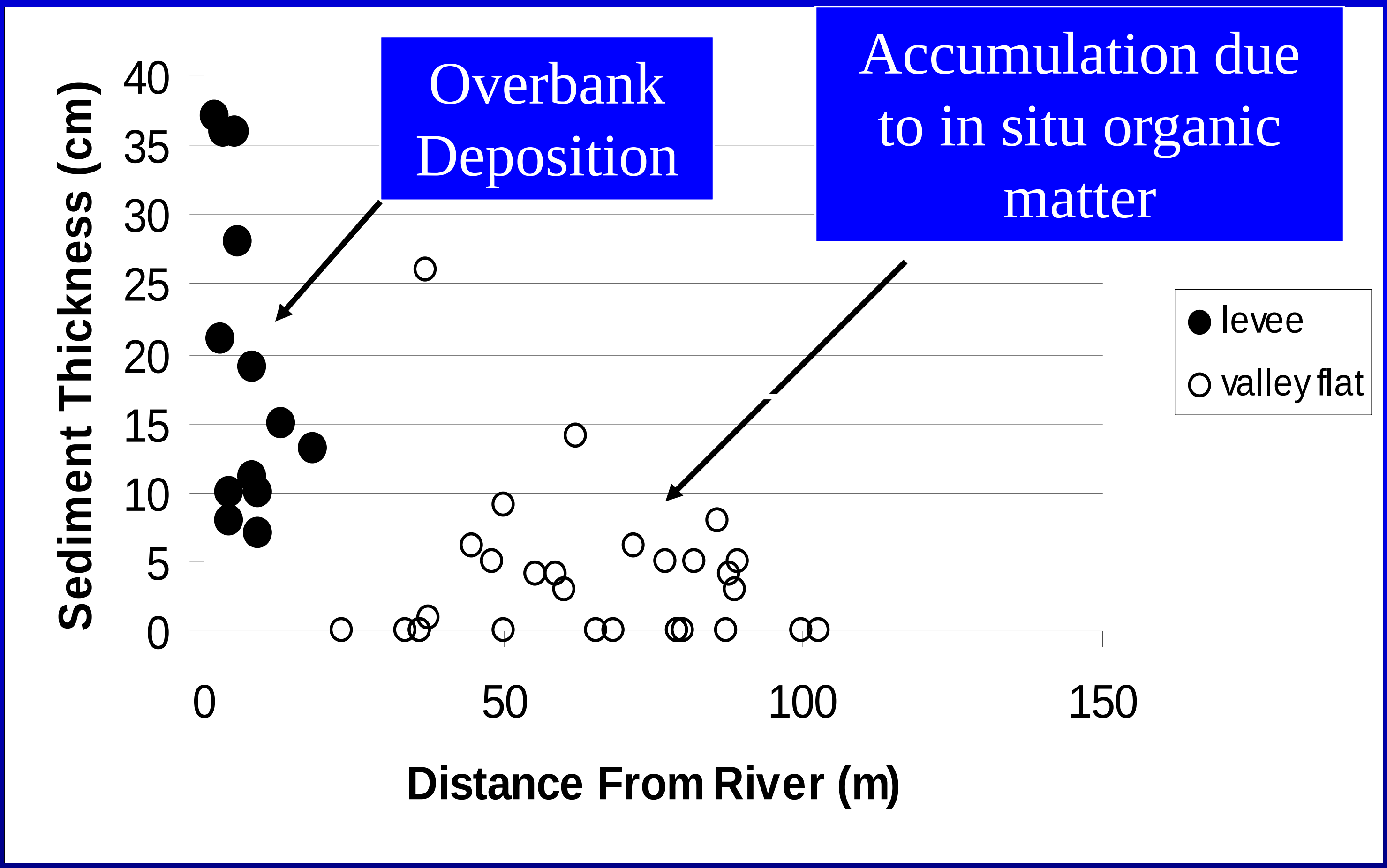
- Overbank deposition
  - Spatial patterns over the last 30 years or so at 1 site
- Accumulation of mud on “potential” natural levees throughout the study area
- Evolution of bank attached active floodplains
- Long term trends in floodplain evolution

Overbank Accumulation During the last ~30 years at….

A Well-developed "Natural Levee"….



