Sustainability Indicators for Mineral Sands Mining in Virginia, USA

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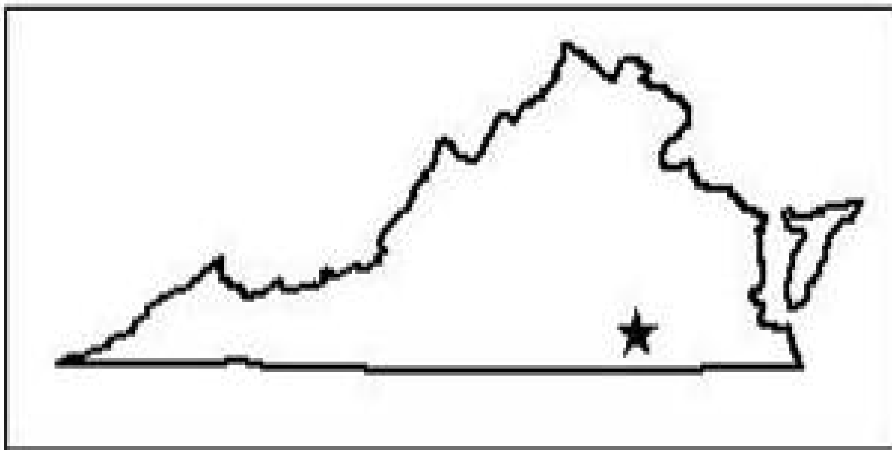
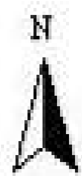
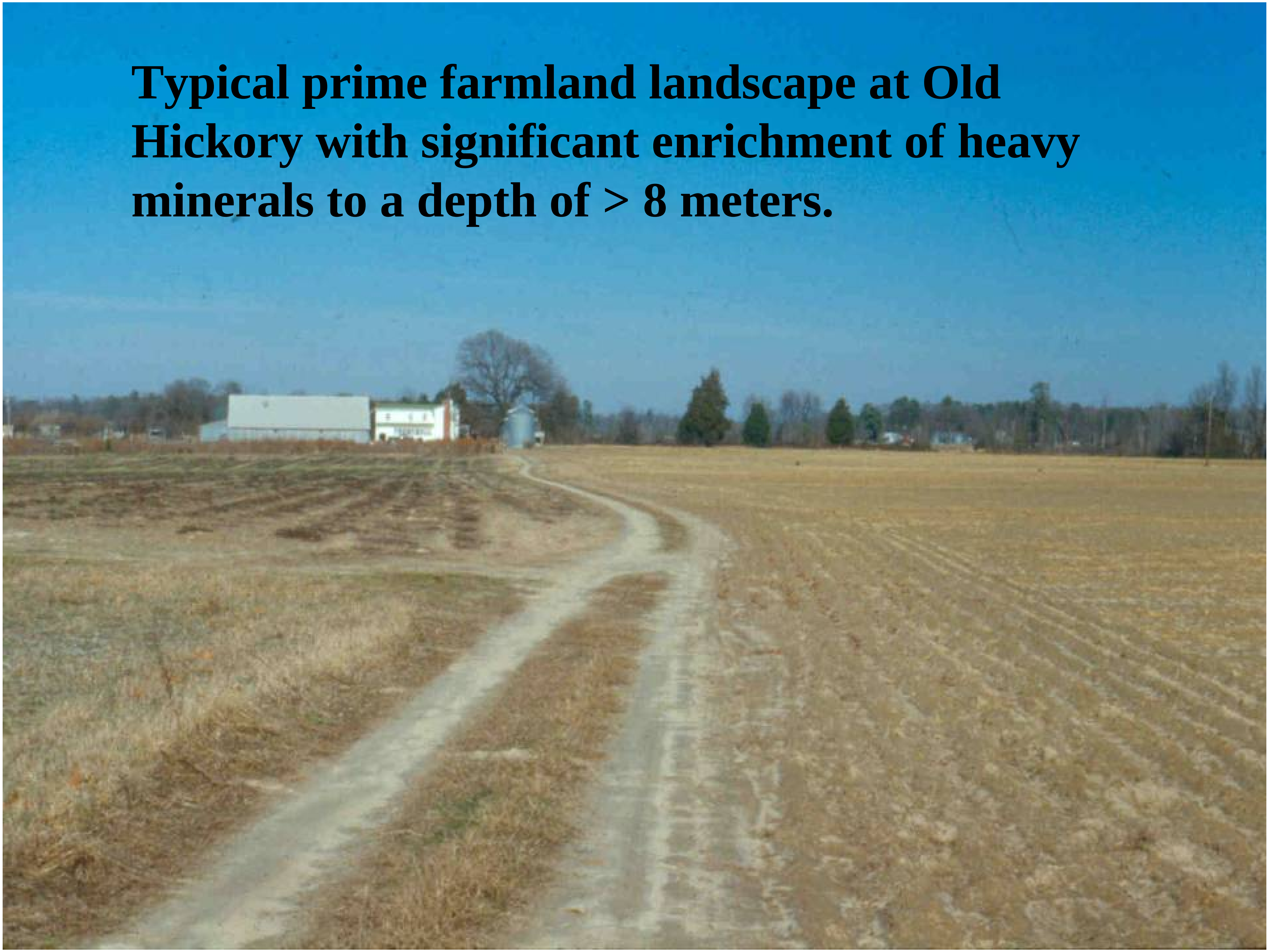
CSES
Crop & Soil
Environmental Sciences



Location of mineral sands ore bodies in Virginia (in red). Similar ore bodies lie approximately 50 miles to south in North Carolina.





