Soil/Site Disturbance and Challenges for Utility Scale Solar facilities in Virginia

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http://www.landrehab.org

Image from Dominion published by Virginia Mercury – Louisa County

Virginia Clean Economy Act – 2020 - Effects

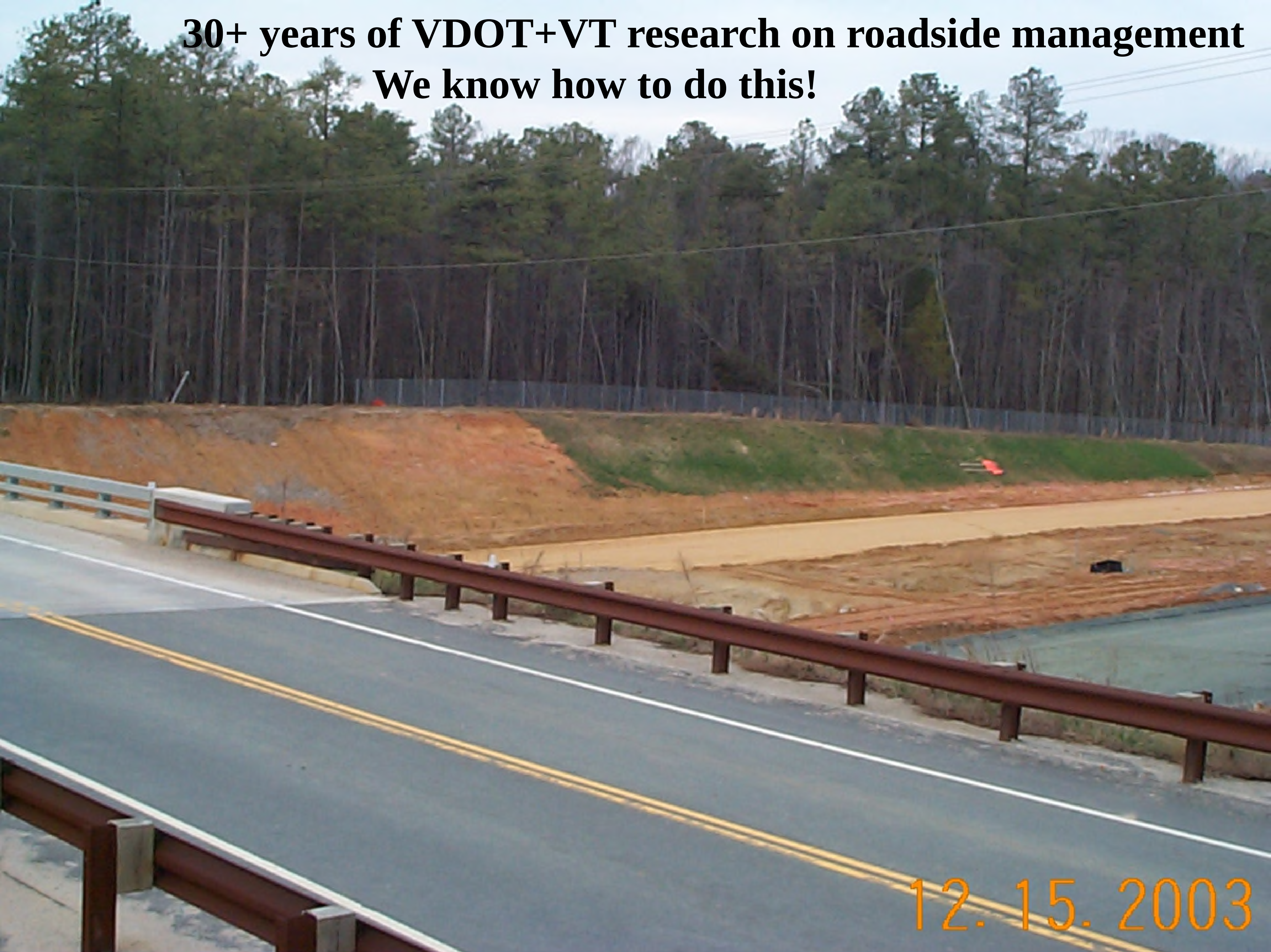
- Mandates VA be completely converted to renewable energy sources by 2050.
- Initial “target” for solar is 16K MW which would affect up to 160,000 acres.
- DEQ estimates are much higher (see later)
- Strong state and federal tax and legislative benefits for the industry.
- Major boom in applications in 2021 to 2023

Overall BMP Approach

- Minimize soil disturbance and runoff risk via application of intelligent *a priori* design practices:
  - *Limit cut/fill, manage topsoil, de-compact soils, specify ESC measures & temporary SWM controls for design storms with bare soils exposed, use appropriate CN's for permanent controls.*
- Recognize and carefully plan for the three critical phases of the process:
  - *Rigorous and immediate application of ESC and SWM BMP's during site clearing, construction & stabilization. Remediate compaction & acidity/clay issues <u>before</u> final seeding.*
  - *Develop long-term soil/vegetation O&M plan(s) for the lifetime (30 years?) of the site that enhance soil quality.*
  - *Final site decommissioning, soil/site remediation and restoration of final post-closure land use will require more inputs/tillage?*

Image from Soilworks.com; marketer of soil stabilization/dust control products.