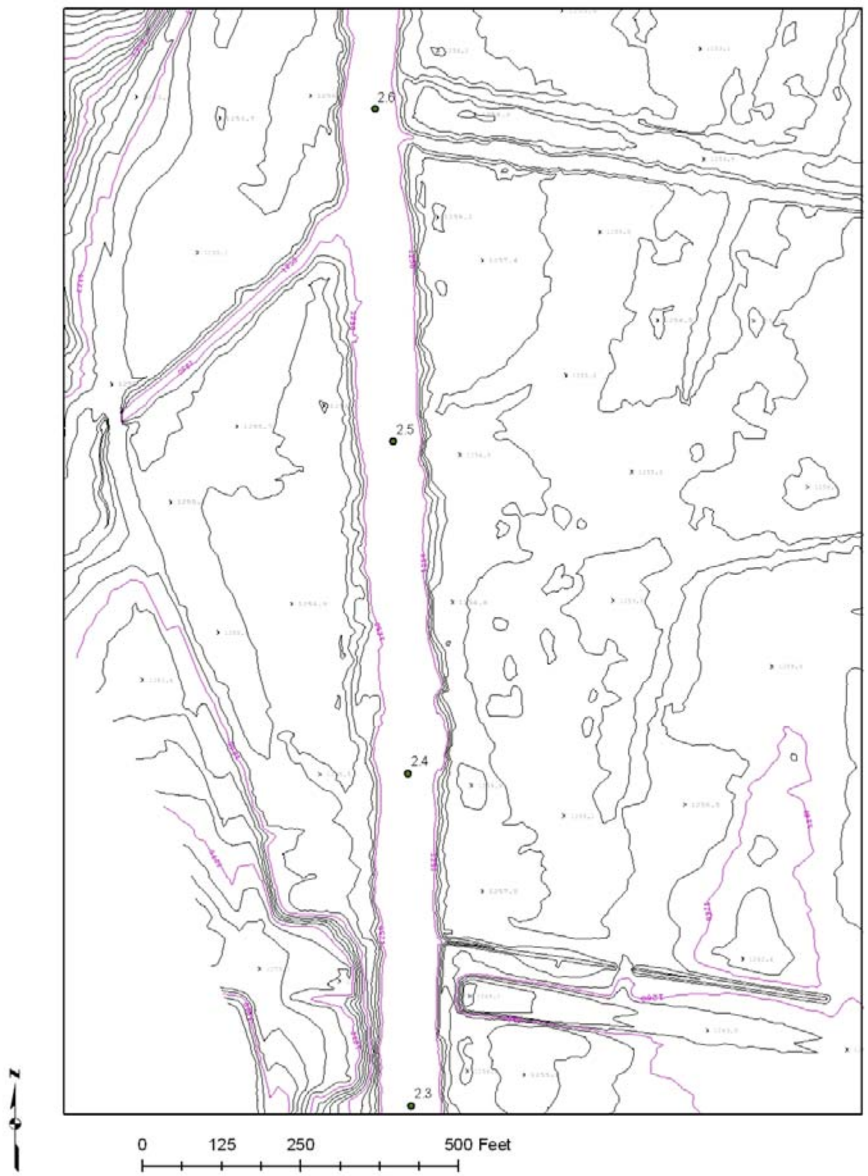
Total Accumulation



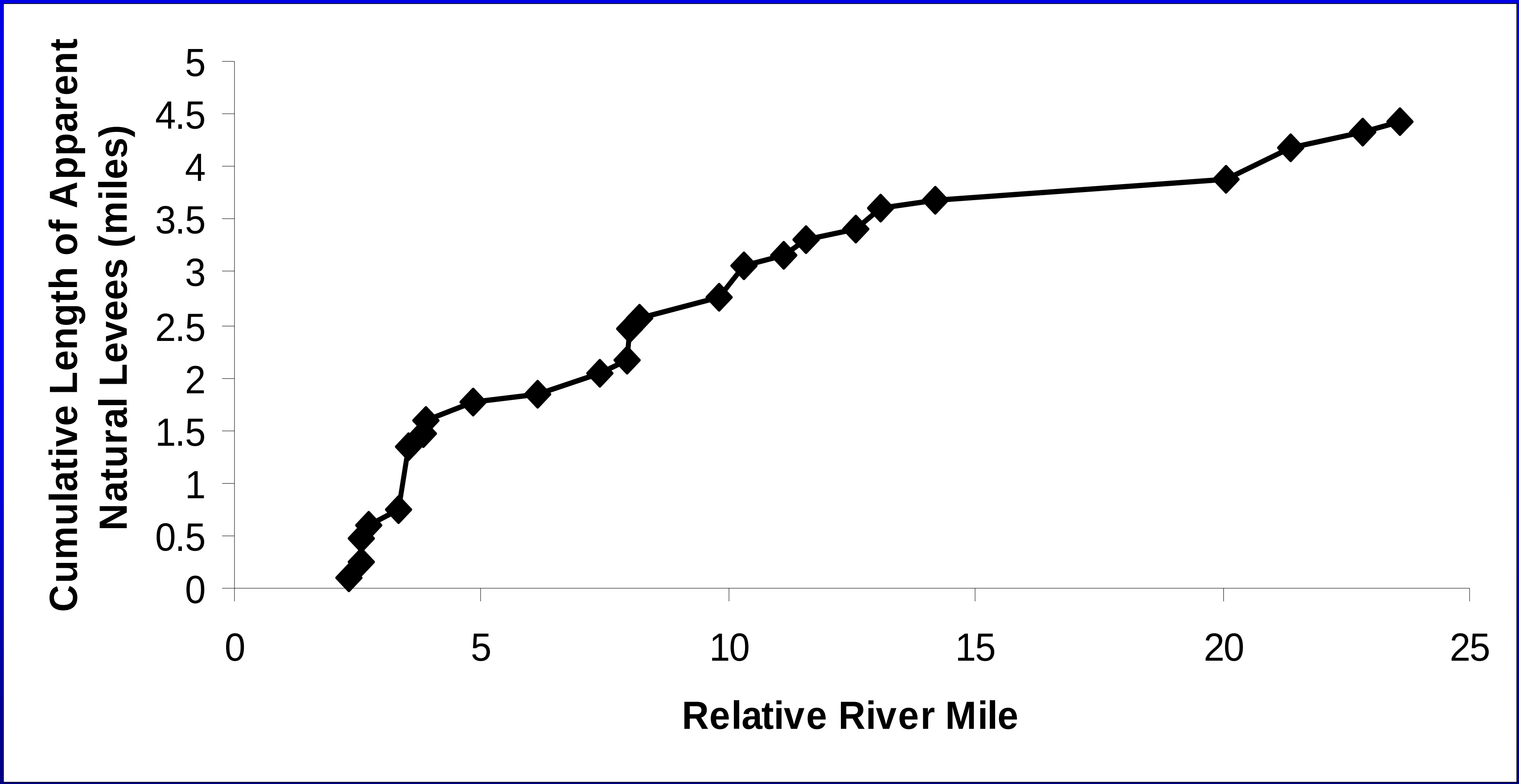
Accumulation Rates on Natural Levees at 5 m Intervals From the Channel

	0-5m	5-10 m	10-15m	15-20m
Levee Accumulation Rate (cm/yr)	0.55	0.51	0.50	0.40
Mass of Silt/clay Accumulation (kg/m/yr)	7	7	7	5

LiDAR Based Topography Used to Map "Potential" Natural Levees Throughout the Study Area



Distribution of Natural Levees vs RRM



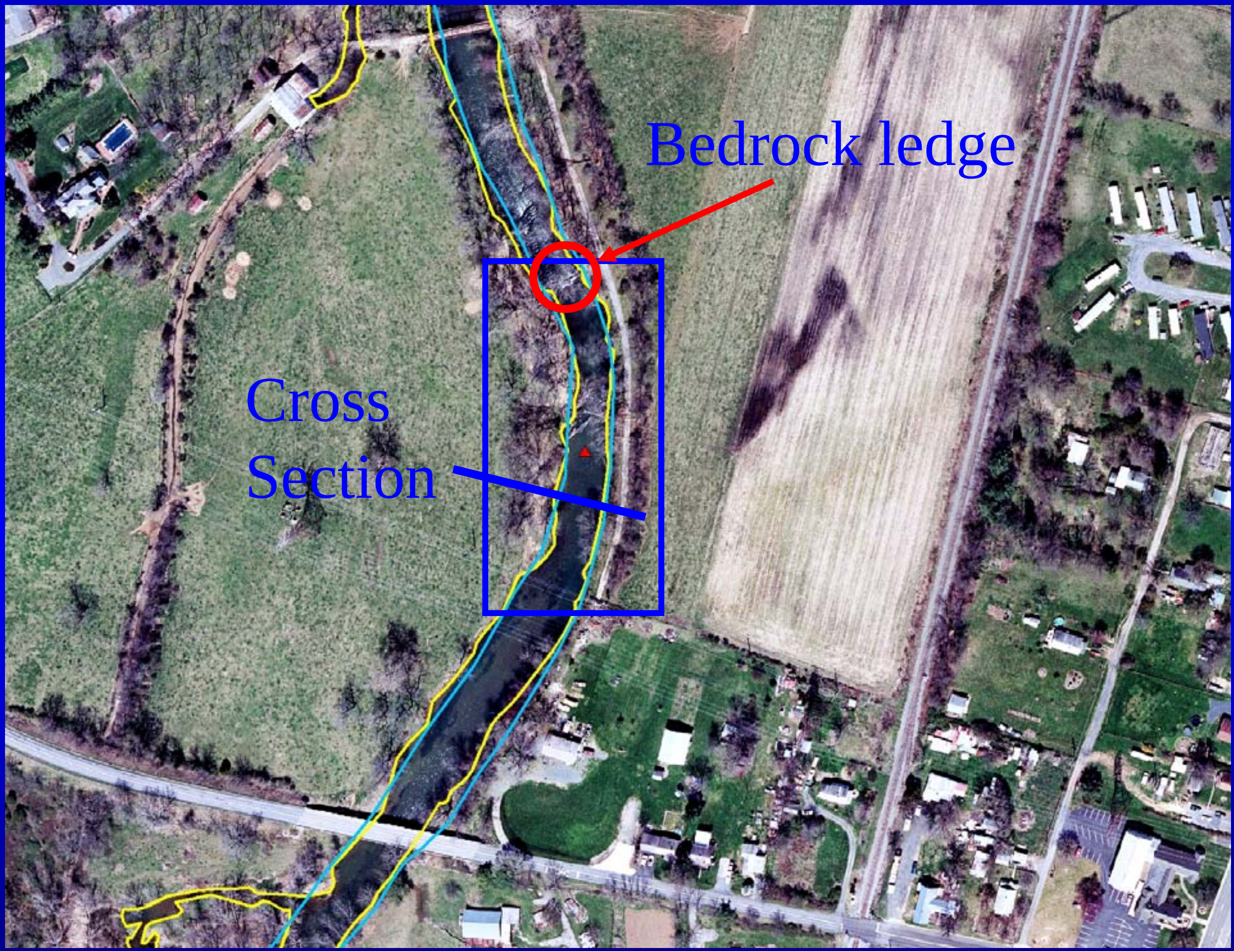
Total Mass and Some Hg Data For Natural Levees

Annual mud accumulation per unit channel length	26 kg/m/yr
Total length of apparent natural levees in the study area	6800 m
Total annual apparent natural levee mud accumulation	**1.76×10^5 kg/yr**

Table 9.8. Summary of Hg analyses for natural levee deposits discussed in the text.