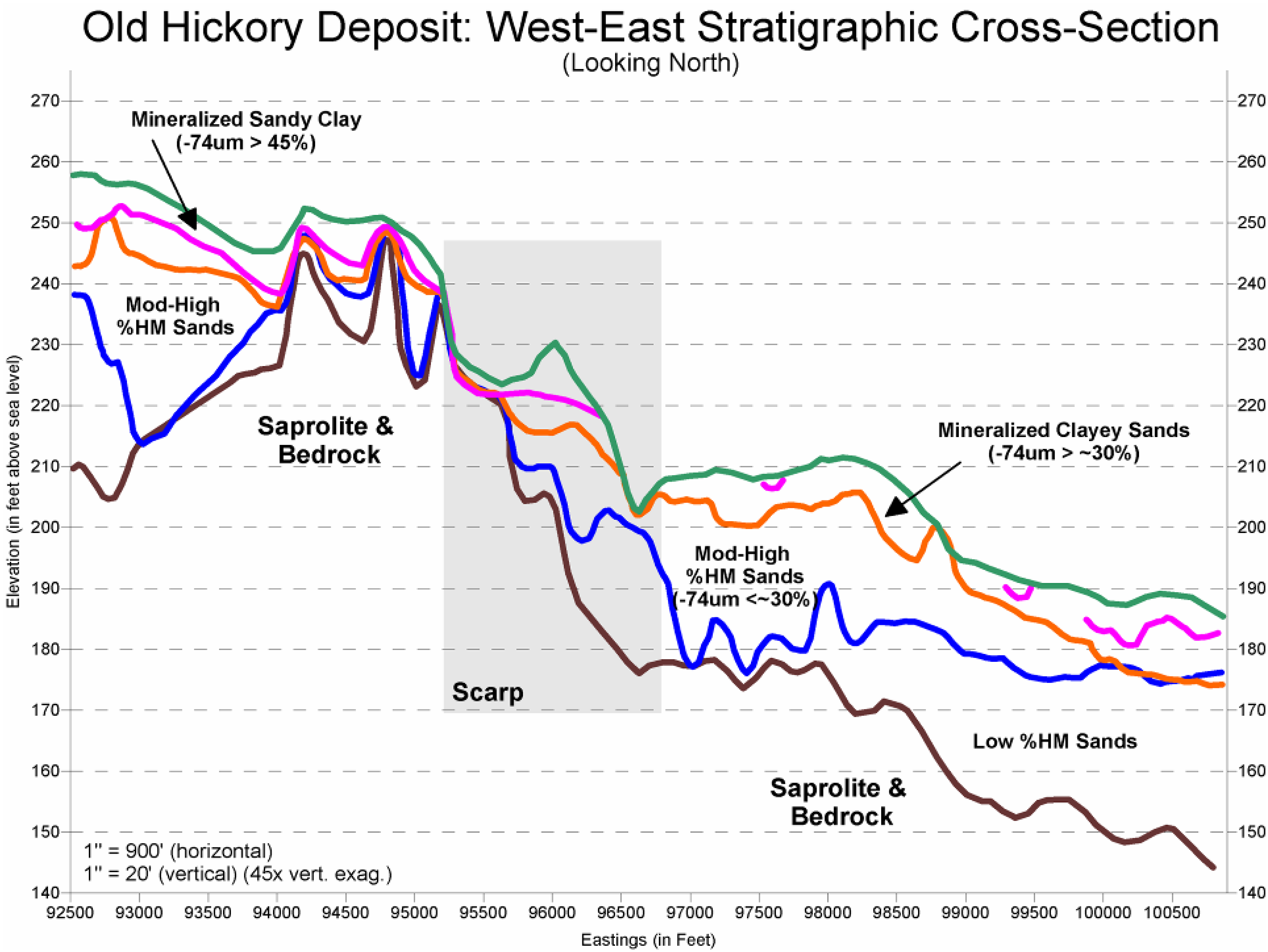
Typical prime farmland landscape at Old Hickory with significant enrichment of heavy minerals to a depth of > 8 meters.

Project History and Background

- **Mineral sand deposits were discovered along the Upper Coastal Plain of Virginia, USA, in the late 1980's**

