Waiting for Wet

Soil Moisture in Freshwater Wetland Restoration

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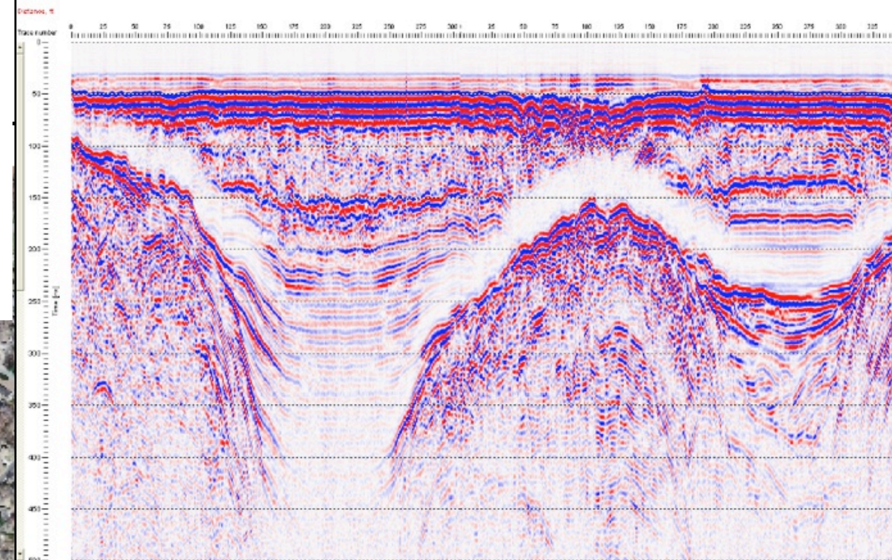
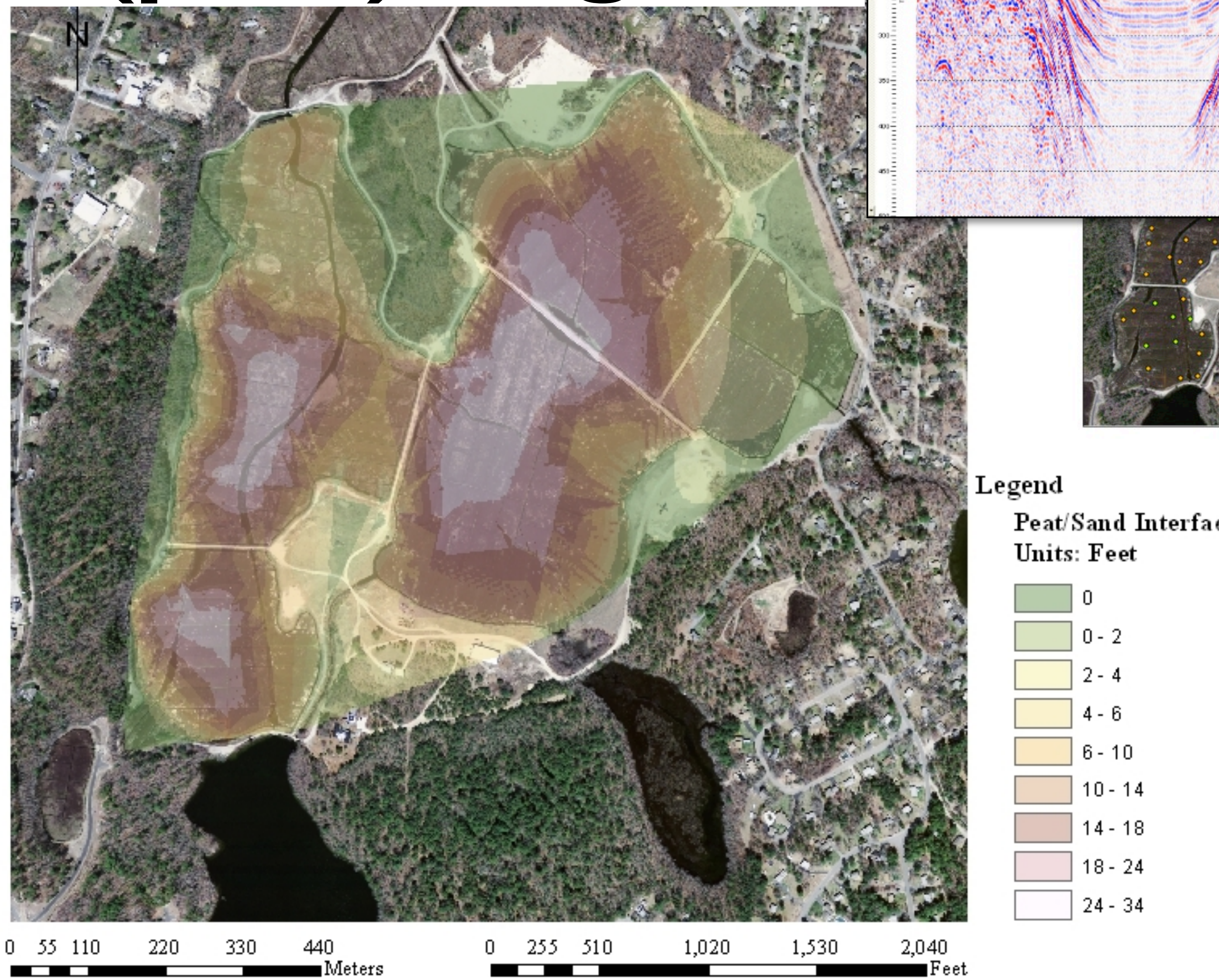
Narrative Arc

- What is a bog and why (and how) do we grow cranberries on them?
- Where is Tidmarsh farms (physically, hydrologically and geologically), and why did it become a freshwater marsh restoration…
- Who cares about soil moisture there, and how do we plan to measure it?
- What can soil moisture tell us (***science***)?
- How is restoration success measured ($\boldsymbol{\theta}$) ?
- More about the restoration, planning observations

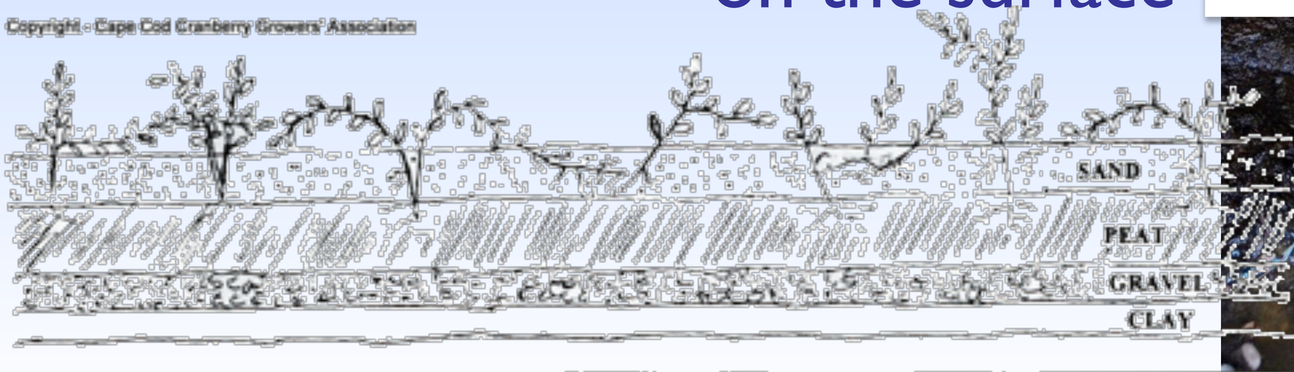
Once upon a (peat) bog…





Cranberry Farming

- Sand is applied every 1-3 years
- Ditched and drained
- Peat below maintains water table on the surface

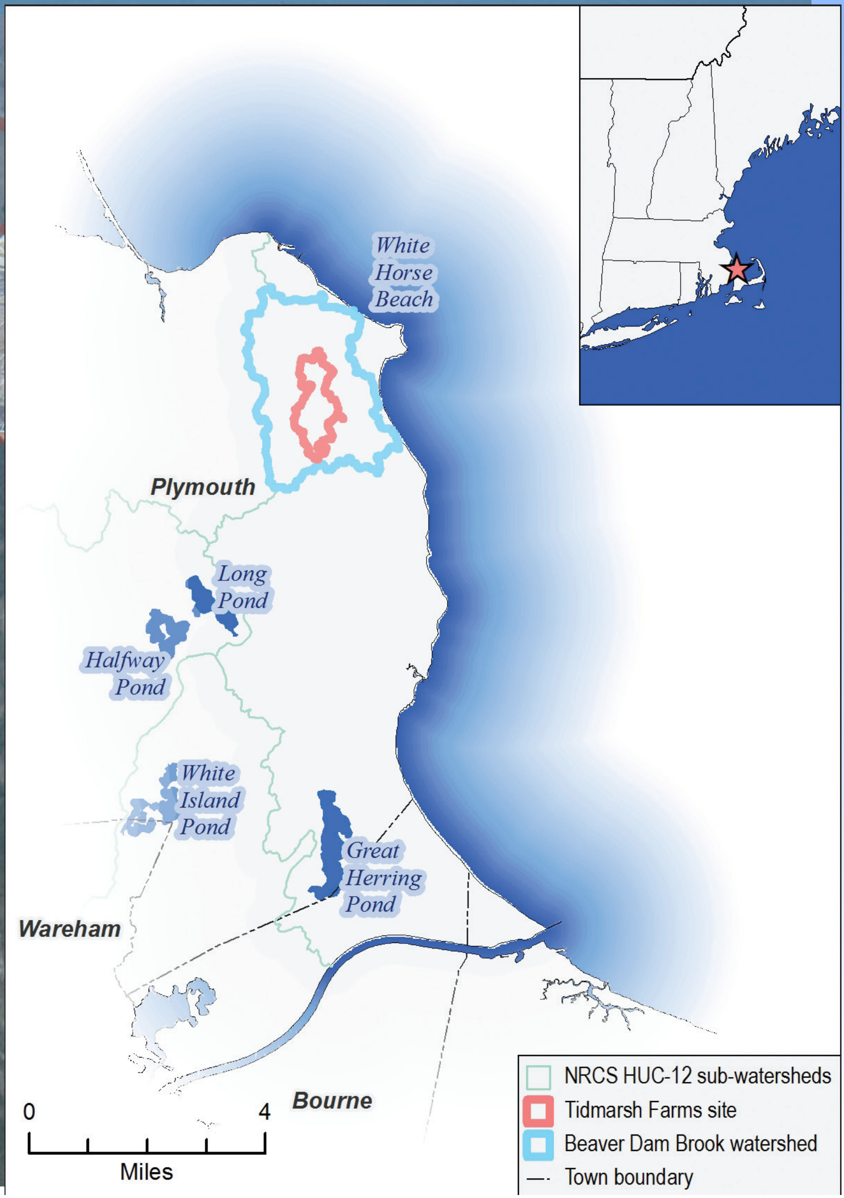


Cranberry farming is water intensive

- Water is used for frost protection and harvest – levels can fluctuate dramatically
- Farm surface is a flat, well-drained monoculture
- Flow-through farm
- Farming impacts (fertilizers, herbicides, pesticides, helicopter work, weed harvesting in river, discharge after flooding) can be disruptive

Where is Tidmarsh Farms?