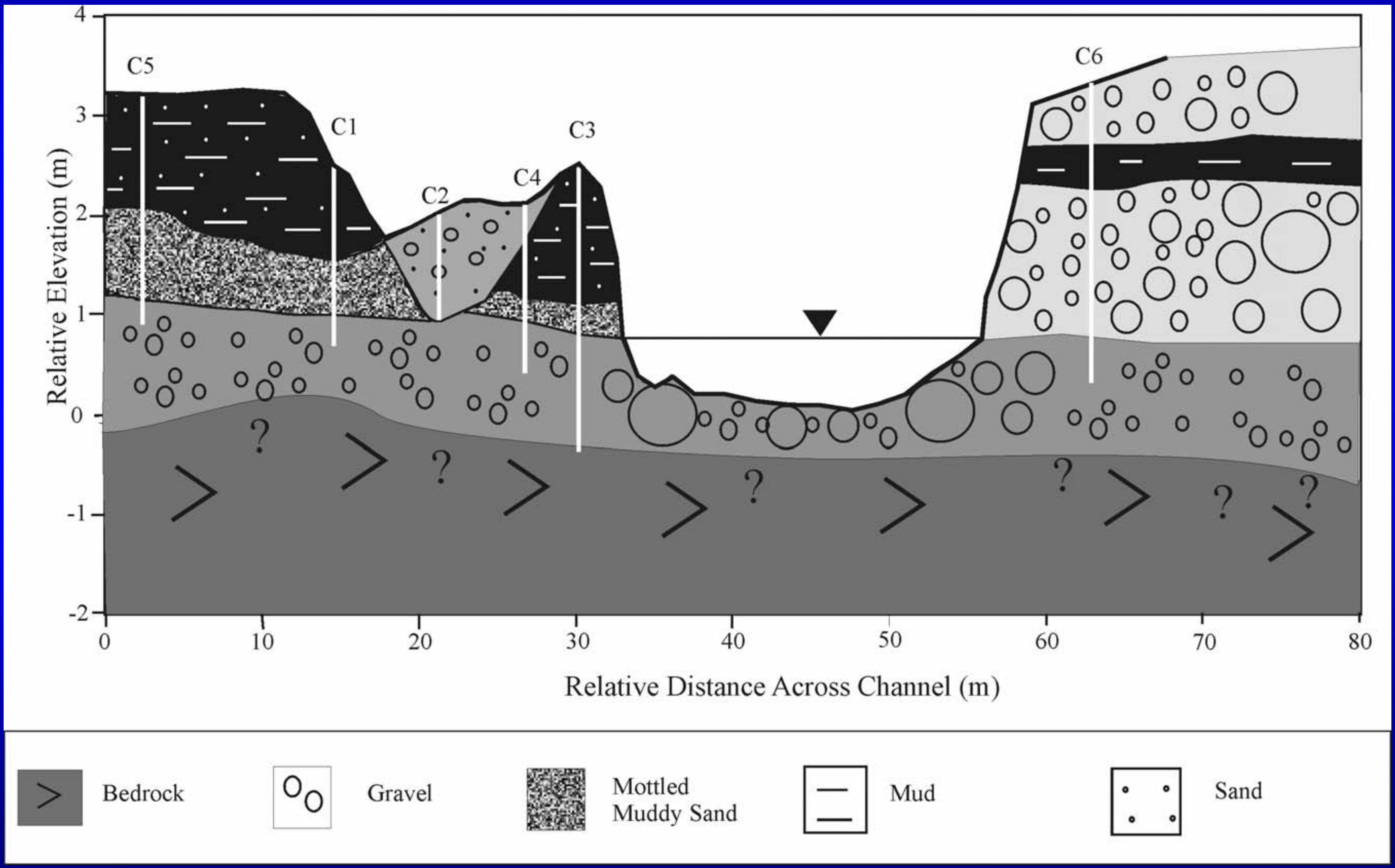
Source	Location	Depth Range (cm)	Average Hg (ppm)
Jensen et al. (2004)	Hopeman Pkway	0-15	6
Cocking et al. (1991)	Hopeman Pkway	0-15	22
Jensen et al. (2004)	Forestry Station	0-15	12
Overall Average			**13**

BAAF Study Site ('37 shoreline – blue, '05 shoreline-yellow)

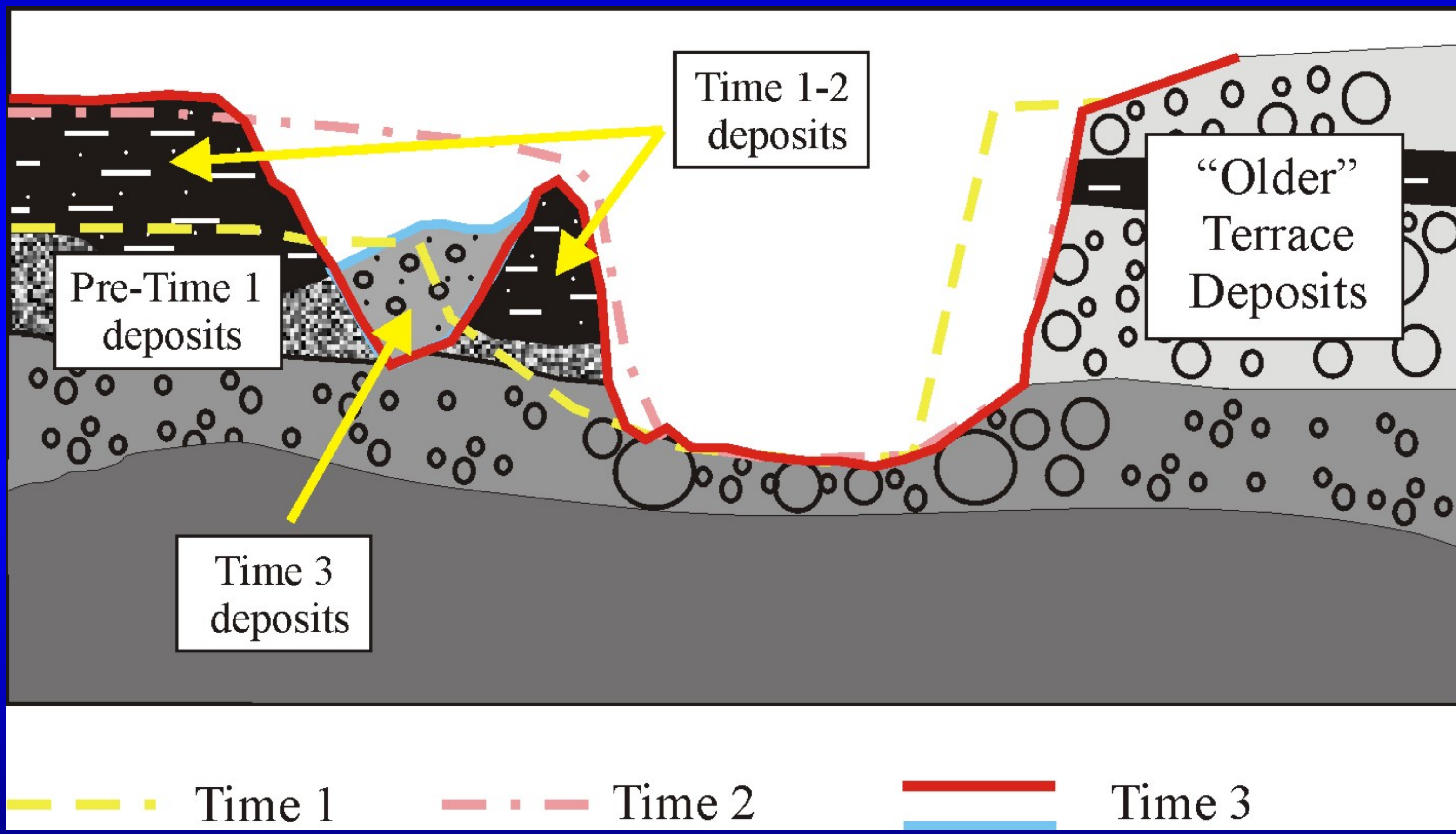


Evidence of Recent Erosion

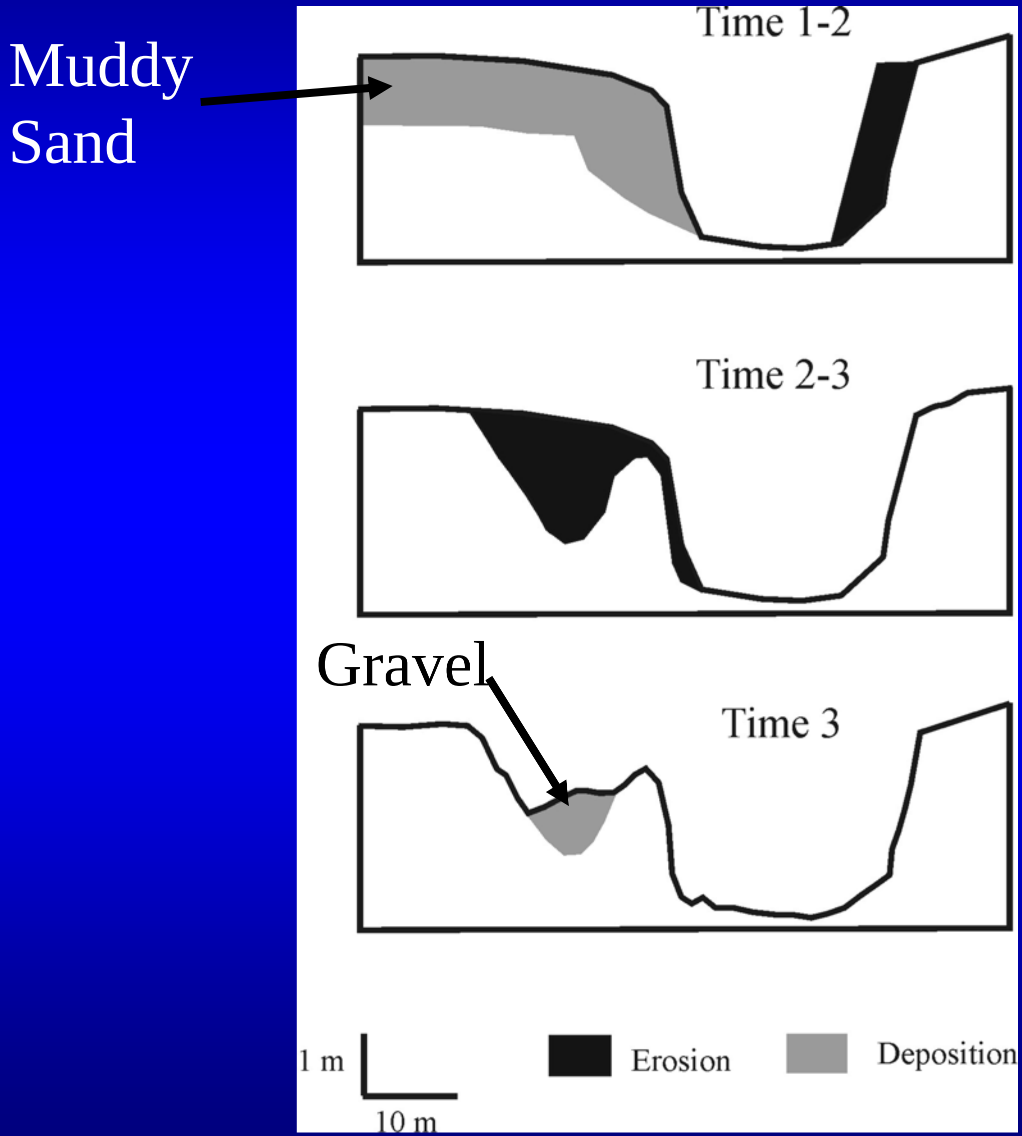
Geologic Cross-Section



Interpretive Cross-Section



Inferred Patterns of Erosion and Deposition



150 years ago ??

