Geomorphology Update

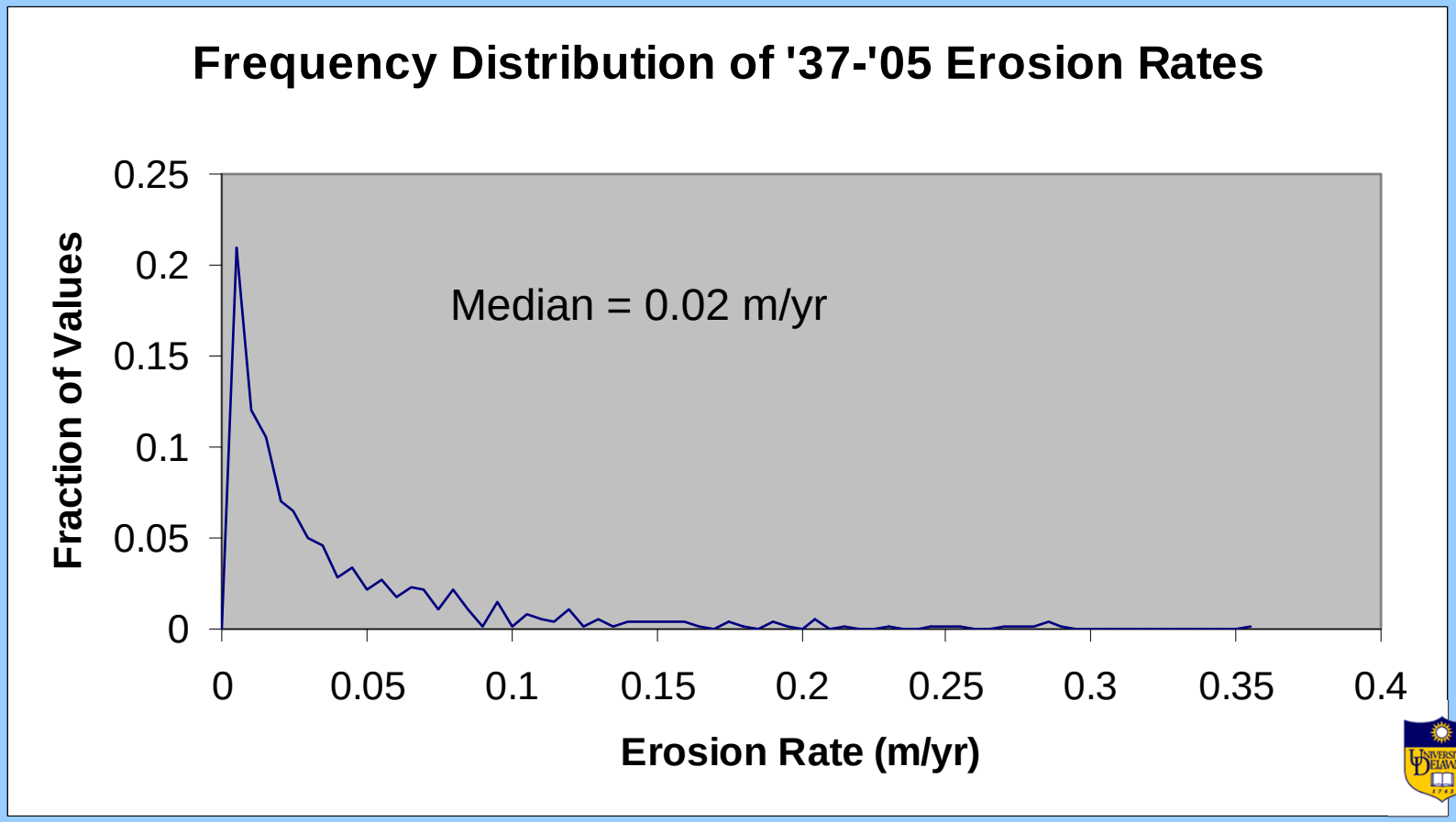
Jim Pizzuto, Geological Sciences
Michael O'Neal, Geography
and graduate students…
University of Delaware

Outline

- Bank Erosion
  - Long-term average bank erosion rates
    - Statistical summary
    - Controls
  - Changes in bank erosion rates through time
    - 1937-1957, 1957-1974, 1974-2005
  - Erosion of silty banks by individual high flows
    - Model results
  - 2006-2007 lidar surveys
- Mapping “Hg Release Age” Floodplain Deposits
- 2007-2008 Program

Frequency Distribution

Many Low Erosion Rates, Few High Rates



Floodplain Erosion by Category

Category	% of Total Erosion, 1937-2005
Island	33.10
Bends	26.31
Other	15.34
Engineered	11.19
Dam Removal	8.28
Confluence Bar	5.64

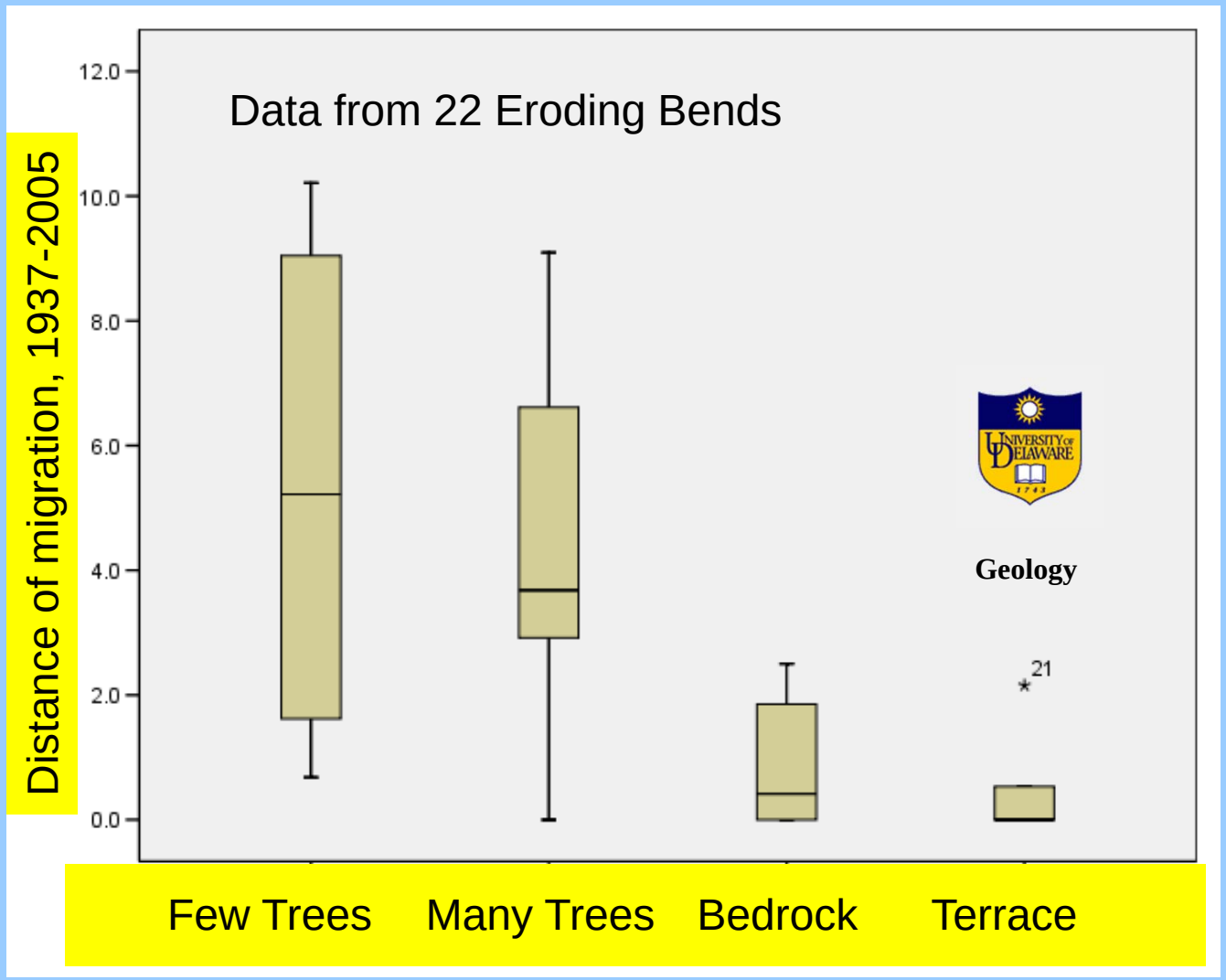
Geology

Category	Definition
Island	New side channel, or forested island erosion, or island deflecting flow causing erosion
Bends	Channel migration forced by curvature with erosion on outside and deposition on inside
Other	Erosion unrelated to channel curvature
Engineered	Active modification to the channel by structures or construction
Dam Removal	Erosion in the vicinity of dams, usually post removal
Confluence Bar	Tributary gravel deposition forces flow into opposite bank

Controls on Long-Term Erosion Rates

- GEOLOGIC SETTING (bank material type)
- Density and size of trees
- Bend Curvature and Geomorphic Setting

Trees Reduce Bank Erosion….But Geology Is The Primary Control!



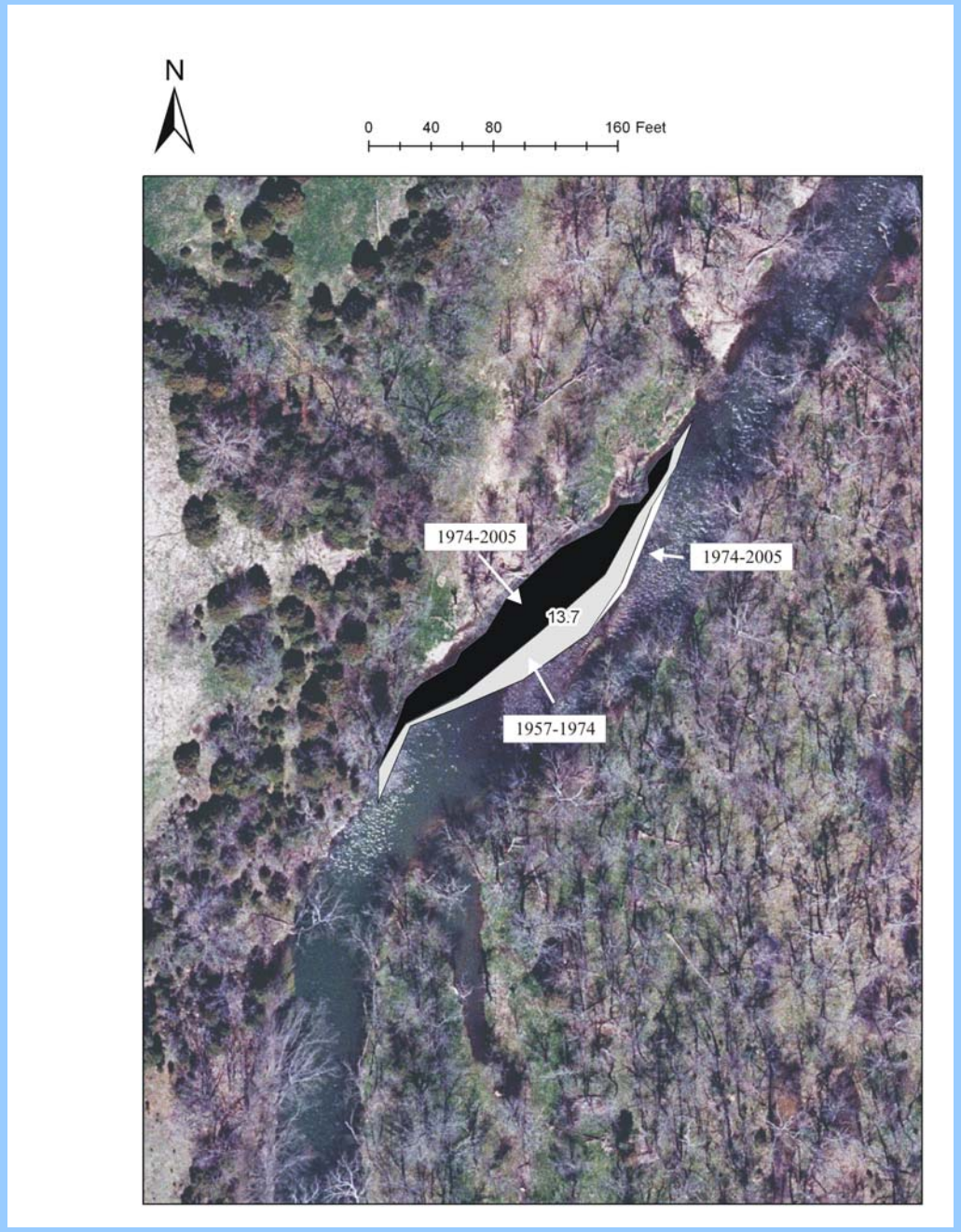
Changes in Long-Term Bank Erosion Rates With Time

- Picked 14 bends
  - Clear historical aerial photographs
  - Significant channel migration
- Measured channel migration at 3 times
  - 1937-1957
  - 1957-1974
  - 1974-2005