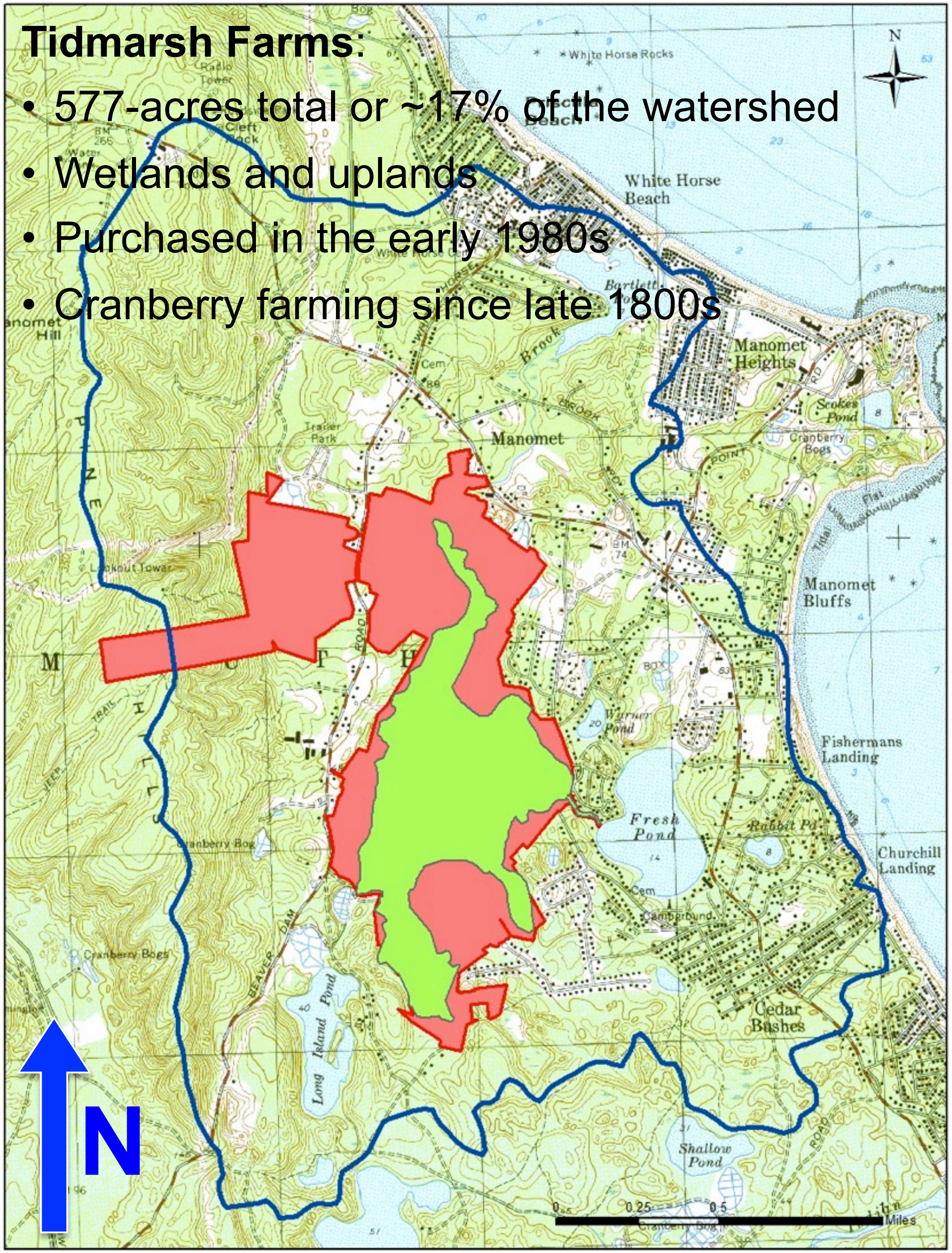
Where is Tidmarsh Farms?



Removal of one barrier: beginning of a restoration project

- Aging infrastructure in poor condition (cost of maintenance and repair; liability)
- Reservoir no longer required for agriculture
- Ecological and visual integrity of stream and wetland ecosystems

Tidmarsh Farms Background



Tidmarsh Farms:

- 577-acres total or ~17% of the watershed
- Wetlands and uplands
- Purchased in the early 1980s
- Cranberry farming since late 1800s

Restoration Site:

- Approximately 250-acres or ~ 7% of the entire watershed
- Includes 192-acres of conservation easement (NRCS WRP program)

Tidmarsh Farms Restoration Project

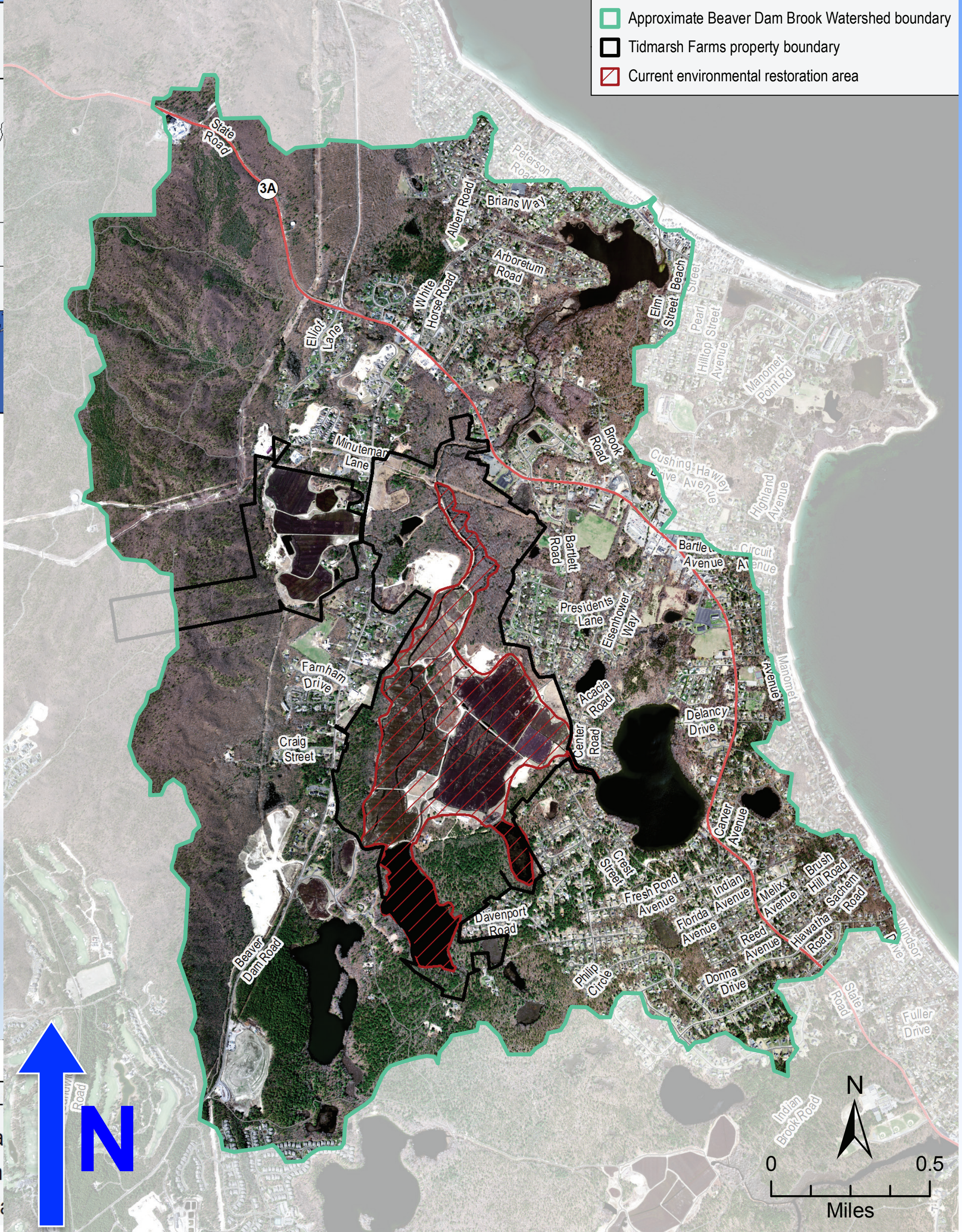
Goals:

1. To transform the site into a diverse and self-sustaining wetland and riverine habitat;
2. To improve fish passage; and,
3. To create a place (or opportunities) for public use and enjoyment.

Actions:

1. An anthropogenic sand layer that is causing the site to dry out and essentially transition away from wetland plant communities;
2. Barriers that prevent the free movement of fish, wildlife, water, and sediment; and,
3. Physical simplification with no hydrologic driver for change (given site and watershed conditions).


White Horse Beach
Plymouth
Long Pond
Halfway Pond
White Island Pond
Great Herring Pond
Wareham
Bourne
0
4
Miles
NRCS HUC-
Tidmarsh Fa
Beaver Dam
Town bounda


Approximate Beaver Dam Brook Watershed boundary
Tidmarsh Farms property boundary
Current environmental restoration area
State Road
3A
Brians Way
Albert Road
Arboretum Road
White Horse Road
Elliot Lane
Elm Street
Beach Street
Pearl Street
Hilltop Avenue
Manomet Point Rd
Minuteman Lane
Brook Road
Cushing Drive
Hawley Avenue
Highland Avenue
Bartlett Road
Bartlett Avenue
Circuit Avenue
Presidents Lane
Eisenhower Way
Farnham Drive
Acacia Road
Manomet Avenue
Delancy Drive
Center Road
Craig Street
Carver Avenue
Crest Street
Fresh Pond Avenue
Indian Avenue
Florida Avenue
Melix Avenue
Brush Hill Road
Sachem Road
Reed Avenue
Hiawatha Road
Davenport Road
Beaver Dam Road
Philip Circle
Donna Drive
State Road
Fuller Drive
Indian Brook Road
N
0
0.5
Miles

Tidmarsh Farms Restoration Project

Criteria for success:

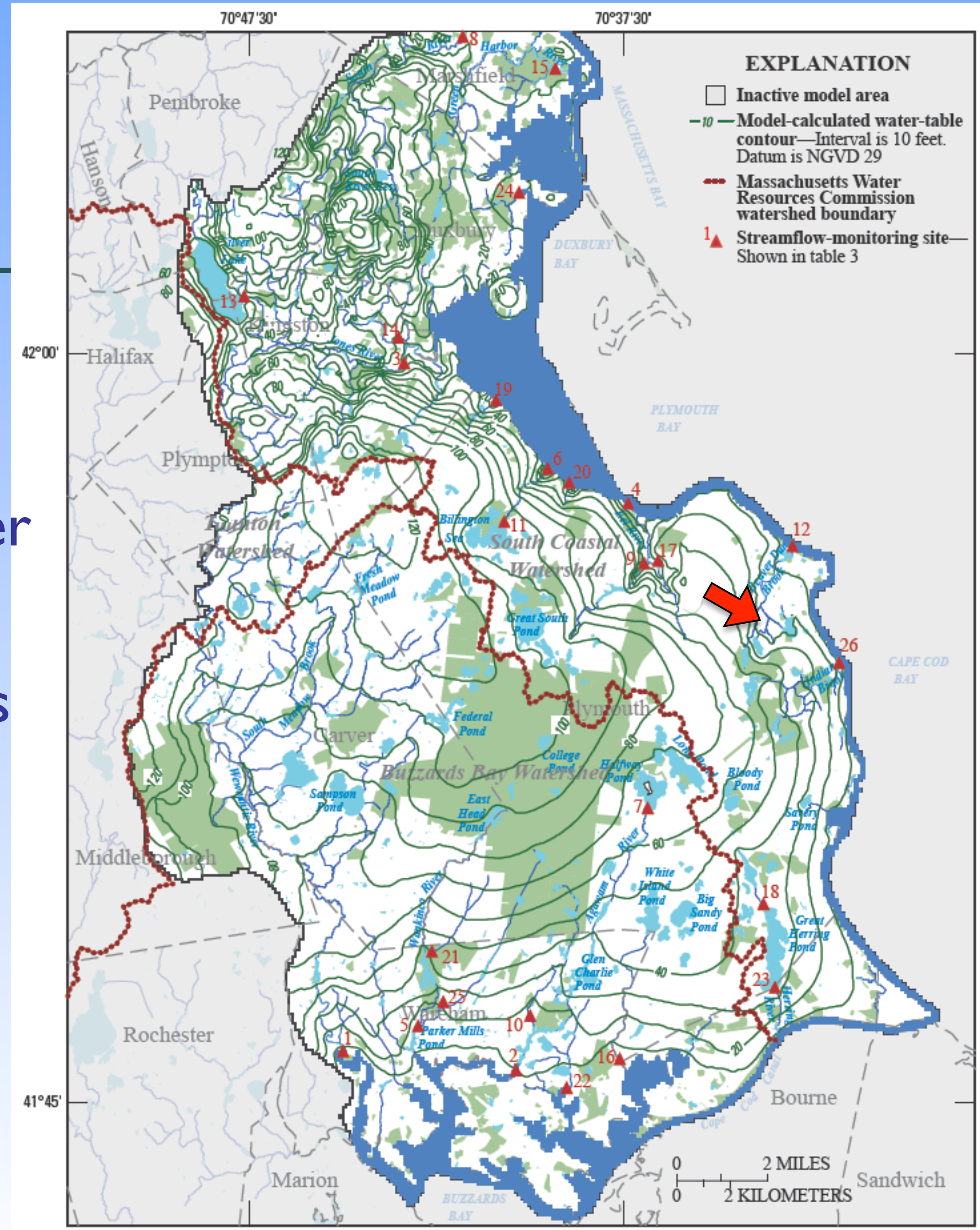
1. establishment of hydrological conditions and a soil moisture regime capable of supporting native wetland plant communities;
2. elimination of all barriers,
3. improvement to stream and wetland habitat.