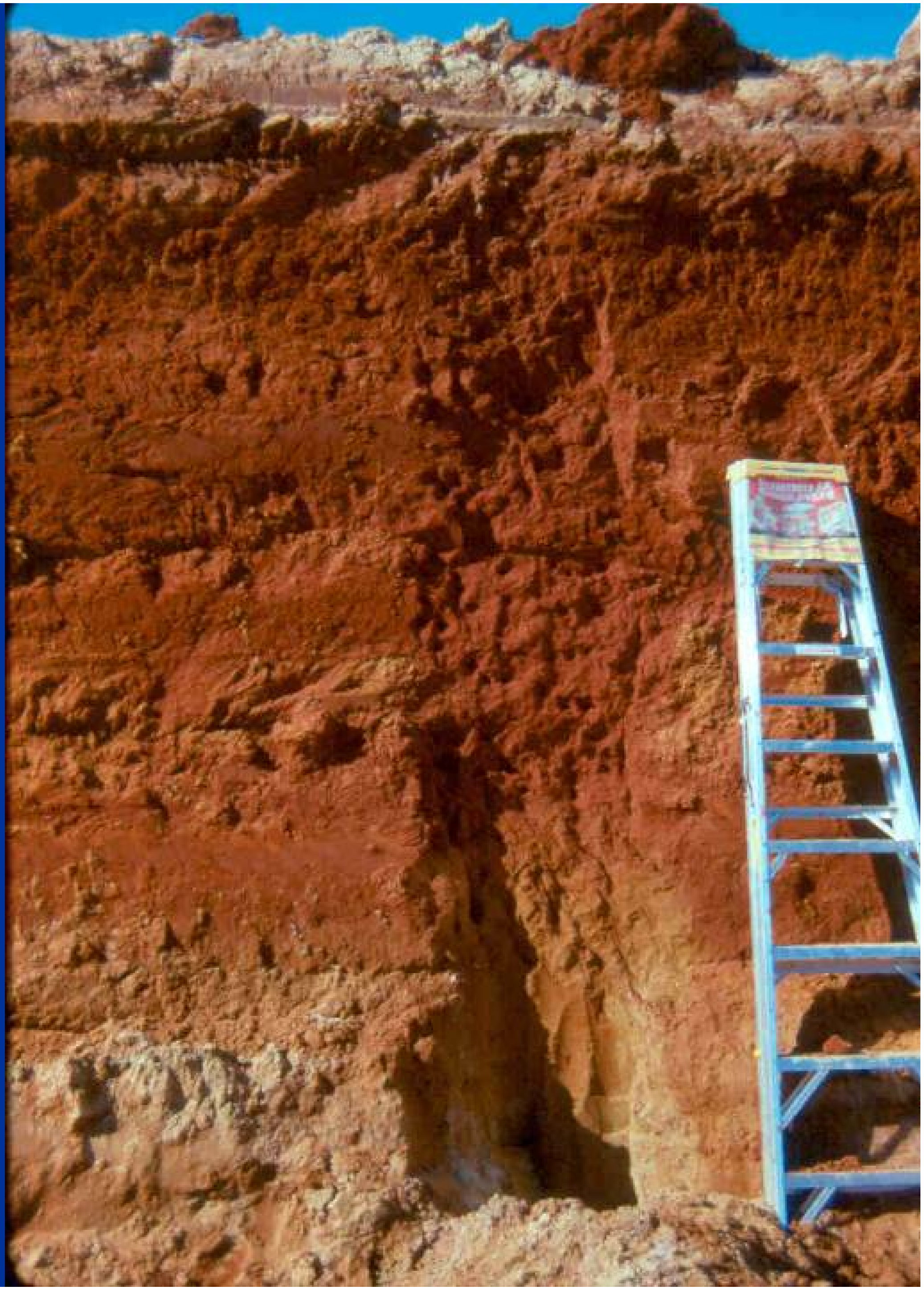
- **Much of the recoverable mineralized area occurs under prime farmlands, and as much as 7,000 Ac. could potentially be disturbed in Virginia and North Carolina**


Typical surface expression of mineral in local topsoil.
QUANTARAY



Old Hickory Deposit: West-East Stratigraphic Cross-Section
(Looking North)
Mineralized Sandy Clay
(-74um > 45%)
Mod-High
%HM Sands
Saprolite &
Bedrock
Scarp
Mineralized Clayey Sands
(-74um > ~30%)
Mod-High
%HM Sands
(-74um <~30%)
Low %HM Sands
Saprolite &
Bedrock
1" = 900' (horizontal)
1" = 20' (vertical) (45x vert. exag.)
Elevation (in feet above sea level)
Eastings (in Feet)
270
260
250
240
230
220
210
200
190
180
170
160
150
140
92500
93000
93500
94000
94500
95000
95500
96000
96500
97000
97500
98000
98500
99000
99500
100000
100500

Old, highly weathered profile west of scarp. This soil is probably 2 to 5 million years old.



Introduction

The Mining Process

- The deposit is mined with excavators, feeding a mobile mining unit
- At the mining unit, the ore is sized, slurried, and pumped to the concentrator

Reclamation Overview

Reclamation Process – Tailings Management

- Tailings are rotated among several ponds. Generally 4 to 6 ponds are in the rotation at any given time.
- Rotation allows time for settling and dewatering
- Some ponds are just being “filled” for the first time while others are nearly completely full and receive small amounts of tails to complete filling

Project History and Background

Landowners negotiated as a block and were assured that lands would be returned to prime farmland status and that Virginia Tech research would be implemented in closure protocols via regulatory permit.

Before this research program, the return of mineral sands mines to intensive agricultural use had not been studied, but USA coal mines had been returned to 90 to 95% prime farmland productivity.


110 Mg/ha Yardwaste Compost + Deep Ripping, + 300 kg/ha P, + 8 Mg/ha Lime applied to Tailings/Slimes
25 cm of Topsoil over Ripped/Limed Tailings/Slimes
10 13 '95

Winter wheat harvest in June, 1996

Table 1. Effect of various soil reconstruction treatments on row-crop yields over four growing seasons at Old Hickory as reported by Daniels et al. (1999).