Some Examples…

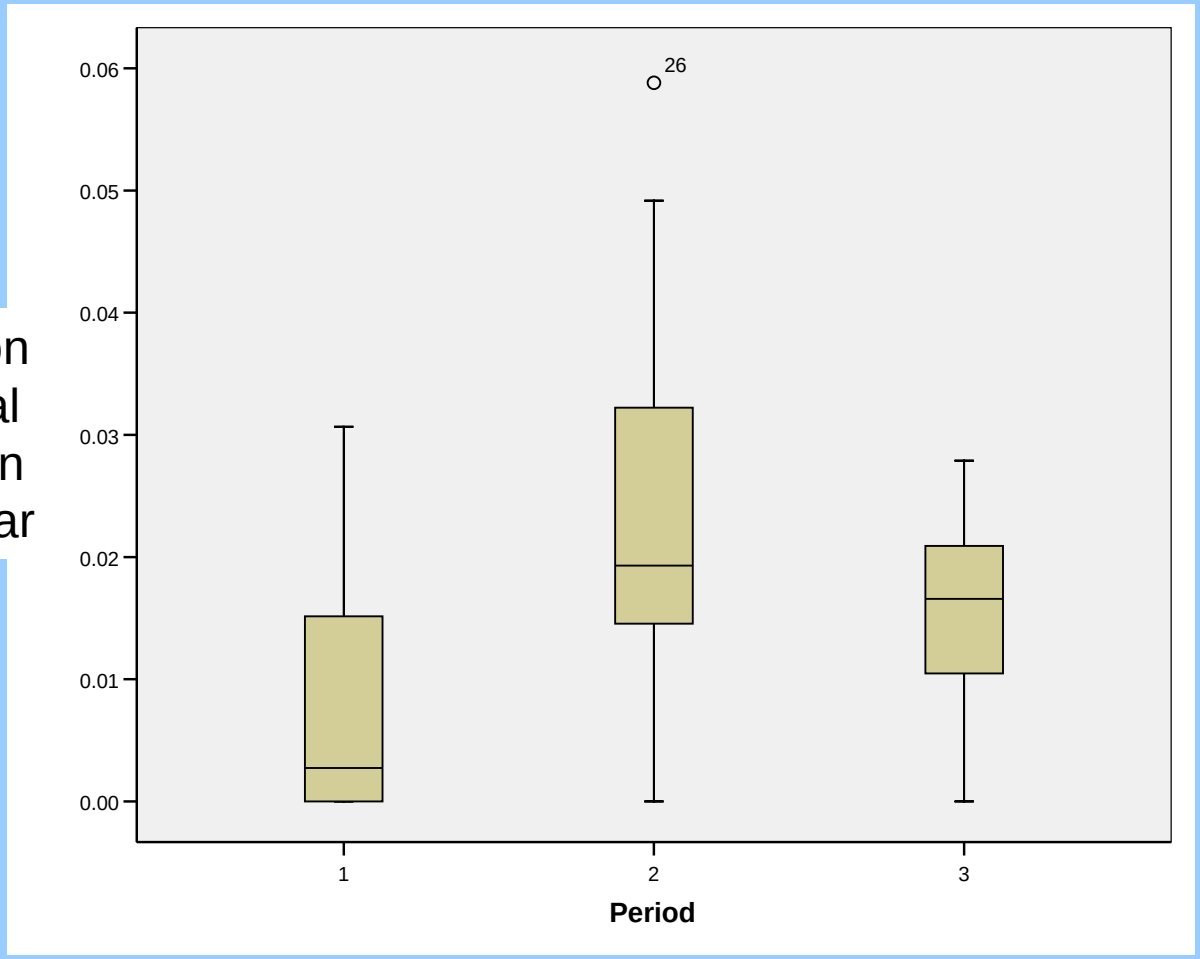
RRM 8.7-8.8

RRM 13.7



Bank Erosion Rates Increased After 1957!!

Fraction Of total Erosion Per Year

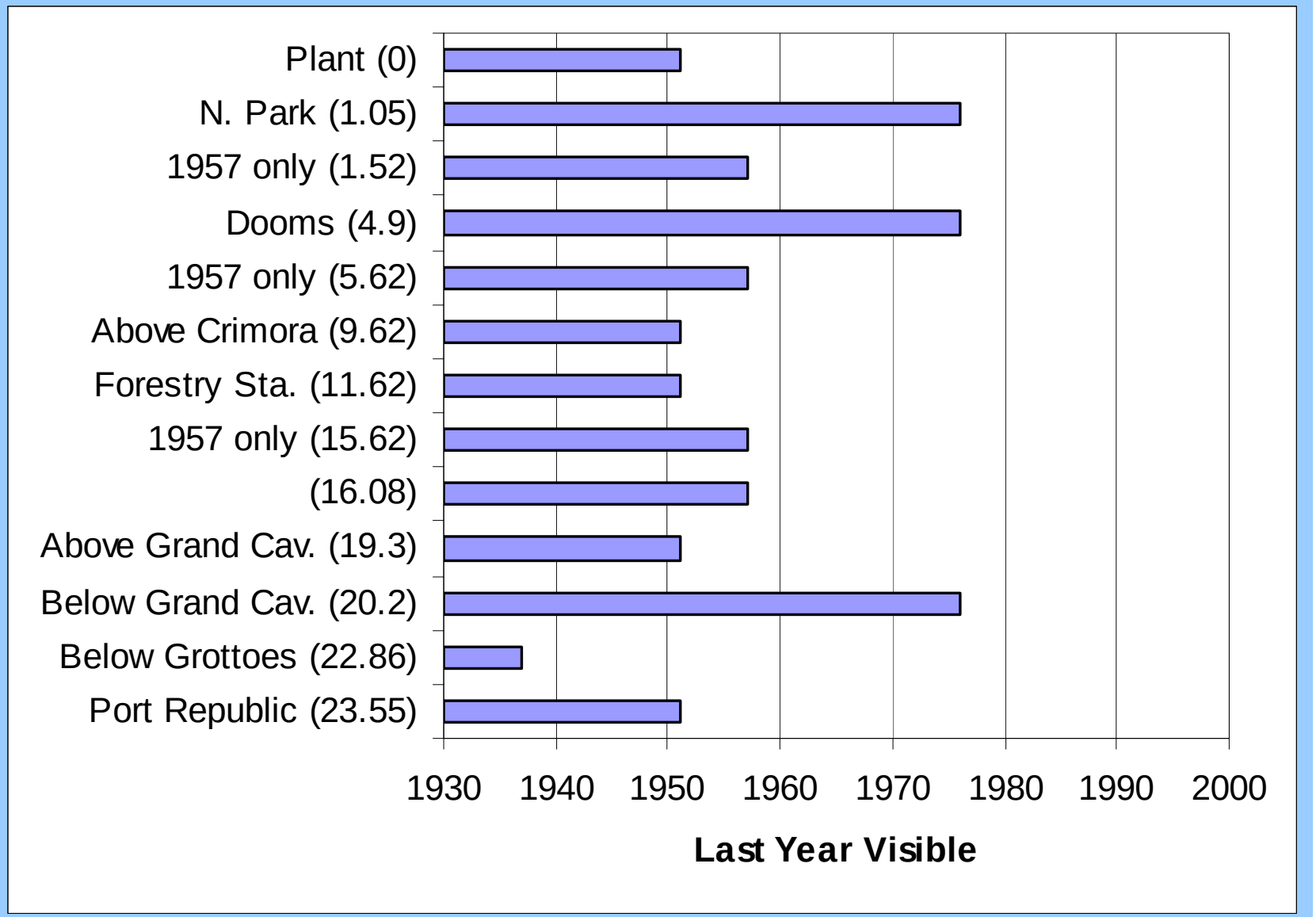


Time Period (1=37-57, 2=57-74, 3=74-05)

WHY??

- Not correlated with:
  - History of high discharges
    - High flows INCREASE in frequency after 1957
  - Changes in riparian vegetation
    - MORE trees after 1957
      - Should be correlated with REDUCED erosion rates
- Correlated in TIME with loss of 13 mill dams

Mill Dams/Obstructions Along South River



But Bank Erosion Rates are NOT Higher Near Dams

- Strong evidence linking dam breaching to increased erosion rates not available

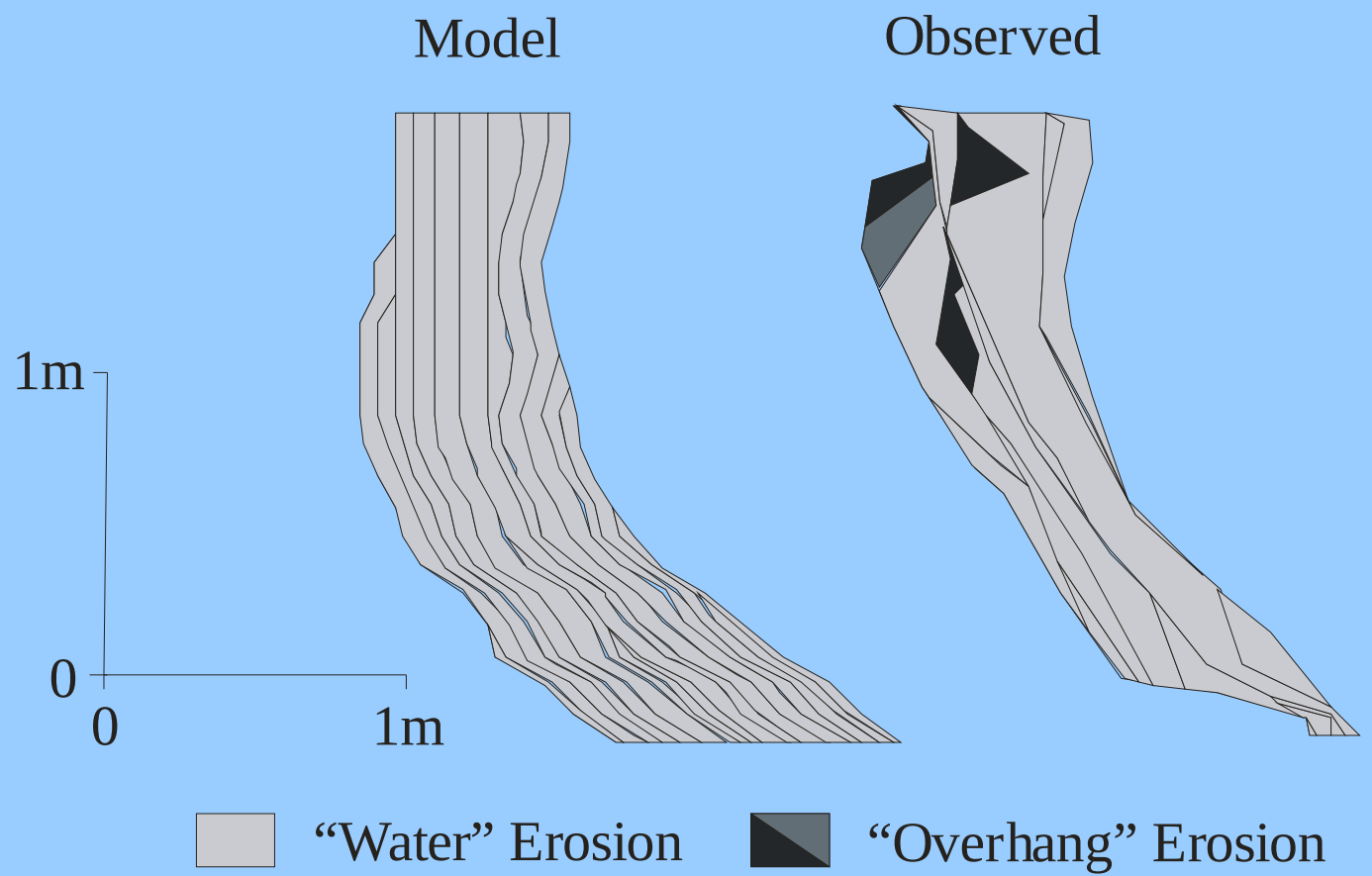
Other hypotheses

- Increased frequency of freezing and thawing after 1957
- Increased sediment supply after 1957
  - Linked to land use changes in the watershed?
  - Hard to evaluate…

Empirical/Statistical Model of Profile Erosion of Silty Banks By Individual High Flows

3 Years of Modeled Bank Erosion

Site 5



Controlling Variables Identified By Empirical Modeling

- Near-bank velocity
- Frequency of Freeze-thaw
- Water level
- Bank steepness

Bank Tripod Lidar Surveys, 2006-2007

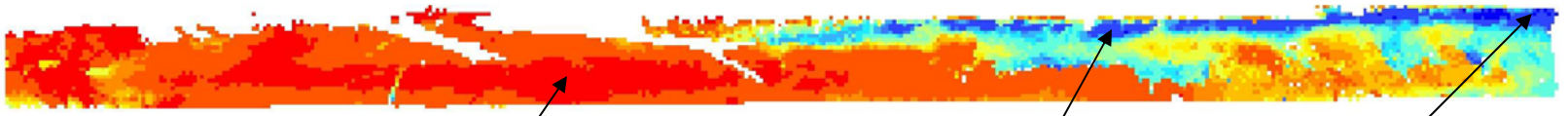
Number	From (RRM)	To (RRM)	Side	1937-2005 Erosion?	Mapped as Currently Eroding?	Setting	Geologic Map Unit	Vegetation Type	Bank Sediment
1	1.55	1.65	Right	no (cutoff)	yes	bend	Alluvium	Forested	Gravel
2	1.7	1.8	Right	no (cutoff)	yes	bend	Alluvium	Pasture	Silt and clay
3	2.15	2.17	Right	yes	no	straight	Alluvium	Trees on bank	Silt and Clay
4	2.88	3	Left	no	yes	bend	Alluvium	Trees on bank	Silt and clay
5	3.08	3.12	Left	yes	no	bend	Bedrock	Trees on bank	Silt and clay over b
6	3.47	3.52	Right	yes	yes	bend	Alluvium	Trees on bank	Silt and clay over g
7	4.7	4.8	Left	yes	yes	confluence	Alluvium	Pasture	Silt and clay
8	5.35	5.351	Left	no	yes	straight	Alluvium	Trees on bank	Silt and clay
9	5.37	5.4	Right	no	yes	straight	Alluvium	Pasture	Silt and clay over g
10	7.25	7.4	Left	yes	no	bend	Alluvium	Trees on bank	Silt and clay
11	7.7	7.8	Left	yes	no	bend	Alluvium	Trees on bank	Silt and clay
12	8.2	8.3	Left	yes	yes	bend	Alluvium	Forested	Silt and clay
13	8.5	8.53	Left	yes	yes	bend	Alluvium	Forested	Silt and clay
14	8.7	8.78	Left	yes	yes	confluence	Alluvium	Pasture	Silt and clay
15	8.8	8.9	Right	yes	yes	island	Alluvial Fan	Pasture	Silt and clay
16	9.7	9.8	Left	yes	yes	bend	Alluvium	Forested	Silt and clay; grave
17	13.05	13.15	Right	yes	yes	island (bend)	Alluvium	Forested	Gravel
18	15.3	15.4	Left	yes	yes	bend (island)	Terrace	Forested	Silt and clay over g
19	15.4	15.42	Left	yes	yes	bend (island)	Terrace	Forested	Silt and clay
20	22.3	22.4	Right	no	yes	bend (island)	Alluvium	Forested	Silt and clay over g
21	22.42	22.6	Right	yes	yes	bend	Alluvium	Pasture	Silt and clay, grave
22	22.6	22.61	Left	yes	yes	bend	Alluvium	Pasture	Gravel
23	23.04	23.15	Right	yes	no	bend (island)	Alluvium	Forested	Gravel