Well-vegetated relatively young site. To be clear, I don’t question our overall ability to successfully stabilize and revegetate these facilities! Photo courtesy of John Ignosh


30+ years of VDOT+VT research on roadside management
We know how to do this!
12. 15. 2003

Major Issues with Disturbed Soils

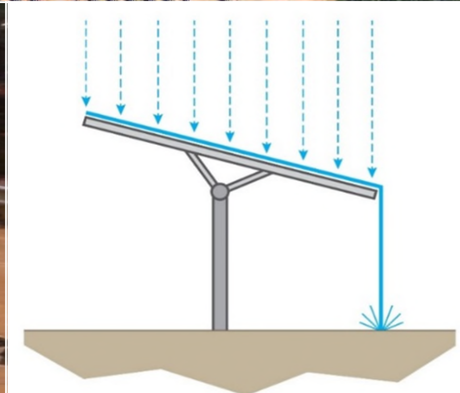
- **Compaction is the dominant management issue in urban soils, VDOT & utility corridors, mining reclamation, etc.**

- **Cuts and fills on a site are fundamentally different in management & remediation needs:**
  - **A. Cuts often have topsoil removed or highly variable properties with depth. May hit acid sulfate soil (ASS) materials in some areas.**
  - **B. Fills are commonly highly compacted and "layered" with dissimilar materials.**
  - **C. Both are commonly acidic and very low in plant-available P.**
  - **D. On a given site, depending on setting, slope & extent of excavation, you can/will have highly variable soil quality, often over short-range.**

- **Acidity/pH and fertility are *relatively easy* to deal with, compaction is not.**

From presentation by M. Rolband, VA DEQ, 4/6/23, CBF x STAC Workshop

DEQ



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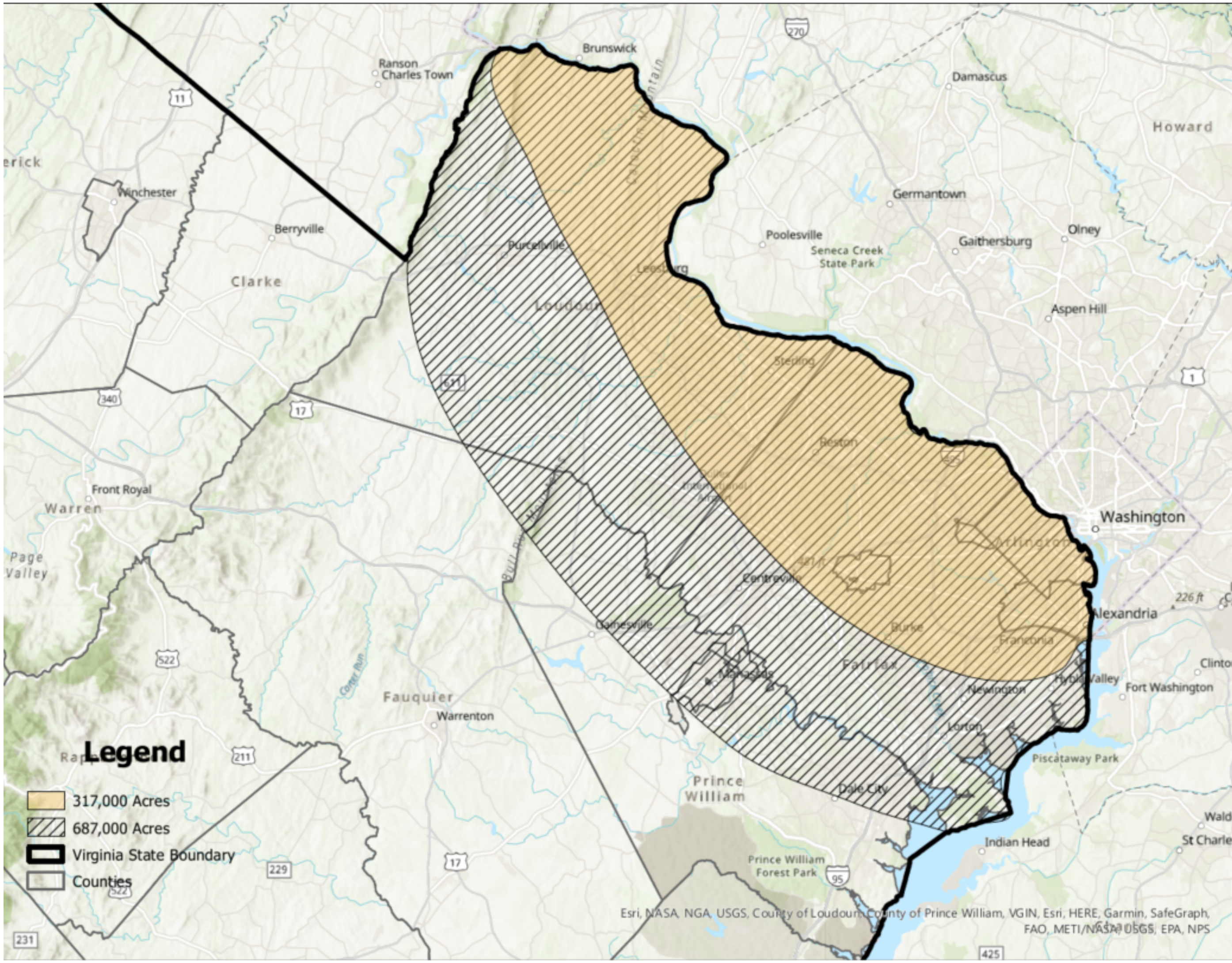
Scale Perspective – Land Use Change Expected in Virginia by 2045