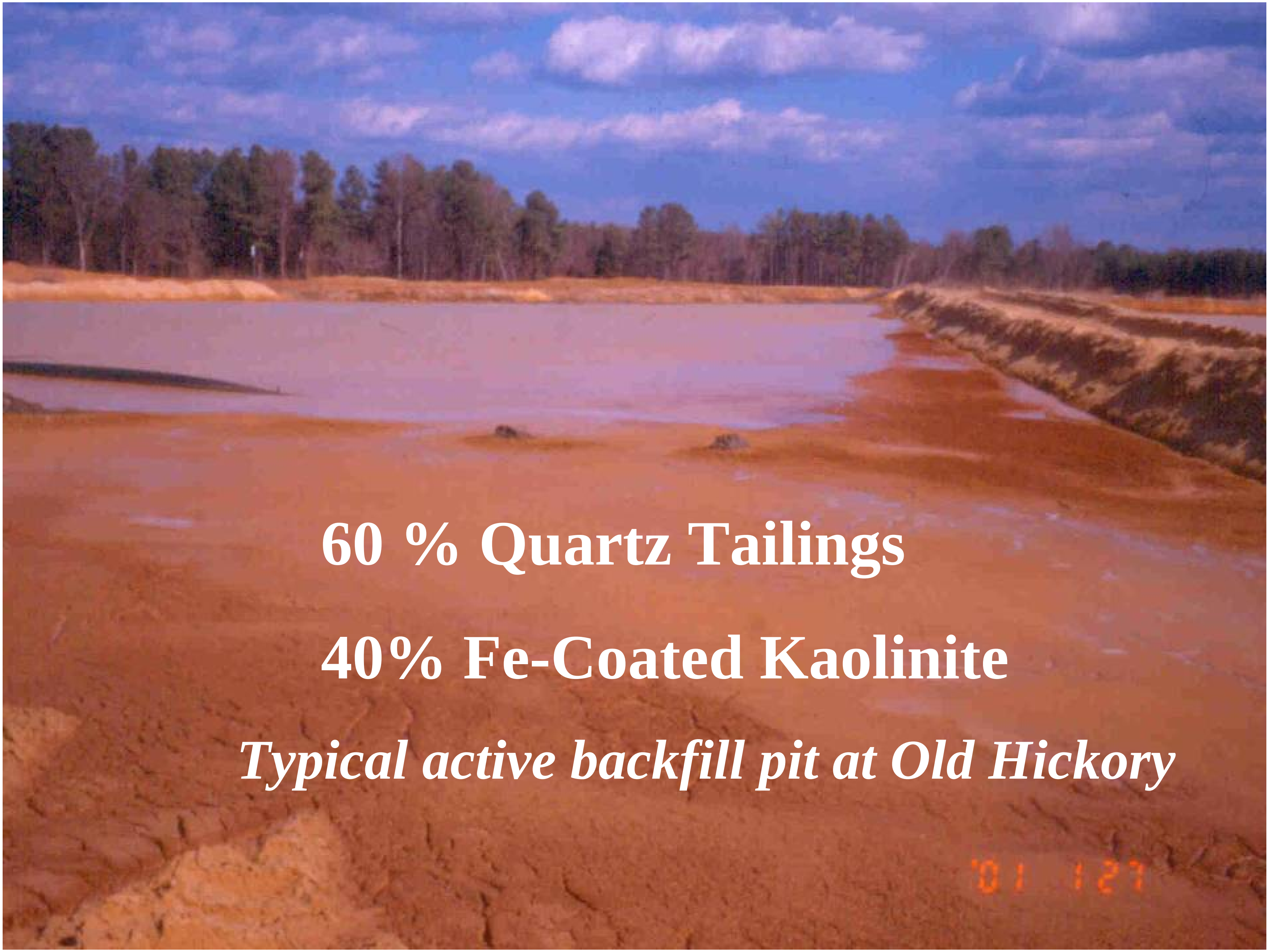
Treatment	1995/1996 Wheat	1996 Soybeans	1997 Corn	1998 Cotton
	kg/ha			
Unmined Control	3750 a*	2449 ab	8553 a	1384 a
Pit#1 Topsoil	3573 a	1810 c	6587 b	1194 b
Pit#1 Compost	2892 b	2386 b	7589 b	1088 b
Pit#3 Topsoil	2756 bc	2684 a	4987 c	1004 b
Pit#3 Compost	2375 c	2594 ab	6620 b	1130 b

*Yields within columns followed by the same letter are not different ($P < 0.05$)

Overall crop yields were reduced approximately 20% relative to unmined control plots. Effects of topsoil return vs. compost amendment were not consistent from crop to crop.