Contingency Plans:

1. Insufficient soil moisture to support wetland communities.;
2. Significant colonization by invasive non-native species.

Hydrologic Context

- Beaver Pond Brook Surface Watershed
- Part of Plymouth-Carver Groundwater Aquifer
- Isostatic rebound drives freshwater discharge toward the coast



Base from U.S. Geological Survey and Massachusetts Geographic Information System data sources, Massachusetts State Plane Coordinate System, Mainland Zone

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Groundwater Dominates

- Control on water temperature
- Responsible for majority of discharge in Beaver Pond Brook
- Strongly dependent on subsurface geology

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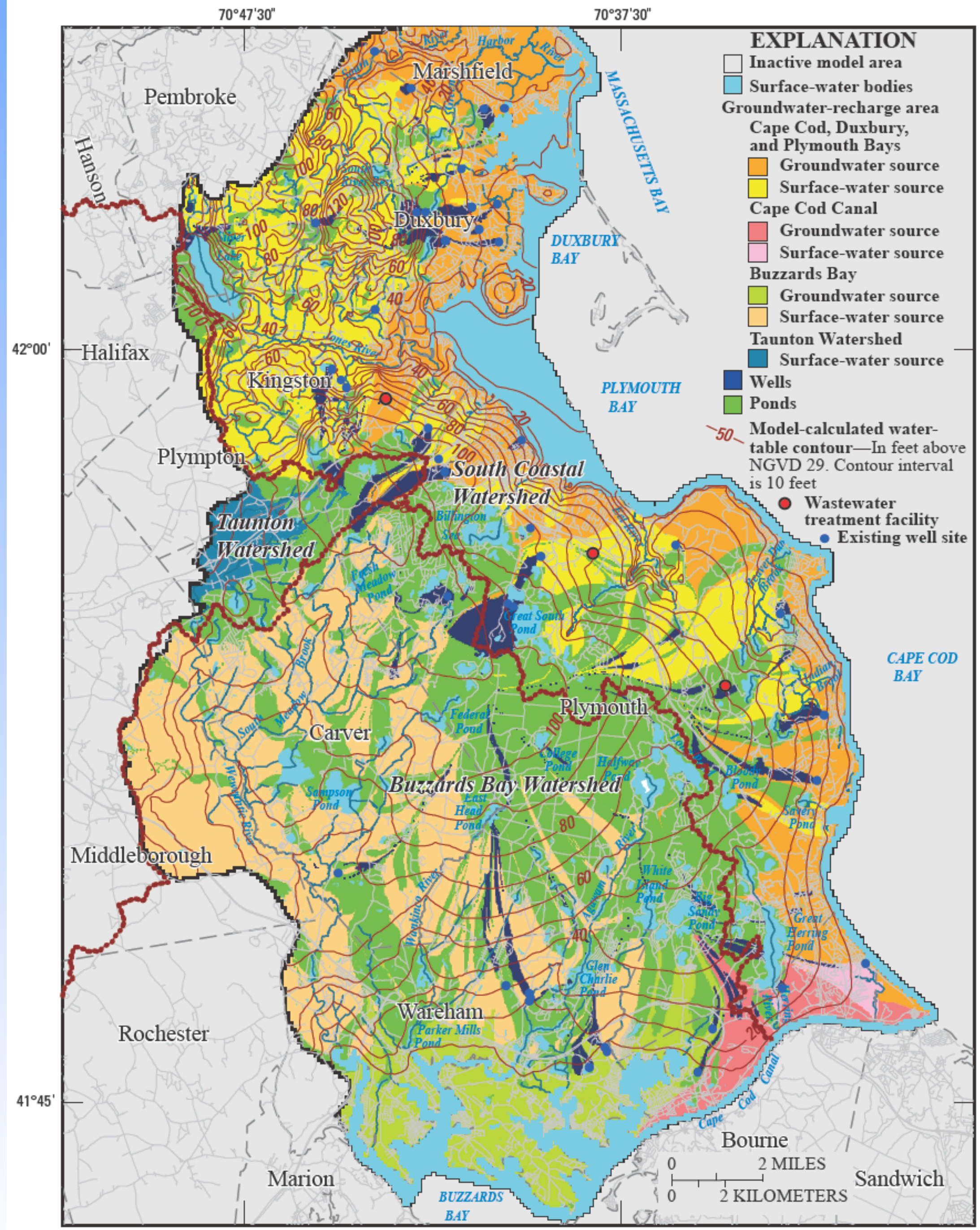
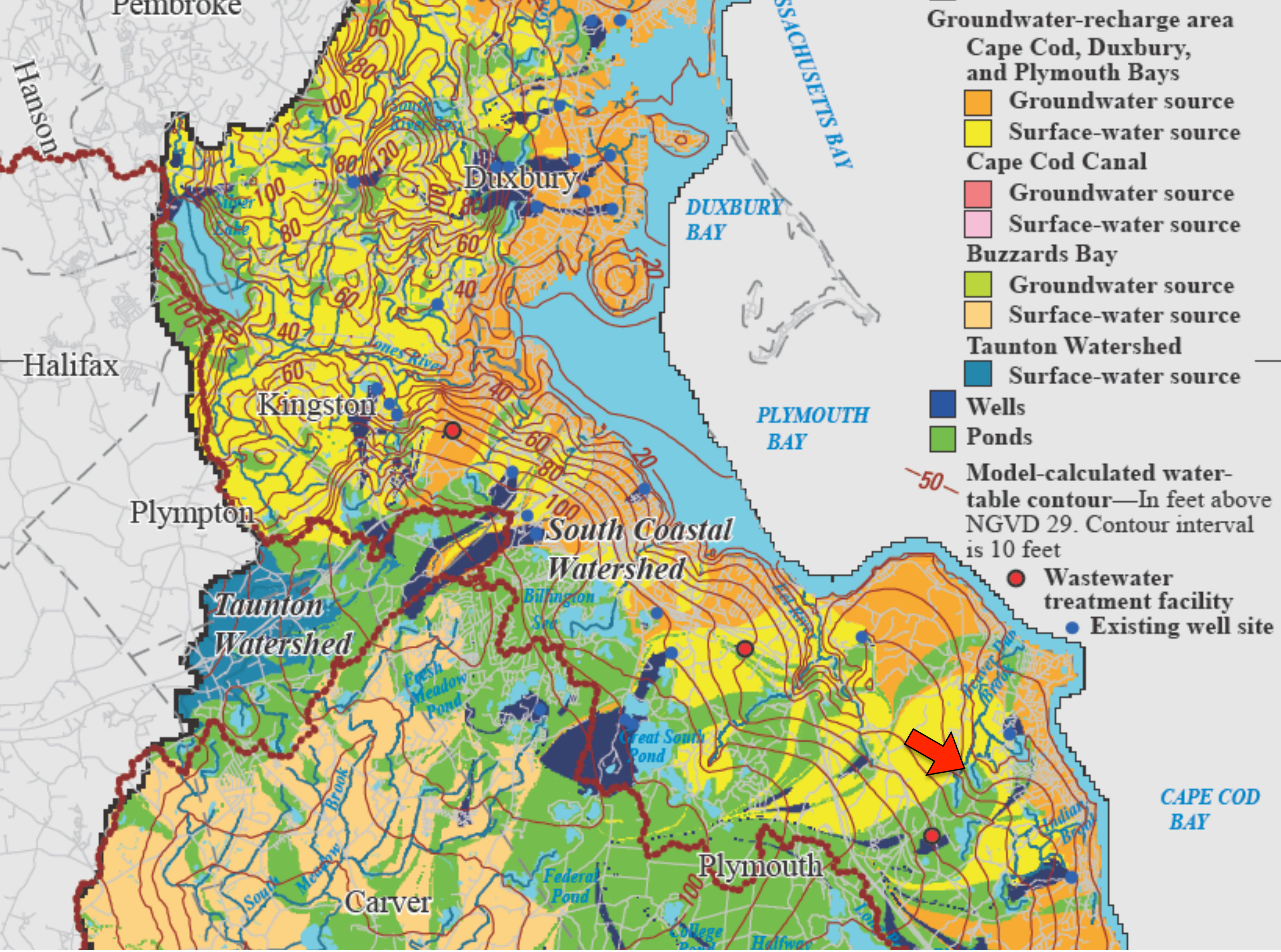
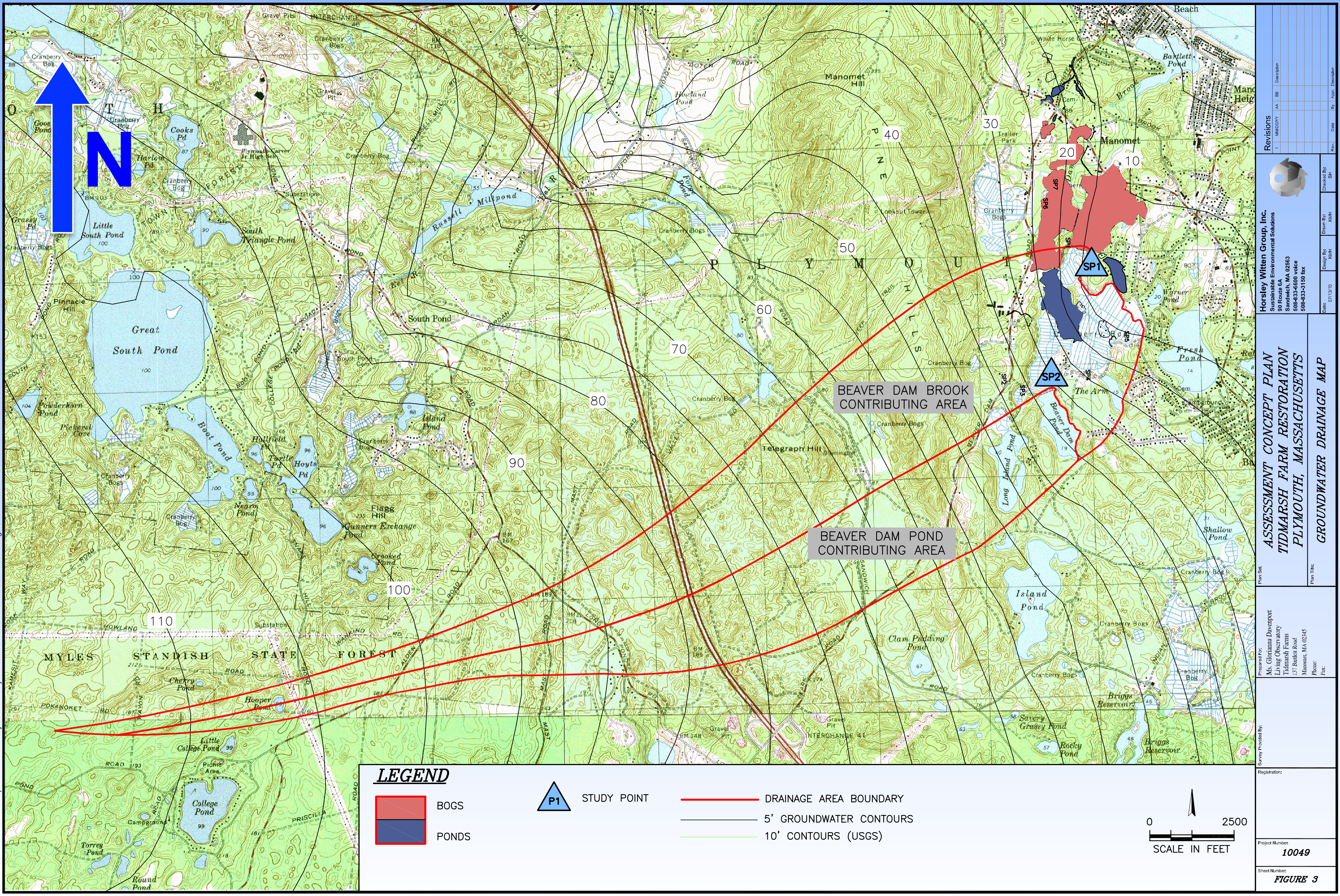