35 years ago??

A few years ago?

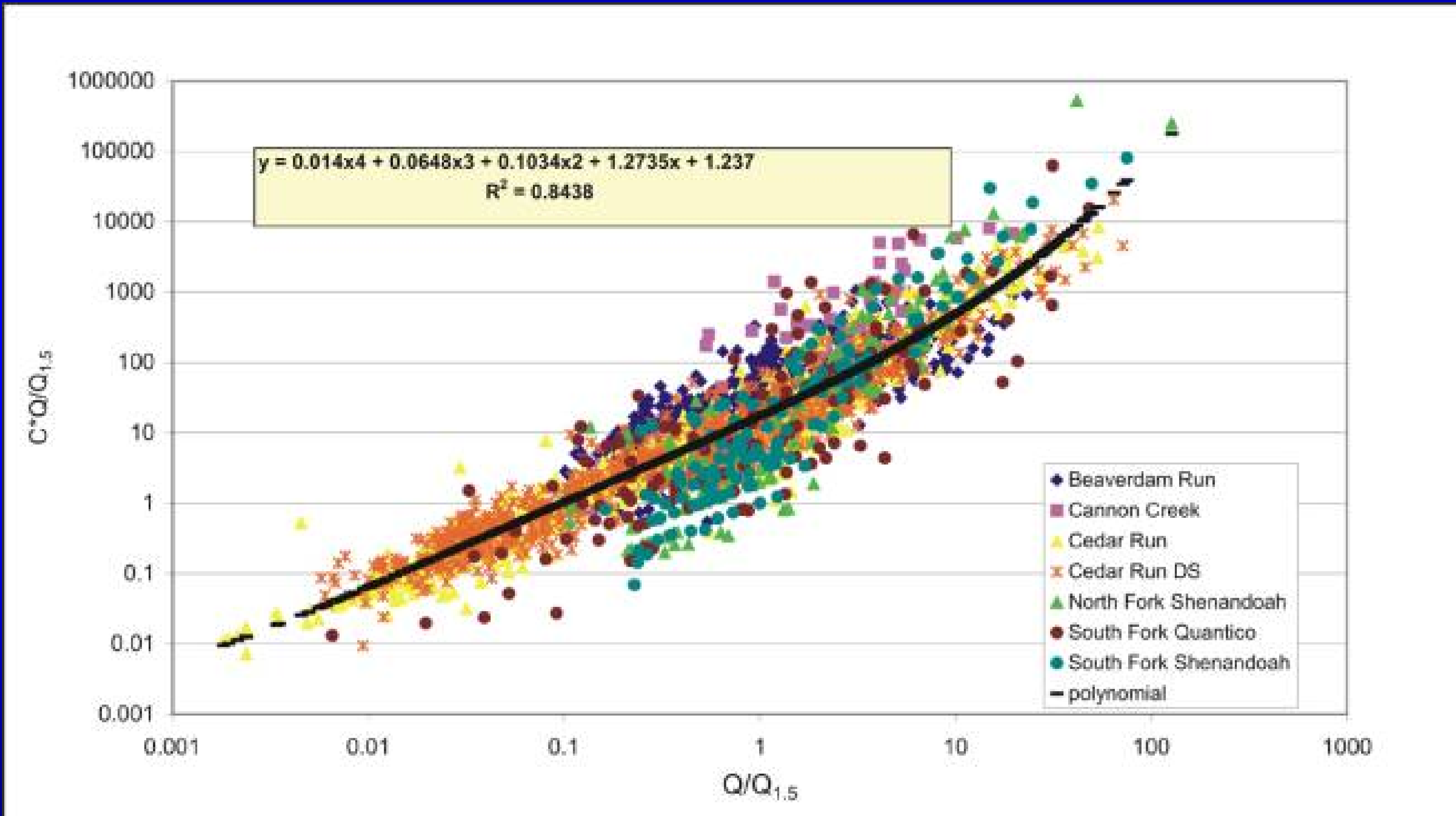
Summary of Floodplain Studies

- Negligible accumulation on valley flat outside of natural levees during the last 30-40 years
- Levee accumulation averages 0.5 cm/yr, and totals 1.5×10^5 kg/yr from Waynesboro to Port Republic
- BAAF deposits likely formed after a period of valley alluviation before the 20th century
  - These deposits are not storing silt and clay in significant amounts today, and may be neglected in a silt and clay budget for the study area
- Silty alluvium of the valley flat is gradually being removed, to be replaced by sand and gravel of the BAAF deposits
  - A working hypothesis!

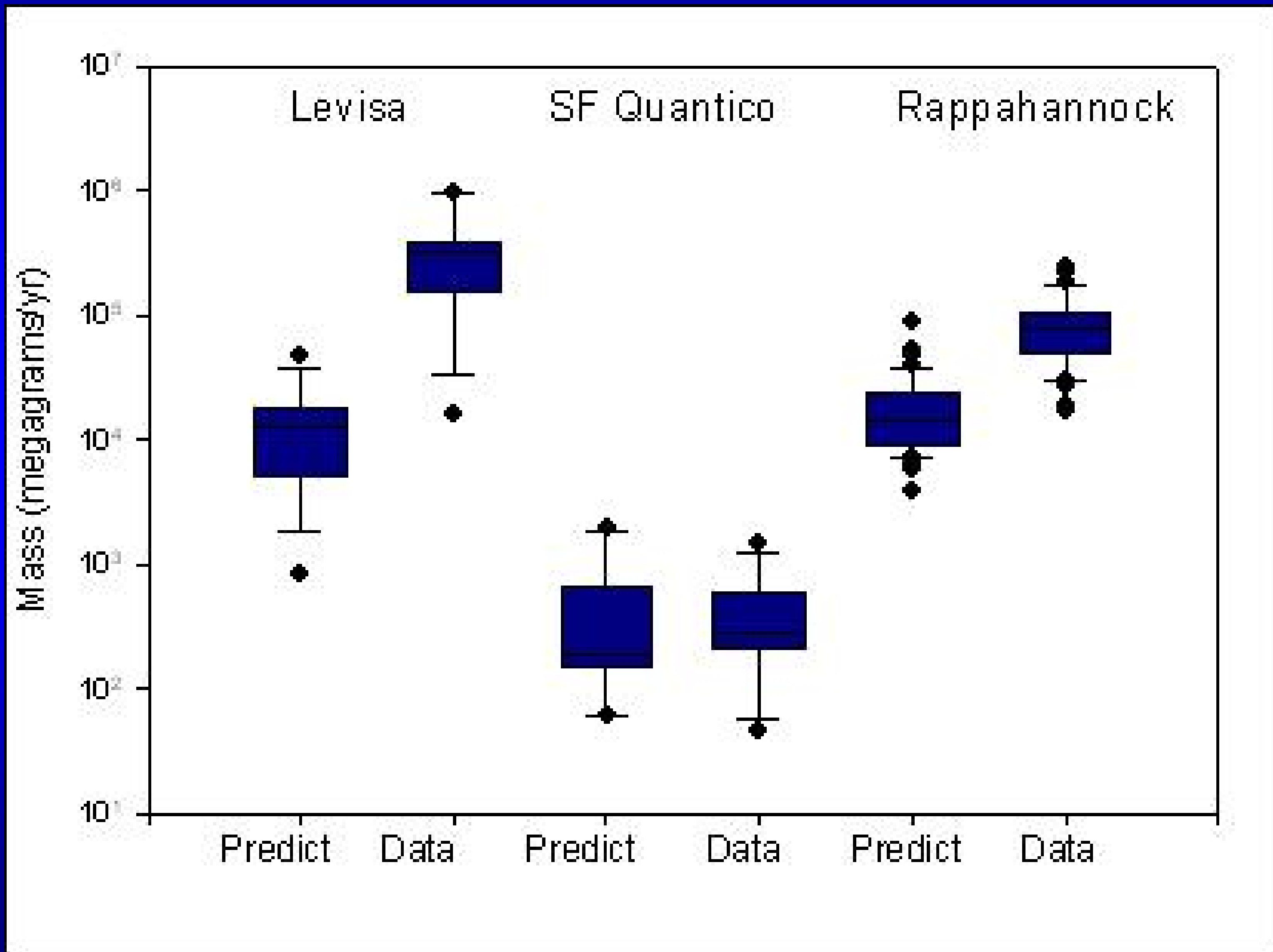
Suspended Sediment Transport

- Development of regional rating curve
- Evaluation of Accuracy
- Application to Waynesboro and Harriston stream gaging records

