Pedogenesis and Local Water Quality Effects of Upland Placement of Saline Dredge Spoils in Virginia

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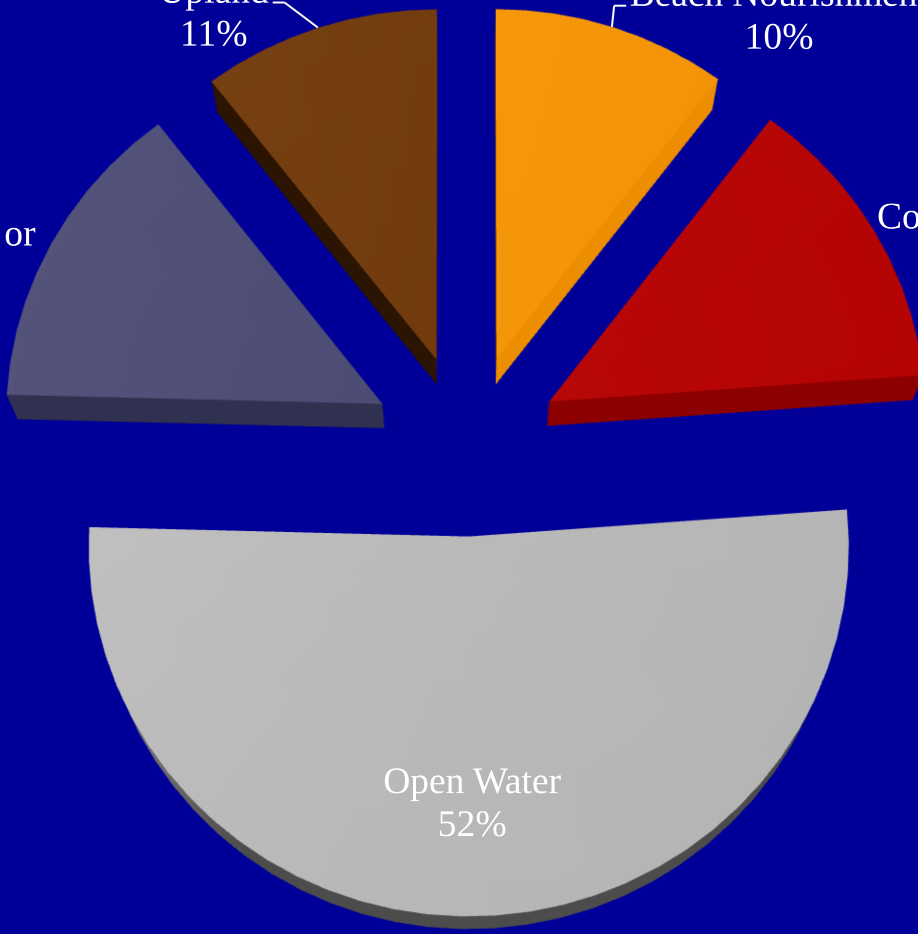
CES Crop & Soil Environmental Sciences

Dredge Materials

- Also known as dredge spoils, dredge sediments, harbor muds, etc.
- Over 200 million yards removed annually from USA waterways
- Vast majority are disposed of in "spoil islands" like Craney Island – Norfolk. Usually at $5-$10 per yard.
- Very little (<15%) used for upland placement or "marsh replenishment".

Dredged Material Placement Alternatives 1997-2010

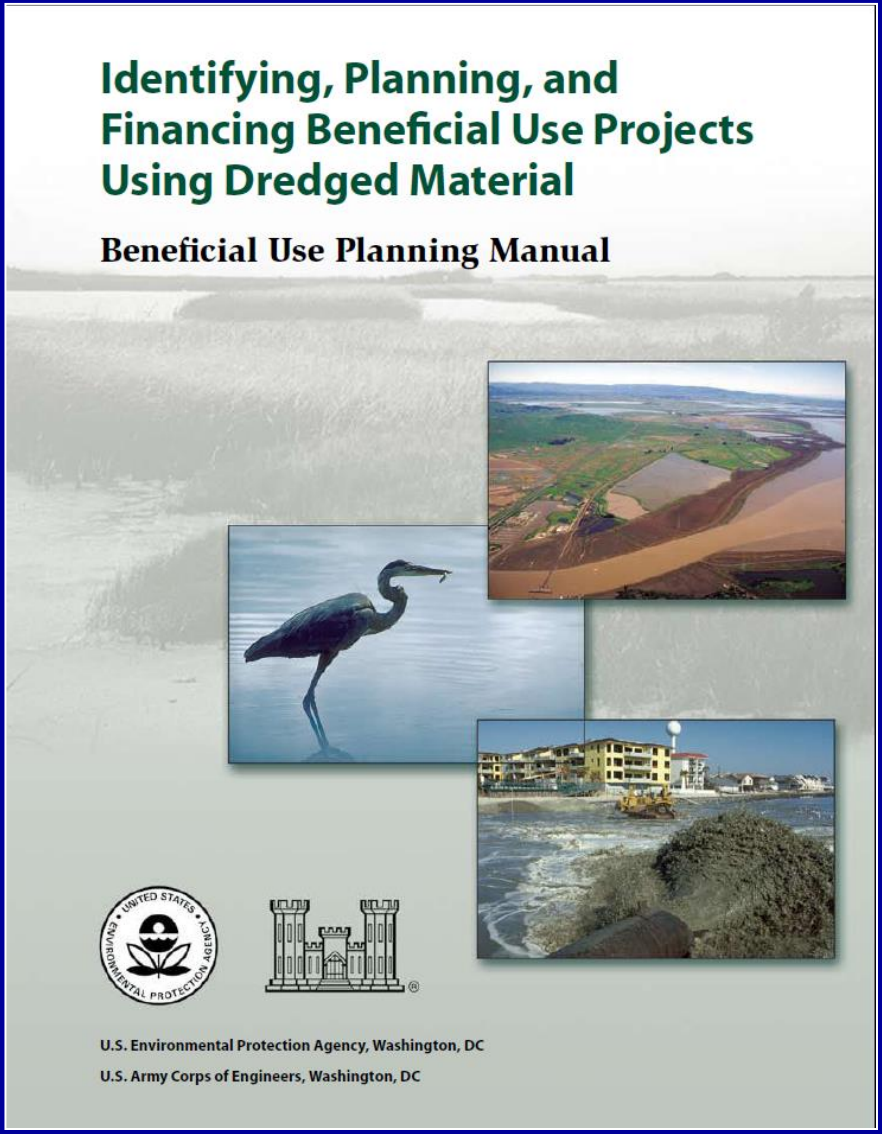


Total USACE Dredged Materials (including contracts) for 1997-2010: 2,400,000,000 m^3

Growing interest in beneficial reuse- dredged material can be reused in many settings.

Beneficial Reuse Alternatives:

- Agriculture
- Beach Nourishment
- Construction Fill
- Cropland Restoration
- Habitat Restoration
- Wetland Nourishment
- Industrial Product
- Mine-lands Reclamation
- *Confined Upland Facility (CUF)*