Base from U.S. Geological Survey and Massachusetts Geographic Information System data sources, Massachusetts State Plane Coordinate System, Mainland Zone

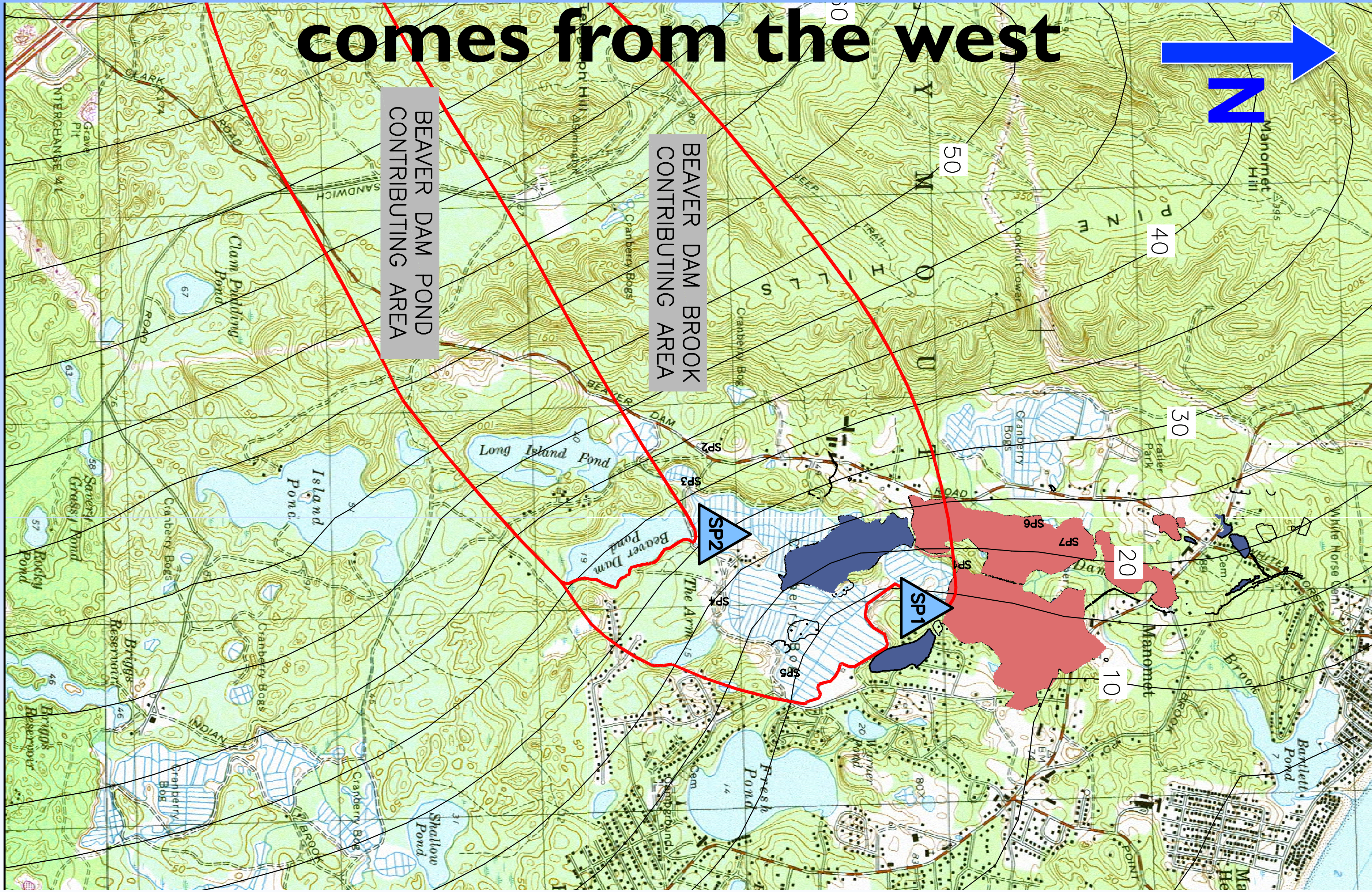

Pembroke
Hanson
Halifax
Kingston
Plympton
Duxbury
Carver
Plymouth
South Coastal Watershed
Taunton Watershed
Silver Lake
Jones River
Billington Sea
Fresh Meadow Pond
Great South Pond
Federal Pond
College Pond
Beaver Dam Brook
Indian Brook
DUXBURY BAY
PLYMOUTH BAY
CAPE COD BAY
MASSACHUSETTS BAY
Groundwater-recharge area
Cape Cod, Duxbury, and Plymouth Bays
Groundwater source
Surface-water source
Cape Cod Canal
Groundwater source
Surface-water source
Buzzards Bay
Groundwater source
Surface-water source
Taunton Watershed
Surface-water source
Wells
Ponds
50
Model-calculated water-table contour—In feet above NGVD 29. Contour interval is 10 feet
Wastewater treatment facility
Existing well site

Looong groundwater flow paths…



last modified: 07/19/10 printed: 07/19/10 by kh H:\Projects\2010\10049 Tidmarsh Farms\Drawings - 10049\10049-MISC\10049-DR-EX.DWG

Groundwater discharge zone, water comes from the west



Soil Moisture Monitoring

Significance?

- soil moisture monitoring is the first indicator of "hydraulic" success of restoration
- soil moisture controls development of wetland plant communities and site ecohydrology

Uncertainties:

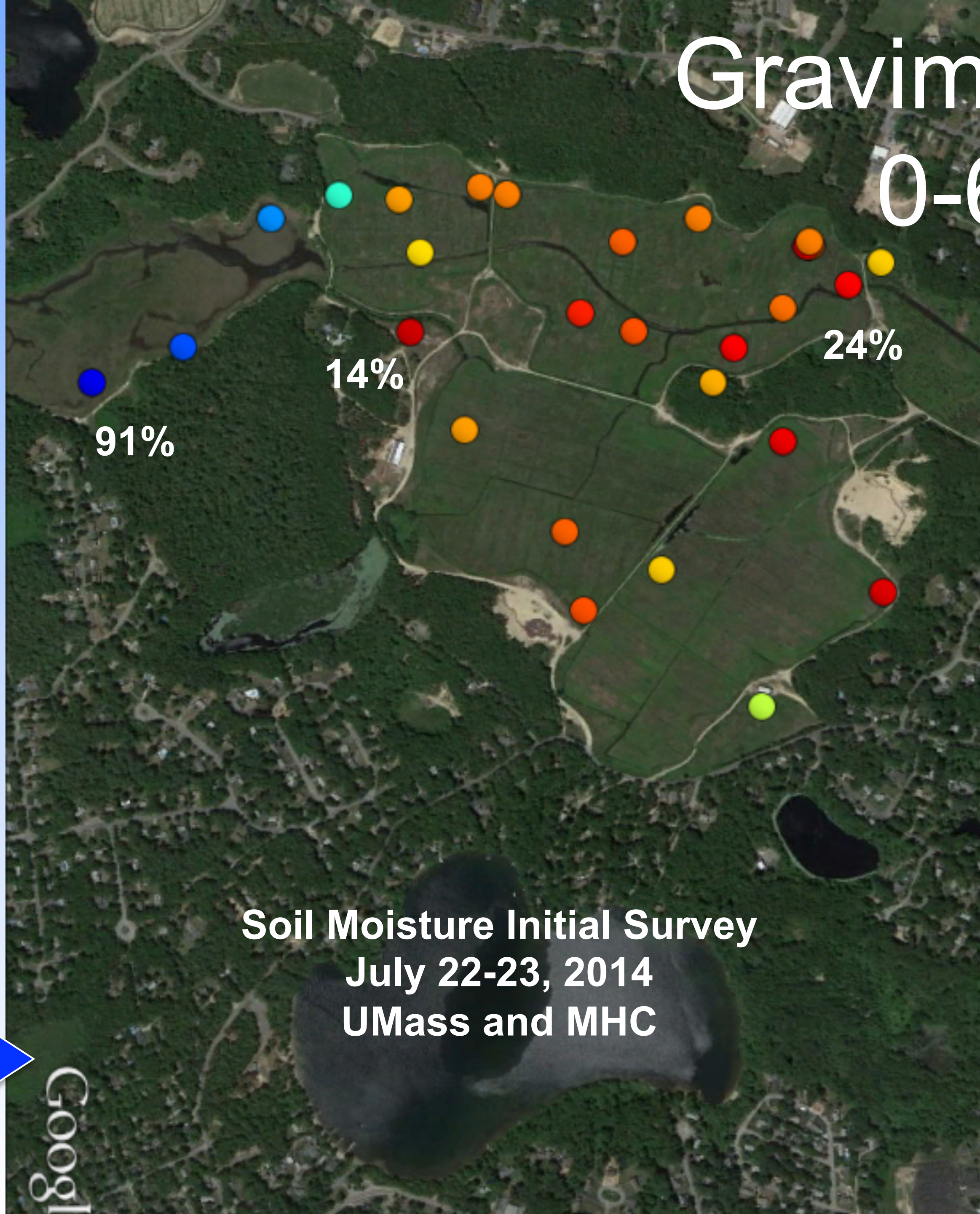
- Will it be wet enough (to support wetland plants)?
- Will invasives take over (before the natives can)?

