GREAT MARSH RESTORATION

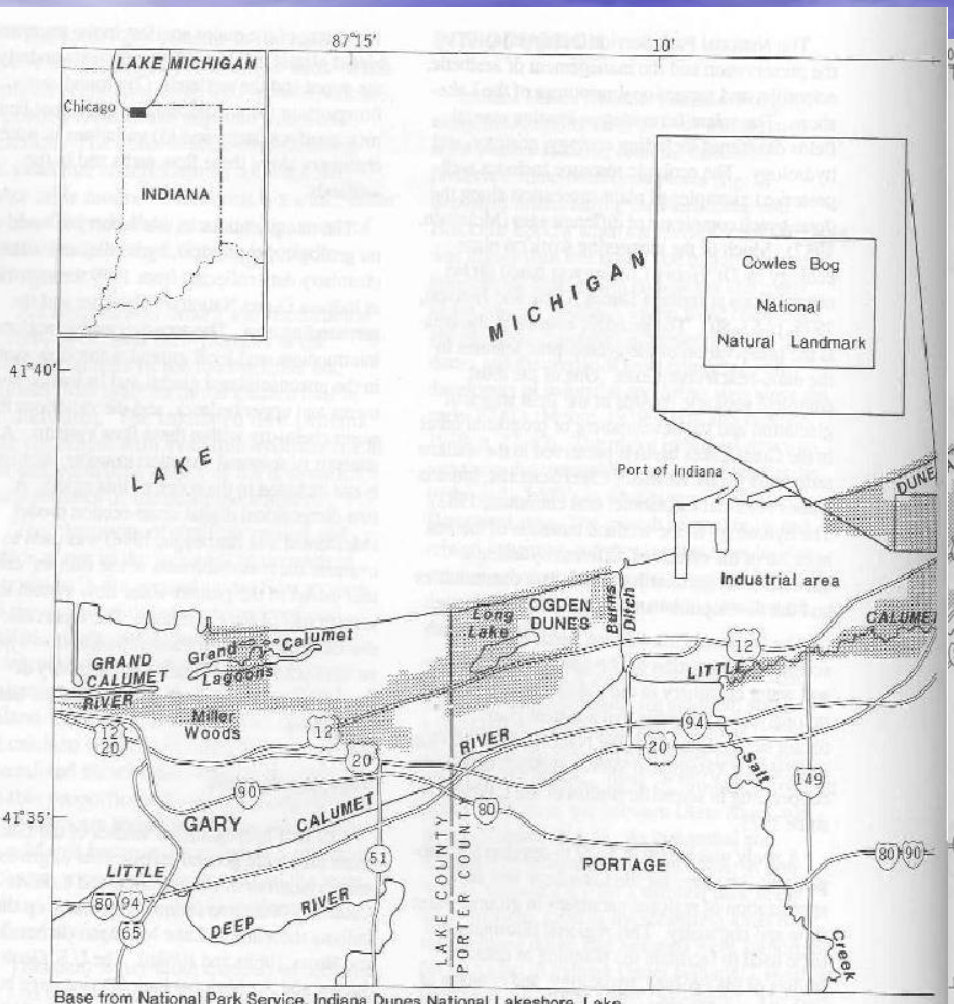
1999 – 2008

A DECADE OF ACTION

PARTNERS

- U.S. Fish and Wildlife Service
- North American Waterfowl Conservation Association
- Indiana Department of Environmental Management
- Student Conservation Association
- Youth Conservation Corps
- Public Land Corp
- Citizen Volunteers
- Nature Conservancy
- Friends of Indiana Dunes
- Hoosier Orchid Company