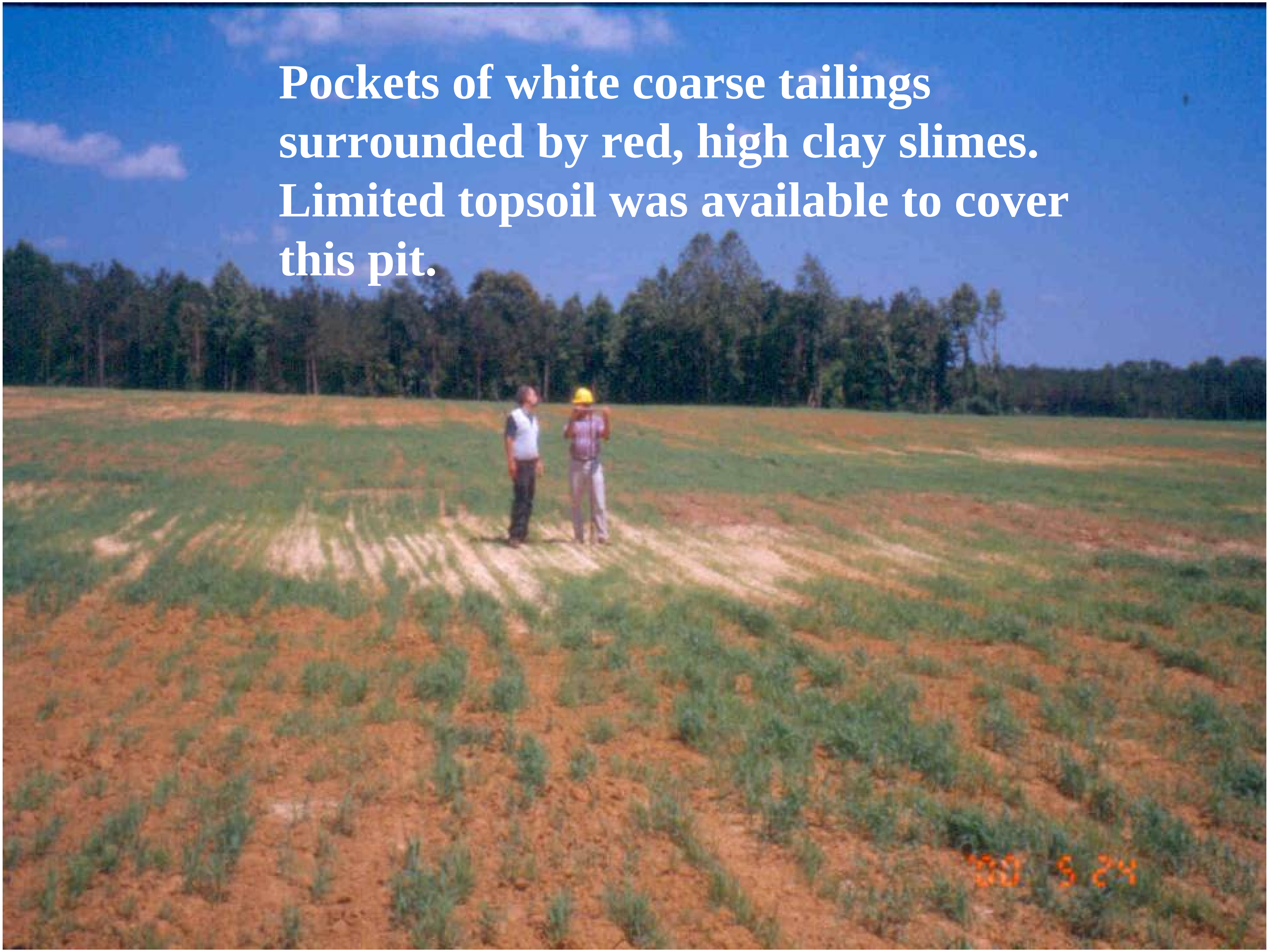
Project History and Background

Active mining at Old Hickory commenced in the summer of 1997, and Iluka Resources acquired RGC in 2001.


60 % Quartz Tailings
40% Fe-Coated Kaolinite
Typical active backfill pit at Old Hickory

Landowner/Company Issues

- In 1989 and 1990, early company officials assured landowners of 100% return to pre-mine row crop productivity.
- Segregation of tailings and slimes within and among pits in early mining (1997 to 2001) led to highly variable post-mine soil conditions.


Pockets of white coarse tailings surrounded by red, high clay slimes. Limited topsoil was available to cover this pit.
'00 5 24

Topsoil Issues

- **Gross values of minerals in 15 cm of topsoil is at least $15,000 per ha.**

- **Previous and ongoing work by Virginia Tech has indicated that topsoil substitutes created from tailings/slimes/organic matter are viable.**

- **Early reclamation in 1997 to 2000 showed very clear benefits from topsoil return, however.**

Landowner/Company Issues

- In many instances, topsoil was used to construct dikes before swell factor was full understood, making it impossible to return topsoil to mine pits.

- Vague regulatory definition of “topsoil” allowed the operator and certain landowners to process topsoil for mineral return.

Final pit dewatering at Old Hickory. Material in foreground is topsoil forming enclosing dike. Overall wet pit surface elevation is 1 to 3 m higher than original ground, but drops with dewatering and final grading.

Landowner/Company Issues

- The local county conditional zoning permit specifically defined topsoil as native A+E horizon materials and the county was asked by several landowners to revoke the mining permit.
- From 2001 to 2003, a number of landowners became increasingly vocal in the local community.

Soil profile from research plots (described later) showing significant buried topsoil and mixing/banding of dissimilar materials in upper profile.

This soil was very compact with almost no rooting below 30 cm or 1 foot.

Iluka’s Efforts to Minimize Tails/Slimes Segregation

- Internal cross-dikes with flashboard risers – implemented originally by Chris Wyatt
- Moving the discharge point periodically
- Reworking slimes pockets with track-hoes
- Final grading to homogenize the surface


Final pit grading; usually done just as soon as dozers can walk the surface, which means it's wet. This maximizes compactive effort.
28. 7. 2004

Compacted, platy replaced topsoil over highly compacted tails/slimes subsoil.

This is the “appropriate ripper” for these kinds of soil problems! Clint Zimmerman (pictured) was primarily responsible for recognizing the need and implementing routine ripping.