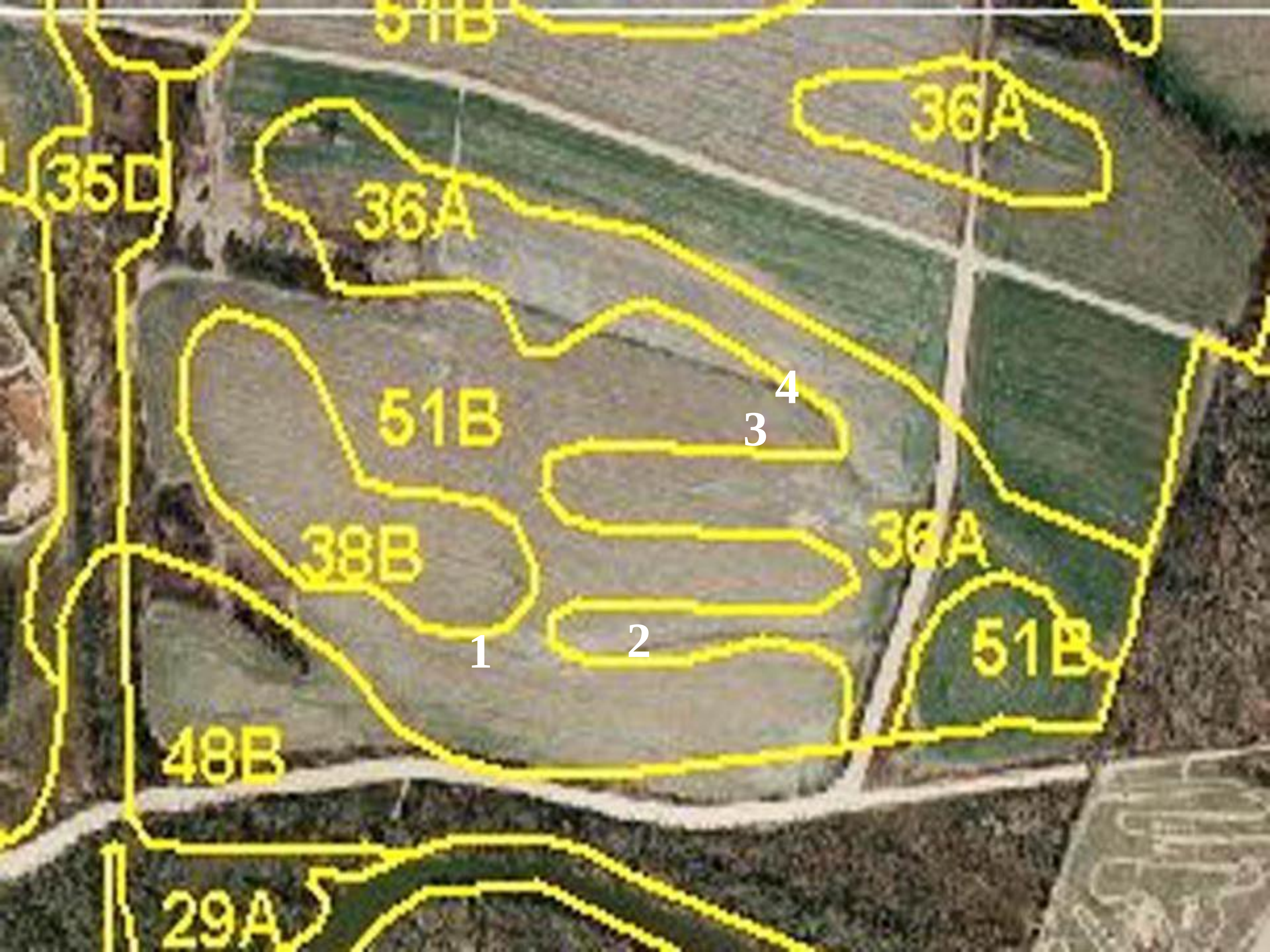


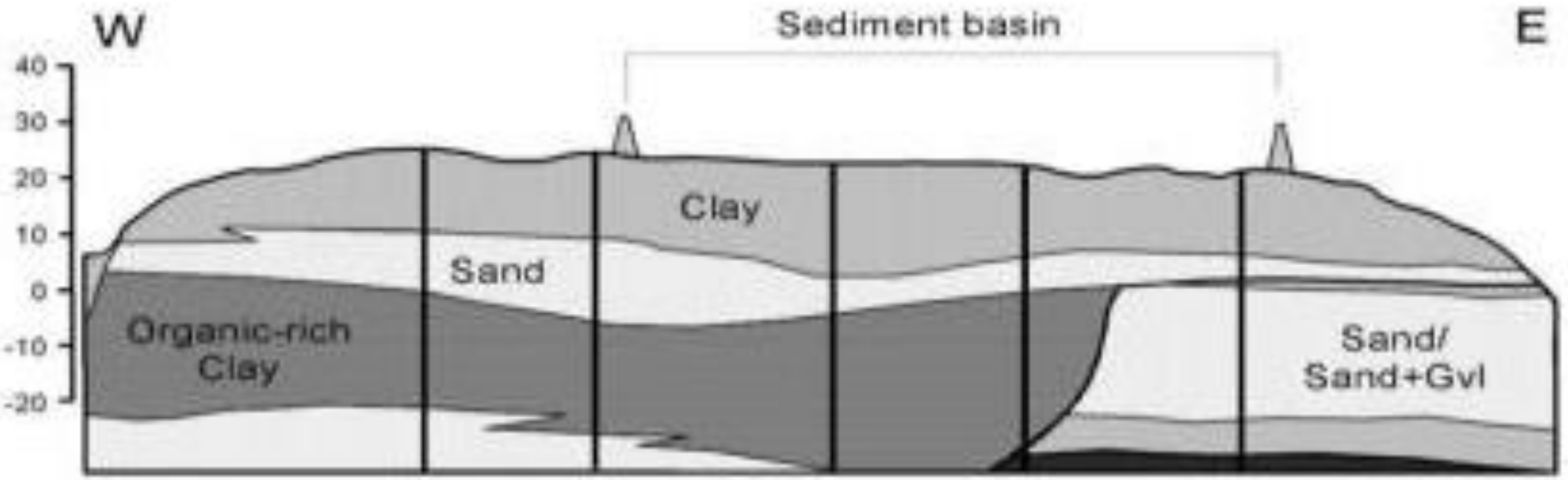
Shirley Plantation / Weanack

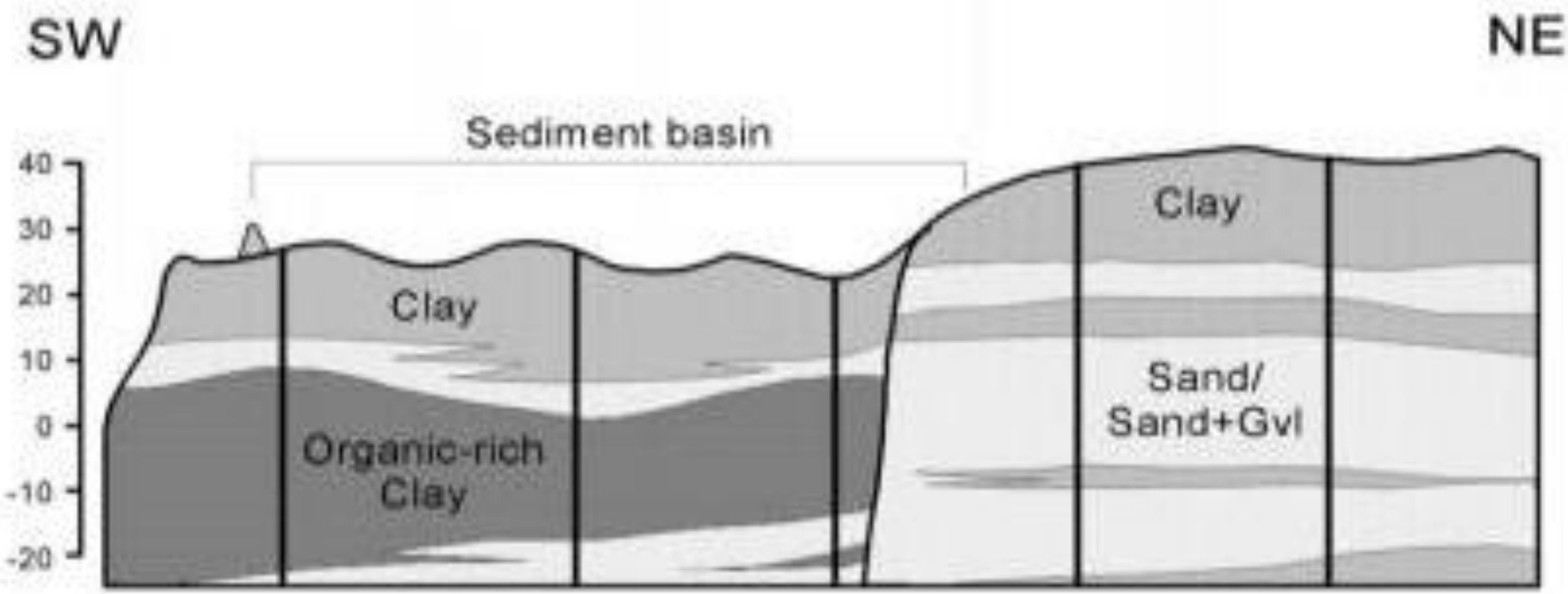
Overview of Woodrow Wilson Bridge (WWB) dredge spoil utilization area on Weanack Land LLP property adjacent to Shirley Plantation. The dredge spoils were transported by barge to the port facility shown in the middle of the photograph. Earle basin to right.