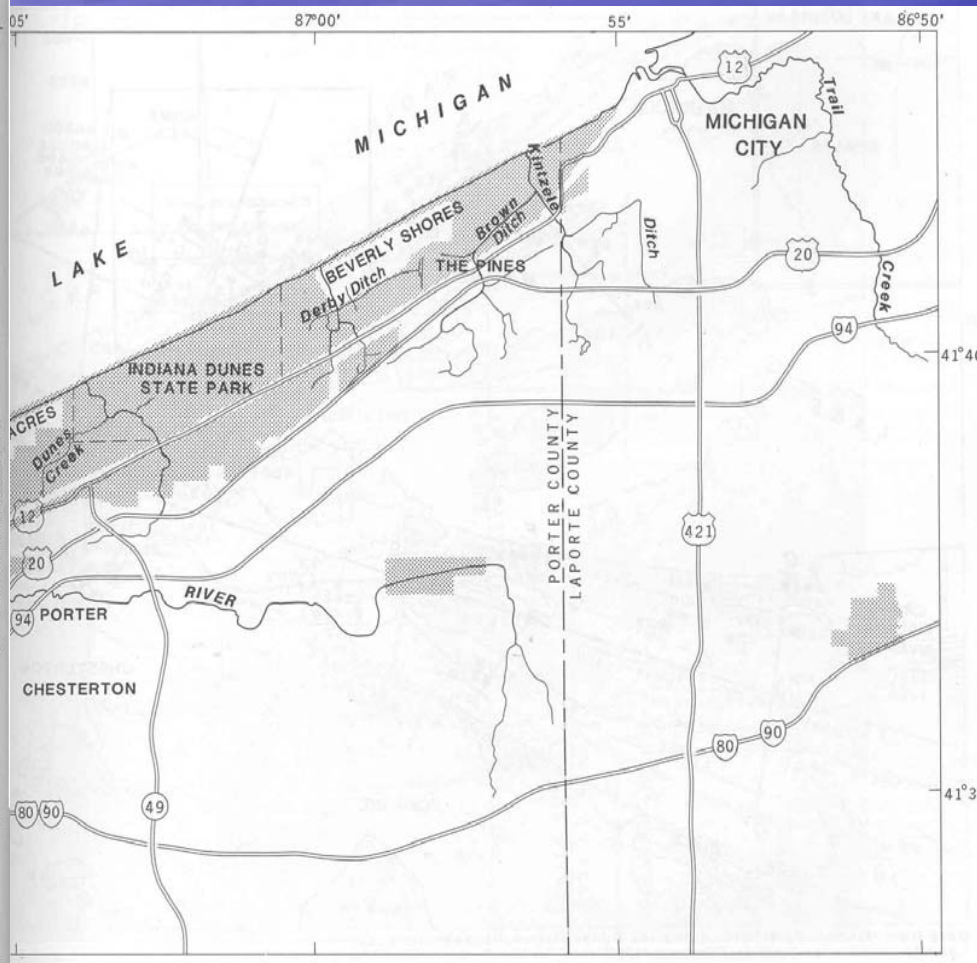
Indiana Dunes National Lakeshore



Base from National Park Service, Indiana Dunes National Lakeshore, Lake, Laporte, and Porter Counties, Indiana, 1986