Tests:

- Distributed and long-term soil moisture

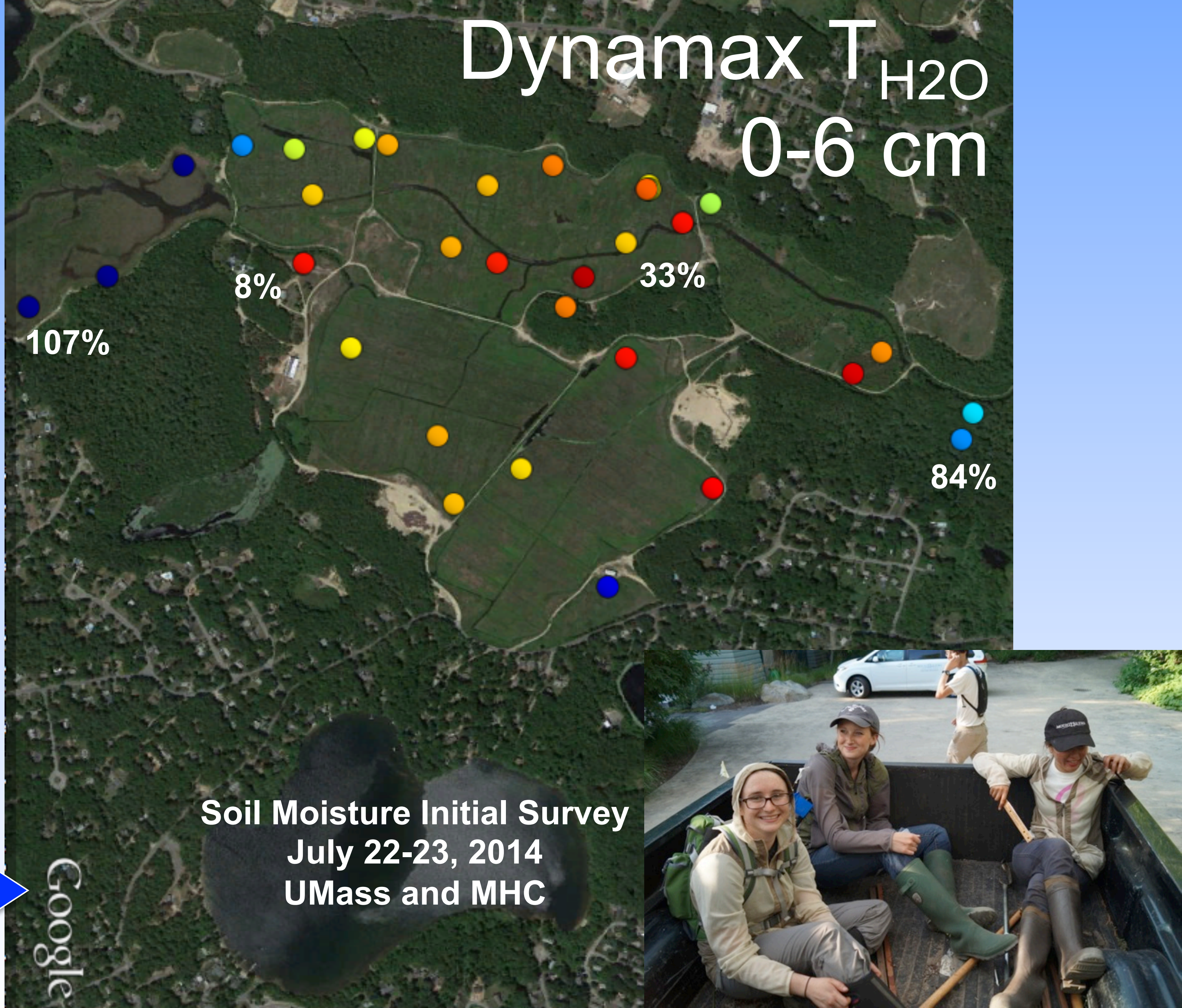
Soil Moisture Monitoring

Gravimetric 0-6 cm



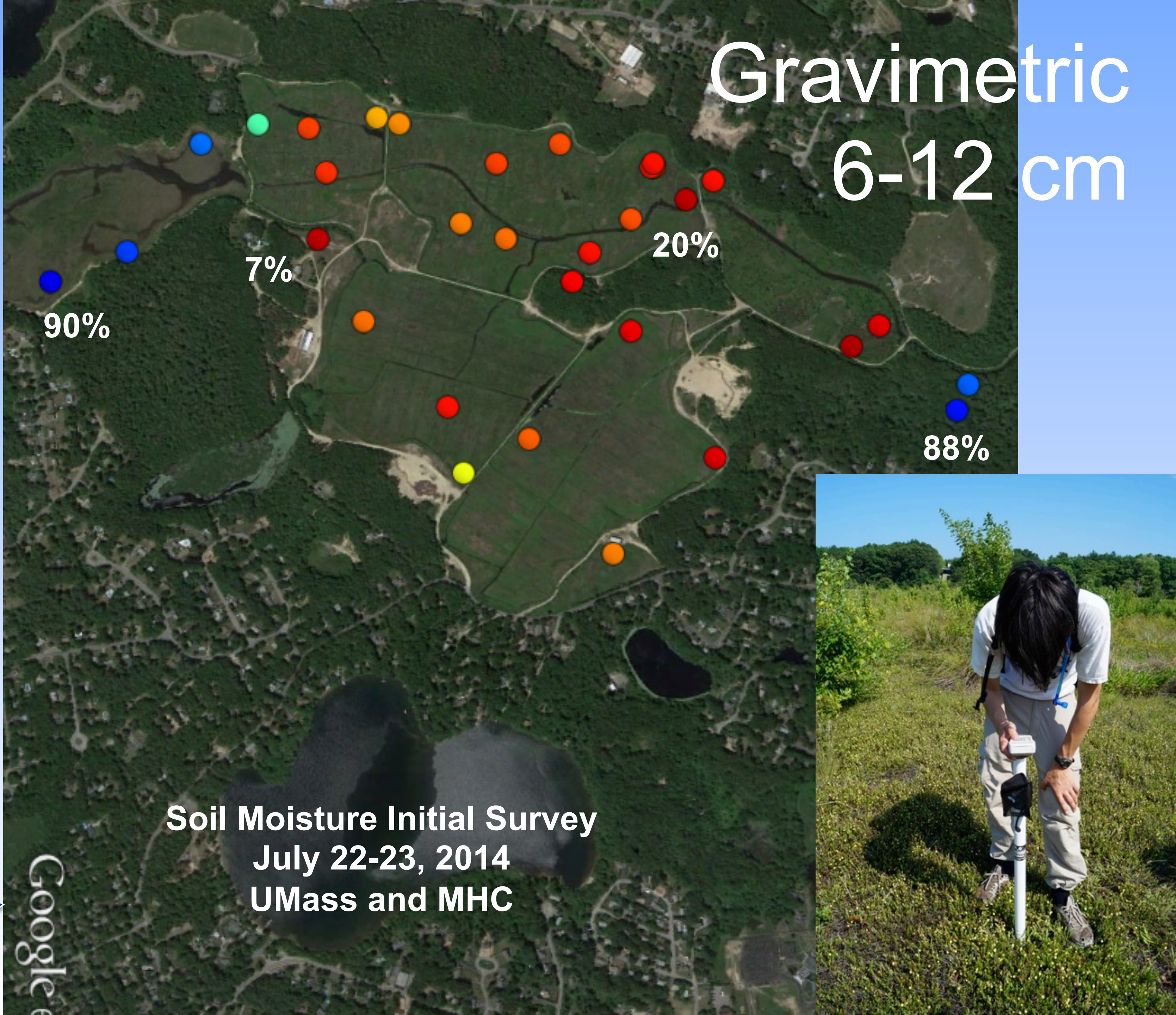
Soil Moisture Initial Survey
July 22-23, 2014
UMass and MHC

Dynamax T_{H2O} 0-6 cm



Soil Moisture Initial Survey
July 22-23, 2014
UMass and MHC

Gravimetric 6-12 cm



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Soil Moisture Monitoring

What question(s) the group is asking (significant/interesting)?

Do soil moisture patterns predict development of ecohydrology?

Do soil thermal properties (and/or moisture profiles) indicate specific nutrient regimes that support different ecotones?

Will microtopography generate large variability in surface moisture?

Will instream and landscape structures increase surface moisture?

What data has been collected and what are the main findings thus far?

Dynamax T_{H2O} and gravimetric soil moisture values are comparable

Further calibration is required for robust comparisons

Surface moisture across the site is varied and too dry for wetland plants

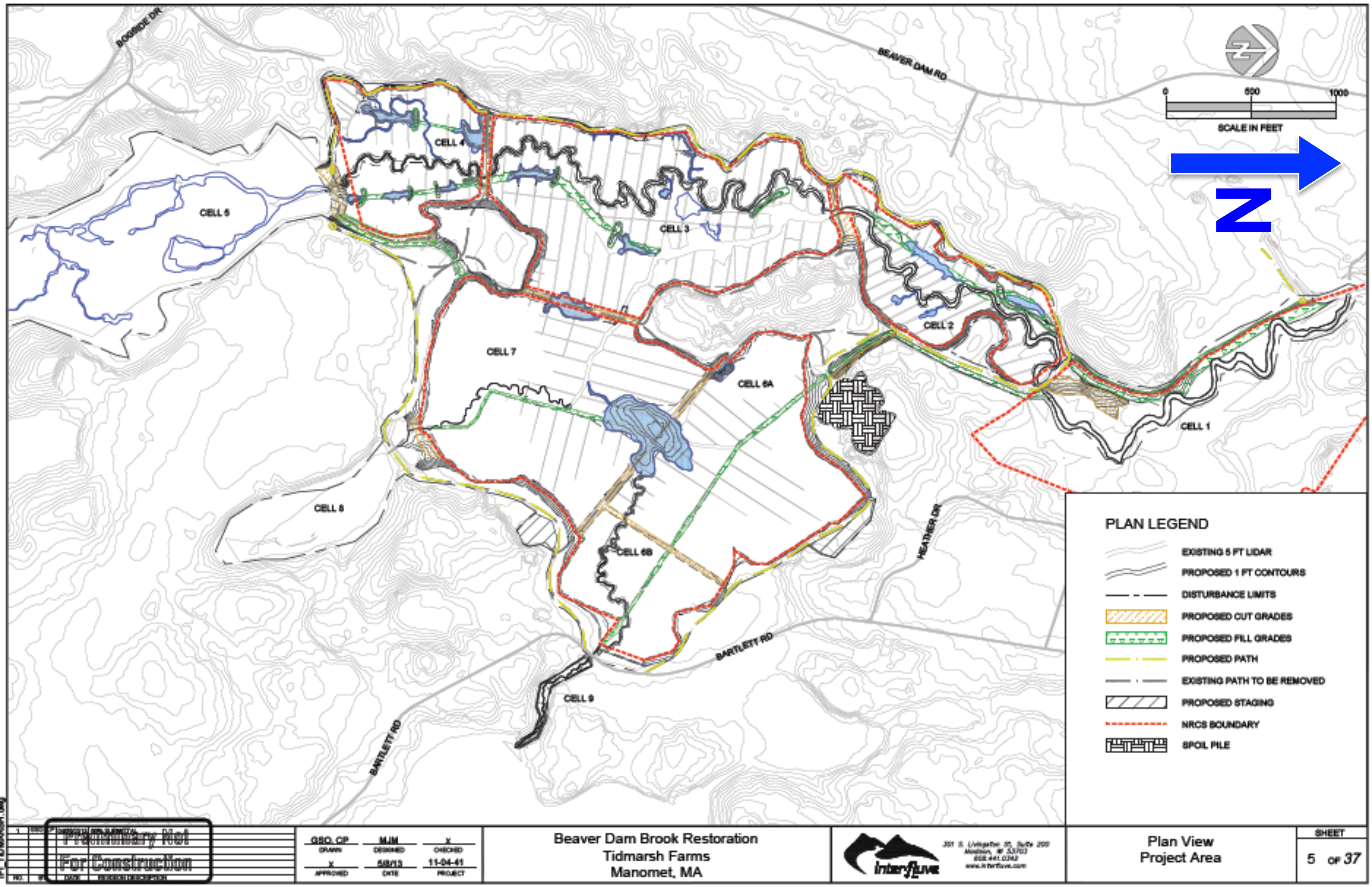
What you are doing next (e.g. 5 year plan)?