Carraway-Winn
Reclamation Research Farm
ILUKA
Cooperators: Iluka Resources, Virginia Tech, the Carraway-Winn Family, Virginia Health Dept., Virginia Division of Mineral Mining, Synagro Technologies Inc., and Clarke Farms, LLC
Rte. 617
Rte. 665
N
Soil reconstruction treatments
forage blocks
row crop blocks
shallow groundwater wells
The agricultural fields behind this sign were mined for heavy minerals (titanium and zirconium oxides) several years ago. Currently, these mined lands are being returned to productive agricultural uses through a Virginia Tech research and demonstration project cooperative with Iluka Resources, the Carraway-Winn family, and others. As can be seen on the map to the left, a portion of the experimental farm is being managed for row-crops while the majority of the land is under intensive forage (hay) management. One of our major objectives is to investigate the effects of organic amendments, topsoil, and conventional lime + fertilizer + tillage treatments on crop productivity. Our second objective is to monitor changes in soil and water quality over time. Please contact us as shown below if you would like more information about this project or if you would like to arrange a tour:
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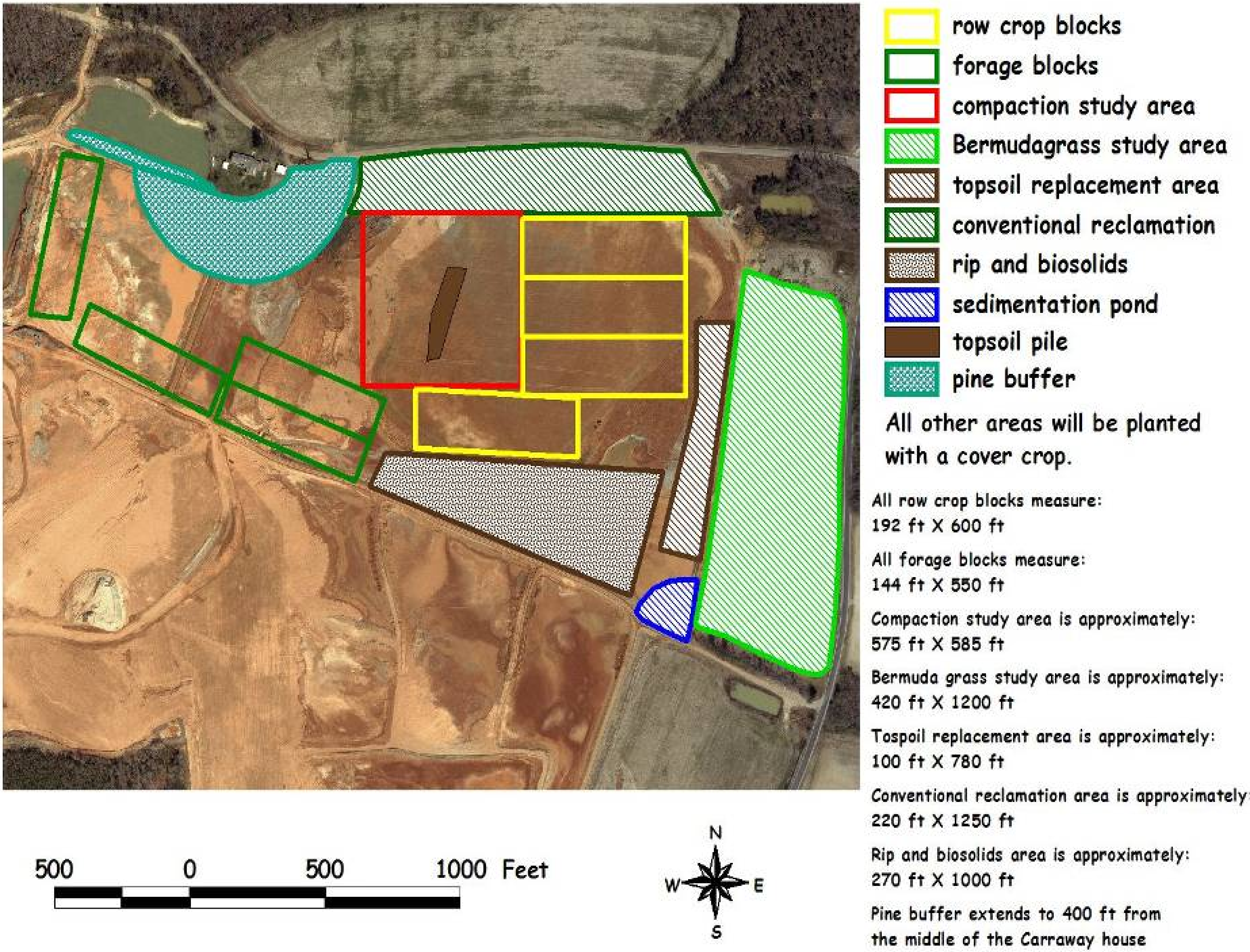
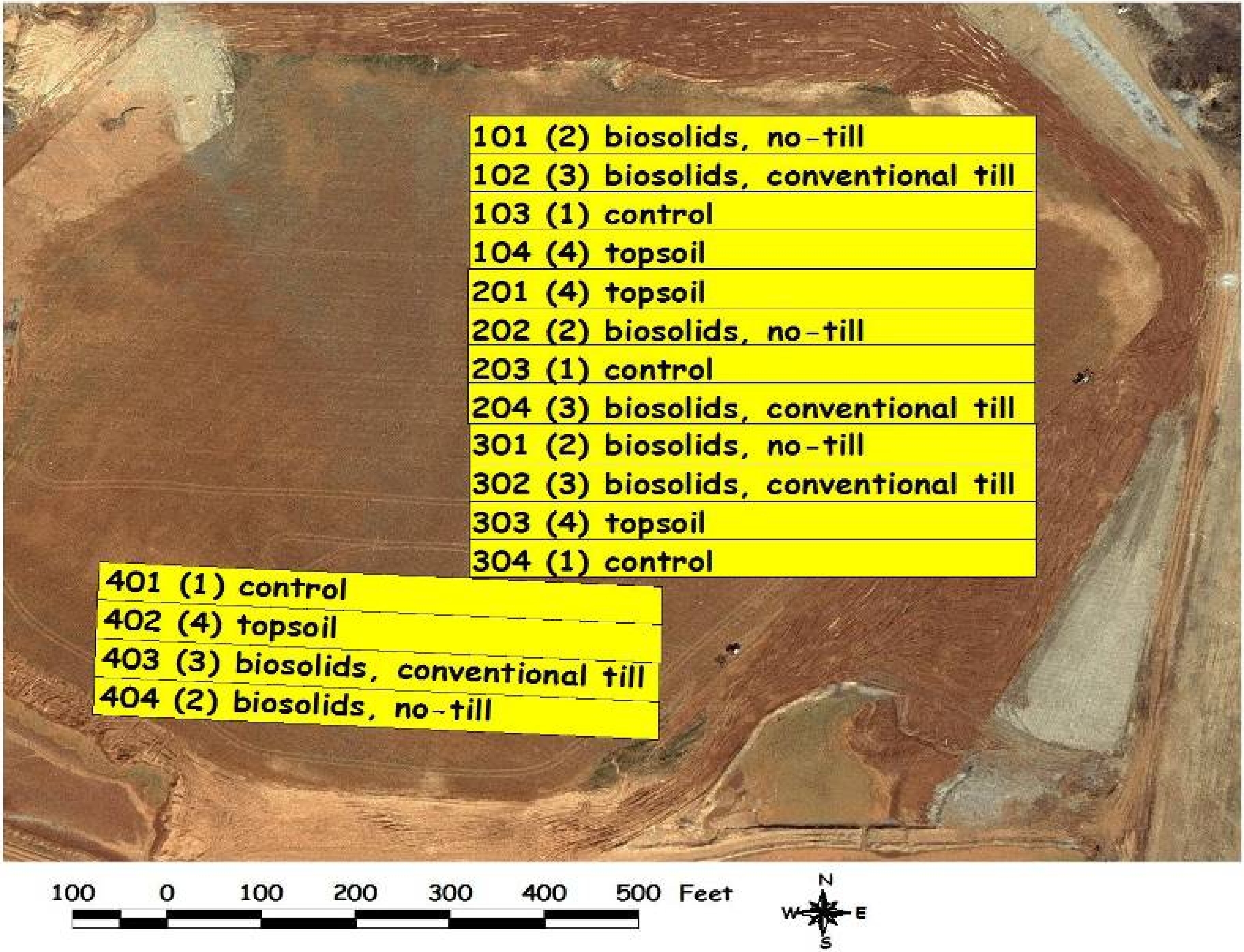
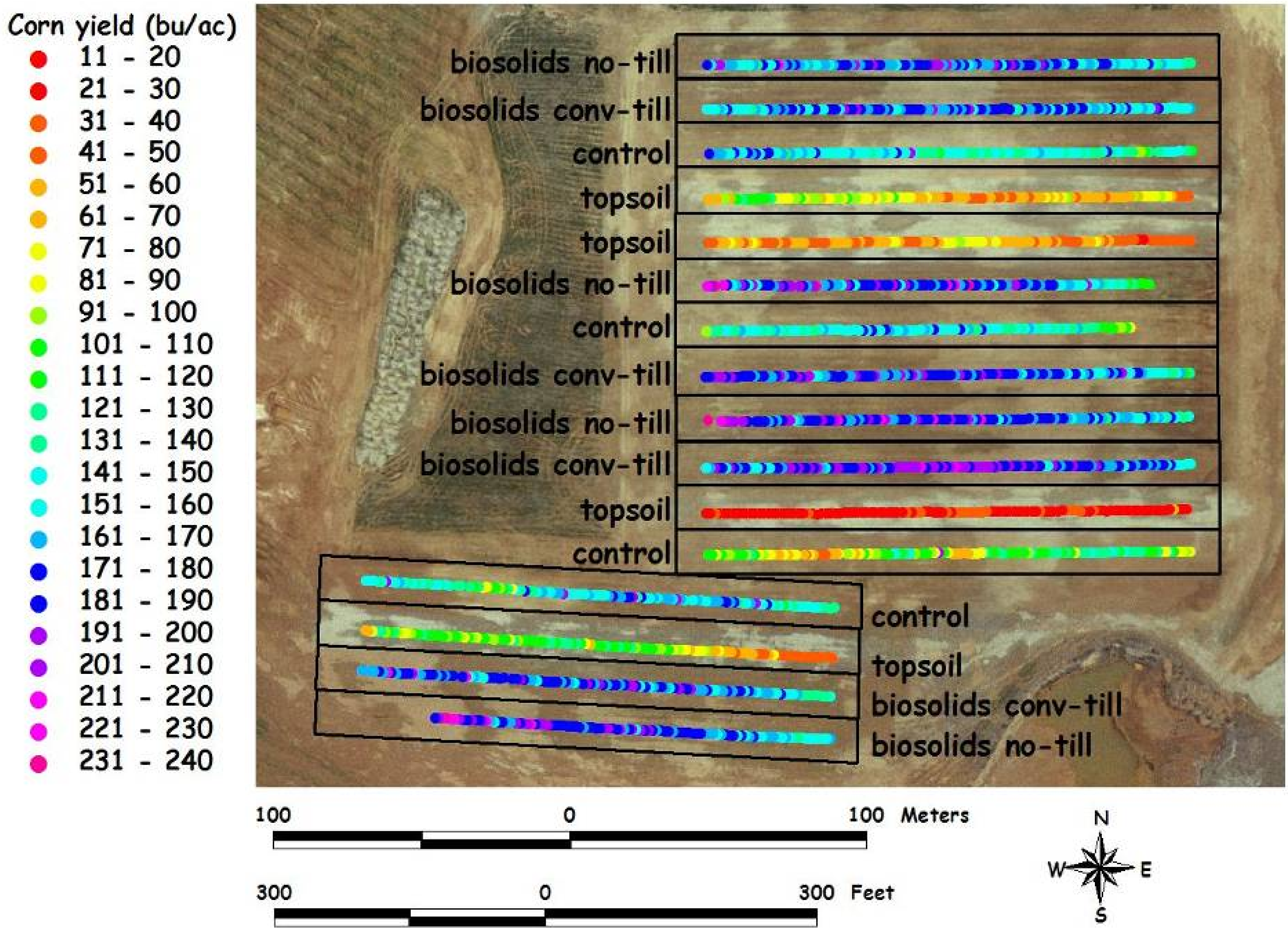
Crop & Soil Environmental Sciences
540-231-5741 zorndorf@vt.edu
Chris Teutsch, Southern Piedmont Agricultural
Research and Extension Center 434-292-5331 ext. 234
09/15/2005