Power (GW)	30	65
Land Area (acres)	317,000	687,000
Panel Area (acres)	57,000	123,000

Land Area (acres):

Washington, D.C.	39,000
Arlington County	16,640
Prince William County	215,040
Fairfax County	250,240
Loudoun County	332,800


Legend
317,000 Acres
687,000 Acres
Virginia State Boundary
Counties
Washington
Alexandria
Loudoun
Fairfax
Prince William
Fauquier
Clarke
Warren
Howard
Leesburg
Reston
Sterling
Centreville
Manassas
Gainesville
Purcellville
Winchester
Berryville
Front Royal
Warrenton
Germantown
Gaithersburg
Poolesville
Olney
Aspen Hill
Damascus
Brunswick
Ranson
Charles Town
Seneca Creek State Park
Burke
Franconia
Newington
Lorton
Dale City
Hybla Valley
Fort Washington
Clinton
Piscataway Park
Indian Head
St Charles
Prince William Forest Park
Esri, NASA, NGA, USGS, County of Loudoun, County of Prince William, VGIN, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS

Key Solar-Specific Management Considerations in Virginia

1. Cut/Fill/Topsoil Burying with Compaction
2. Lack of Vegetative Cover

   Permanent or temporary soil stabilization shall be applied to denuded areas within ***seven days*** *after final grade is reached on any portion of the site.* (9VAC25-840-40.1)

3. Curve Numbers
   a. Compaction
   b. Panel Imperviousness
4. Maintenance of Controls
5. Improper Installation of Controls
6. Disregard for Natural Drainage Divides

Compliance Snapshot

Permitted USS	124	
DEQ is VSMP	77	
Final Consent Orders	12	16%
Pending Consent Order	11	14%
March Inspections:		
• Notices of Violation	1	3%
• Warning Letters	8	20%
• Corrective Action Needed	21	54%
• No Issues	9	23%
• **Total Sites**	**39**	**100%**

$\frac{53}{77}$ = **At least 69% have "Issues"**

DEQ

Initial Site Development Challenges

- **Soil disturbance can vary widely from < 10% to complete cut/fill & regrading of the entire site.**
- **Major disturbances are roads, trenches, regrading to level panel arrays, water conveyances, stormwater basins, compaction for structural support, etc.**
- **Acidic subsoil materials exposed or filled at the surface need heavy liming and P applications.**
- ***<u>Initial/construction ESC and SWM controls are critical; these are construction sites and need to be aggressively managed as such!</u>***
- **Existing DEQ/local ESC/SWM guidance <u>is more than adequate</u> to allow for safe development *if implemented rigorously*.**
- **Must avoid acid forming materials (ASS) at all costs.**
- **Every site x design is unique!**

What can we do?