Eco study sites
Baseline survey
Second Survey
Third Survey
Fifth Survey


Z
X

RM 1.6

10/25/2006 and 2/16/2007



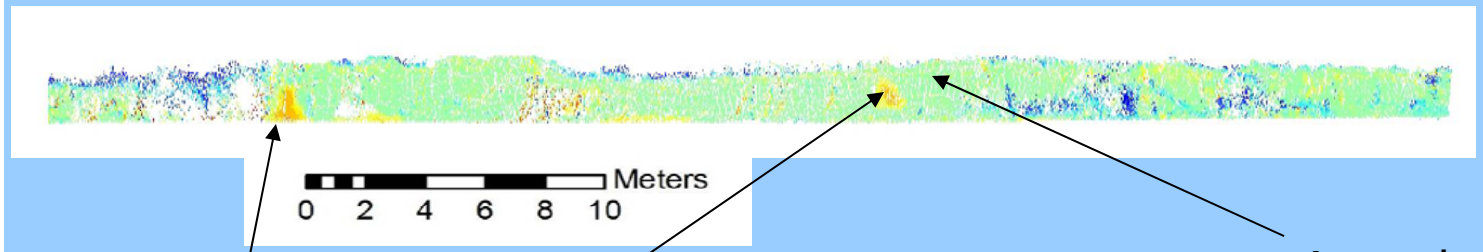
< -1.0
-0.5 - -1.0
-0.4 - -0.5
-0.3 - -0.4
-0.2 - -0.3
-0.1 - -0.2
0.0 - -0.1
0.0 - -0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.1
> 1.0

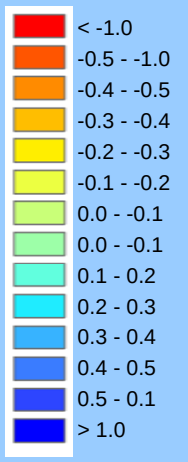
Apparent deposition – an artifact of filtering

Erosion of > 1m/yr in non-cohesive gravelly bank sediments!

RM 1.75 (Oxbow)

1/31/2006 and 6/2/2006





Several decimeters of erosion localized in “holes”

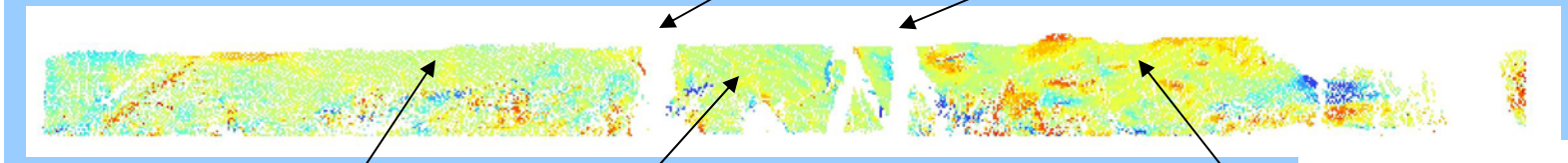
Areas in light green (most of the bank) show no changes!!

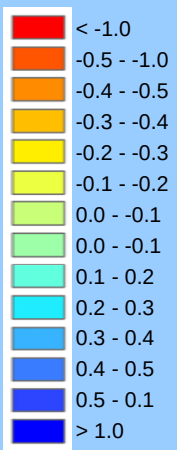
Apparent deposition in blue tones are artifacts of data filtering!

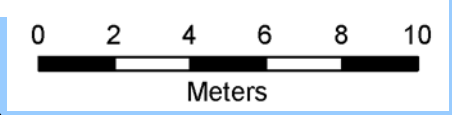
RM 2.95

2/1/2006 and 3/27/2007

Note: Erosion here is too slow to be resolved on historical aerial photographs





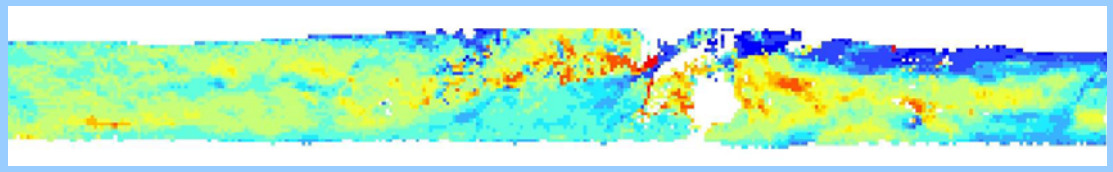


Small areas of erosion (yellow and light green)

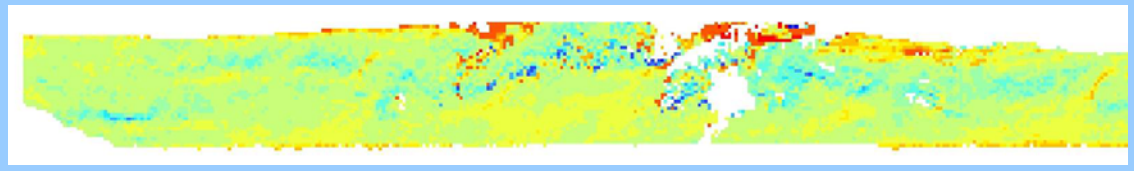
Several decimeters of bank erosion behind large trees

RM 5.35 (River Left)

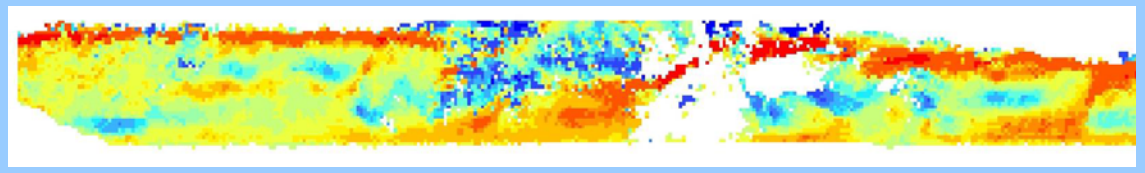
2/17/2007 - 11/20/2006



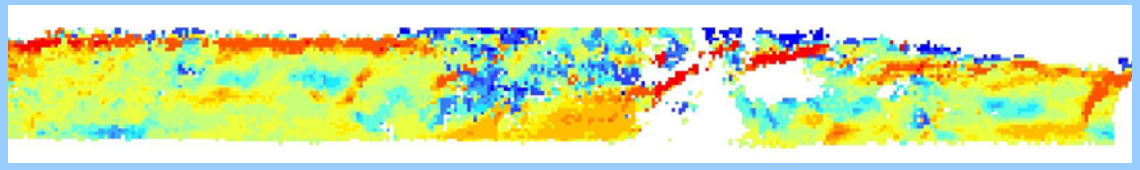
3/06/2007 - 2/17/2007

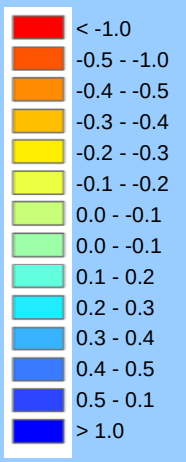


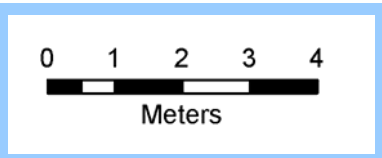
4/27/2007 - 3/6/2007



4/27/2007 - 11/20/06







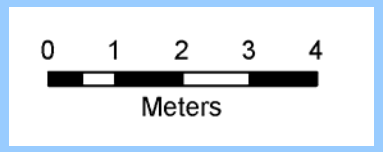
11/20/2006

2/17/2007

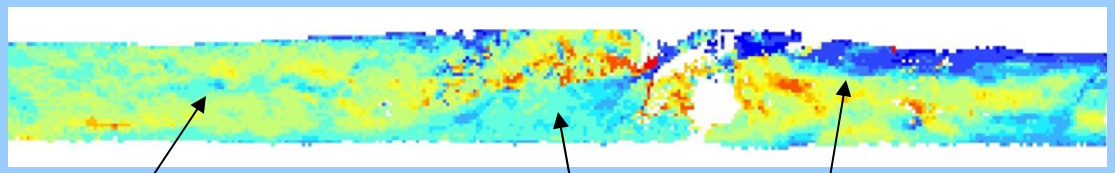
3/6/2007

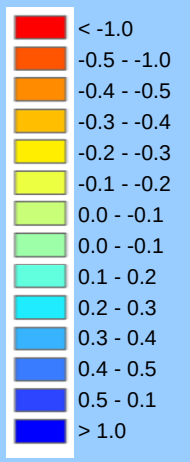
4/27/2007

RM 5.35 (River Left)



2/17/2007 - 11/20/2006





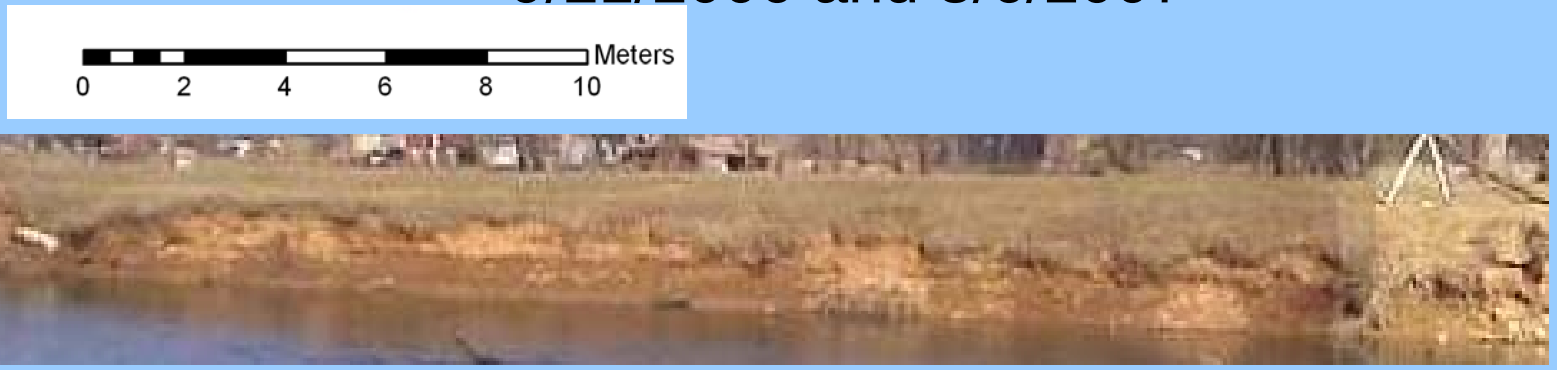
~ Decimeter of erosion (yellow, green) or no change (green, blue green)

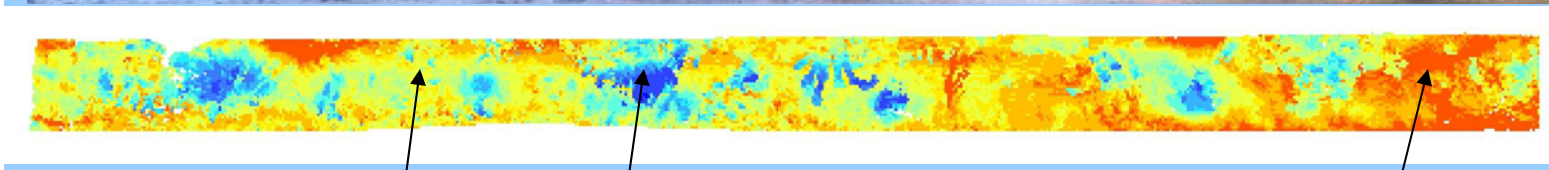
“Deposition” is snow!

~Decimeter of erosion of middle of bank

RM 5.37 (River right)

9/21/2006 and 3/6/2007





Apparent growth of shrubs (blue)

Several decimeters of erosion (yellow)

Up to 1 m of erosion on cattle path

Lidar Surveys – Take Home Points

- Current rates of bank erosion in localized areas can exceed 1 m/yr
    - Gravelly bank materials
    - Cattle and other localized influences
- Bank erosion patterns are spatially complex
  - Results are totally groundbreaking
    - No available methods for extrapolation to larger areas or longer timescales
- Filtering vegetation remains a challenge
- Annual surveys will definitely provide useful results
  - More frequent surveys confounded by snow, vegetation, etc.
- Results generally support conclusions from aerial photo analysis
  - Trees reduce bank erosion rates
  - Bank sediment type is key controlling variable

Mapping “Hg-Release Age” Floodplain Deposits

- Floodplain deposits with significant amounts of silt and clay
- Deposited from 1937-1950s

Initially Identified By….