Earle Naval Weapons Station
Shirley Plantation/Weanack
N
Atlantic Ocean
UNITED STATES
PENNSYLVANIA
MARYLAND
WEST VIRGINIA
VIRGINIA
DELAWARE
NEW JERSEY
NEW YORK
OHIO
New York
Philadelphia
Baltimore
Washington, D.C.
Richmond
Norfolk
Chesapeake
Chesapeake Bay

Plantation House
Woodrow Basin
MPA Plot
Port
Earle Basin
Image: 2130m


51B
36A
35D
36A
51B
4
3
36A
38B
1
2
51B
48B
29A


W
Sediment basin
E
40
30
20
10
0
-10
-20
Clay
Sand
Organic-rich
Clay
Sand/
Sand+Gvl

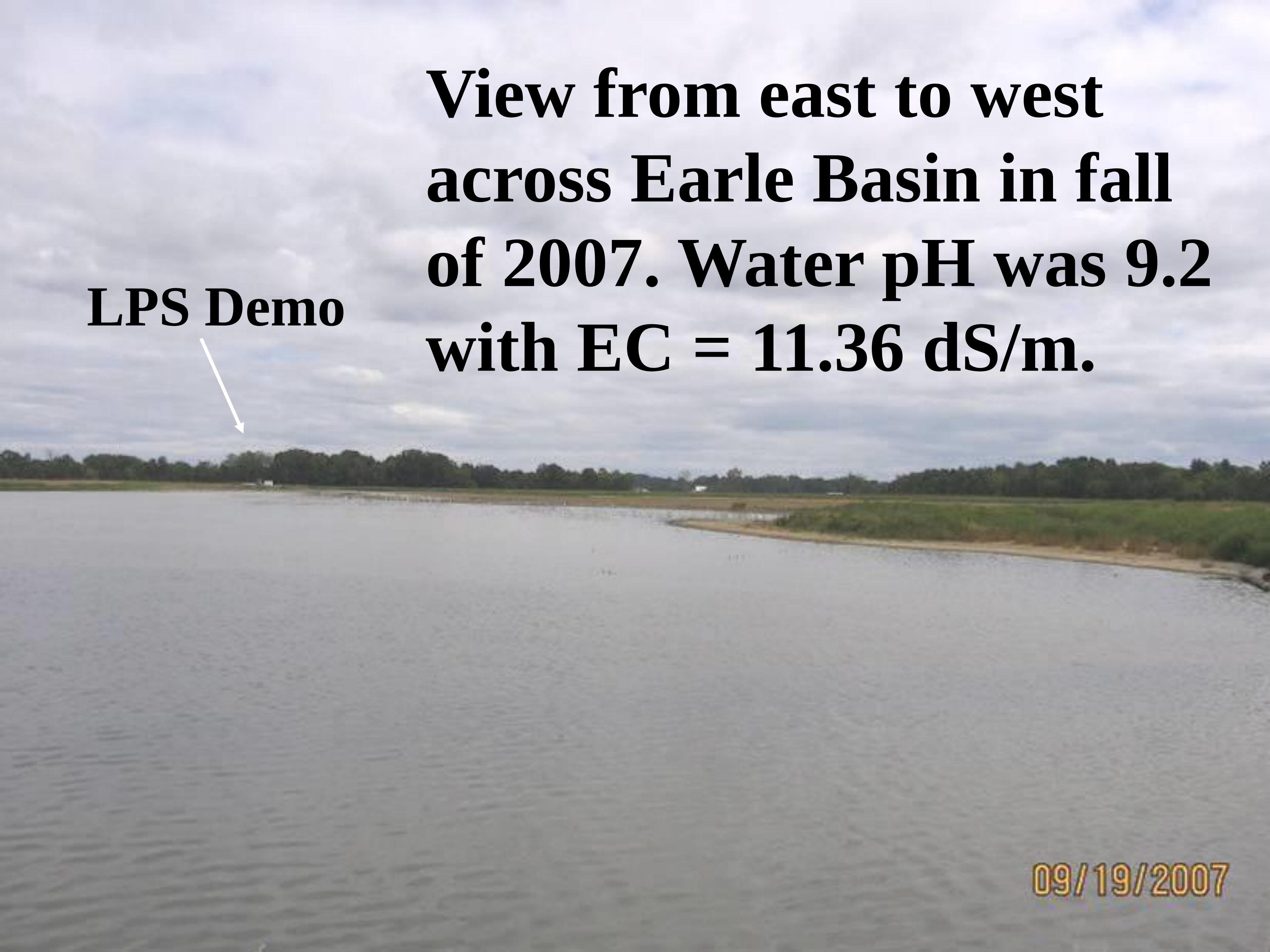

SW
NE
Sediment basin
40
30
20
10
0
-10
-20
Clay
Clay
Organic-rich
Clay
Sand/
Sand+Gvl

The Earle Dredge Basin

- Material is saline with low organic contaminants
- Variability in texture (plot area and majority of the basin has a fine texture)

- ~230,000 m^3 of Earle material in basin
- ~25 ha in size

Parameter	Average
pH	8.3
EC	36 dS m^{-1}
Cl-	17,675 mg kg^{-1}
Total organic C	2%
Total solids	47%


View from east to west across Earle Basin in fall of 2007. Water pH was 9.2 with EC = 11.36 dS/m.
LPS Demo
09/19/2007


03/08/2007


09/19/2007


03/08/2007

April 2007

pH = 8.9 @ 6”

EC = 27 dS/m

September 2007

pH = 7.5

EC = 6.6 dS/m

October 2009

pH = 7.0

EC = 2.5 ds/m

Development of dredged material after deposition in CUF: general timeline

1) **Deposition**
2) **Dewatering**
3) **Prism formation**

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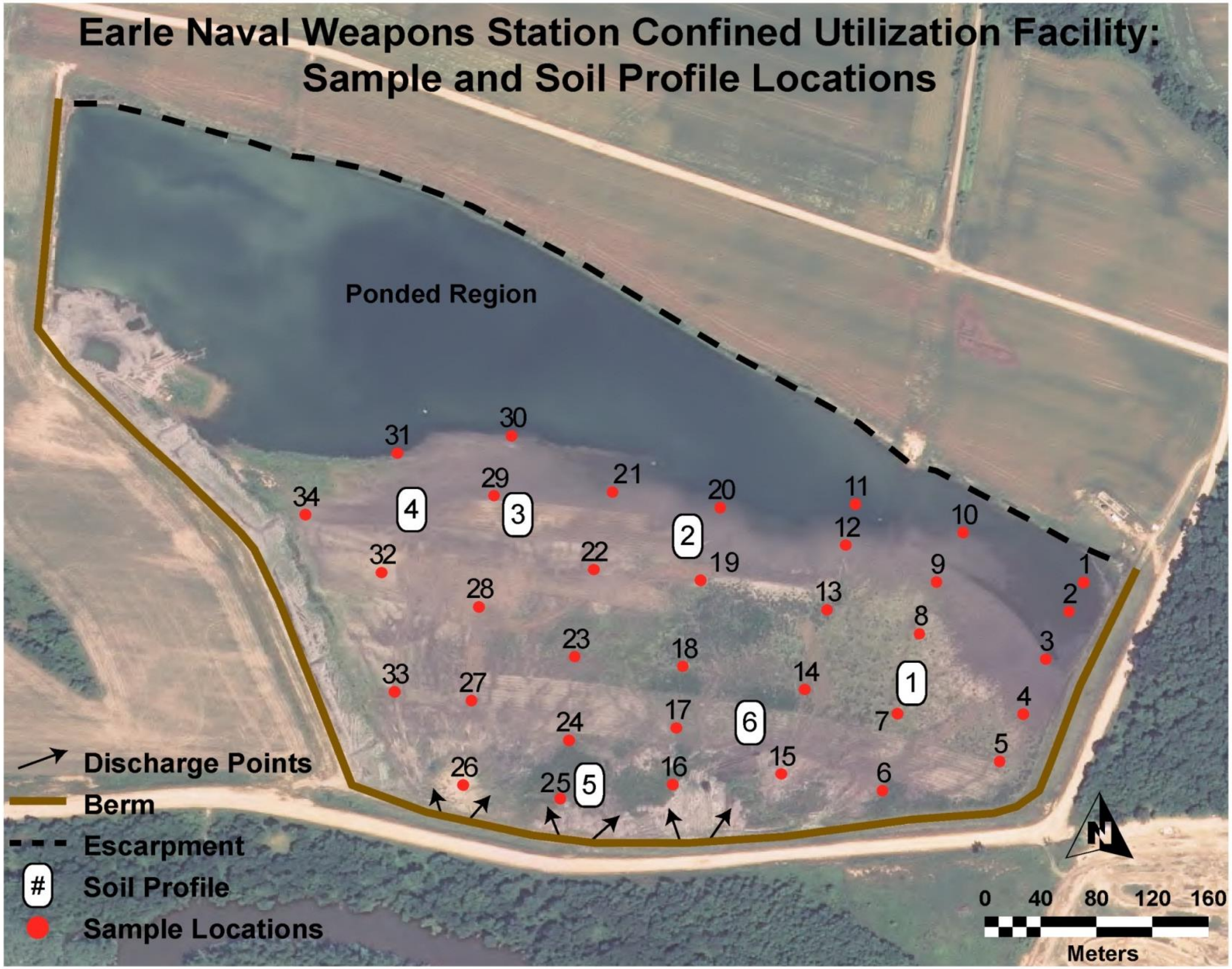
4) **Prism oxidation and breakdown**
5) **Redox redistribution of iron**