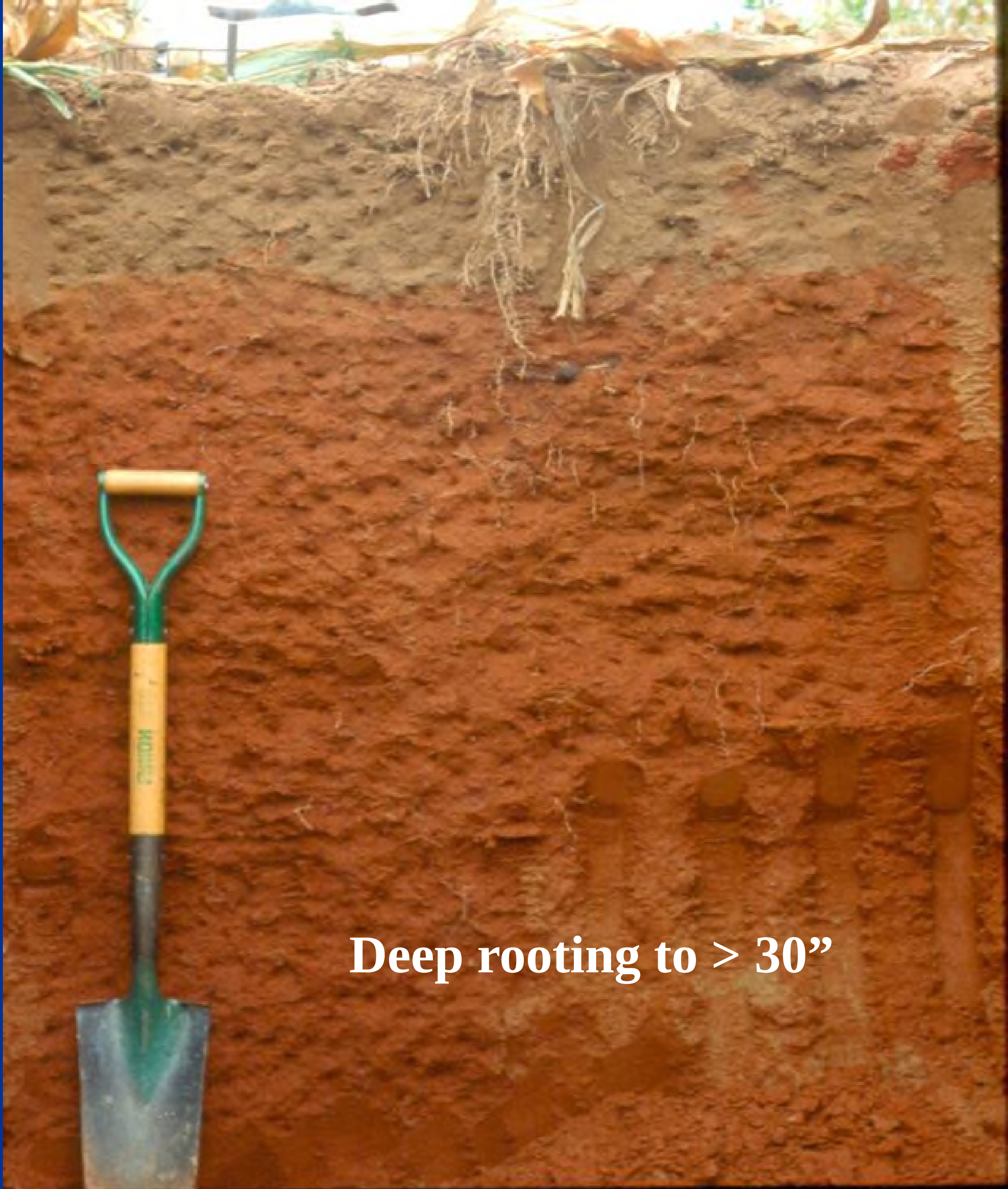
- Save, preserve and reapply topsoil
- Use liberal amounts of lime, P and organic matter amendments on both exposed subsoils *and* returned topsoil layers
- Apply tillage (ripper, chisel-plow, rotovator, etc.) to reconstructed areas to both compacted subsoils and returned topsoil.
- Anticipate that a second round of remedial actions will be needed when old infrastructure is removed in 25 to 35 years?

Active mineral sands mining at Old Hickory. Over 3000 acres of land have been disturbed to date with approximately 1500 reconstructed/revegetated.

Surface (topsoil) enrichment of ilmenite+rutile+zircon is frequently > 15% W:W. Subsoil is often > 5%.

Typical highly productive soil in the Old Hickory area. The topsoil is usually 3x enriched in HM relative to subsoil.

Productivity of this soil in greatly enhanced by the low bulk density, well structured subsoil that readily allows rooting to 36” or more.



Sequence of photos (by Chuck Stilson/Iluka) showing ripping of subsoil and application of topsoil for final reclamation. The topsoil is spread with dozers and then tilled/ripped again to loosen compaction. Ripping usually occurs below topsoil; but can also cut both.

Lime (5 T/Ac) + P_2O_5 (350 lb/Ac) are added to the subsoil before ripping and then lime + N-P-K are added again to the topsoil based on soil test results.

2X Ripper Plot at Iluka Resources.

Here the ripper is running back up the “middles” of previous pass. This doubles the rips per unit area. Another option is to “cross-rip” if possible. Obviously, complicated by installed panel arrays!