- Mapping shoreline changes on historical aerial photographs

Categories of Deposits (very draft)

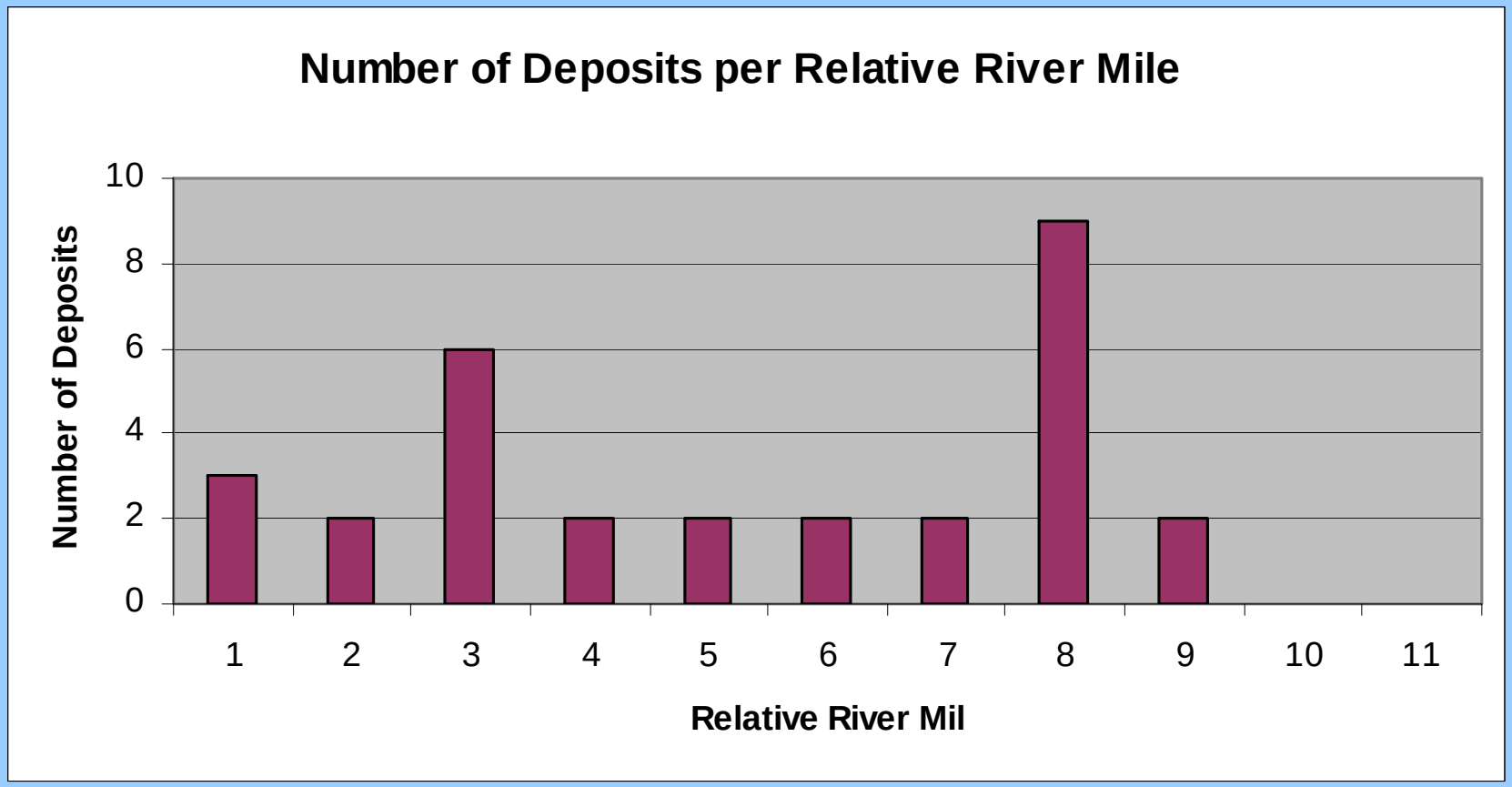
- Mill dam deposits
- “Point bar/bench” deposits
- Concave bank bench deposits
- Tributary confluence deposits
- Cattle deposits

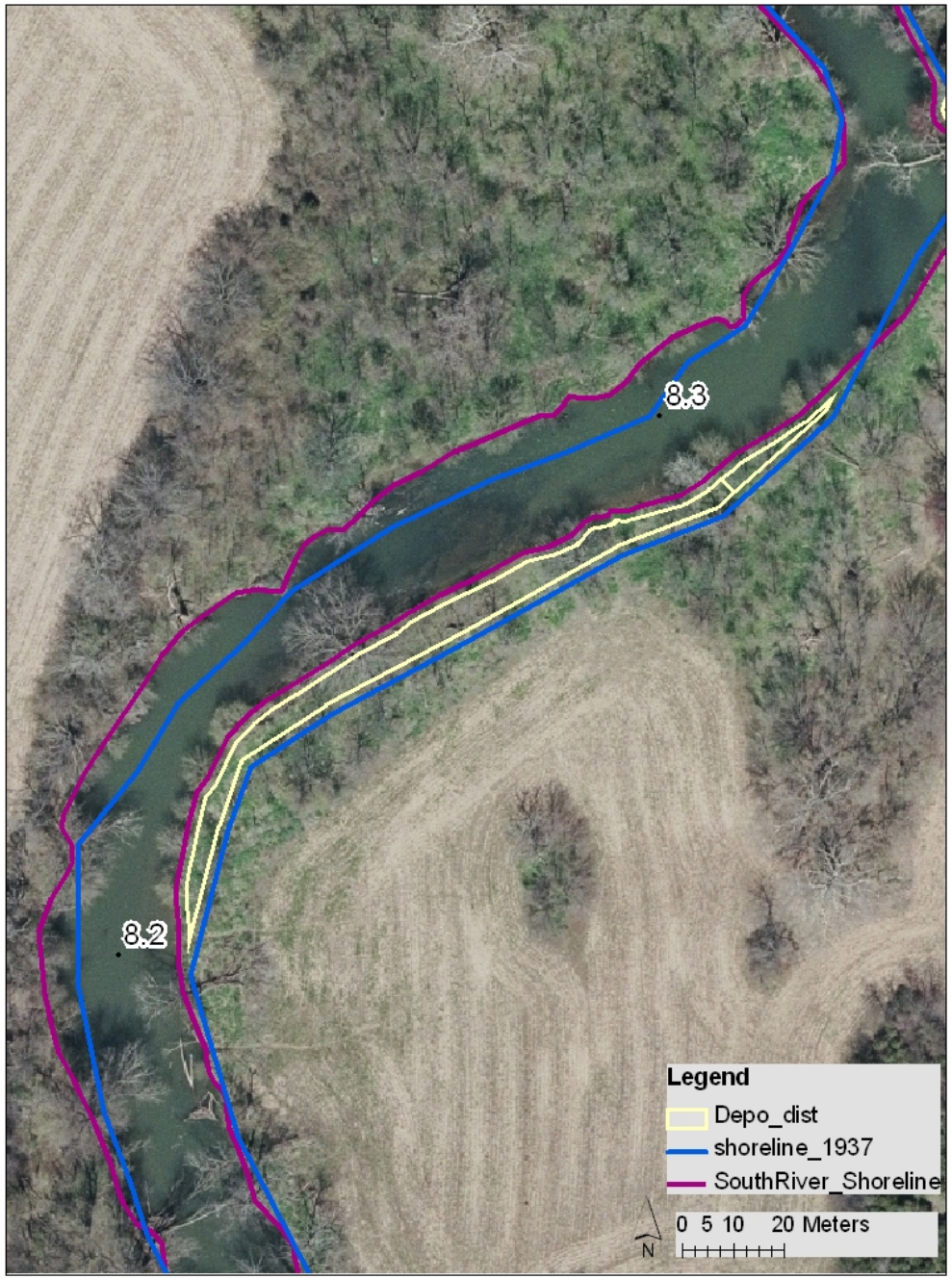
Current Draft Listing

RM	Side	Category
0	Right	Mill Dam
1.5	Left	Point Bar/Bench
1.6	Left	Point Bar/Bench
1.8	Left	Point Bar/Bench
2.8	Right	Point Bar/Bench
2.9	Right	Point Bar/Bench
3.1	Right	Point Bar/Bench
3.4	Right	Island
3.5	Left	Point Bar/Bench
3.65	Left	Point Bar/Bench
4.1	Right	Point Bar/Bench
4.25	Right	Cattle
4.7	Right	Tributary Confluence
5.2	Left	Point Bar/Bench
5.5	Right	Cattle
5.67	Right	Tributary Confluence
6.46	Right	Point Bar/Bench
6.8	Right	Tributary Confluence
7	Right	Cattle
7.2	Right	Cattle
7.2	Left	Cattle
8.05	Right	Concave Bank Bench
8.1	Left	Point Bar/Bench
8.25	Right	Point Bar/Bench
8.4	Left	Point Bar/Bench
8.48	Left	Concave Bank Bench
8.51	Right	Point Bar/Bench
8.6	Right	Concave Bank Bench
8.6	Left	Point Bar/Bench
8.7	Right	Tributary Confluence
9.25	Left	Tributary Confluence
0.7 -1.1	Left	Mill Dam
11.3 -11.6	Right	Mill Dam
3.2 -3.3	Left	Point Bar/Bench
3.9 -4.1	Left	Point Bar/Bench
4.8-4.9	Right	Mill Dam
5.3 -5.4	Right	Cattle
7.3 -7.4	Right	Point Bar/Bench
7.6 -7.7	Right	Point Bar/Bench
9.2 -9.3	Right	Point Bar/Bench
9.4 -9.6	Right	Mill Dam

Distribution (excluding cattle and Mill Dam deposits)

More Mud Here??





Point Bar Deposit

Medium Brown sandy mud.

Root and fibers present

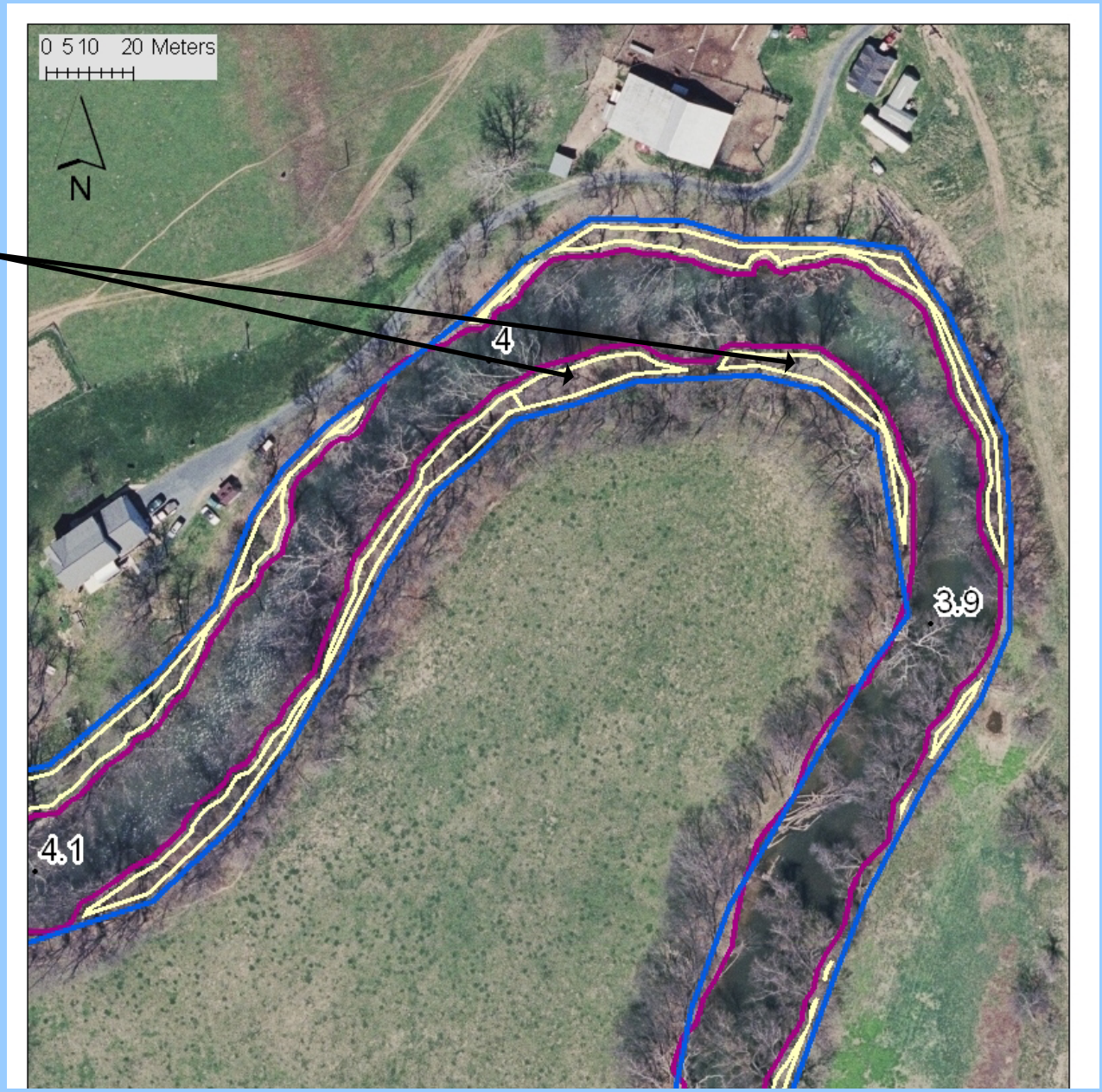
Three layers of laminated light brown sand