Development of dredged material after deposition in CUF: general timeline

1) Deposition
2) Dewatering
3) Prism formation
4) Prism oxidation and breakdown
5) Redox redistribution of iron
6) Desalinization
7) Plant Invasion
8) Formation of B horizons



Initial properties:

pH 8.2; EC 36 dS m^{-1}; TOC ~2% (dry wt); TKN 2,045 ppm; Ortho-P 1.8 ppm; Total Solids 47%; CCE 4.9%; PPA 0.3 T $CaCO_3$/ T Material

Soil Genesis & Classification

Processes in Action:
ripening-gleization-rubification-desalinization

Diagnostic Soil Properties:

- *aquic cambic horizon*
- *ochric epipedon*

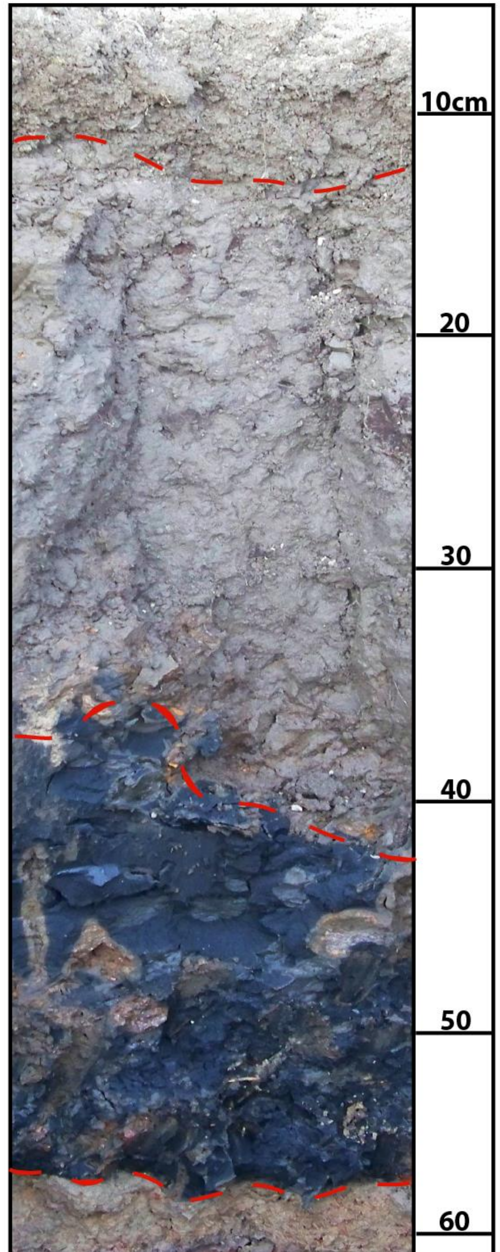
Soil Taxonomy

- All of the CUF classified as *Inceptisols* in < 5 years

Accelerated soil development:

(1) fine-loamy textures
(2) organic matter levels exceeding 4.5%
(3) fluctuating water table and
(4) thermic temperature regime

SP4 — Typic Halaquepts



^Ap
0 to 14 cm; olive brown (2.5Y 4/3); weak fine granular parting to weak medium subangular blocky

^Bg
14 to 39 cm; gray (2.5Y 5/1); strong very coarse prismatic structure parting to weak medium subangular blocky; few medium distinct strong brown (2.5YR 4/4) redoximorphic accumulations

^Cg
39 to 57cm; black (5Y 2.5/1); massive; common extremely coarse prominent red (2.5YR 4/6) redoximorphic accumulations

2Btb

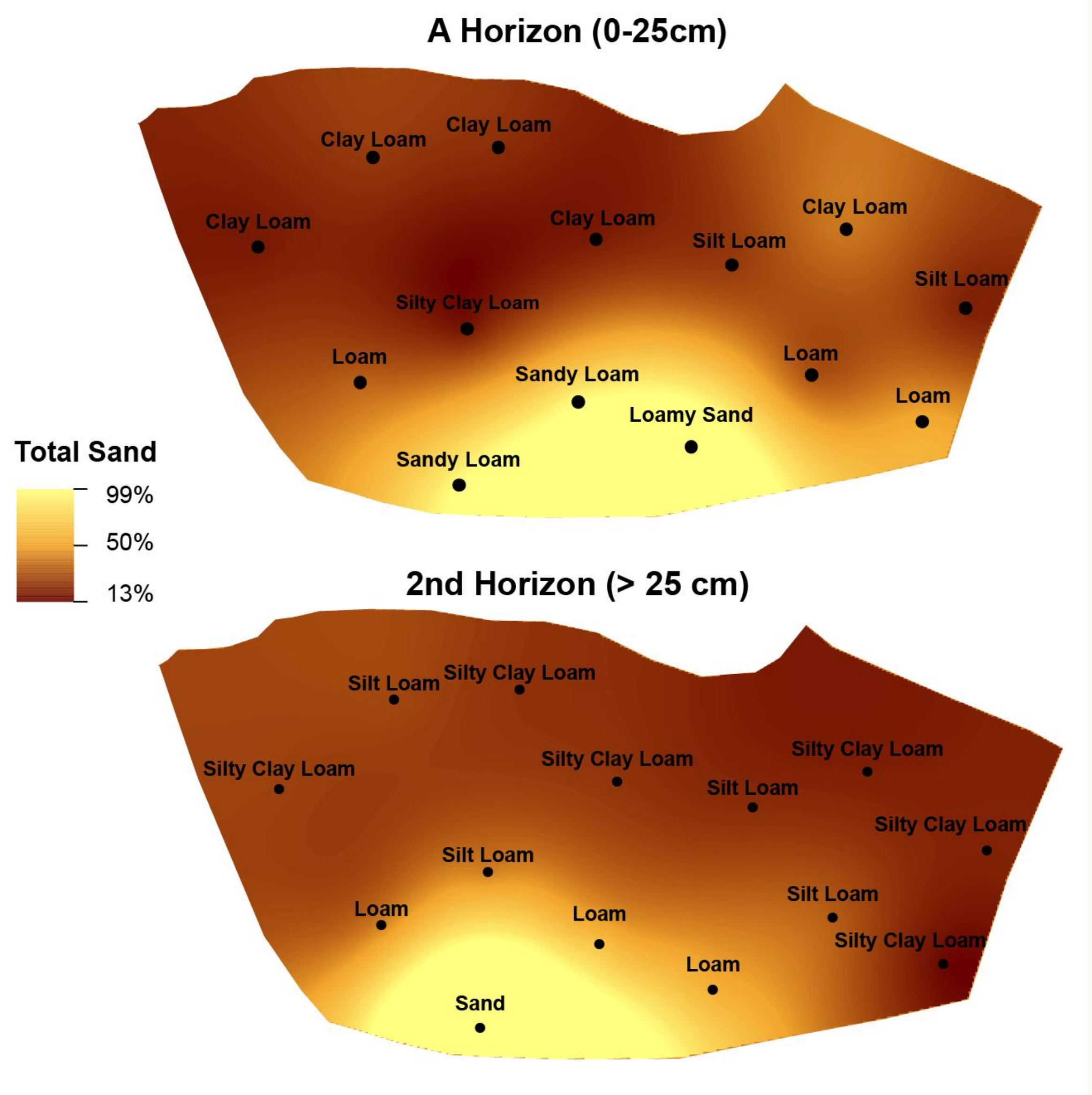
Lower level classification divided soils into 2 groups dependent on their proximity to the point of discharge.