0 1 2 3 4 MILES

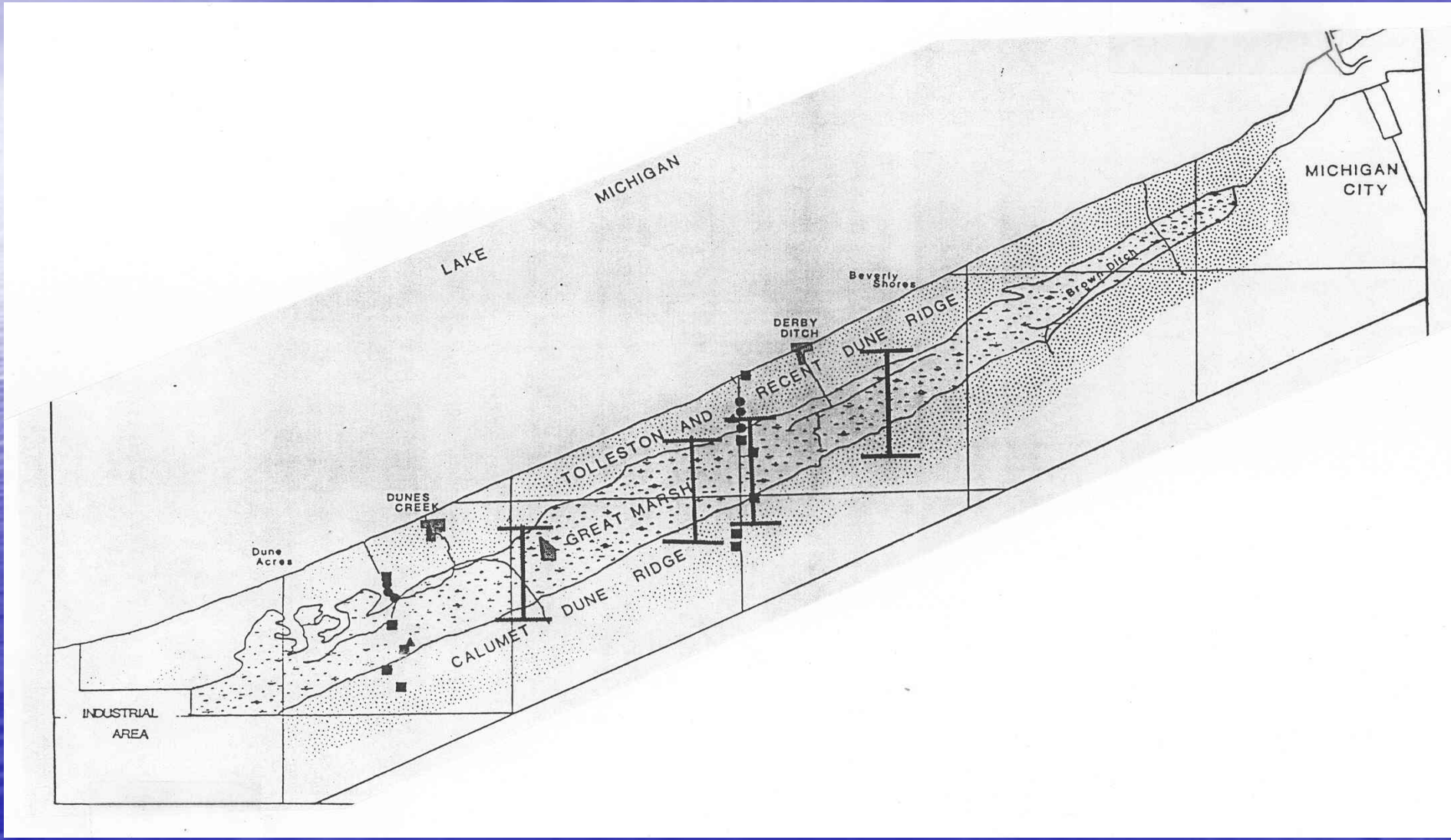
0 1 2 3 4 KILOMETERS



EXPLANATION

INDIANA DUNES NATIONAL LAKESHORE

Extent of the Great Marsh