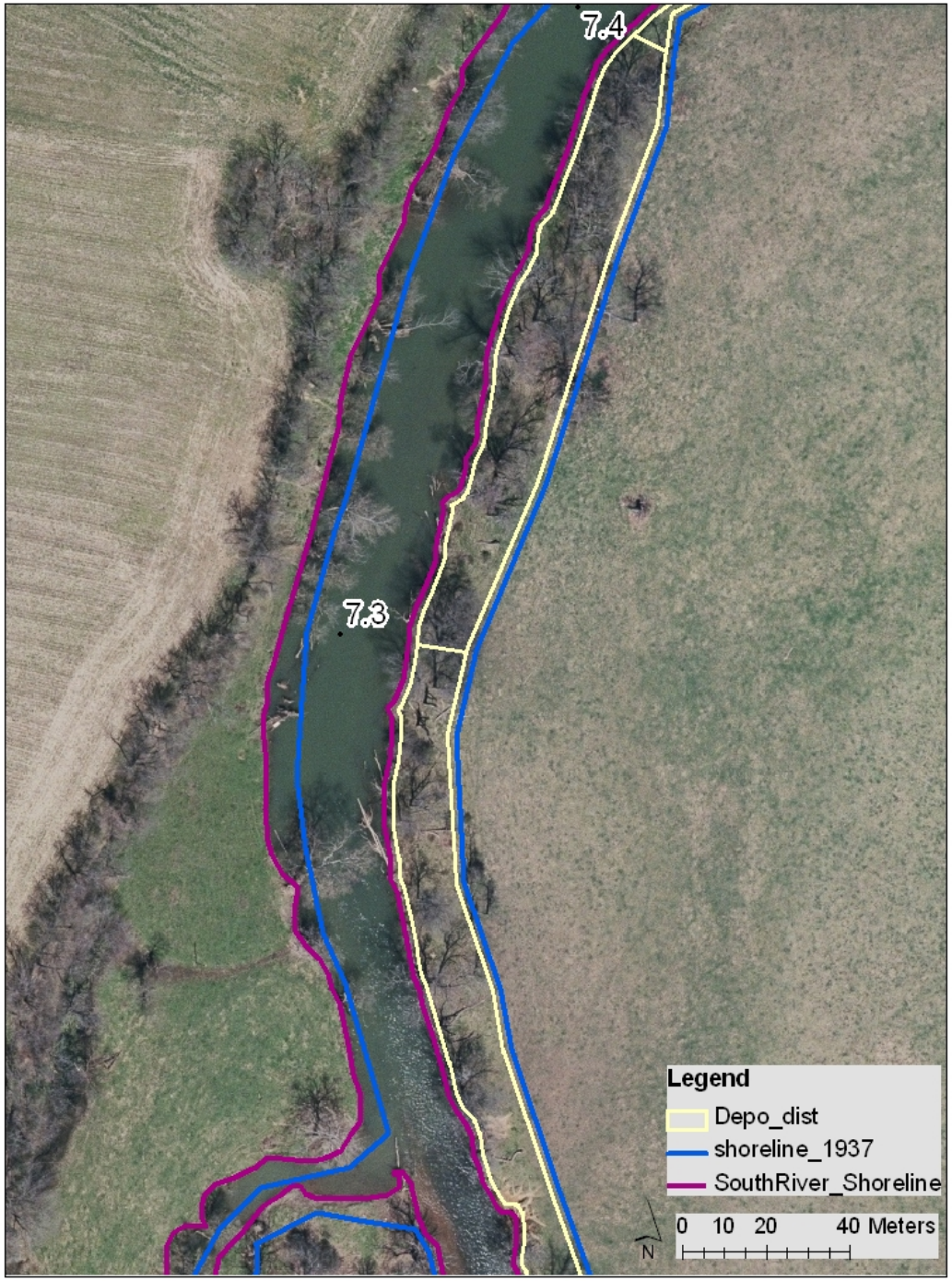
Medium Brown sandy mud.
Coarser than upper layers.
Roots and fibers present.

Coarse sand.

Muddy sand. Darker brown.

Pt Bar Deposit, RRM 3.95 (it's bench-like)





Pt. Bar or Bench Deposit In a Gentle Bend…

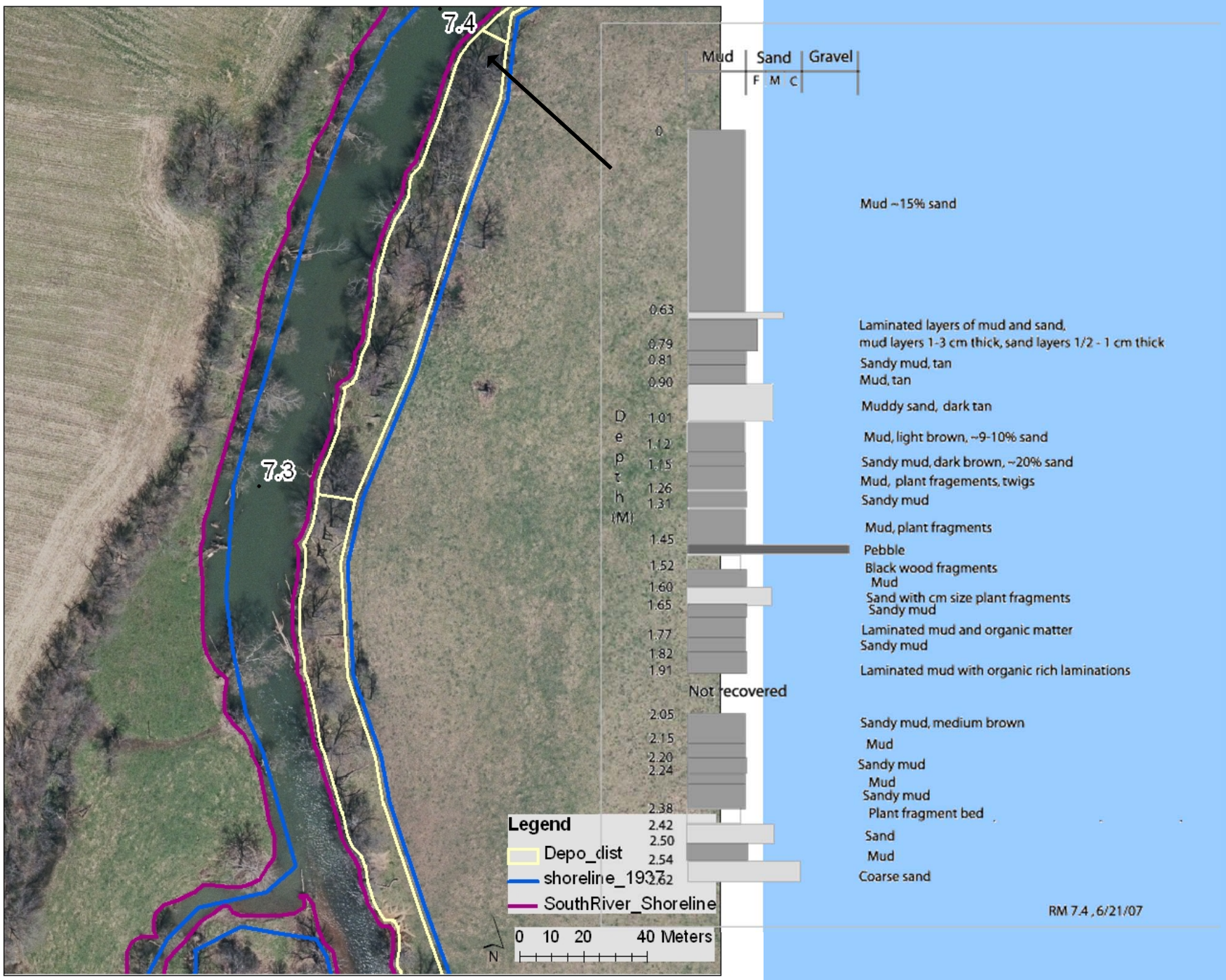
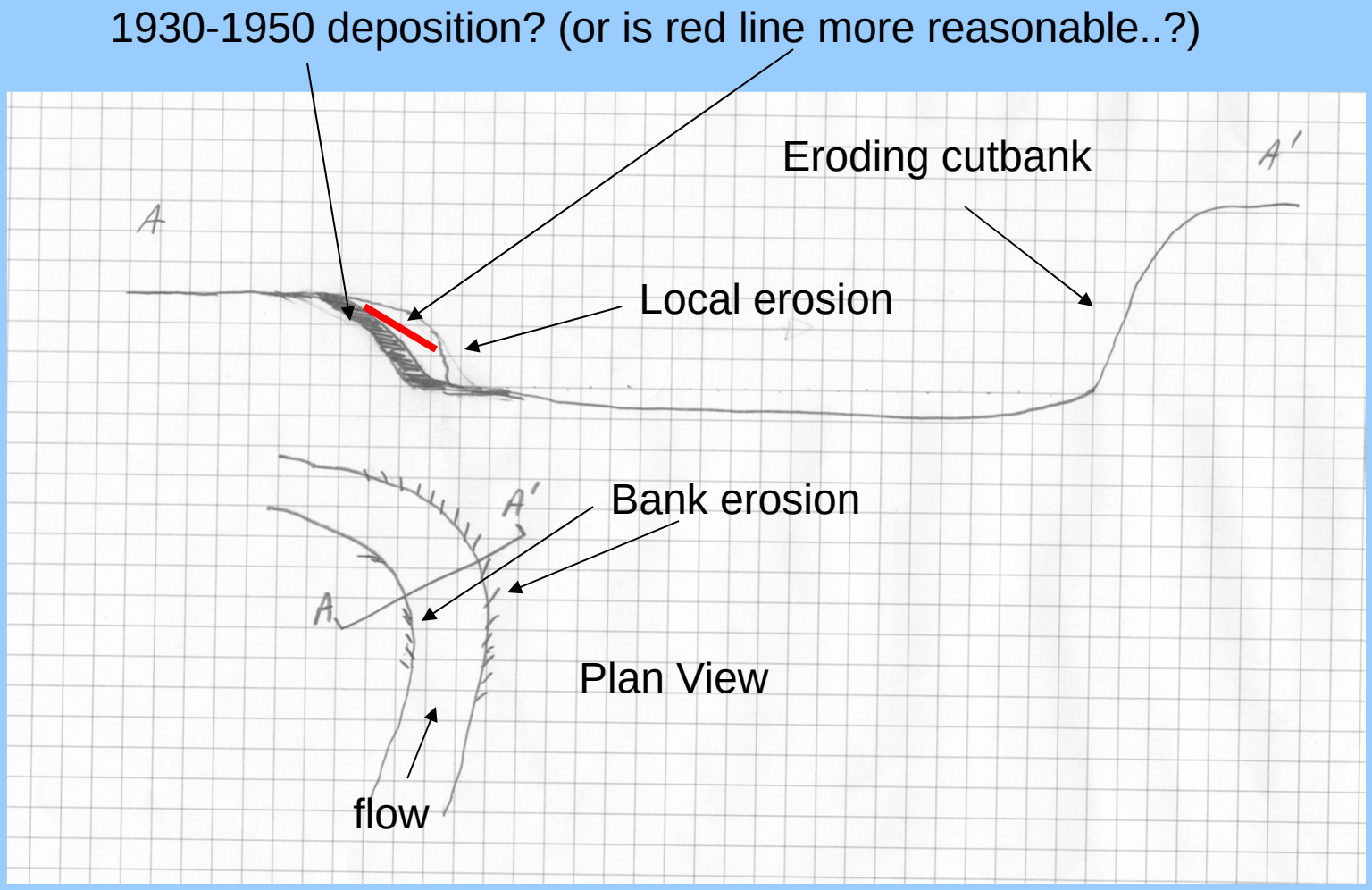
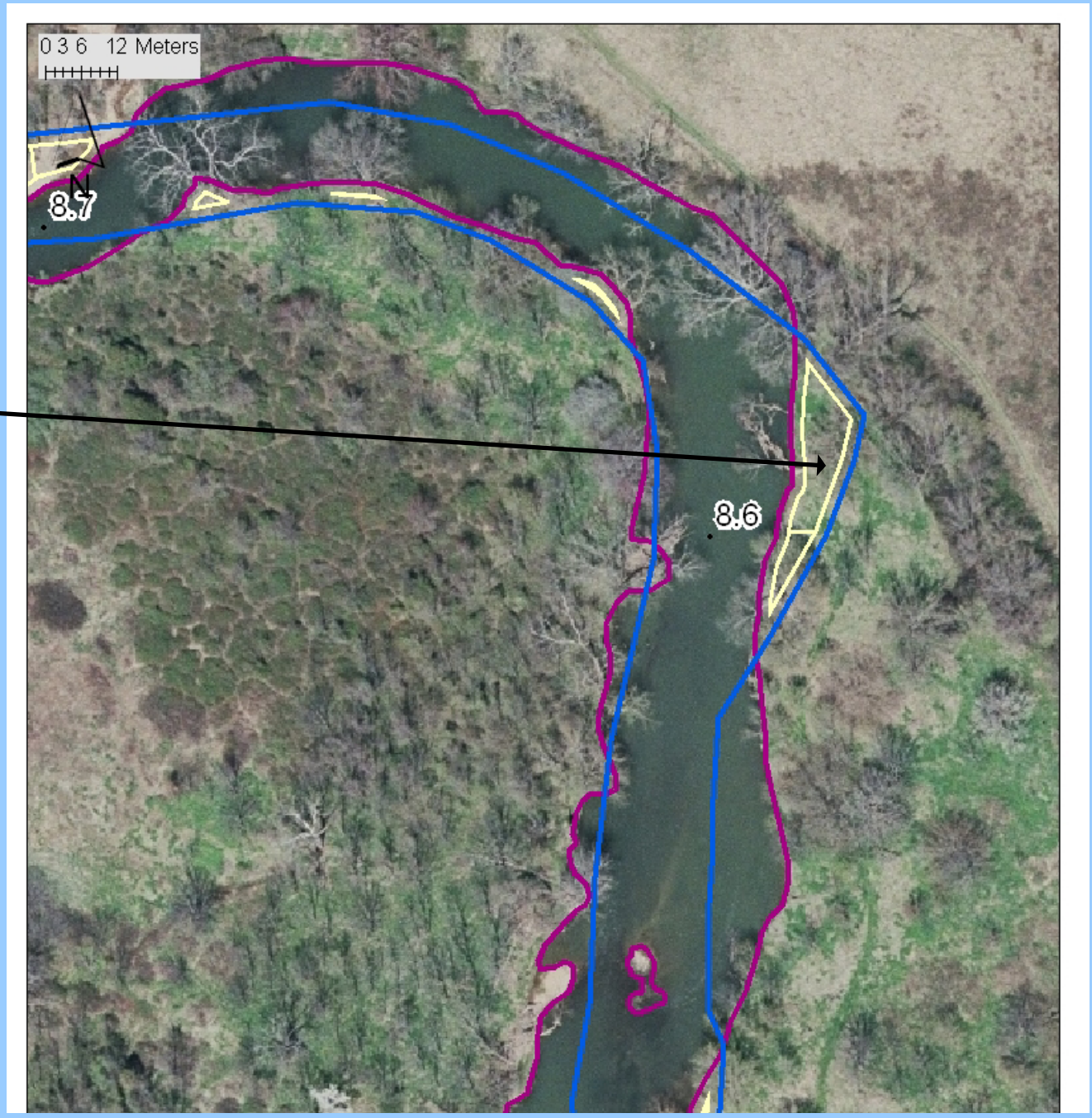