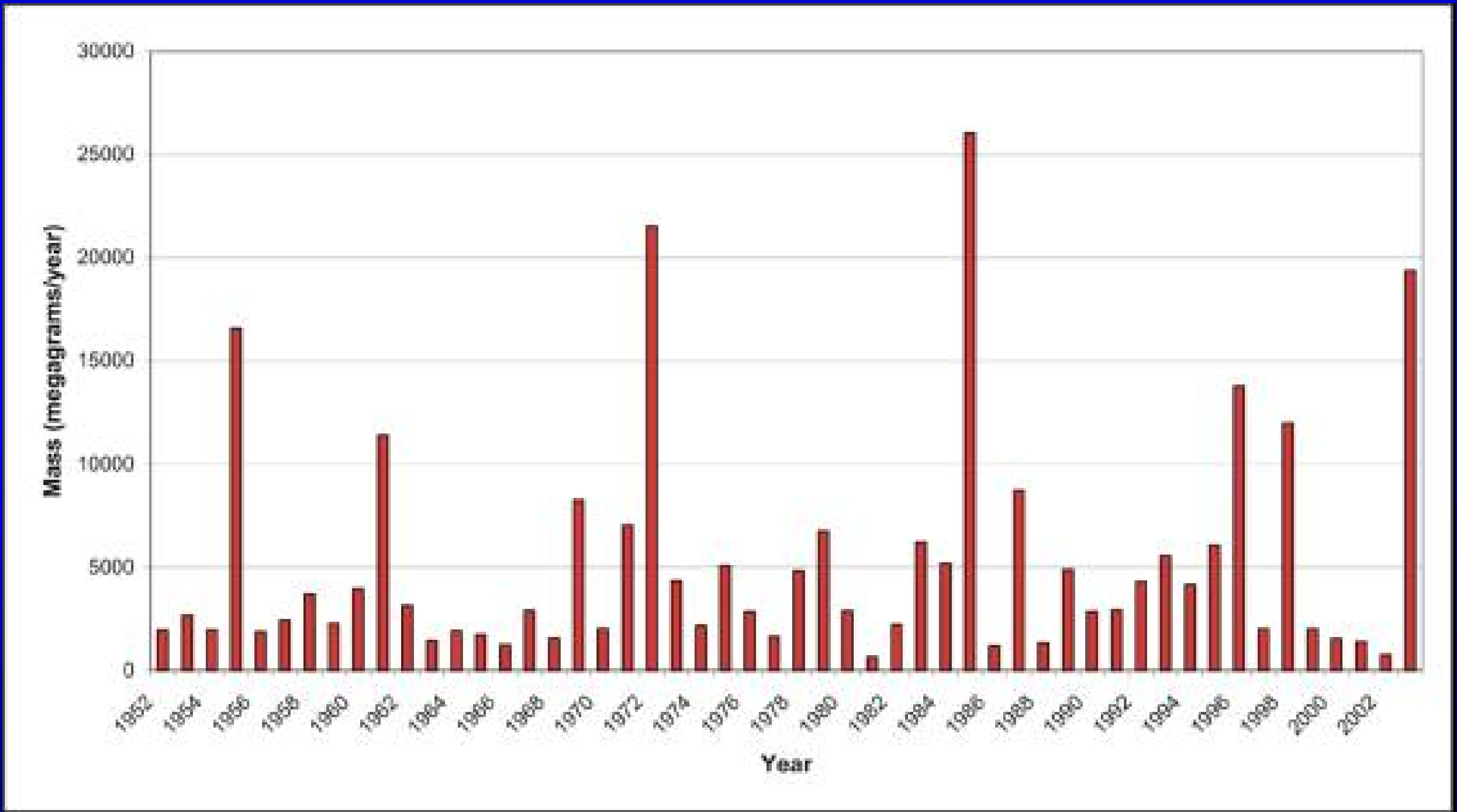
The Regional Rating Curve



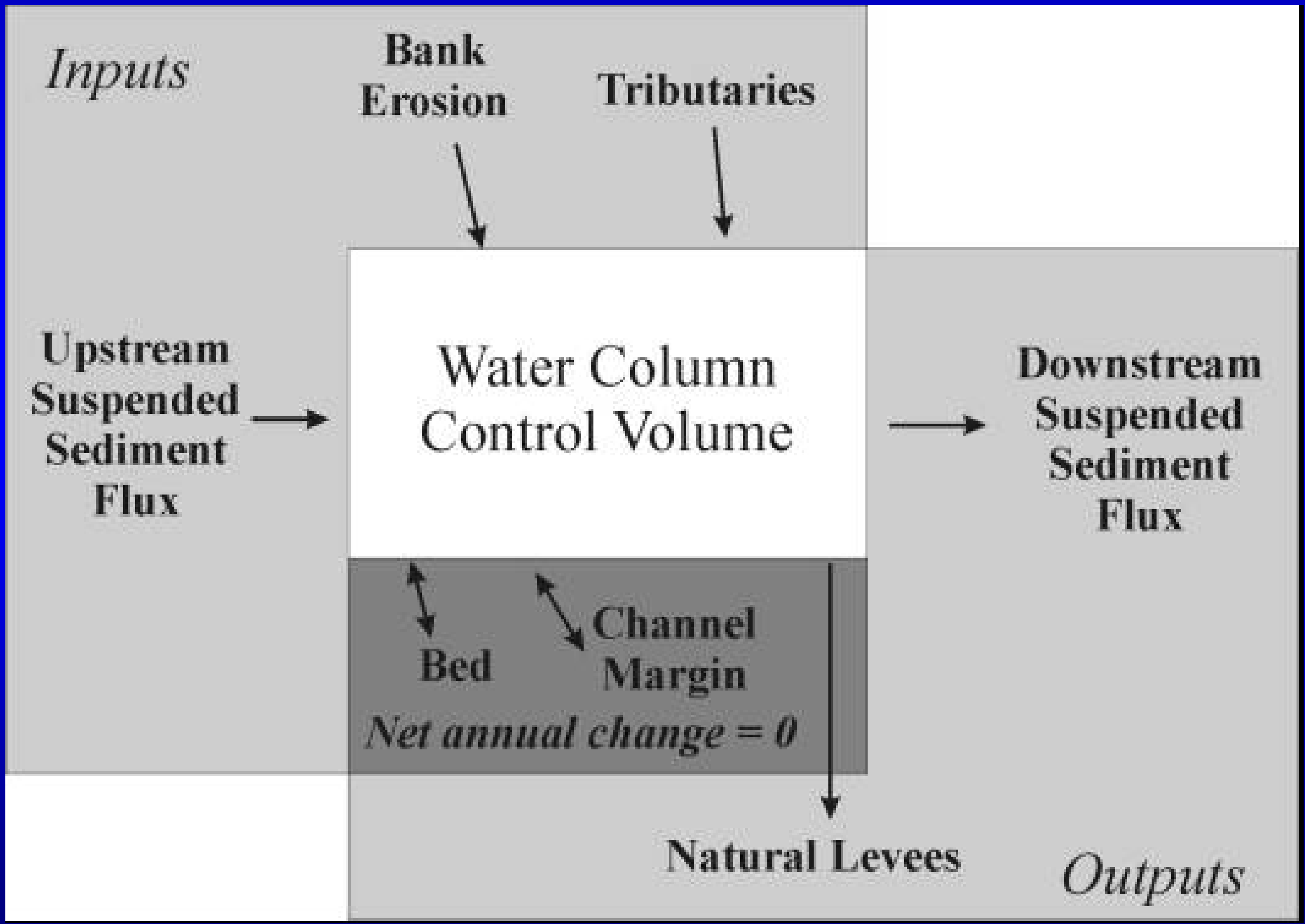
The rating curve approach is imprecise…



Annual Suspended Sediment Fluxes At Waynesboro – a few "big years" dominate transport!