Install fiber-optic temperature transect (permanent)

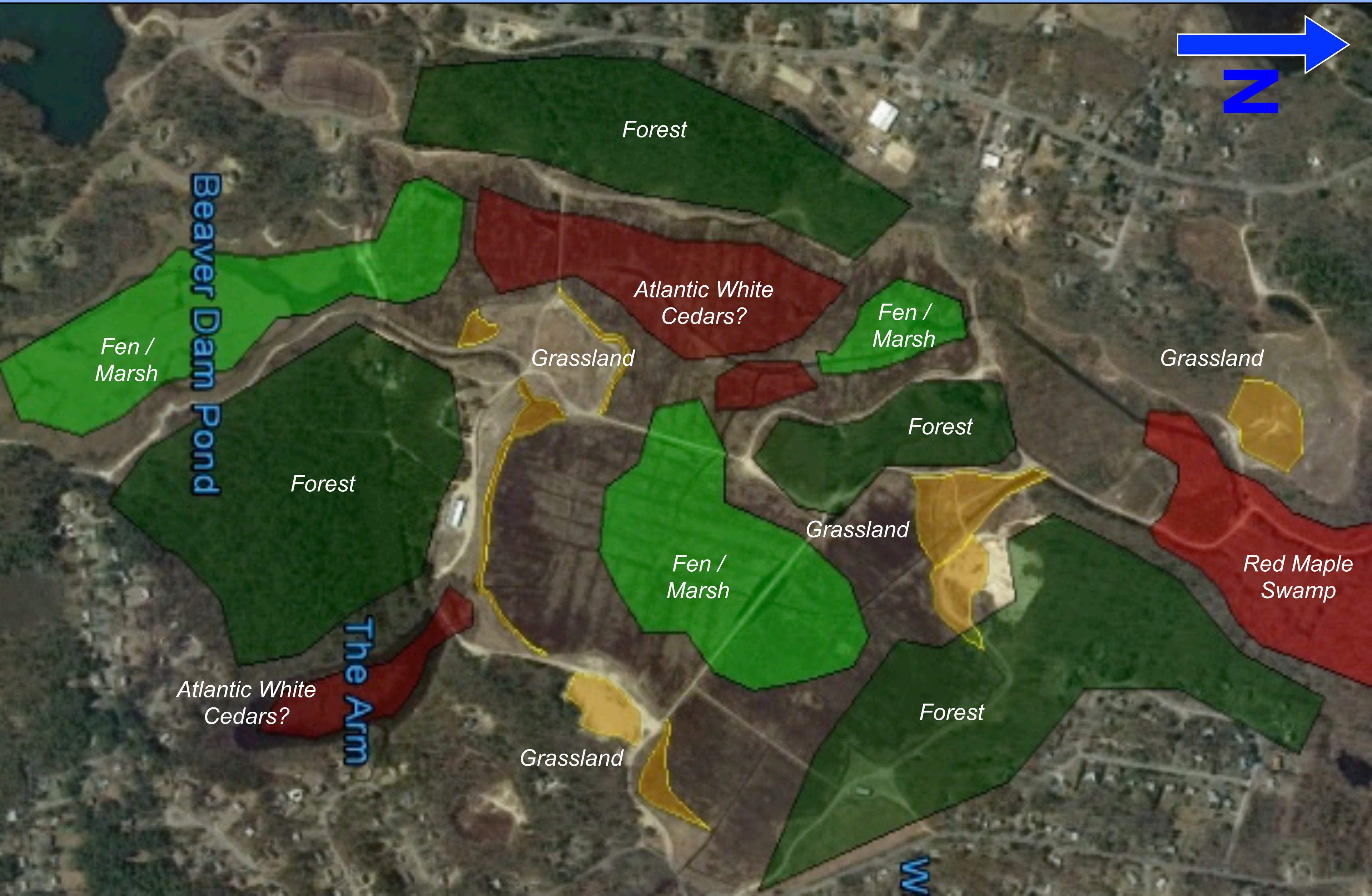
Install 3-4 long-term monitoring stations for ground-truthing all sensor networks

Collect periodic gravimetric and Dynamax T_{H2O} survey data

Engineering Plans for Restoration



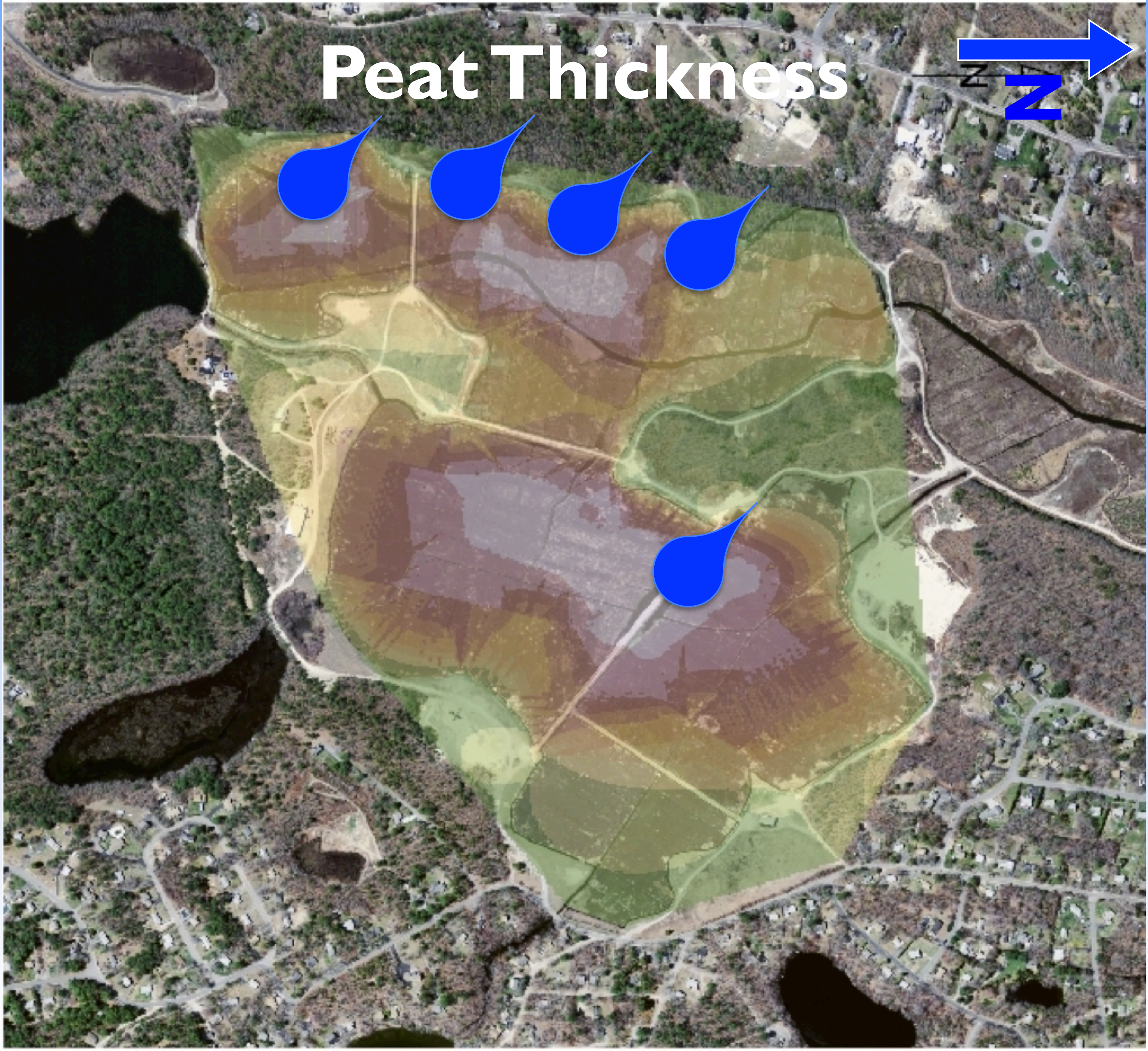
Where are habitat types expected?



Goals for cable placement

- Capture as many expected habitat/ ecosystem types as possible – represent entire site
- ~1500m (4900ft) linear transect across the site
- Intersect places that were dry and will be wet
- Intersect places that were wet and will be dry
- Cross new/ restored and former channel
- Cross old ditches, run down old ditches
- ***Feasible*** and complement individual sensors

Peat Thickness



Mother Nature and Father Time[1]

The end of "construction" is the start of restoration trajectory

Photos from Eel River Headwaters (Plymouth)
First comprehensive cranberry farm restoration project

1. *Commonly credited to William Mitch, OSU*

- Farming ceased in 2009
- Impoundment was drained in 2010

November 2010

August 2011

September 2012

Wetland Communities in 5, 10, 25, 50, 100 years???