7.4
7.3
Mud
Sand
F M C
Gravel
Depth (M)
0
0.63
0.79
0.81
0.90
1.01
1.12
1.15
1.26
1.31
1.45
1.52
1.60
1.65
1.77
1.82
1.91
2.05
2.15
2.20
2.24
2.38
2.42
2.50
2.54
2.62
Mud ~15% sand
Laminated layers of mud and sand,
mud layers 1-3 cm thick, sand layers 1/2 - 1 cm thick
Sandy mud, tan
Mud, tan
Muddy sand, dark tan
Mud, light brown, ~9-10% sand
Sandy mud, dark brown, ~20% sand
Mud, plant fragements, twigs
Sandy mud
Mud, plant fragments
Pebble
Black wood fragments
Mud
Sand with cm size plant fragments
Sandy mud
Laminated mud and organic matter
Sandy mud
Laminated mud with organic rich laminations
Not recovered
Sandy mud, medium brown
Mud
Sandy mud
Mud
Sandy mud
Plant fragment bed
Sand
Mud
Coarse sand
RM 7.4 , 6/21/07
Legend
Depo_dist
shoreline_1937
SouthRiver_Shoreline
N
0 10 20 40 Meters

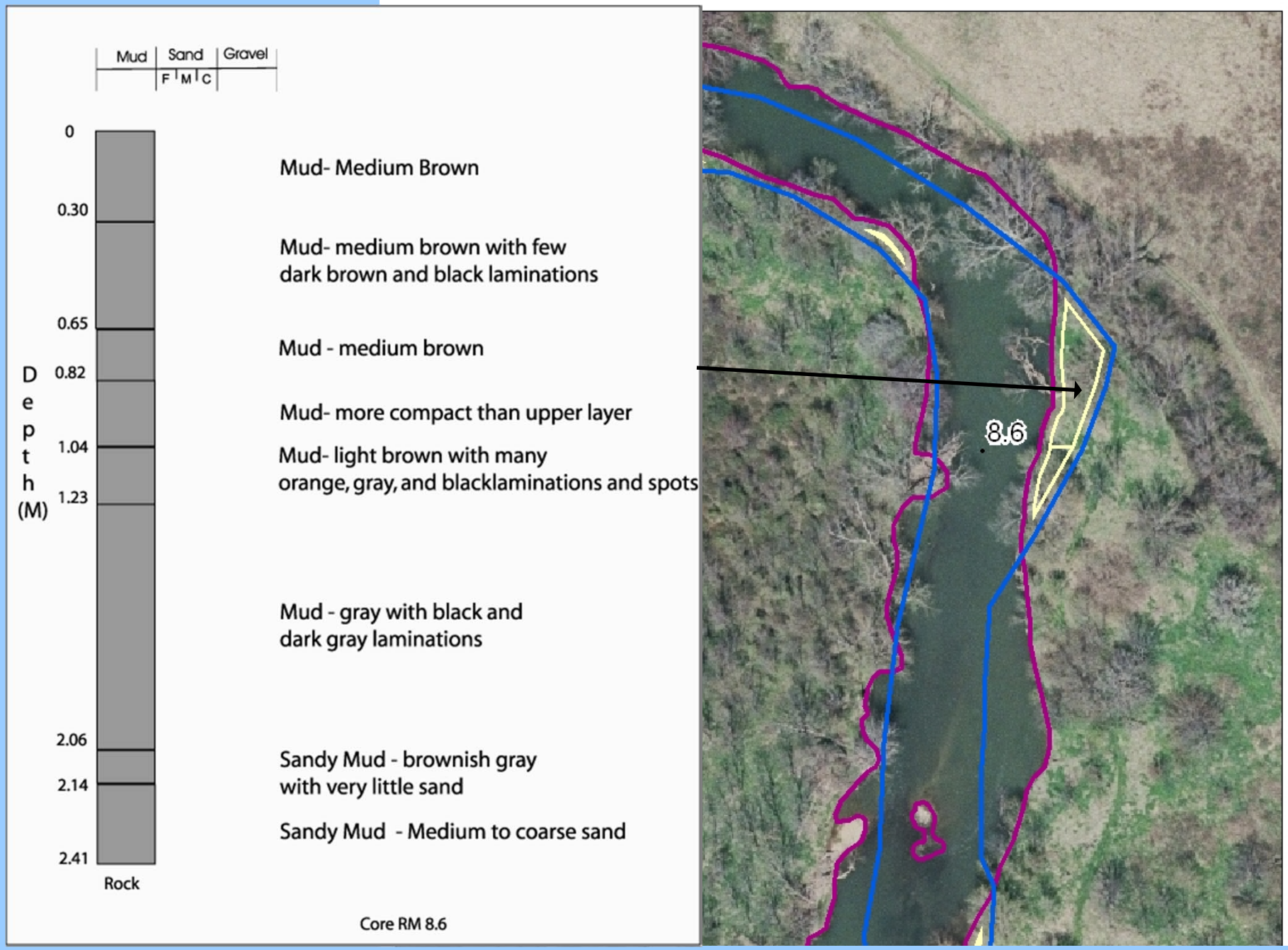
Photo of Core RRM 7.4

Draft Point Bar/Bench Depositional Model

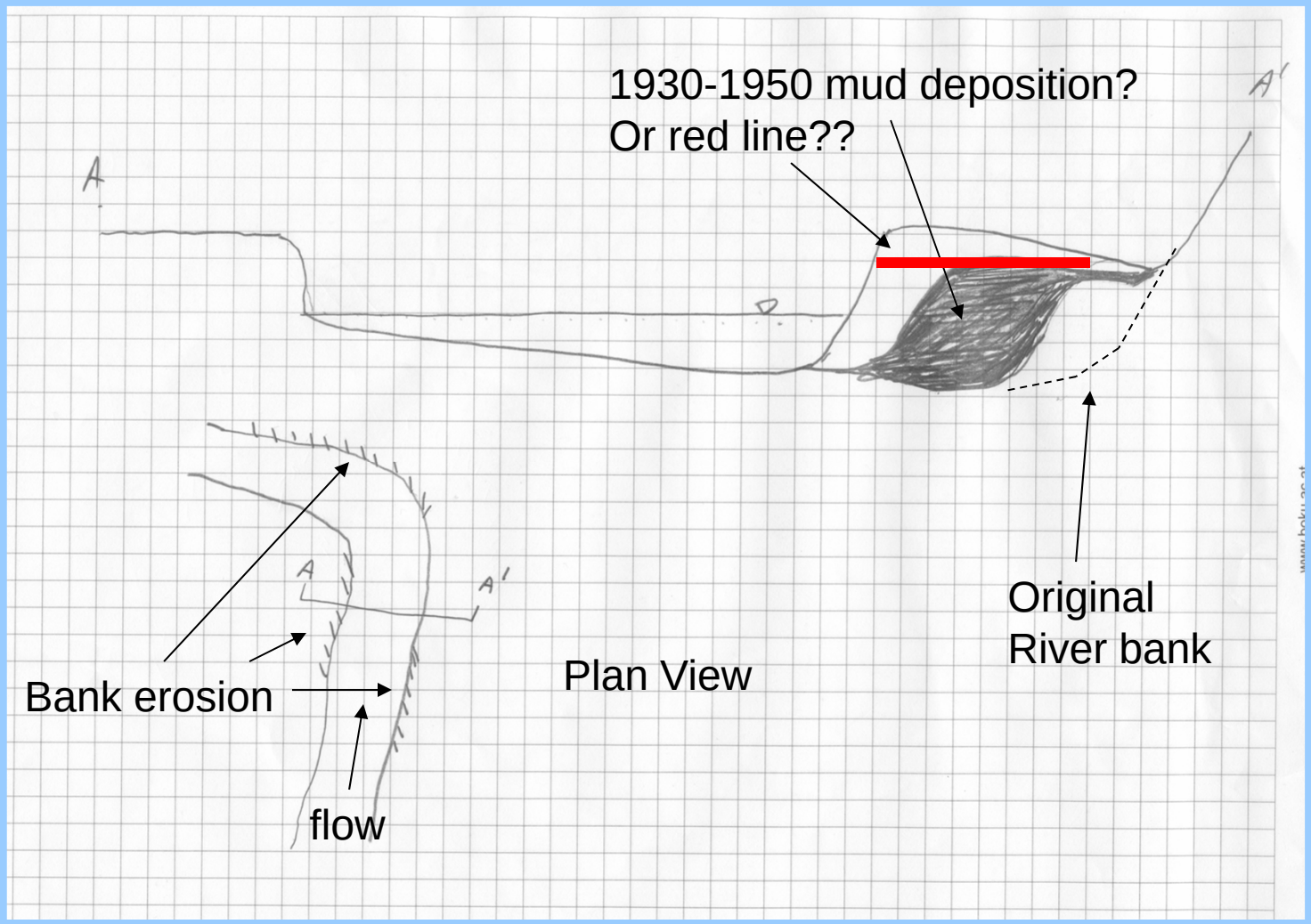


Concave Bank Bench



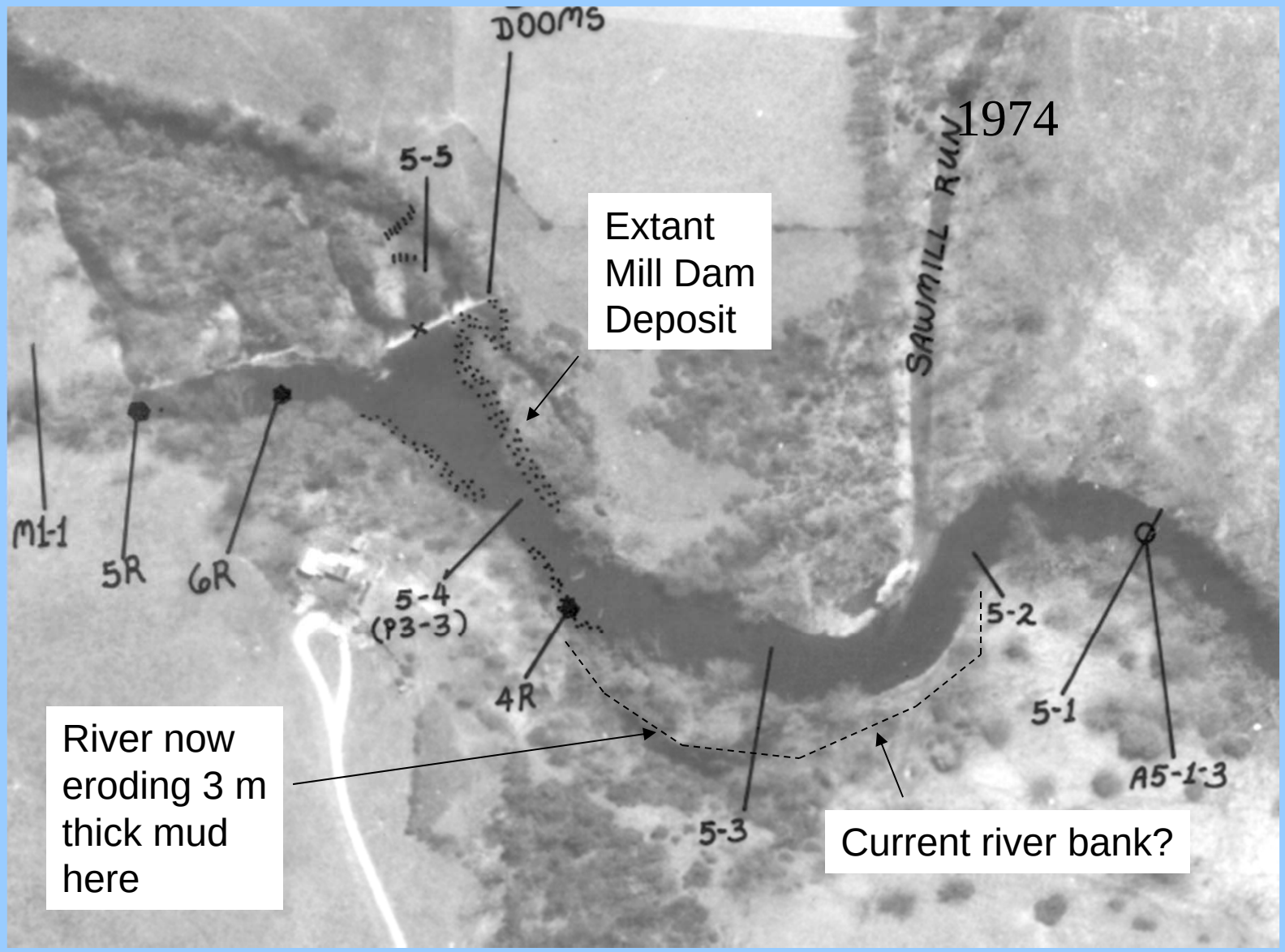

Mud
Sand
F M C
Gravel
0
0.30
0.65
0.82
1.04
1.23
2.06
2.14
2.41
Rock
Depth (M)
Mud- Medium Brown
Mud- medium brown with few dark brown and black laminations
Mud - medium brown
Mud- more compact than upper layer
Mud- light brown with many orange, gray, and blacklaminations and spots
Mud - gray with black and dark gray laminations
Sandy Mud - brownish gray with very little sand
Sandy Mud - Medium to coarse sand
Core RM 8.6
8.6