Success is dependent upon ideal moisture so that minimal subsoil being pulled up.

Chisel plow plot operating at tillage/ripper study in Dinwiddie County. Smaller scale (narrow) tillage loosening to 12" or so can also be accomplished via a pull-behind roto-tiller, smaller rippers, etc. ***Application of remedial tillage on sloping sites with installed panel arrays is obviously much more complicated!***

Soybeans established in wheat stubble on Carraway-Winn farm, July 2006

TABLE 2

Crop yields from the Carraway-Winn Reclamation Research Farm, a local unmined prime farmland soil, and Dinwiddie County averages as applicable. Crops on all areas received identical management, including irrigation as needed.

Treatment	2005	2006	2007	2008		2009	2010		2011	2012		2013
	Corn (Mg/ha)	Wheat (Mg/ha)	Corn (Mg/ha)	Wheat (Mg/ha)	Soybean (Mg/ha)	Cotton (Mg/ha)	Wheat (Mg/ha)	Soybean (Mg/ha)	Corn (Mg/ha)	Wheat (Mg/ha)	Soybean (Mg/ha)	Corn (Mg/ha)
LBS-CT[a]	10.85 a[b]	5.04 a	3.62 b	6.27 a	2.42 ab	1.17 a	2.74 a	0.96 a	4.77 a	3.17 a	2.49 a	12.99 a
LBS-NT	10.90 a	5.16 a	3.43 b	5.65 a	2.51 a	1.18 a	2.76 a	1.11 a	4.75 a	3.20 a	2.45 a	13.03 a
TS	3.79 c	4.29 b	7.23 a	4.89 b	2.20 ab	1.18 a	2.68 a	1.15 a	4.13 a	3.18 a	2.51 a	12.24 a
C	8.53 b	4.10 b	7.30 a	4.64 b	2.11 b	1.05 a	2.51 a	1.10 a	5.30 a	3.11 a	2.34 b	11.87 a
UM	14.36	6.90	9.91	3.90	3.21	1.62	4.72	1.73	12.48	4.45	2.21	16.01
COMP	6.07	4.33	3.18	1.75	ND[c]	ND	ND	ND	ND	ND	ND	ND
County average	6.70	3.76	3.9	4.90	1.75	1.18[d]	3.27	1.01	8.2	4.51	2.51	9.89

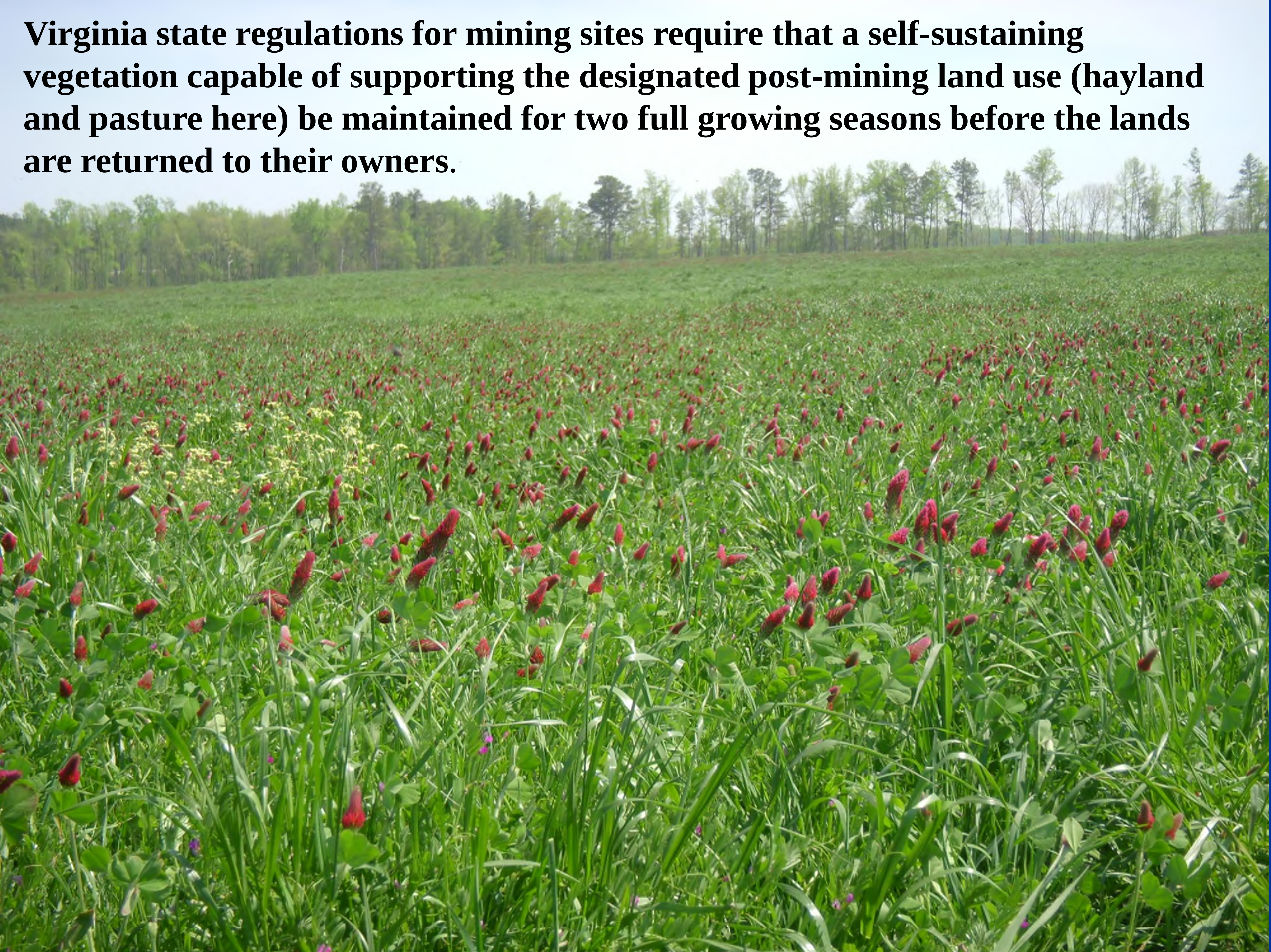
a. LBS – lime stabilised biosolids @ 78 Mg/ha; CT – conventional tillage; NT – no tillage; TS – 15 cm topsoil return; C – limed and fertilised control; UM – unmined control area; COMP – compacted, non-ripped zone. b. Means in the same column followed by the same letter are not significantly different at $\alpha = 0.05$. Data analysed via one-way analysis of variance followed by pairwise contrasts (Fisher's protected least significant difference). c. ND – not determined. d. Virginia South-Eastern Agricultural District average (county average not available).