The Annual Silt and Clay Budget Components



Annual Silt and Clay Budget, Waynesboro-Harriston

Inputs	Annual Values	Units	Source of Estimate	Comments
Upstream Suspended Sediment Flux	5.2×10^6	kg/yr	Chapter 11	
Bank Erosion	8.5×10^5	kg/yr	Chapter 6	
Tributaries	3.3×10^6	kg/yr	Chapter 12	From Solving Equation 12.1
Total input	**9.3×10^6**	**kg/yr**	Chapter 12	Sum of all inputs
Outputs	**Annual Values**	**Units**		
FGCM Storage	0	kg/yr	Chapter 5, 12	
Floodplain Levees	1.7×10^5	kg/yr	Chapter 9	
Bed Storage	0	kg/yr	Chapter 10	Assumed annual residence time
Downstream Suspended Sediment Flux	9.2E+06	kg/yr	Chapter 11	
Total output	**9.3E+06**	**kg/yr**	Chapter 11	Sum of all outputs
Net change in storage in water column control volume	**0**	**kg/yr**	Chapter 12	Assumed

Budget Components as % of Annual Suspended Sediment Load at Harriston

Parameter	Units	Percent of Suspended Sediment Flux at Harriston
Suspended Sediment Flux at Waynesboro	Mass/time	57
Bank Erosion	Mass/Time	9.2
Tributaries	Mass/time	36
FGCM storage	Mass	16
Floodplain levees	Mass/time	2
Bed storage	Mass	<1

Testing a Simple Box Model of Sediment-Related Hg in South River Channel Perimeter

"Hg rich" sediment from eroding banks

Banks

Upstream

Channel perimeter

Lots of "clean" suspended sediment from upstream (10x supply from eroding banks)

Hg on sediment in channel represents a diluted mixture from both sources

Predicted Hg Concentrations Based on the "Well-mixed" Hypothesis

Table 13.1. Sources of sediment and Hg to the annual budget of South River.

Sources	Annual Mass of Sediment (kg/yr)	Ave. Hg concentration (ppm)	Annual Mass of Hg (kg/yr)
Upstream Suspended Sediment Flux	5.2E+06	0.2	1.0
Bank Erosion	8.5E+05	10.0	8.5
Tributaries	3.3E+06	0.2	0.7
Total input (final result rounded)	**9.3E+06**	**1.1**	**10**

Table 13.2 Predicted vs. actual concentrations of Hg for various components of the budget. Measured water column Hg concentrations of suspended particulates are discussed in the text below.

Component	Predicted Hg concentration (ppm)	Actual Hg concentration (ppm)
Water Column	1	NA
FGCM deposits	1	30
Natural levees	1	13
Channel bed	1	12

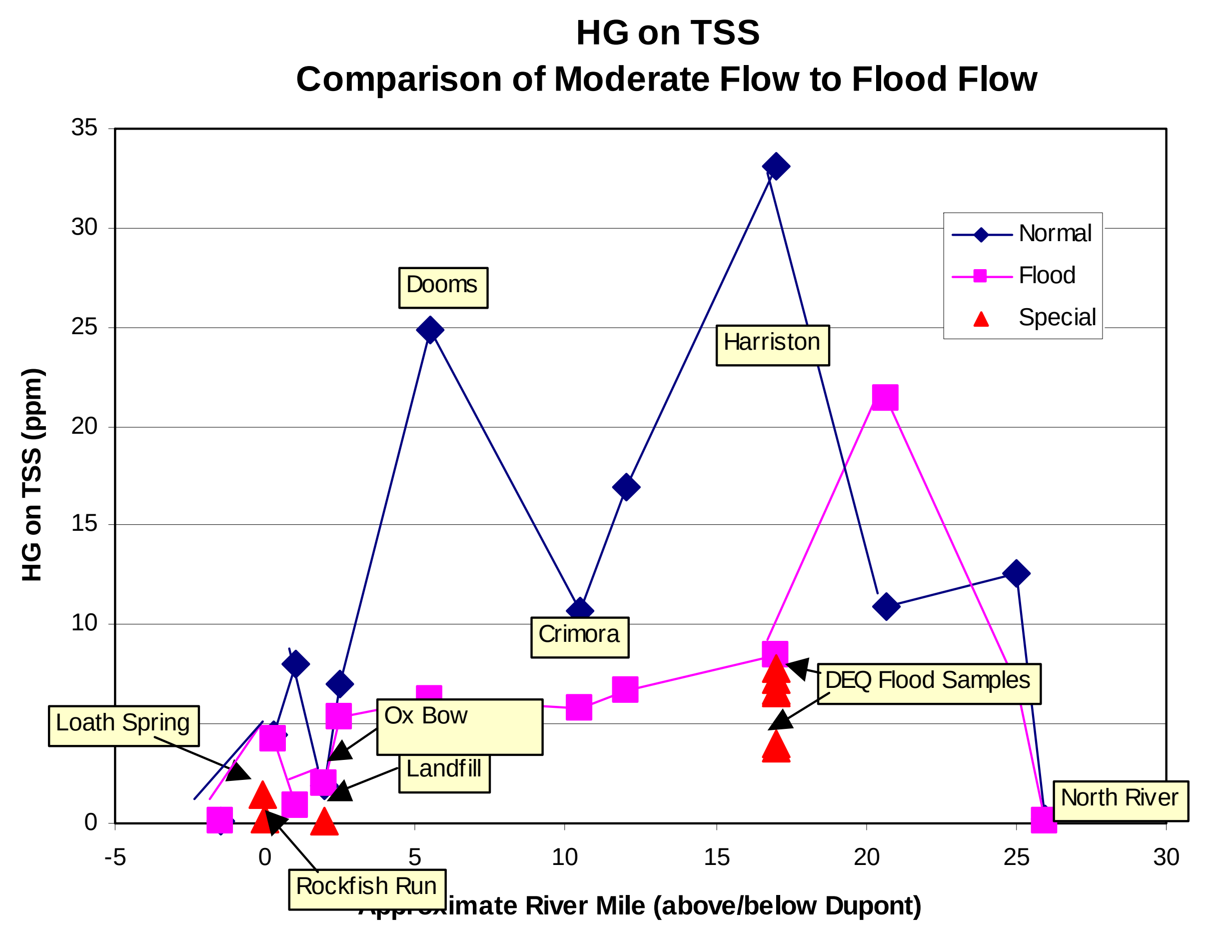
Some Working Hypotheses Based on These Results

- Very large discharge events that transport most of the sediment are NOT responsible for the distribution of “sediment-related Hg” typically sampled in the channel and on natural levees
  - Sediment with low Hg concentrations is likely transported at high discharges and flushed through the study reach *without significant storage*
- Sediment and associated Hg are distributed and stored within the study reach by “low-medium” discharges

Additional Evidence….

- During high flows, Hg concentrations on suspended solids appears to decrease, possibly through dilution from “clean” material supplied from outside the study area

Flood Hg on TSS is lower than at "moderate" flow (Jensen and Turner…)



USGS Flood Samples

Date	Time	Discharge (ft^3/s)	Discharge (m^3/s)	Suspended Solids Concentration (mg/L)	Particulate Total Hg (ng/L)	Hg on TSS (ppm)
11/29/05	11:30 AM	2765	78	377	4022	11
11/30/05	12:30 AM	11776	333	277	1346	5
11/30/05	04:30 AM	9143	259	227	817	4
11/30/05	11:00 AM	5795	164	118	416	4