GREAT MARSH-DERBY DITCH

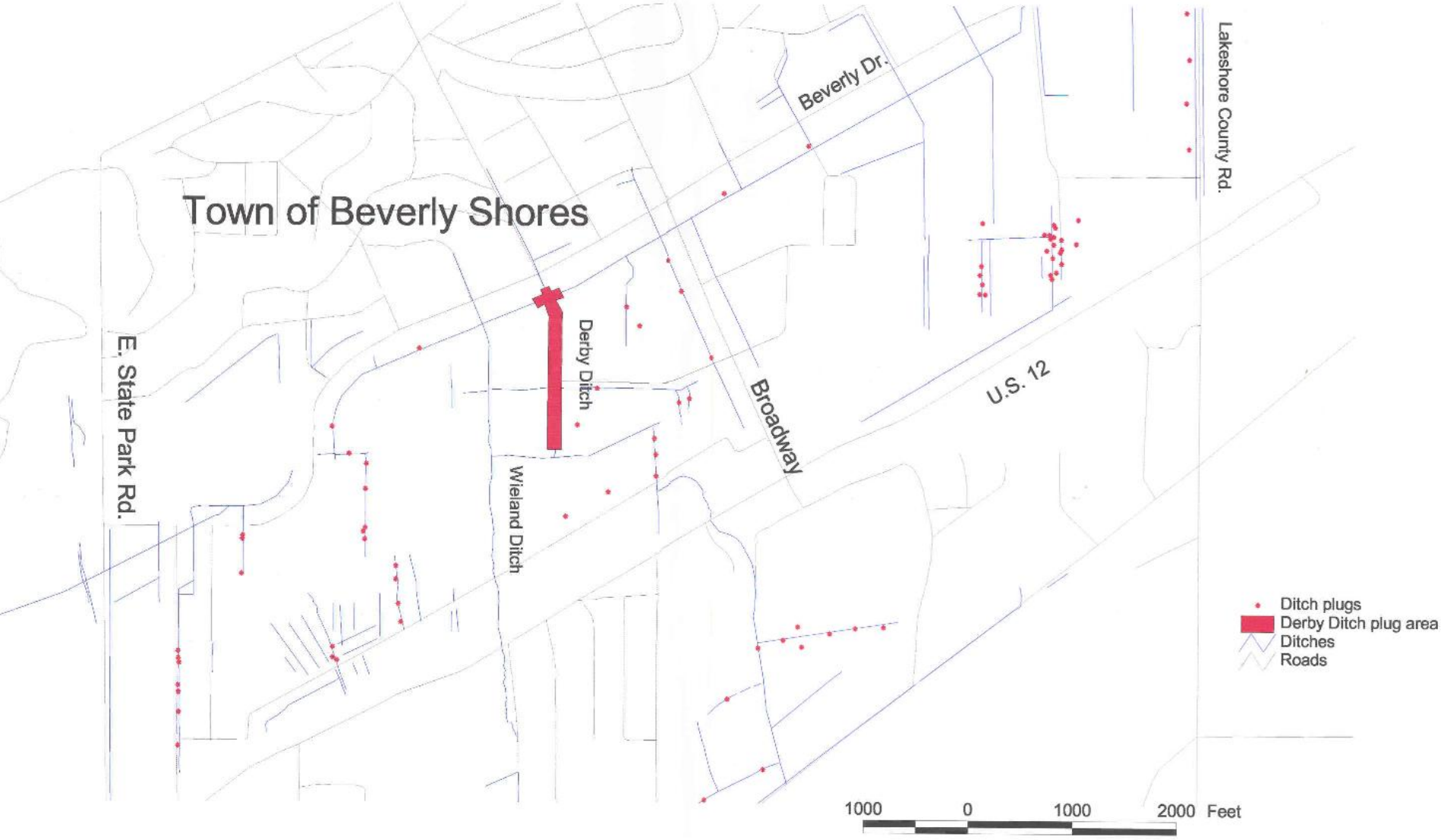
- 500 acres
- 1998 – 2001 (restoration of hydrology)
- 2001 – present (establishment of native vegetation)