Long term crop yields on reconstructed prime farmland soils following mineral sand mining. All soils were deep ripped initially and limed, fertilized or biosolids amendend, and tilled annually as/if needed. Compared with adjacent unmined lands under identical management, *crop yields were reduced by ~25% in most years*, but often exceeded overall county average yields for "all soils in production for that crop". This and other papers/reports available at https://landrehab.org/.

Topsoil yields in first two years were reduced by compaction and heavy crusting that required remedial tillage. These "problems" are typical of the topsoil replacement process at many sites.

Beyond the research plot work, we continue to work with Iluka and their contractors to apply appropriate rehabilitation protocols. Here, one-year old forages are being mowed on an area that received lime, deep ripping, N-P-K fertilization and topsoil.

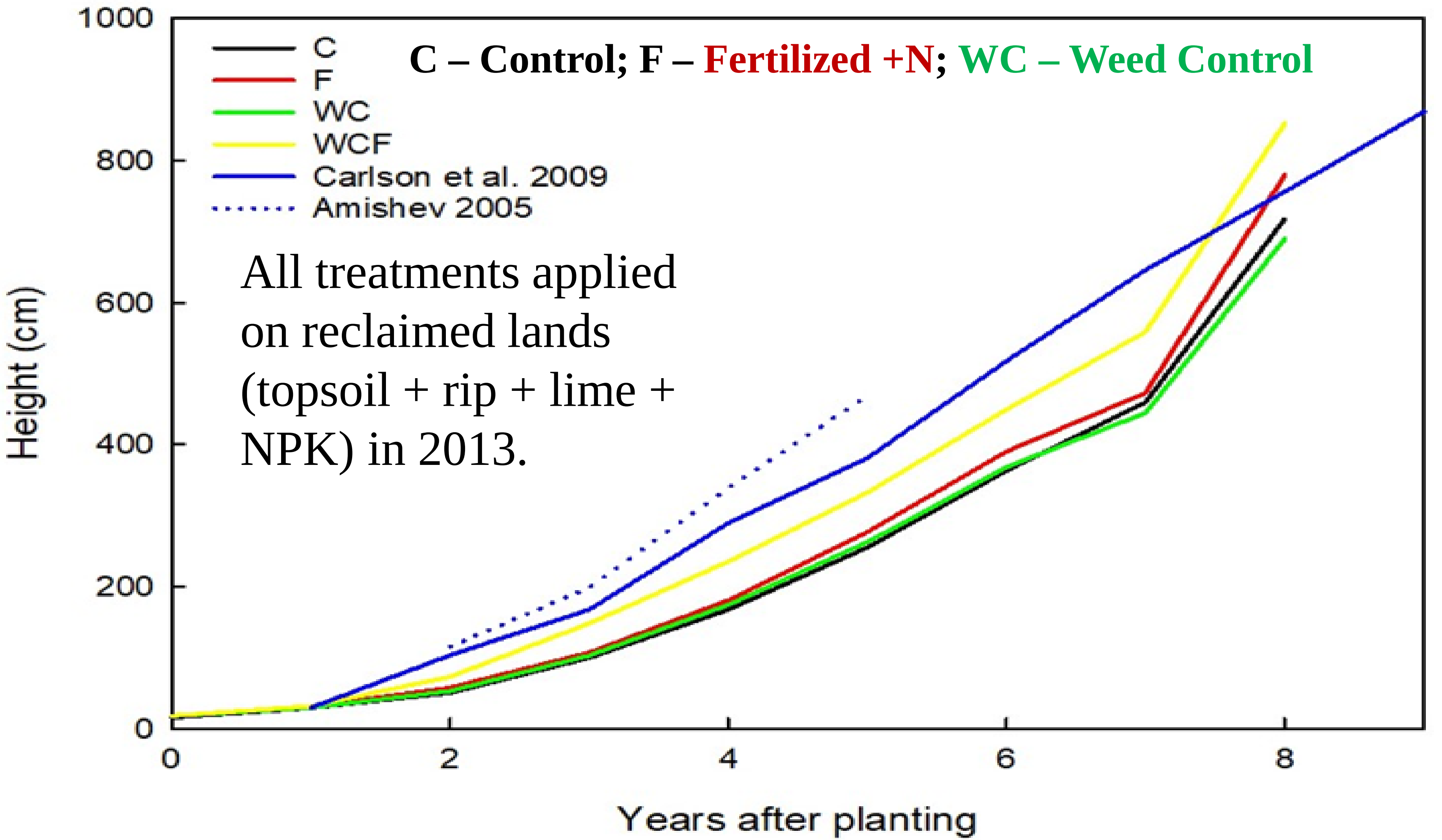
Virginia state regulations for mining sites require that a self-sustaining vegetation capable of supporting the designated post-mining land use (hayland and pasture here) be maintained for two full growing seasons before the lands are returned to their owners.



Effects of subsoil compaction on 4-year old loblolly pine plantings at Iluka mineral sands soil reconstruction site. This site received deep ripping of the subsoil and topsoil replacement.

Even tap-rooted pines cannot penetrate when the subsoil B.D. is too high. At This site, subsoil is clay loam and the bulk density is 1.7 to 1.8 g/cm^3

Upper image shows taproot deflected sideways at 6”; lower image shows lateral extent of finer lateral roots extending to acquire water and nutrients.



Eight-year growth comparison of the four silvicultural treatments on reclaimed mineral soils vs. two studies of loblolly pine growth on native soil plantations in the Virginia Piedmont. Note sharp increase in growth rates in year 8 which continued in years 9 and 10 (data not shown).

Operational Phase Soil Challenges

Soil compaction of certain areas is inevitable during the construction phase and may be difficult to remediate once the site is operational. Topsoil stripping and return amplifies compaction and subsoil "smearing" unless ripped/remediated.