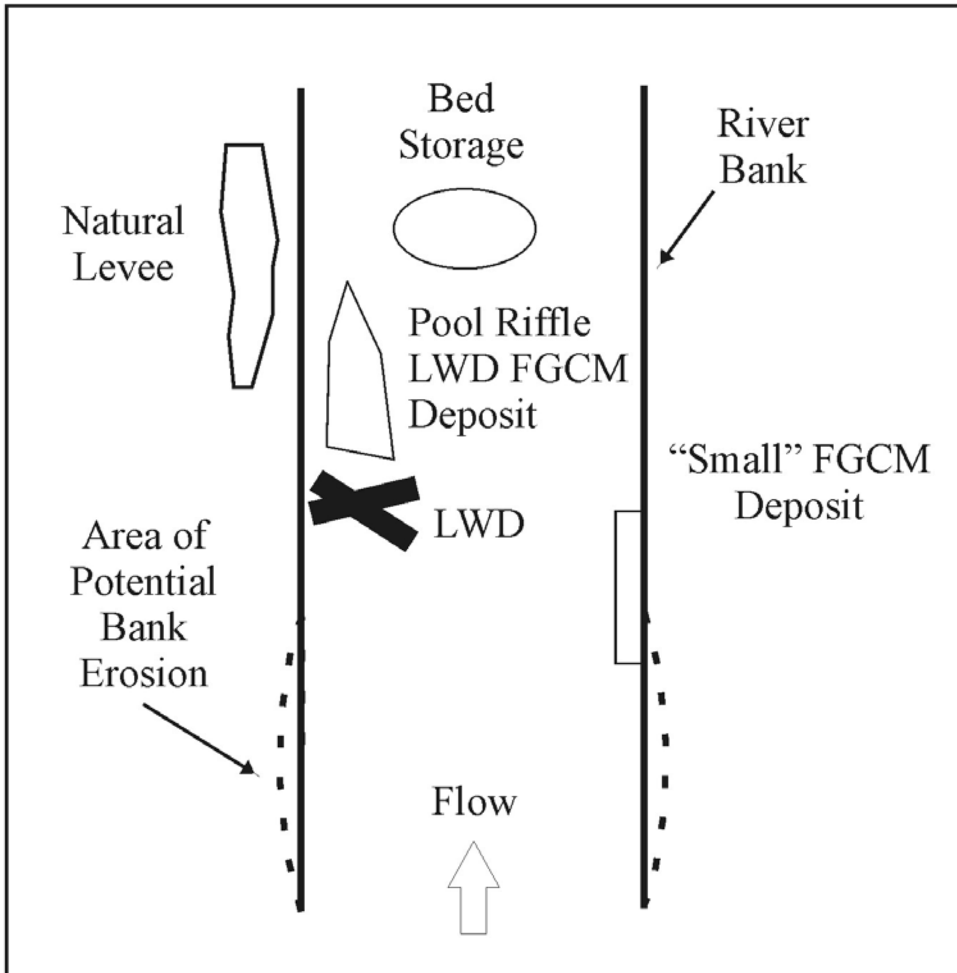
Some Conceptual Models of Particulate and Hg Transfer Between Sediment Budget Components at Different Discharges

1 Day of Base Flow Conditions

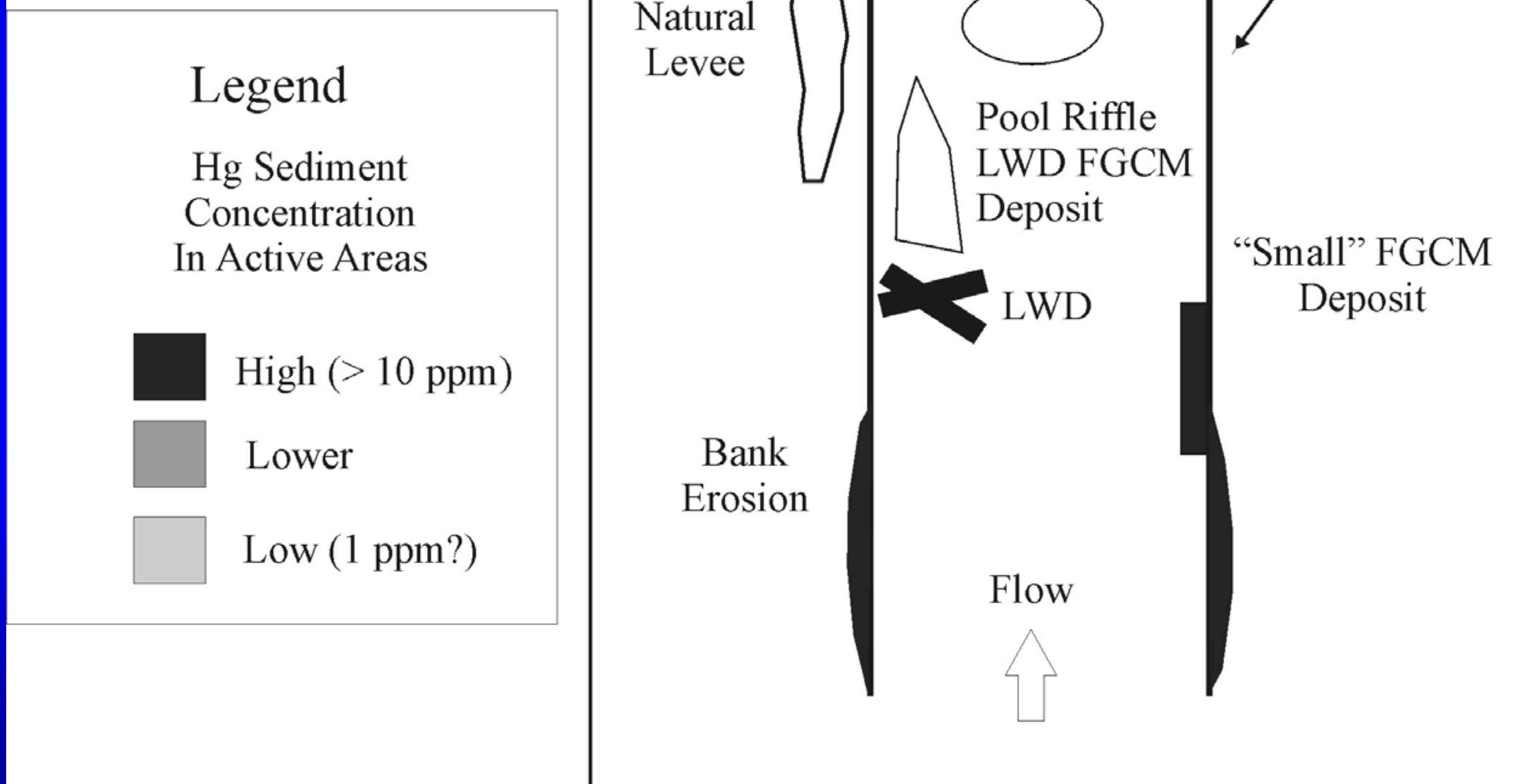
Legend

Hg Sediment Concentration In Active Areas

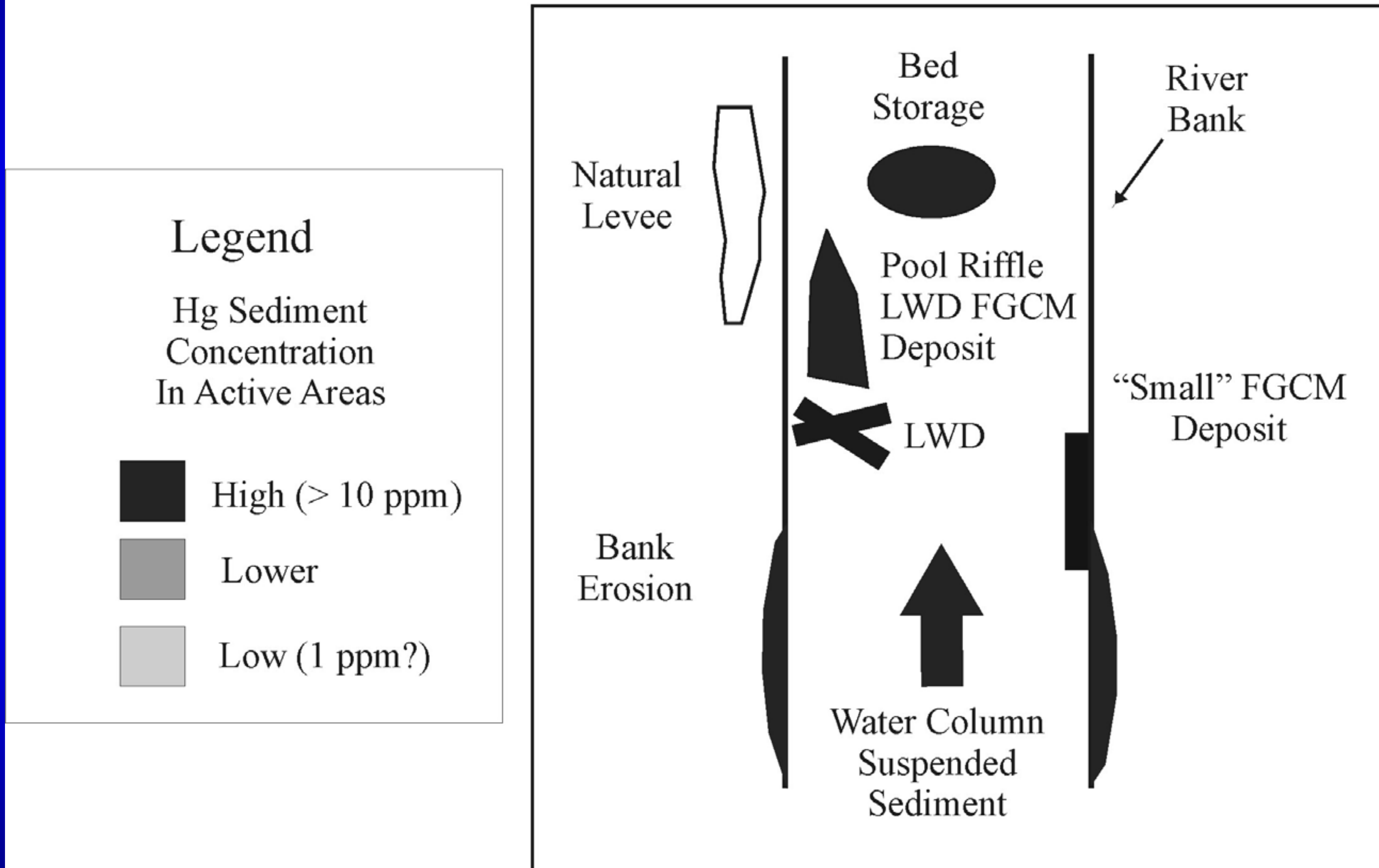
- High (> 10 ppm)
- Lower
- Low (1 ppm?)