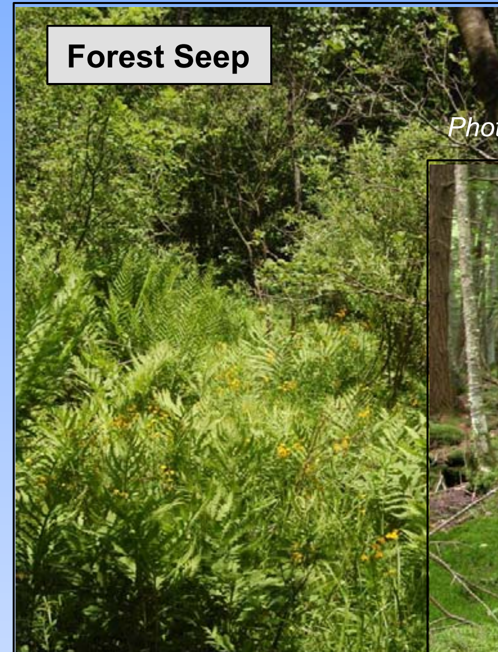
Other Habitat Types already established


Sandplain Grassland


The Knoll with Little Bluestem


Snapping Turtle looking for a spot

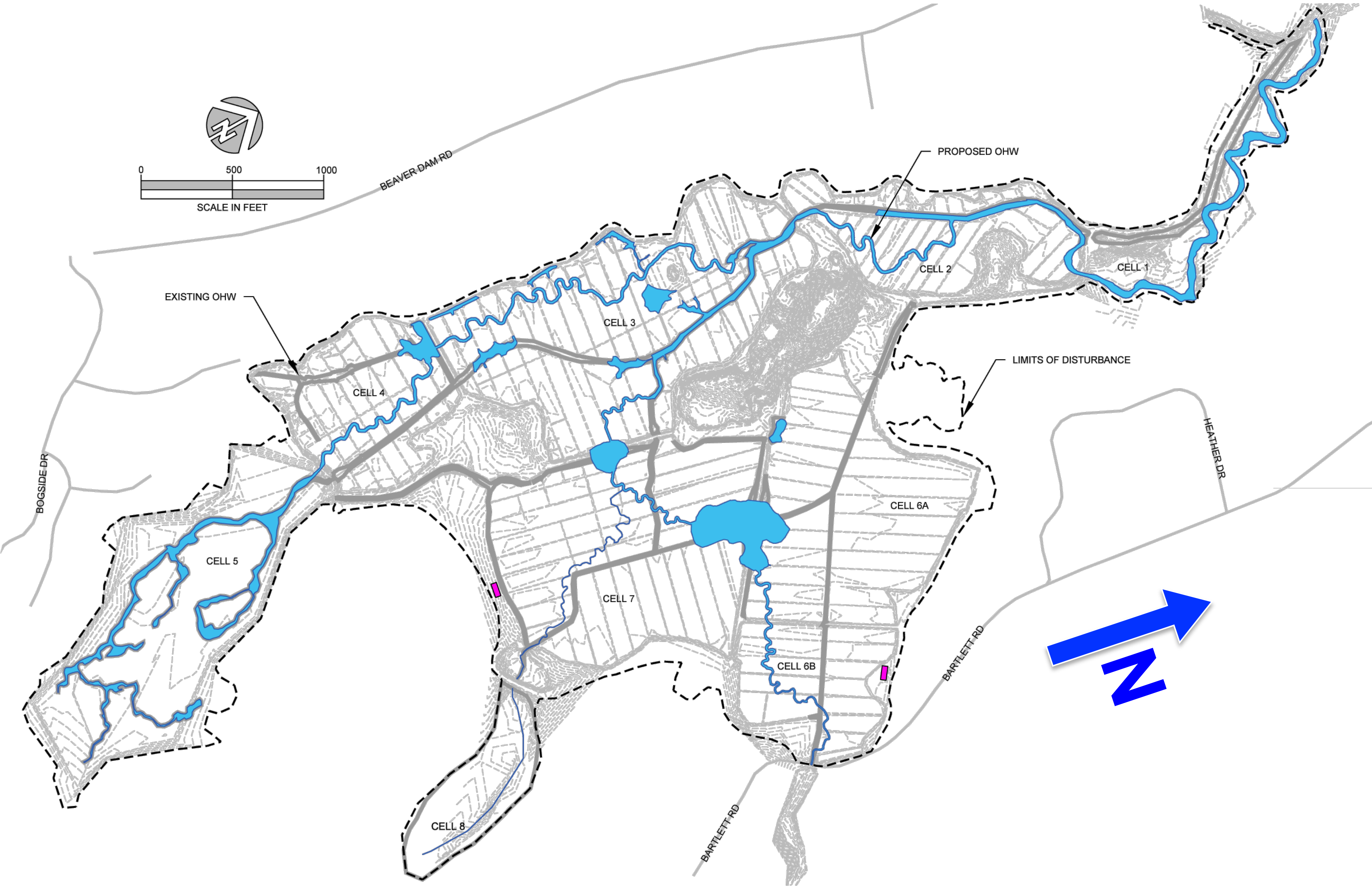
G. Davenport


Forest Seep

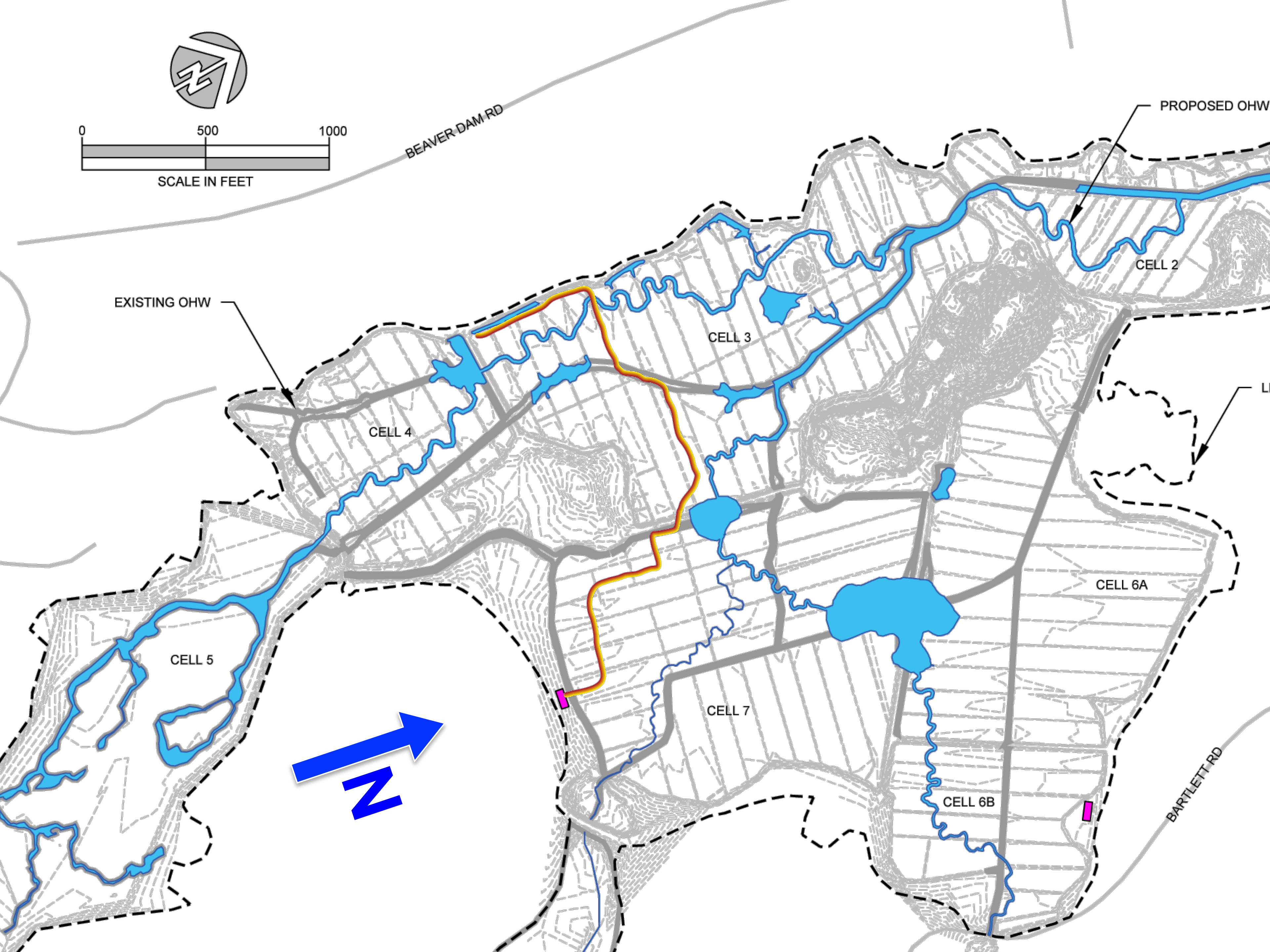
Photos courtesy of NHESP Fact Sheets

G. Davenport


Upland Forest & Woodlands



0
500
1000
SCALE IN FEET
BEAVER DAM RD
PROPOSED OHW
EXISTING OHW
LIMITS OF DISTURBANCE
CELL 1
CELL 2
CELL 3
CELL 4
CELL 5
CELL 6A
CELL 6B
CELL 7
CELL 8
BOGSIDE DR
HEATHER DR
BARTLETT RD
BARTLETT RD
N



0
500
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SCALE IN FEET
BEAVER DAM RD
PROPOSED OHW
EXISTING OHW
CELL 2
CELL 3
CELL 4
CELL 5
CELL 6A
CELL 6B
CELL 7
BARTLETT RD

0
500
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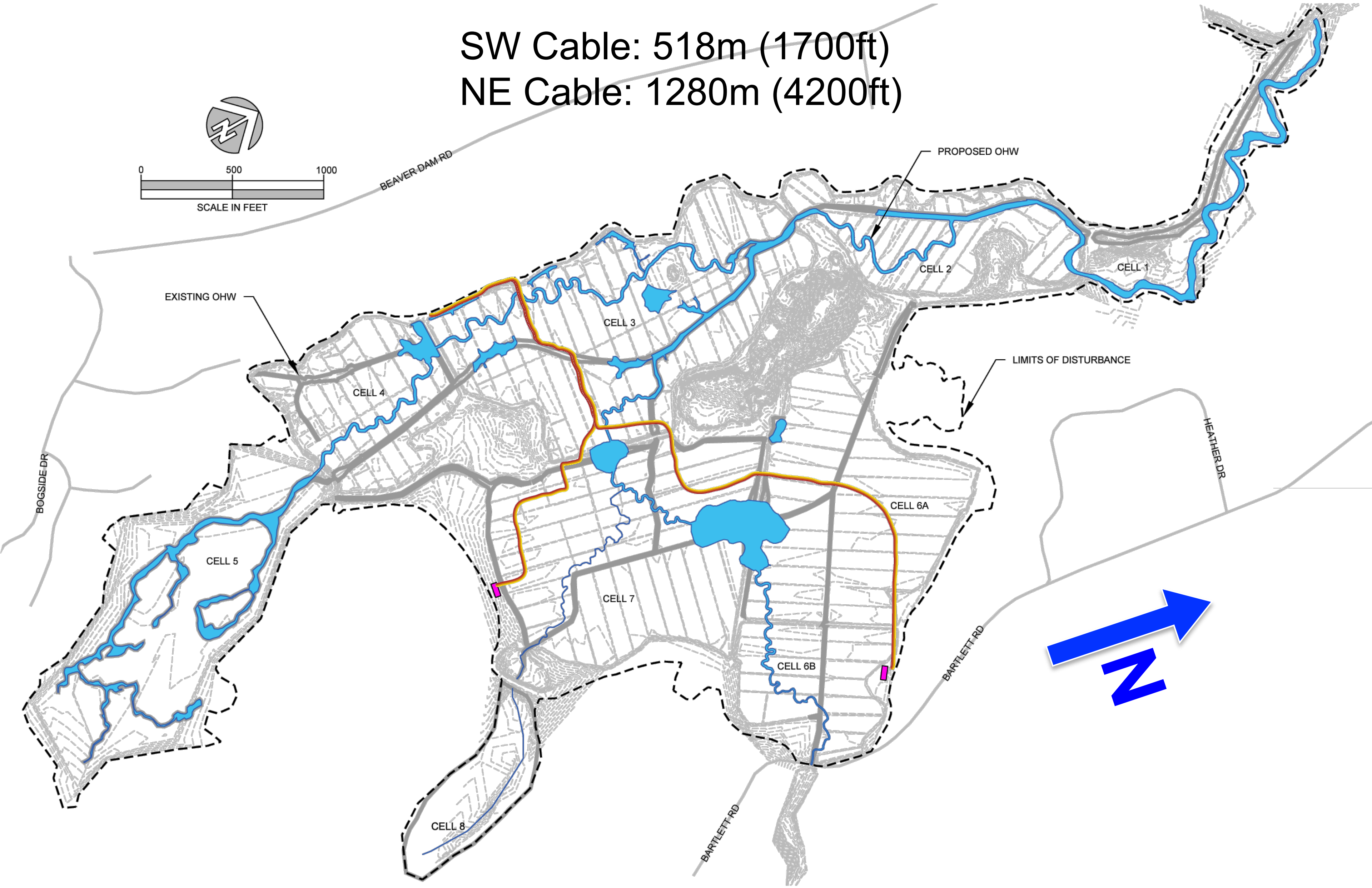
SCALE IN FEET
BEAVER DAM RD
PROPOSED OHW
EXISTING OHW
CELL 2
CELL 3
CELL 4
CELL 5
CELL 6A
CELL 6B
CELL 7
N
BARTLETT RD

SW Cable: 518m (1700ft)
NE Cable: 1280m (4200ft)



Science Questions for DTS

• How do invasives (phragmites?) behave hydrologically or thermally that is different than wetland plants? Can we resolve these differences? Can we devise an "early warning"?