Panels (particularly fixed) concentrate local runoff onto a "drip line" that can lead to local surface ponding, concentrated flows, rilling & enhanced runoff.

Actual effects of panel arrays on stormwater runoff peak flows are not well studied. VT and VSU have a new study funded by DEQ that will be installed at six sites statewide this year and monitor actual SW, TN, TP and TSS levels at replicated locations (4 within solar site and 3 external controls) each.

Establishing and maintaining uniform vegetation under certain panel arrays; particularly low fixed panels can be challenging. Many of these areas (under panels) will also be extensively disturbed. However, maintaining at least 90% living cover is critical to SWM and long term soil recovery processes.

Well-vegetated relatively young site. To reiterate, I don't question our overall ability to successfully stabilize and revegetate these facilities! The operant questions are: (a) What can we do to limit short-term sediment losses during construction?; (b) Can we manage the existing soil/plant system over time to minimize runoff?; and (C) What will it take to return the land to reasonable levels of productivity following closure?

Long-Term Site Closure Challenges

- **Removal of site infrastructure will result in another round of soil disturbance, including more soil compaction, re-exposure of subsoil materials to clear subsurface conduits etc.**

- **Return to previous land uses, particularly rowcrop agriculture will be very difficult unless large amounts of soil amendments (compost, lime, P, etc.) and heavy tillage (repeated chisel-plowing etc.) regimes are employed.**

- **Heavily disturbed areas (roads and extensively re-graded and disturbed areas) will more than likely have hayland/pasture or forestry as their highest and best use. Return of up to 100% of pre-disturbance productivity for those uses is possible.**

- **Any assurance that highly productive agricultural lands (e.g. rowcrops) can be readily returned to even approach existing (>80%) levels of soil productivity must be made *very carefully*.**

Acid sulfate soil impacts to soil quality in a subdivision in Fredericksburg and immediately adjacent (behind house) surface water impacts.