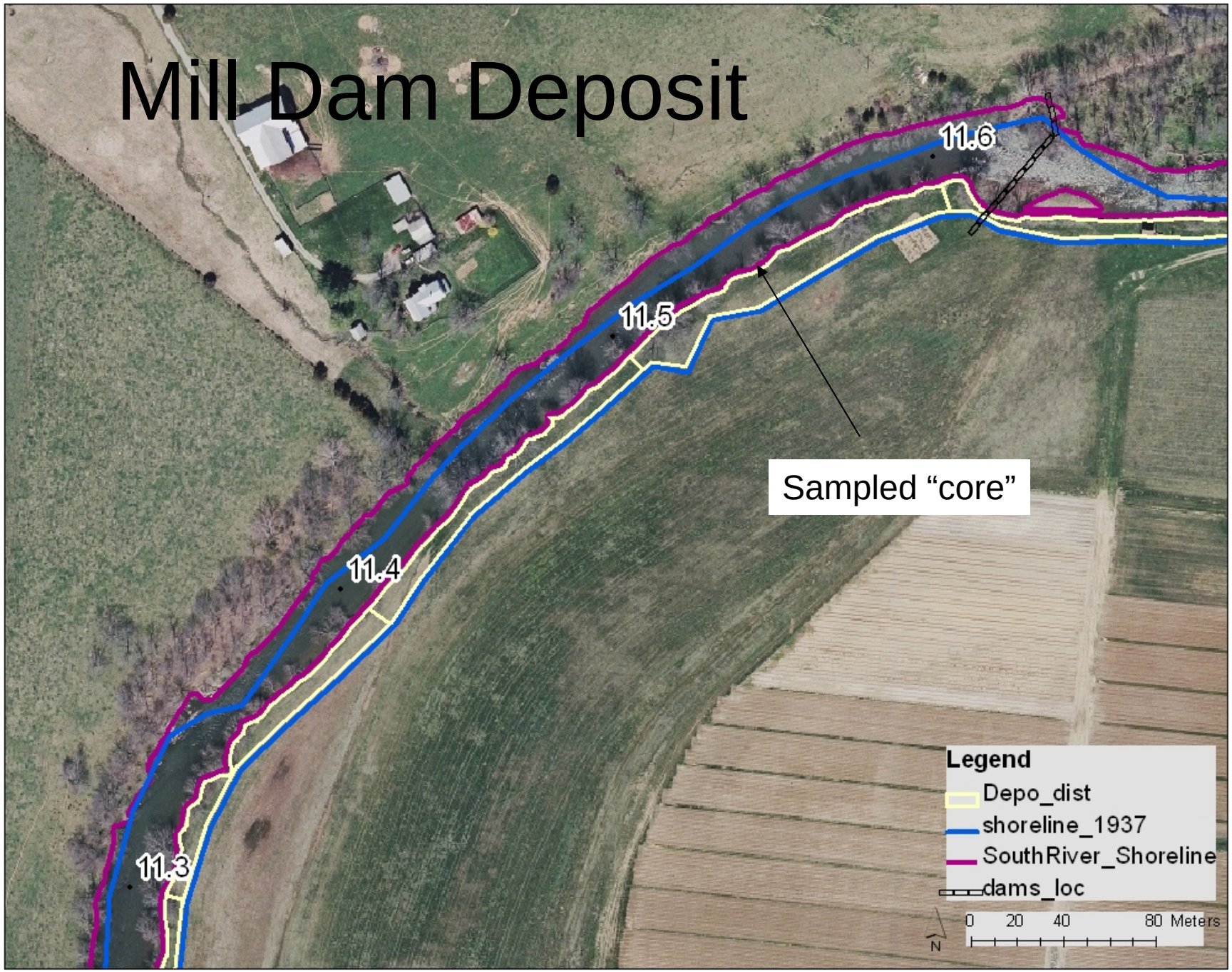
Draft Concave Bank Bench Depositional Model



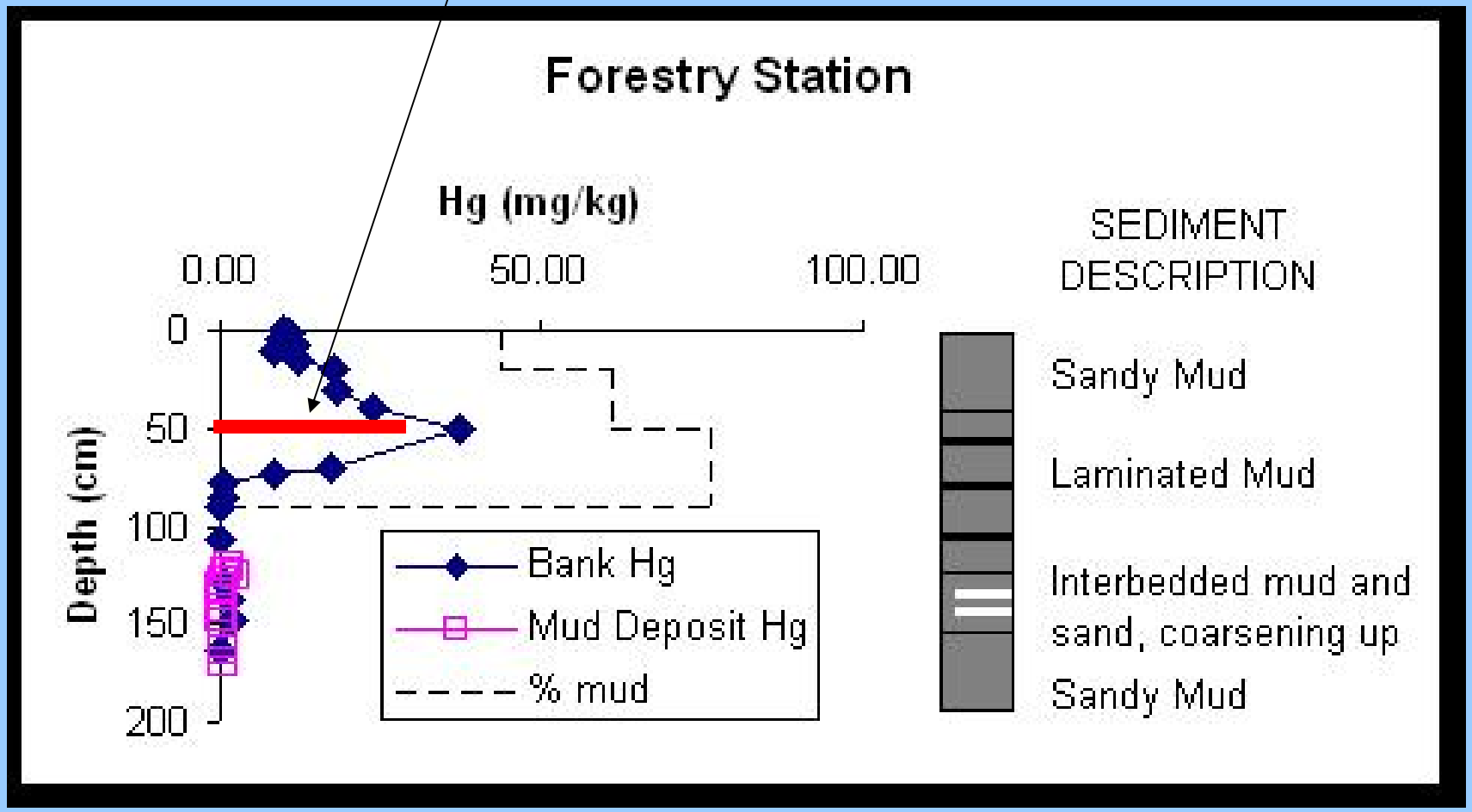
Mill Dam Deposits

Dooms Dam


DOOMS
1974
SAWMILL RUN
5-5
Extant
Mill Dam
Deposit
M1-1
5R
6R
5-4
(P3-3)
4R
5-2
5-1
A5-1-3
5-3
River now
eroding 3 m
thick mud
here
Current river bank?

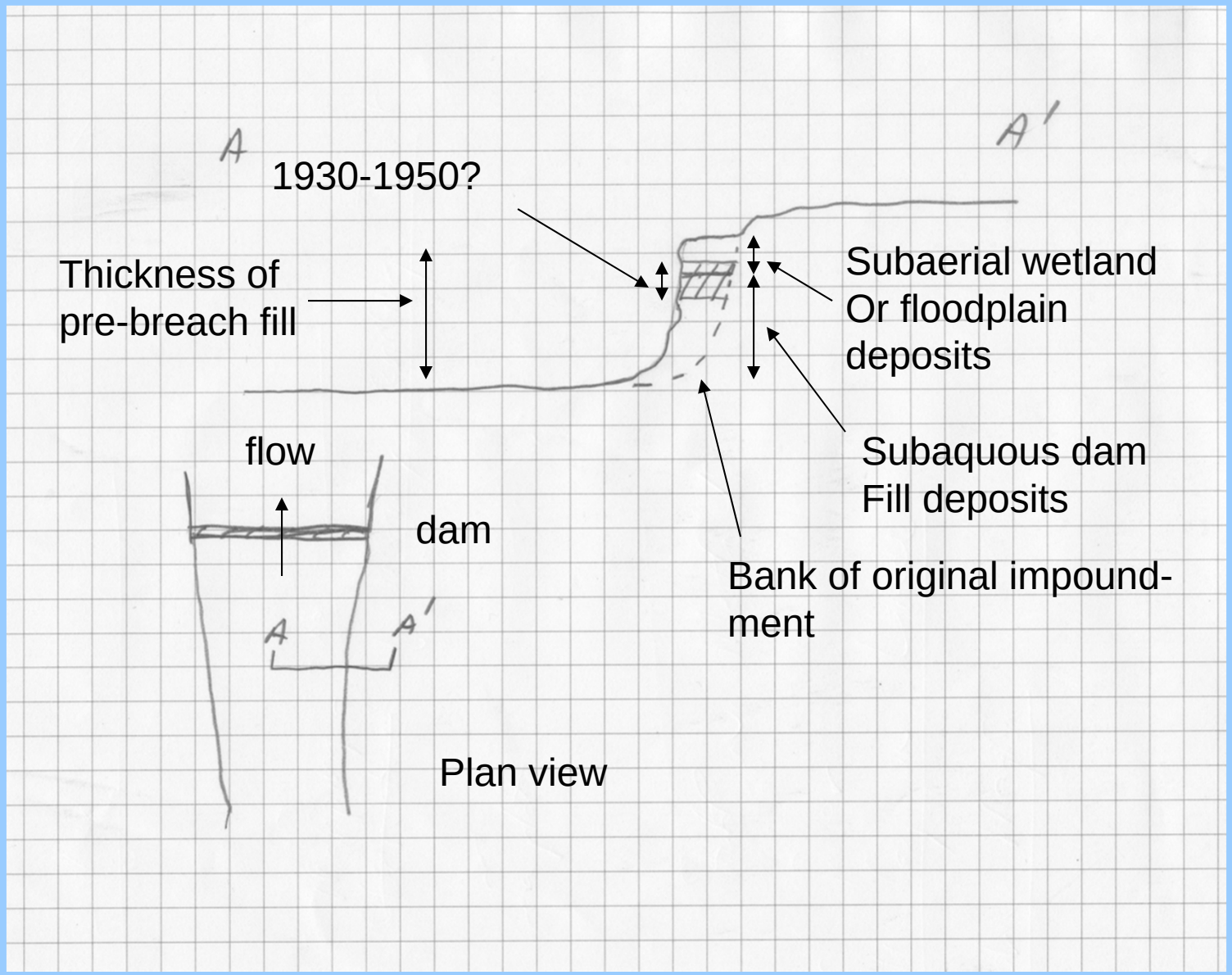

Mill Dam Deposit
11.6
11.5
11.4
11.3
Sampled “core”
Legend
Depo_dist
shoreline_1937
SouthRiver_Shoreline
dams_loc
0 20 40 80 Meters
N

High Hg zone from 1930s-1950?