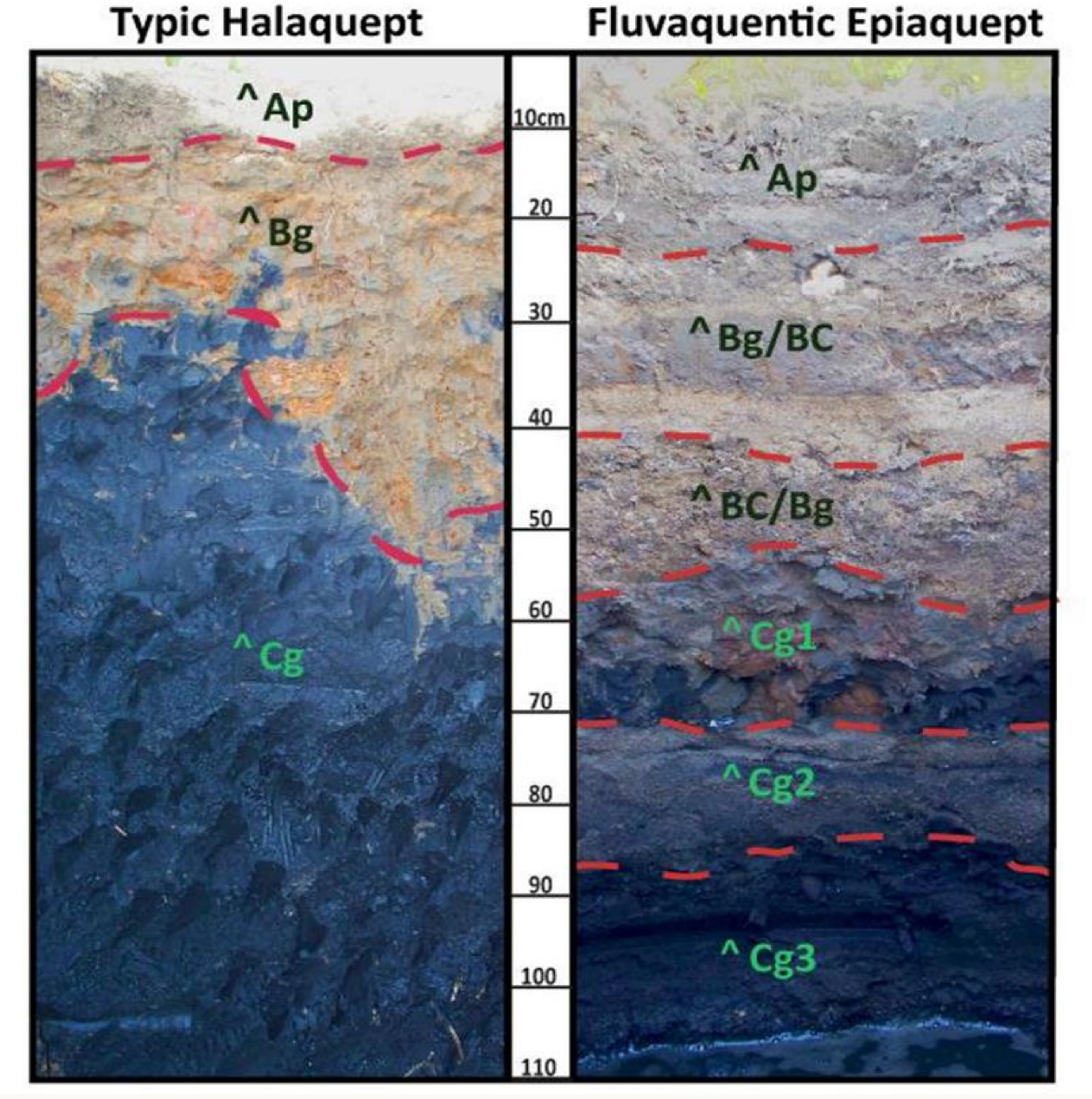
Greatgroup:
***Hala**quepts* for sodium adsorption ratio (SAR) ≥ 13 in a horizon(s) ≥ 25 cm within 50 cm of the surface

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}] + [Mg^{2+}]}{2}}}$$

Subgroup:
***Aeric** Halaquepts* if any horizon between 15-75 cm has a matrix chroma ≥ 3; *or*

***Typic** Halaquepts*

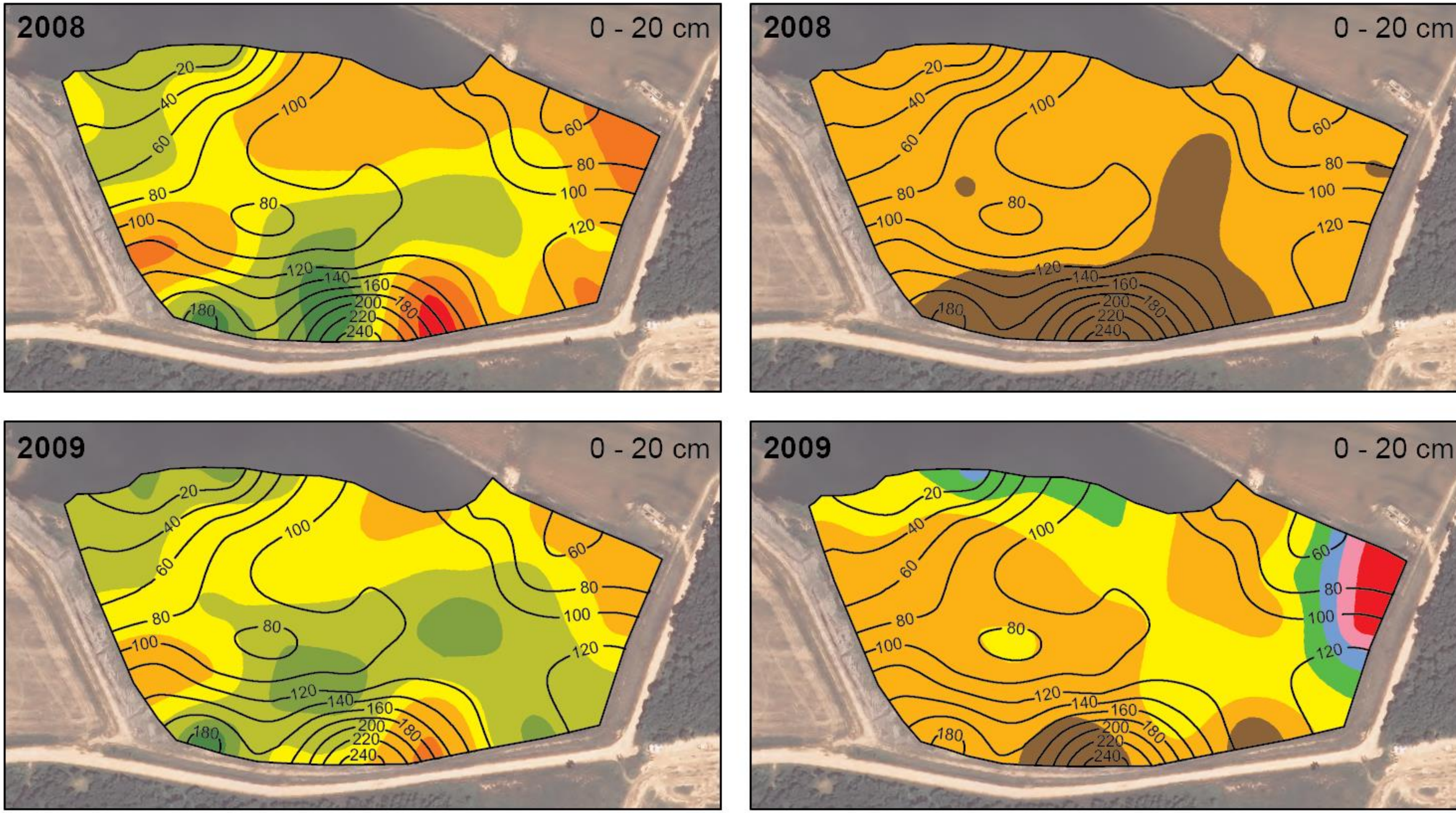



Typic Halaquept
Fluvaquentic Epiaquept
^Ap
^Bg
^Cg
10cm
20
30
40
50
60
70
80
90
100
110
^Ap
^Bg/BC
^BC/Bg
^Cg1
^Cg2
^Cg3