row crop blocks
forage blocks
compaction study area
Bermudagrass study area
topsoil replacement area
conventional reclamation
rip and biosolids
sedimentation pond
topsoil pile
pine buffer
All other areas will be planted with a cover crop.
All row crop blocks measure: 192 ft X 600 ft
All forage blocks measure: 144 ft X 550 ft
Compaction study area is approximately: 575 ft X 585 ft
Bermuda grass study area is approximately: 420 ft X 1200 ft
Tospoil replacement area is approximately: 100 ft X 780 ft
Conventional reclamation area is approximately: 220 ft X 1250 ft
Rip and biosolids area is approximately: 270 ft X 1000 ft
Pine buffer extends to 400 ft from the middle of the Carraway house
500 0 500 1000 Feet
N
W
E
S

Row crop plots with numbers and treatments




Topsoil strip after grading and disking in April 2005.
75 Mg/ha Biosolids


Corn yield (bu/ac)
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
101 - 110
111 - 120
121 - 130
131 - 140
141 - 150
151 - 160
161 - 170
171 - 180
181 - 190
191 - 200
201 - 210
211 - 220
221 - 230
231 - 240
biosolids no-till
biosolids conv-till
control
topsoil
topsoil
biosolids no-till
control
biosolids conv-till
biosolids no-till
biosolids conv-till
topsoil
control
control
topsoil
biosolids conv-till
biosolids no-till
100 0 100 Meters
300 0 300 Feet
N
W
E
S

2005 Corn Yields (kg/ha)

Topsoil/Lime/NPK	**4782 c***
Tails + Biosolids:	**13,041 a**
Tails + Lime + NPK:	**10,666 b**
Unmined adjacent:	**17,561**
County Average: (2000 – 2005)	**7,683**

Adjacent prime farmland – Orangeburg Soil with same management as plot area.

**Yields within experiment followed by different letters were different at p > 0.01*

Topsoil yields were reduced by compaction and heavy crusting. Are these “problems” typical of the topsoil replacement process?

2006 Wheat Yields (bu/ac)

Topsoil/Lime/NPK 4301 b

Tails + Biosolids: 4906 a

Tails + Lime + NPK: 4300 b

Winter Wheat on Carraway-Winn Farm in May of 2006

Unmined adjacent: 6921

County Average: 3561

(2000 – 2005)

Adjacent prime farmland – Orangeburg Soil with same management as plot area.

A Rational Standard for Success?

- The current regulatory framework <u>requires</u> that mined lands returned to row crop agriculture must equal long term county averages. We now have three years of data indicating that we can actually exceed county averages and that we can "topsoil substitute".

- Rather than direct comparison with pre-miner productivity, we are now using 75% of pre-mining as a "voluntary target".

Harvested (non-topsoiled) mined land in Fall 2005

CONCLUSIONS

The return of post-mining agricultural productivity is considered by multiple stakeholder groups to be one of the most critical aspects of the operations' long term sustainability.

CONCLUSIONS

Results obtained to date from the cooperative demonstration farm indicate that these lands can be successfully returned to levels of agricultural production equal to or above the local region, but that some loss of productivity from the very best agricultural lands should be expected.

CONCLUSIONS

Perhaps most importantly, this collaborative research/ demonstration effort greatly enhances the transparency of the overall mining and reclamation operation with respect to long-term sustainability objectives.

Acknowledgments

Iluka - Denis Brooks, Elliott Mallard, Geoff Moore, Clay Newton, Fiona Nichols, Allan Sale, Chee Saunders, Chuck Stilson, Steve Potter, Steve Winkelmann, Chris Wyatt and Clint Zimmerman have worked diligently with us over the years to improve mined land reclamation protocols applied at Old Hickory.

We also want to thank Carl Clarke for his management of the research farm. John Tucker and Steve Bunch for assistance with revegetation protocols, and Steve Nagle and Kelly Burdt (from VT) for help in the field.