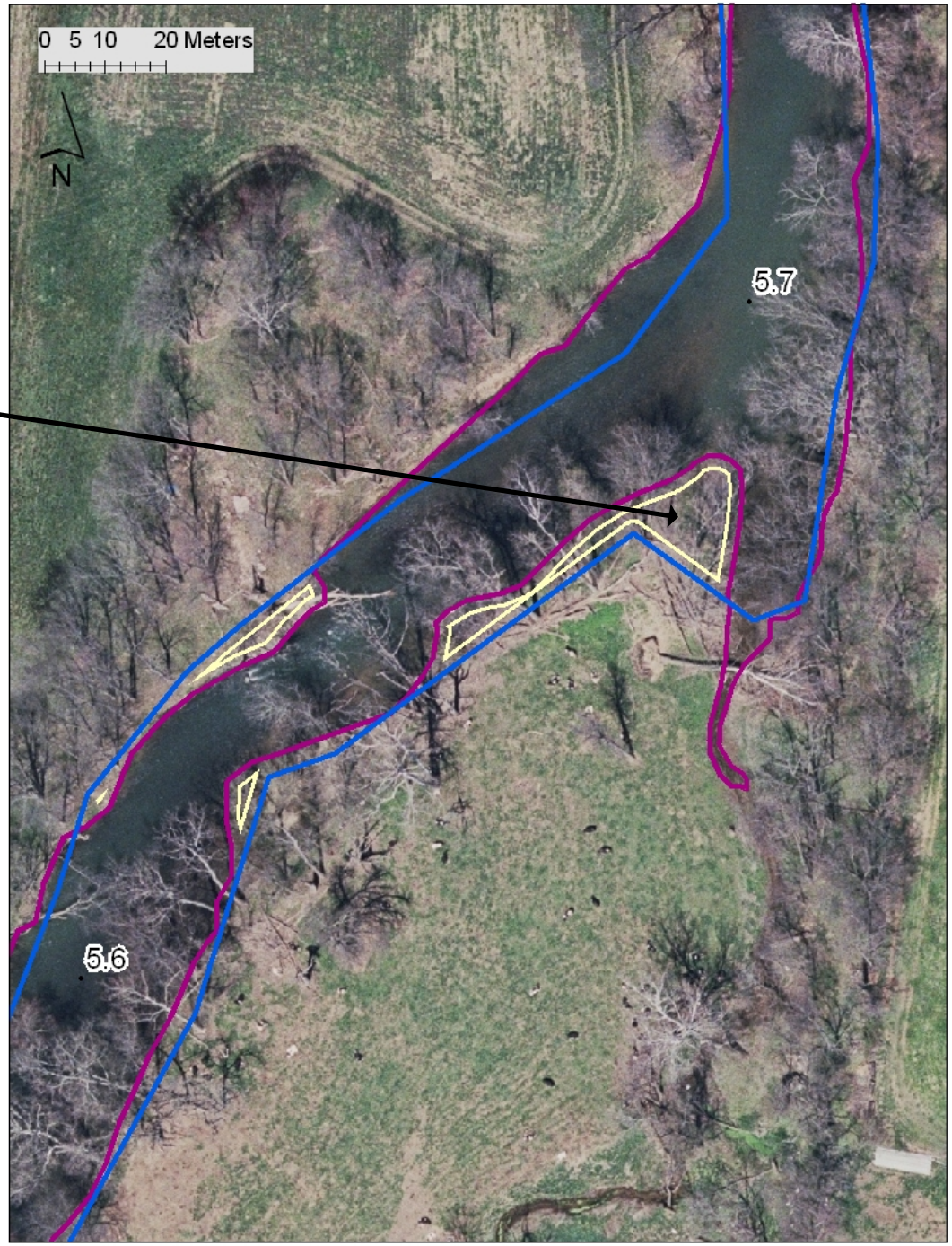


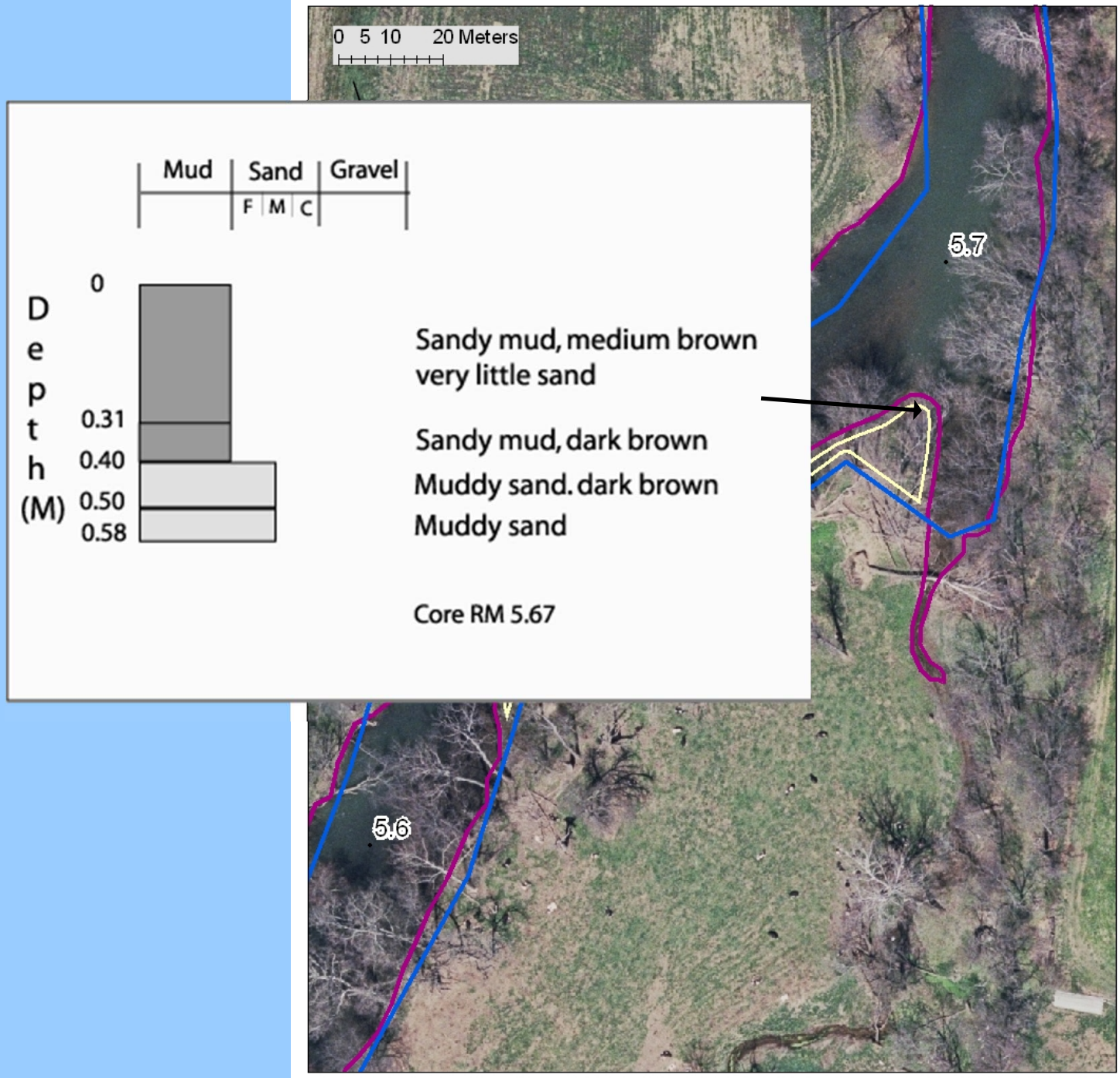
Core FS-2
34-60 cm

Draft “Marginal” Mill Dam Depositional Model

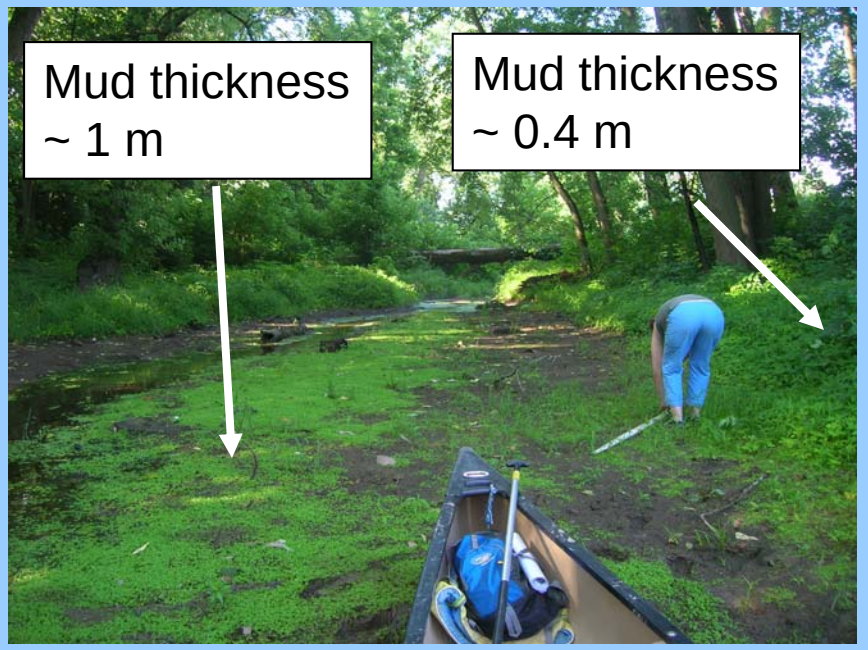


Tributary Confluence




0 5 10 20 Meters
Mud
Sand
F M C
Gravel
Depth (M)
0
0.31
0.40
0.50
0.58
Sandy mud, medium brown
very little sand
Sandy mud, dark brown
Muddy sand. dark brown
Muddy sand
Core RM 5.67
5.7
5.6

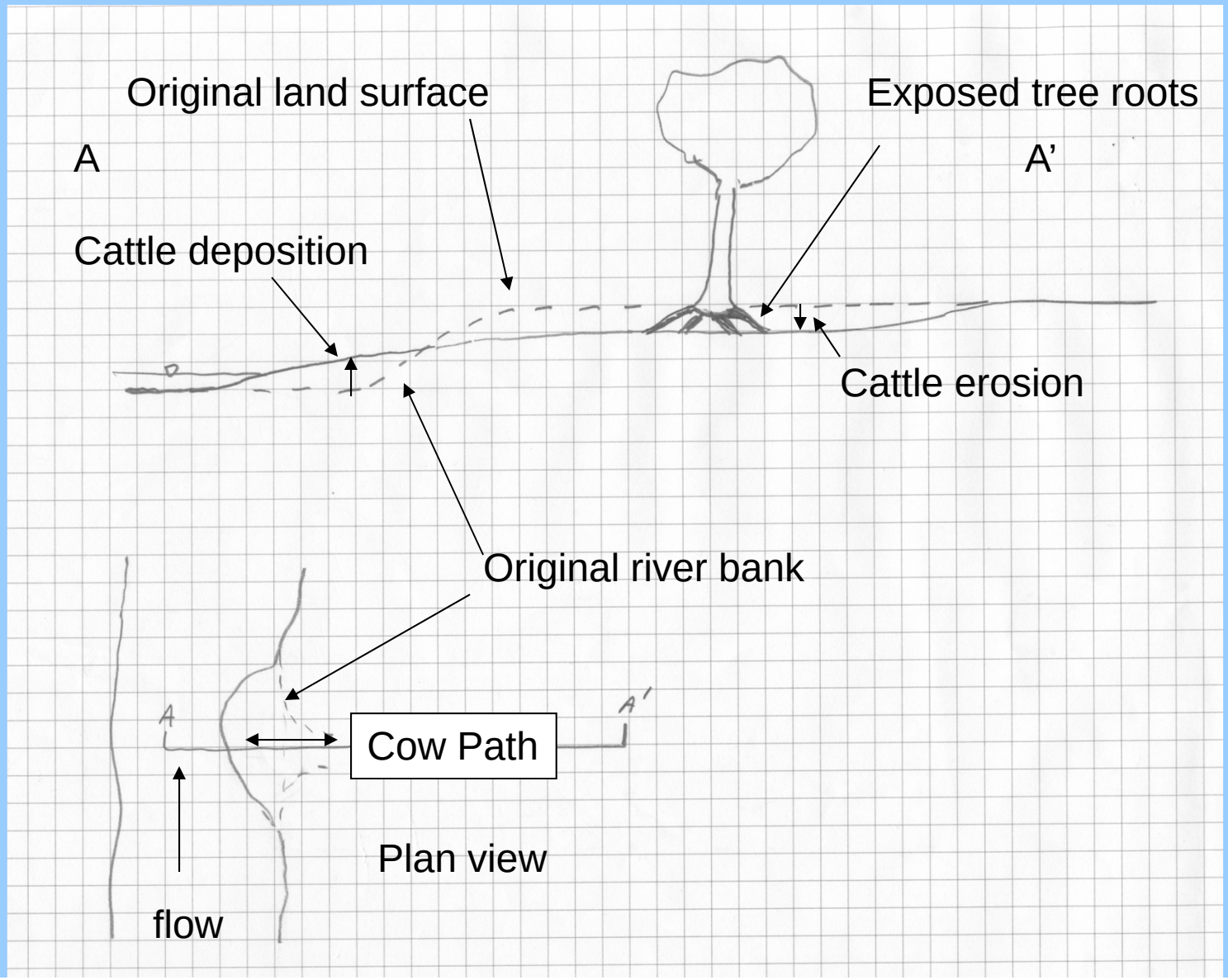
“Muddy” Tributary Deposit, RRM 5.67



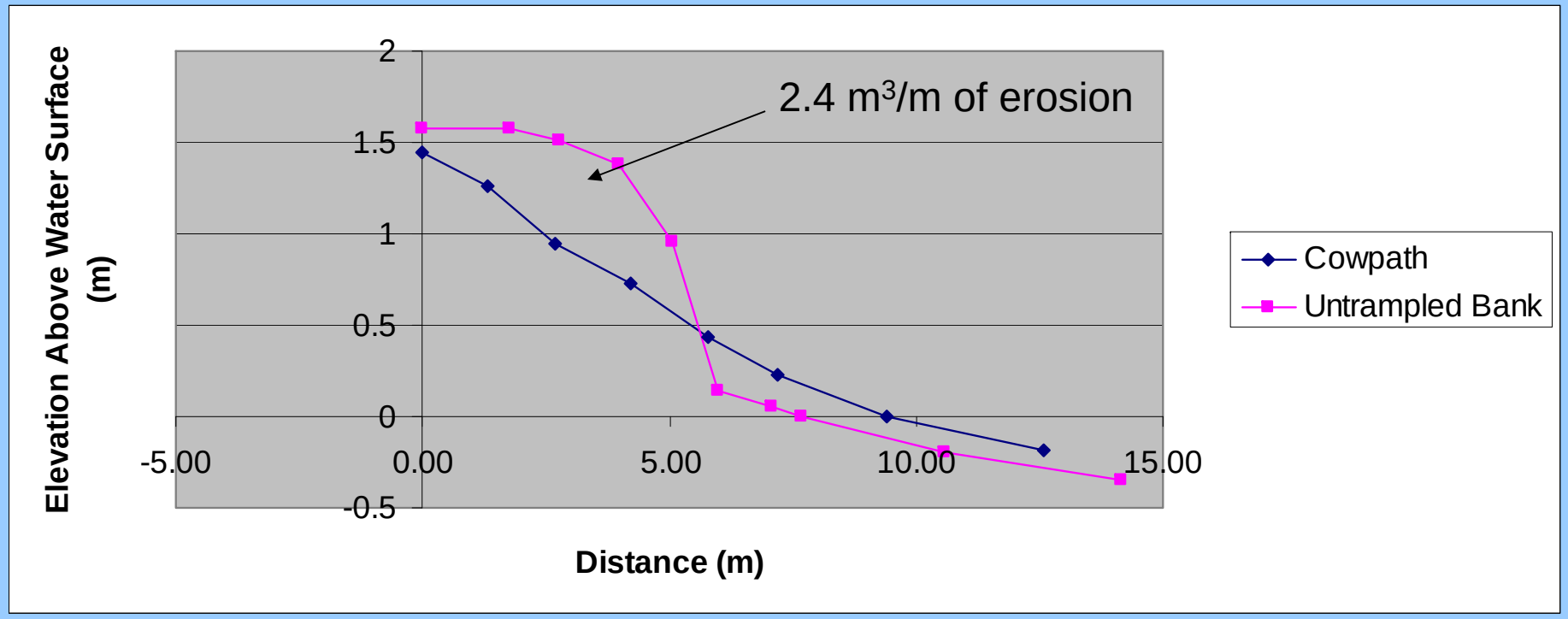
Cattle Deposit – RRM 4.3

Floodplain Erosion By Cattle

Draft “Cattle” Depositional Model



Cattle erosion is equivalent to ~ 50 years of “background“ bank erosion along South River



2007-2008 Activities

- Lidar 4 banks 2 times each
  - Develop improved conceptual and quantitative models for loading by bank erosion
    - Extrapolate to rest of study area
- Sample eroding bank surveyed with lidar for Hg, grain size
  - Improved loading rates
- Monitor pilot bank stabilization project
- Continue to characterize floodplain deposits
- Sample floodplain deposits for Hg concentrations
  - Identify release-age deposits
  - Assist with floodplain Hg sampling and interpretation
- Improve understanding of particle transport and storage