Pedogenesis & Cation Conversion with Time

Soils	Exchangeable Cations (% of Total)				Reference
	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	
Suspended seawater clay	16	32	6	47	(Drever, 1988)
CUF initial properties	36	44	< 1	22	
CUF 2008-09 Cg horizon	69	15	4	12	
CUF 2008 surface	79	12	3	5	
CUF 2009 surface	82	11	3	4	
~25 year old freshwater DM	82	15	3	1	(Darmody & Marlin, 2002)

Spatial and Temporal Changes during Pedogenesis of ENWS Dredged Materials in a Confined Utilization Facility at Weanack, Virginia



Electrical Conductivity (dS/m)

- 0.1 - 2
- 2.1 - 4
- 8.1 - 12
- 4.1 - 8
- 12.1 - 18
- 18.1 - 24
- 24.1 - 30

pH

- 5.0 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0
- 8.1 - 8.5

Meters

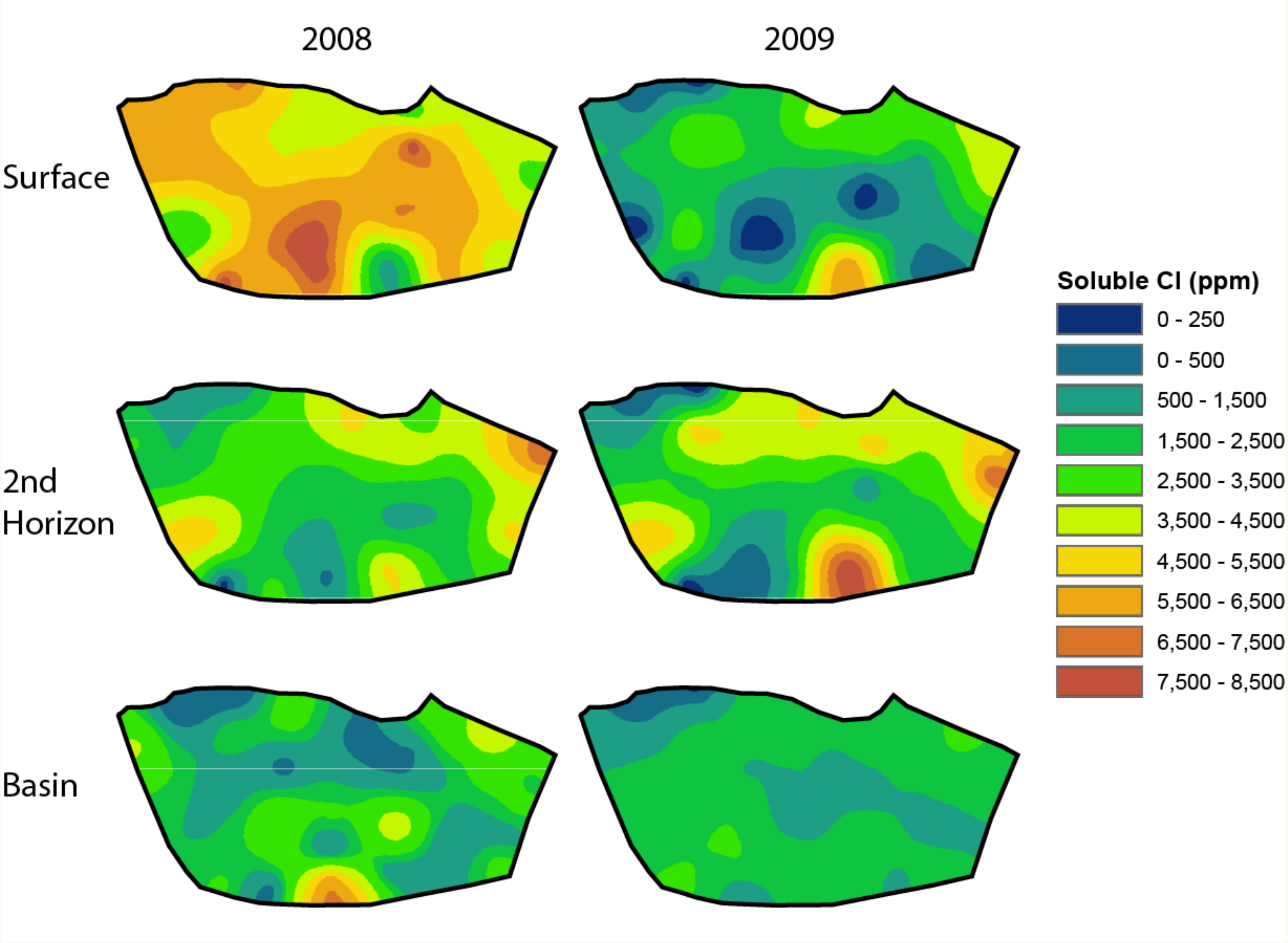
0 100 200 300

—— 20 cm Depth to Basin Contours

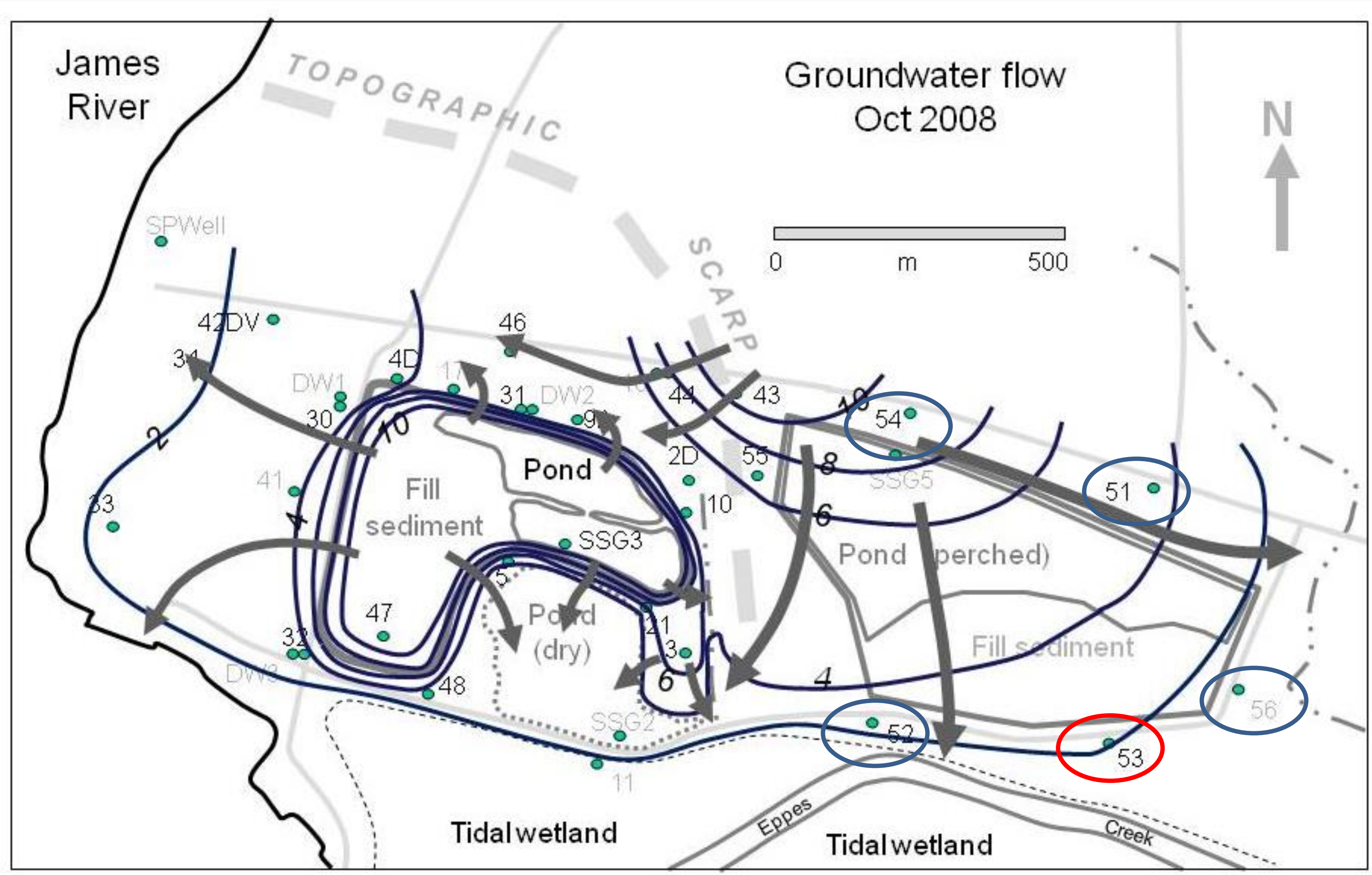
N

Projection: Lambert Conformal Conic
Central Meridian: 80° W
Standard Parallel 1: 37° N
Standard Parallel 2: 40° N

Chloride concentrations in the "initial" dredged materials averaged 17,675 ppm.



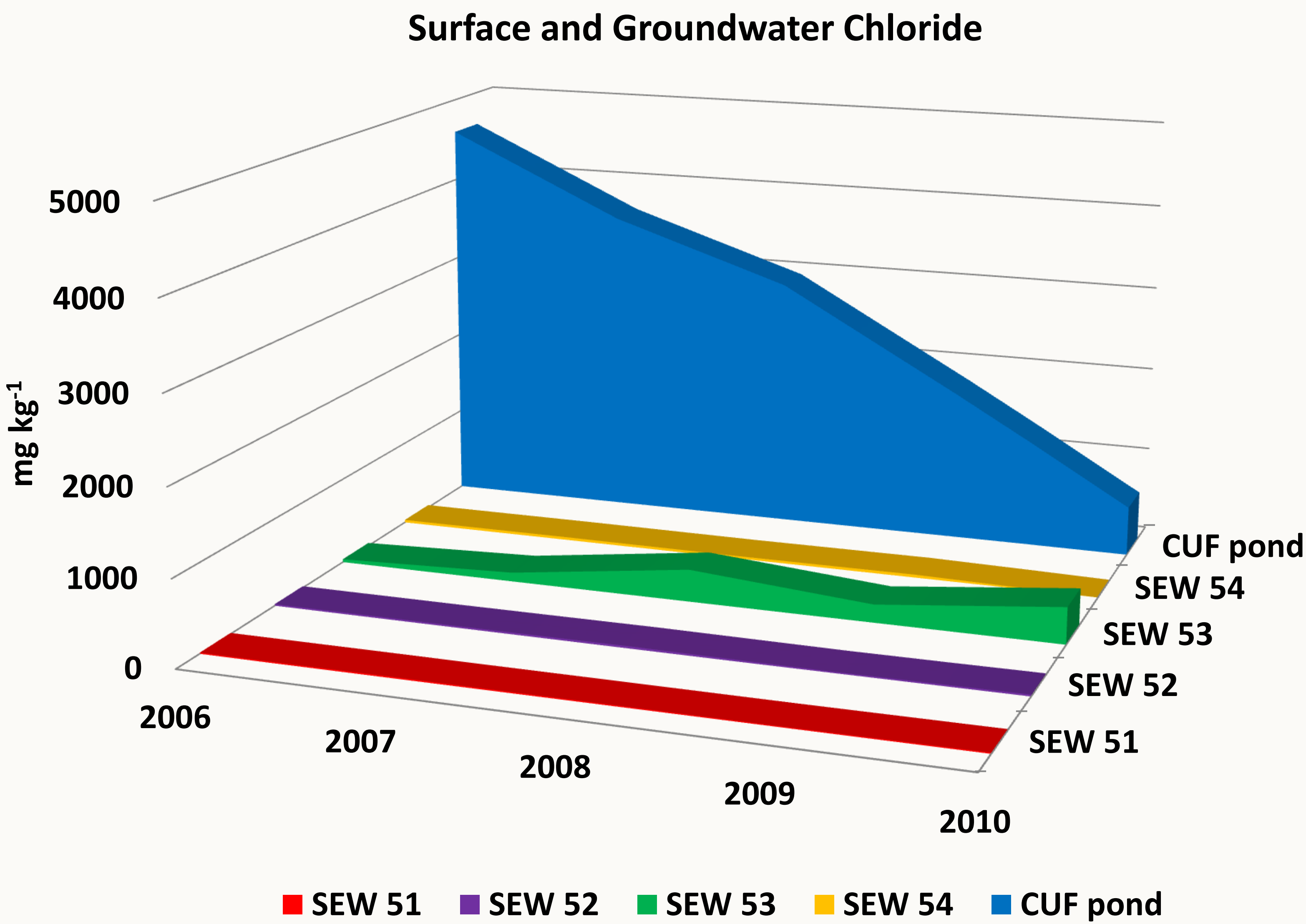
Where do the salts ultimately go?