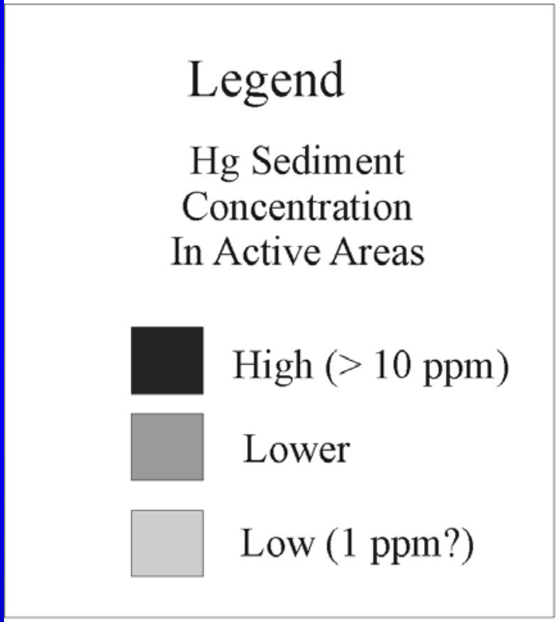
Feb.-April, w/o Significant Flows

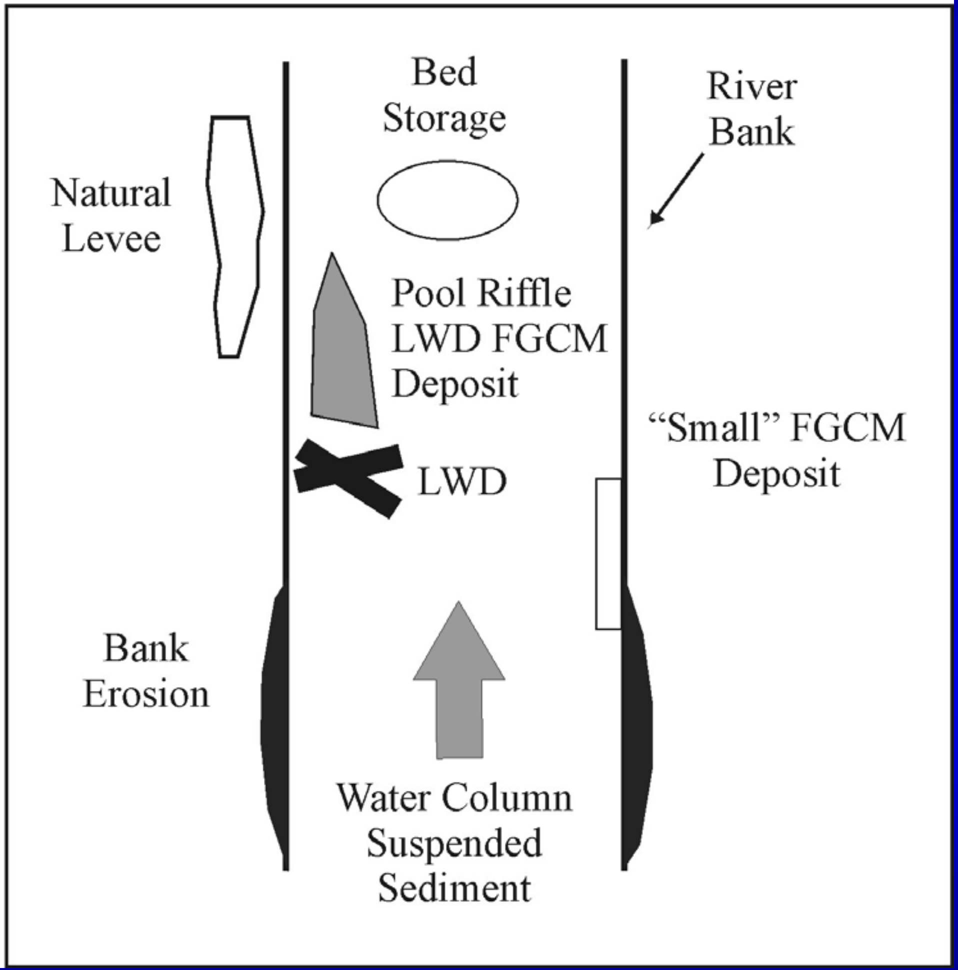


During a 1/3 Bankfull Flow

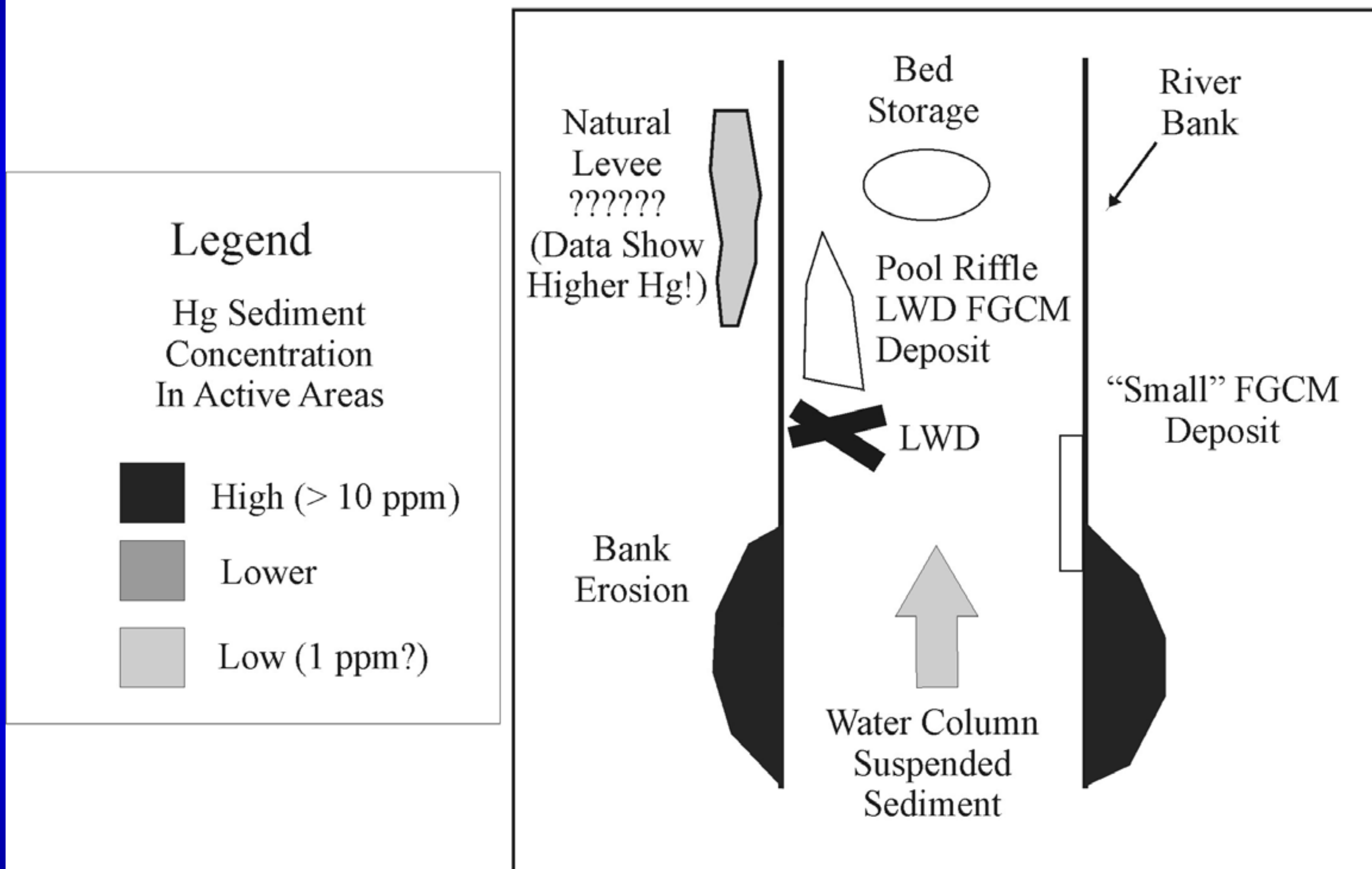


During a 3/4 Bankfull Flow





During a 5-10 Yr Flow



Summary – Responses of Sediment Budget Components vs Discharge