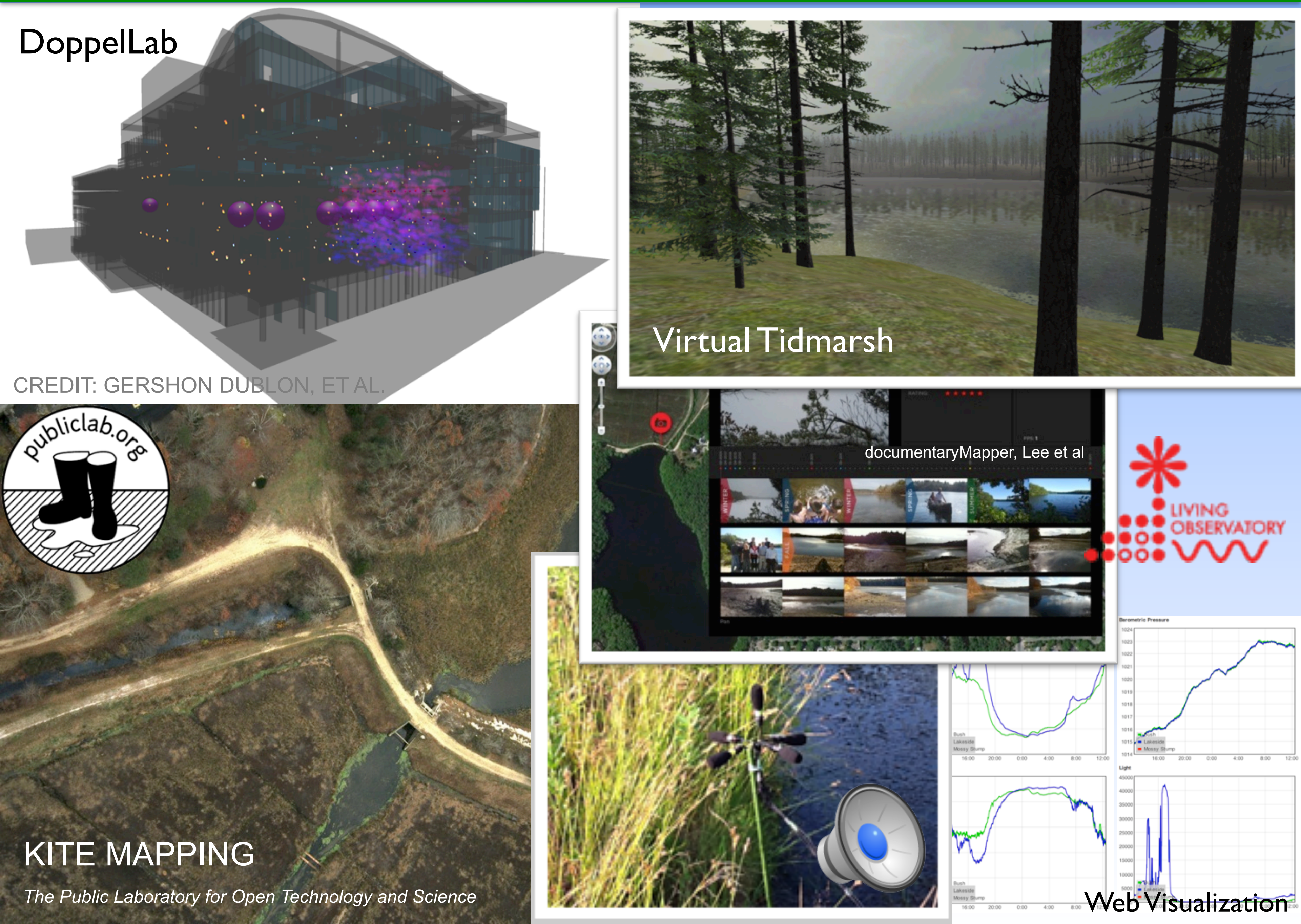
• Can we resolve microhabitat structure? Do these correspond to evolving surface plant communities?

• How effective is the cut-and-fill approach to changing the hydrology on the site? Is there significant flow through (sand) filled ditches? Is this thermally distinct from parallel flow through untrenched areas?

• How effectively was the main channel diverted? Is it colder than it was (i.e. more GW)? Is there still significant flow through the former (anthropogenic) channel?

• Where would long-term ground-truth monitoring be most effective? 3 or 4 sites.

Physical and Virtual Extensions: *Mapping, Soundscapes, Real-time Data, Science for Public Engagement*



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http://tidmarshfarms.com/

Much of the material presented here courtesy of: **Alex Hackman**, Mass. Division of Ecological Restoration, and **Glorianna Davenport** & **Evan Schulman**, Tidmarsh Farms, Inc. and Living Observatory

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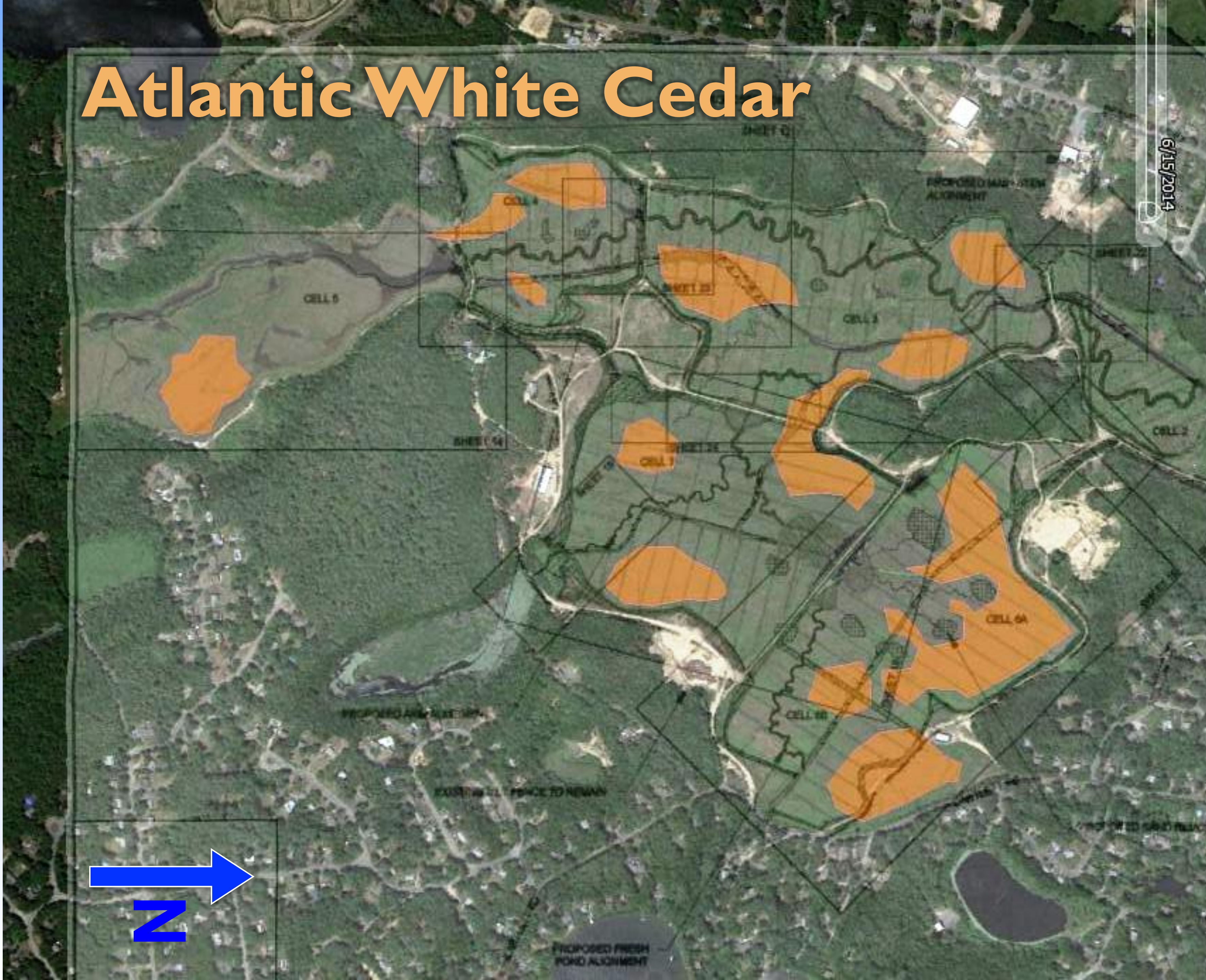
Atlantic White Cedar



Soil Moisture Monitoring

Soil Moisture Monitoring DATA

Site name	Location (Decimal degrees)		Date Time	Mineral	Gravimetric Moisture	
	Northing (dec. deg)	Westing (dec. deg)		θ (%)	0-6cm θ (%)	6-12cm θ (%)
GSM 001	41.897850	70.568733	7/22/14	107	91%	90.4%
GSM 002	41.899217	70.569450	7/22/14	106.2	81%	82.4%
GSM 003	41.900533	70.572033	7/22/14	100.5	75%	77.1%
GSM 004	41.902767	70.571350	7/22/14	33.6	35%	17.1%
GSM 005	41.901550	70.572500	7/22/14	73.9	59%	55.4%
GSM 006	41.902450	70.572417	7/22/14	43.2	28%	18.5%
GSM 007	41.902617	70.569750	7/23/14	14.7	8%	7.1%
GSM 008	41.903667	70.572667	7/22/14	39.2	26%	30.0%
GSM 009	41.904067	70.572517	7/22/14	30.6	26%	27.1%
GSM 010	41.905167	70.570133	7/23/14	29.4	16%	26.3%
GSM 011	41.905800	70.571567	7/22/14	31.8	22%	19.3%
GSM 012	41.905967	70.569767	7/23/14	15.1	20%	24.4%
GSM 013	41.906933	70.572033	7/22/14	25.7	25%	19.8%
GSM 014	41.903433	70.567783	7/23/14	37.2	29%	24.0%
GSM 015	41.904933	70.565733	7/23/14	30.3	22%	14.6%

Site name	Location (Decimal degrees)		Date Time	Mineral	Gravimetric Moisture	
	Northing (dec. deg)	Westing (dec. deg)		θ (%)	0-6cm θ (%)	6-12cm θ (%)
GSM 016	41.905217	70.564150	7/23/14	32.3	20%	39.6%
GSM 017	41.906383	70.564967	7/23/14	34.9	34%	22.9%
GSM 018	41.907883	70.562217	7/23/14	92.6	44%	24.8%
GSM 019	41.909700	70.564517	7/23/14	12.8	10%	9.8%
GSM 020	41.908200	70.567550	7/23/14	14.1	11%	10.6%
GSM 021	41.907150	70.568733	7/23/14	25.4	30%	13.4%
GSM 022	41.907467	70.569433	7/23/14	6.9	12%	15.1%
GSM 023	41.908200	70.570233	7/23/14	33.1	24%	19.9%
GSM 024	41.908583	70.571483	7/22/14	43.1	30%	21.6%
GSM 024.1	41.908558	70.571483	7/22/14	22.5	10%	16.0%
GSM 024.2	41.908600	70.571572	7/22/14	36.6	26%	14.1%
GSM 024.3	41.908619	70.571483	7/22/14	35.5	21%	18.4%
GSM 025	41.909183	70.570700	7/22/14	13.6	12%	6.8%
GSM 026	41.909667	70.571150	7/23/14	45.6	34%	14.8%
GSM 027	41.912133	70.567183	7/23/14	9.9	8%	4.3%
GSM 028	41.912633	70.567683	7/23/14	27.4	22%	9.8%
GSM 029	41.914017	70.565650	7/22/14	74.4	84%	88.4%
GSM 030	41.914217	70.566267	7/22/14	66.4	75%	79.4%