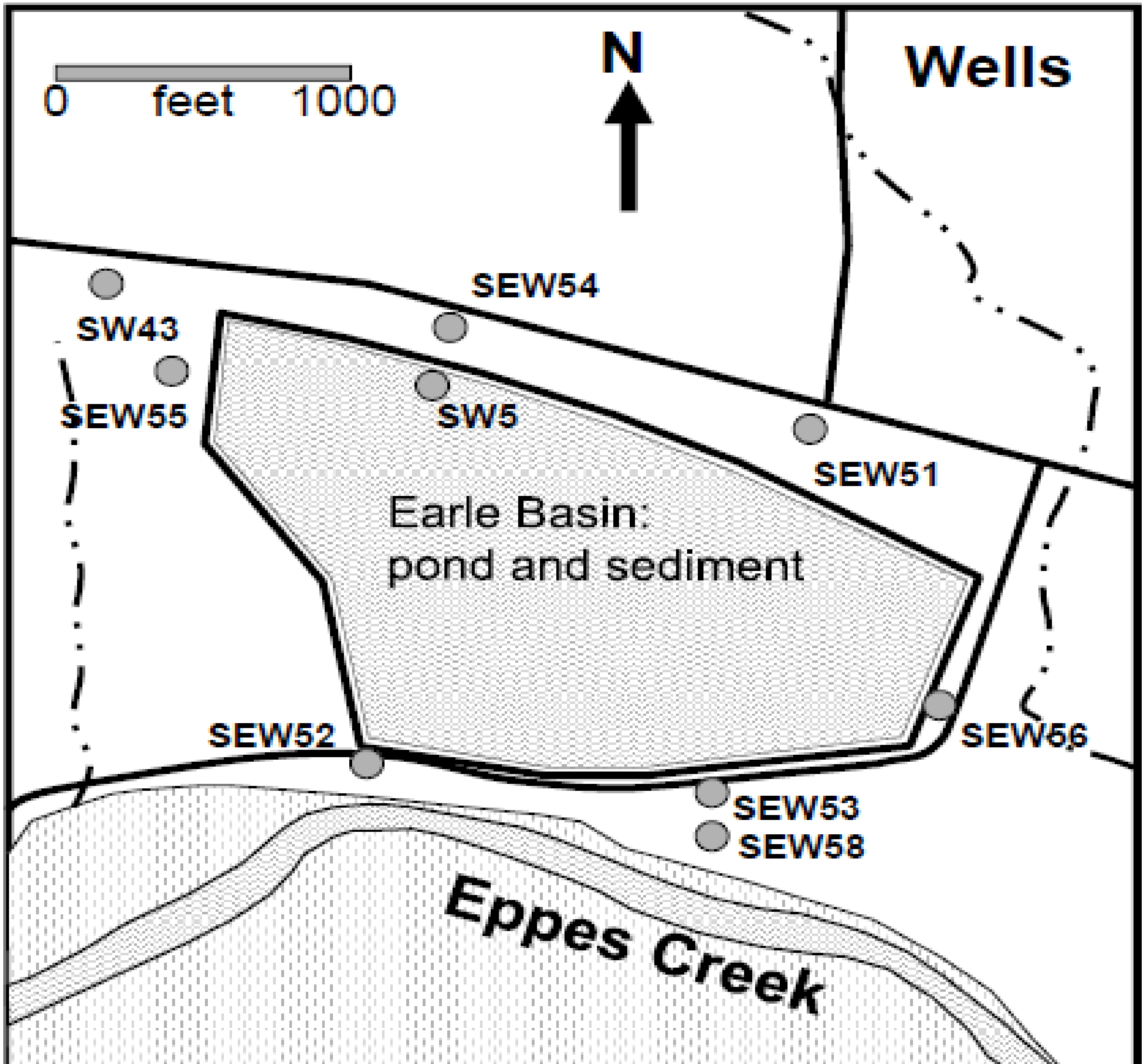


Groundwater Flow

Groundwater Isolines

Early results indicated a small Cl^- migration from CUF to groundwater.




0 feet 1000
N
Wells
SEW54
SW43
SEW55
SW5
SEW51
Earle Basin:
pond and sediment
SEW52
SEW56
SEW53
SEW58
Eppes Creek

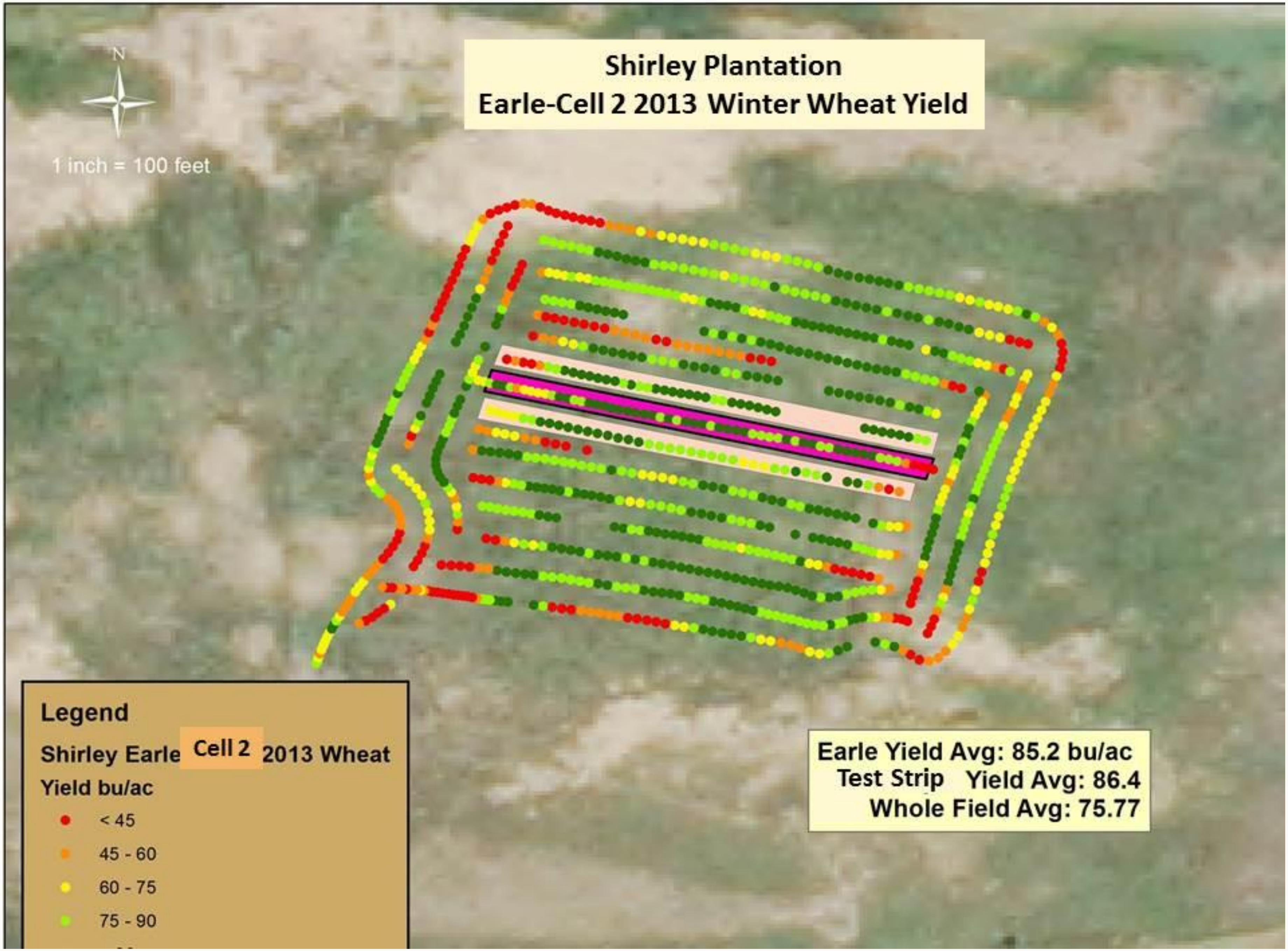
EC and Cl^- Over Time

- In well 53 (immediately outside of dike), EC increased from 300 to 4400 µs/cm and Cl^- increased from < 200 to 1400 mg/L. Levels between 2013 and 2014 are stable and not increasing further. The "rock road drain" was sealed in early 2013.

- Two other wells, clearly downgradient, have shown no effect with time.

- In 2012, we installed another well (58) further downgradient towards Epps Creek. EC Levels increased from ~400 µs/cm in 2012 to 870 µs/cm in early 2014.


In 2011-2012 another layer of material from Yorktown Annex was deposited and the basin was subdivided.
Cell 4
Cell 1
Cell 2
Cell 3
N
© 2013 Google
Google earth
1994
Imagery Date: 10/21/2012 37°20'12.37" N 77°14'35.67" W elev 26 ft eye alt 2952 ft



Shirley Plantation
Earle-Cell 2 2013 Winter Wheat Yield
N
1 inch = 100 feet
Legend
Shirley Earle Cell 2 2013 Wheat
Yield bu/ac
< 45
45 - 60
60 - 75
75 - 90
Earle Yield Avg: 85.2 bu/ac
Test Strip Yield Avg: 86.4
Whole Field Avg: 75.77

Important Upland Placement Criteria for Agricultural Use

- **Salinity** – must be reduced to < 4.0 ds/m (mmhos/cm); ideally to < 2.0 over time. Where do the salts go?
- **Texture** – Ideally < 25% clay and < 70% silt+clay; Should be > 25% soil sized (< 2mm)
- **TOC** – levels above 5% are problematic
- **Potential Acidity** – Never routinely analyzed for; commonly a major problem!

4 year old soil in Baltimore Harbor dredged materials with *sulfuric horizon* to 30 cm with pH 3.3 formed from *sulfidic materials* like black Cg horizon at base of profile with pH about 7.0.

Conclusions

- **Less than four years after placement/ dewatering, all soils had ripened sufficiently to form “wet” cambic horizons.**

- **The more leached soils were Fluvaqentic Epiaquepts while the more saline soils classified as Typic Halaquepts.**

- **Large reductions in salinity (> 50% initial EC) were evident in all horizons including unaltered Cg horizons, although most of the soils would still be classified as saline-sodic for agricultural purposes.**

Conclusions

- **Cation redistributions on the exchange complex with depth over time suggest the soils underwent rapid pedogenesis and achieved the composition of 30 year-old confined freshwater dredged materials in less than five years.**

- **A significant increase of TDS in one downgradient groundwater well was noted just outside of the retention berm, but not at two others. EC, Cl and SO_4 are regulated with secondary non-enforceable criteria. Is this a problem?**

- **Following a second deposition of saline dredge and subsequent curing, winter wheat was established on the central portion of the CUF and 2013 yields were similar to surrounding undisturbed prime farmland.**

Questions or Comments

Nick Haus and Steve Nagle sampling Earle Basin