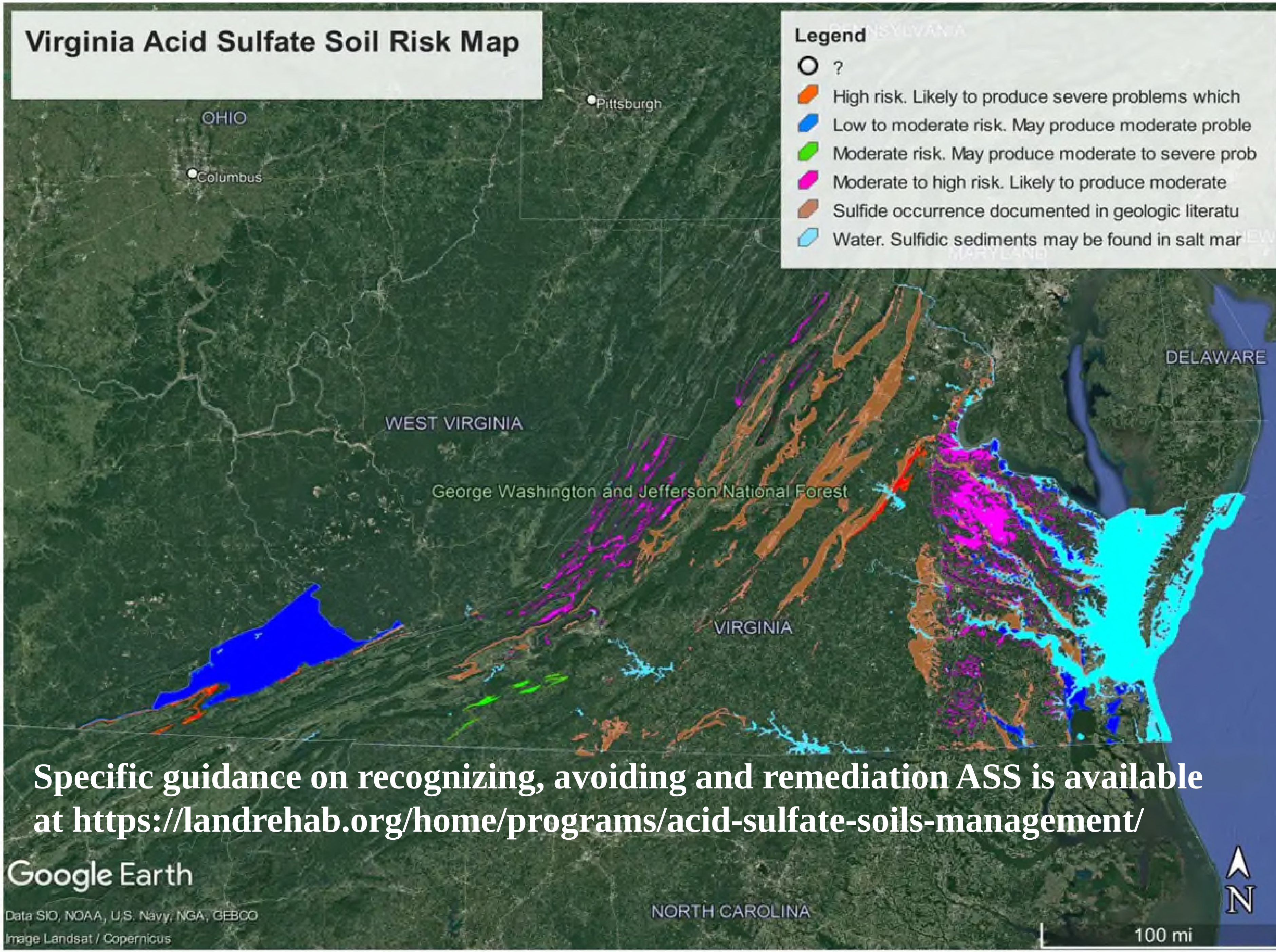
Naturally occurring S containing sediments and rocks are frequently exposed by construction activity and then quickly oxidize to for sulfuric acid soil conditions.

Sulfidic materials underlie much of the Coastal Plain at variable depths (usually > 5 to 10 feet). They also are common in certain regions of the Piedmont.

On solar sites, most likely encountered in lower landscapes in stormwater ponds

Remediated yard, summer 2006

Neighbor's yard, Summer 2006



Specific guidance on recognizing, avoiding and remediation ASS is available at https://landrehab.org/home/programs/acid-sulfate-soils-management/

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