The Great Marsh in the 1930's

The Great Marsh in 1958

The Great Marsh in 1969

Wetland Restoration at Indiana Dunes National Lakeshore
Beverly Shores Area



YCC Workers Constructing a Ditch Plug

A Secondary Spillway

Constructing the Spillway

Derby Ditch
October 2001

Cowles Bog Wetland Complex Glory; Demise; Resuscitation

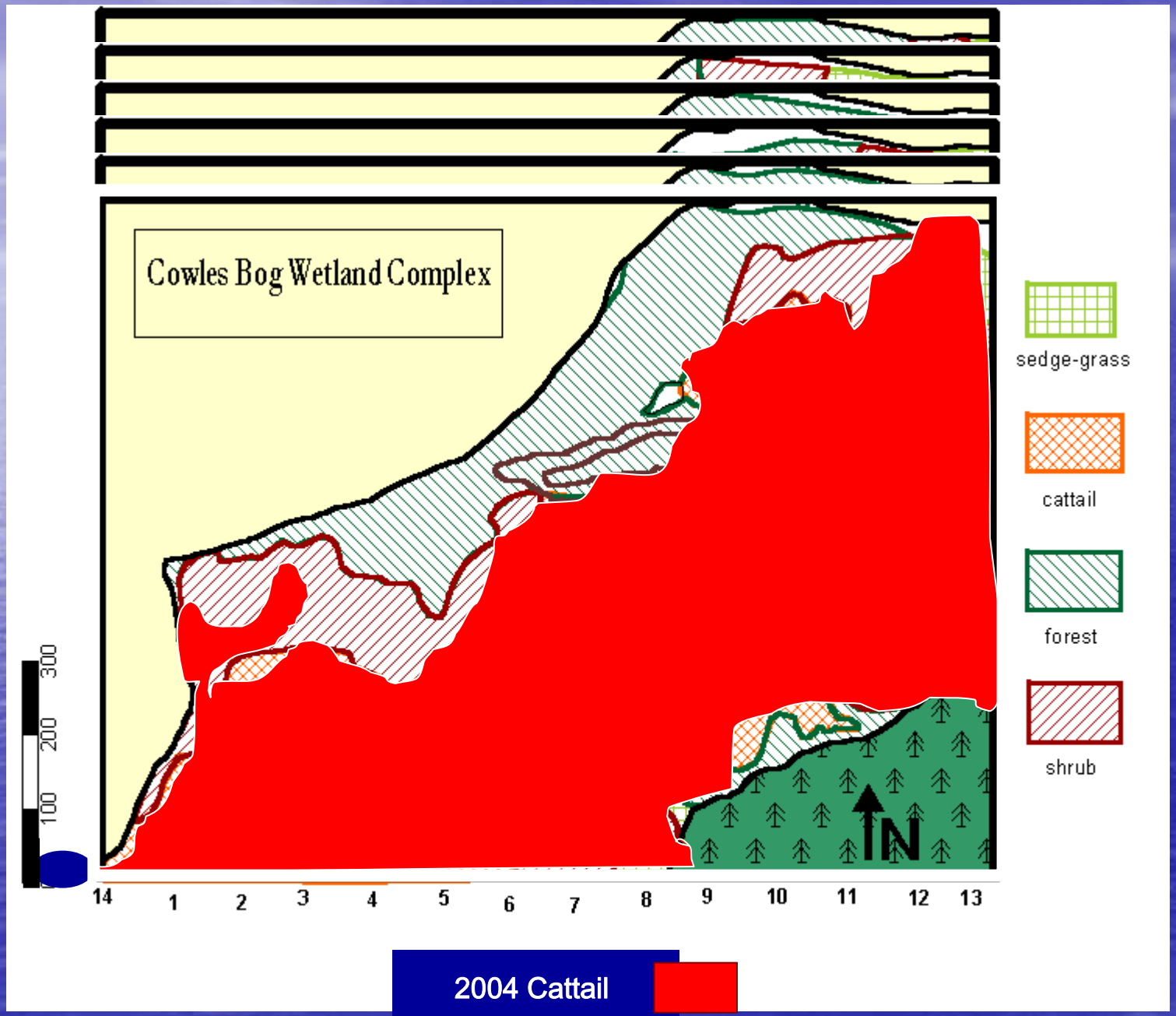
Glory Days

International Phytogeographic Excursion

Sept. 1916: Cowles Bog with absence of Cattail

Cypripedium acaule
Calopogon tuberosus

Cornus canadensis



Figures provided by Dan Mason and Adam Vaughan, Indiana Dunes National Lakeshore

Sept. 1916: Cowles Bog with absence of Cattail

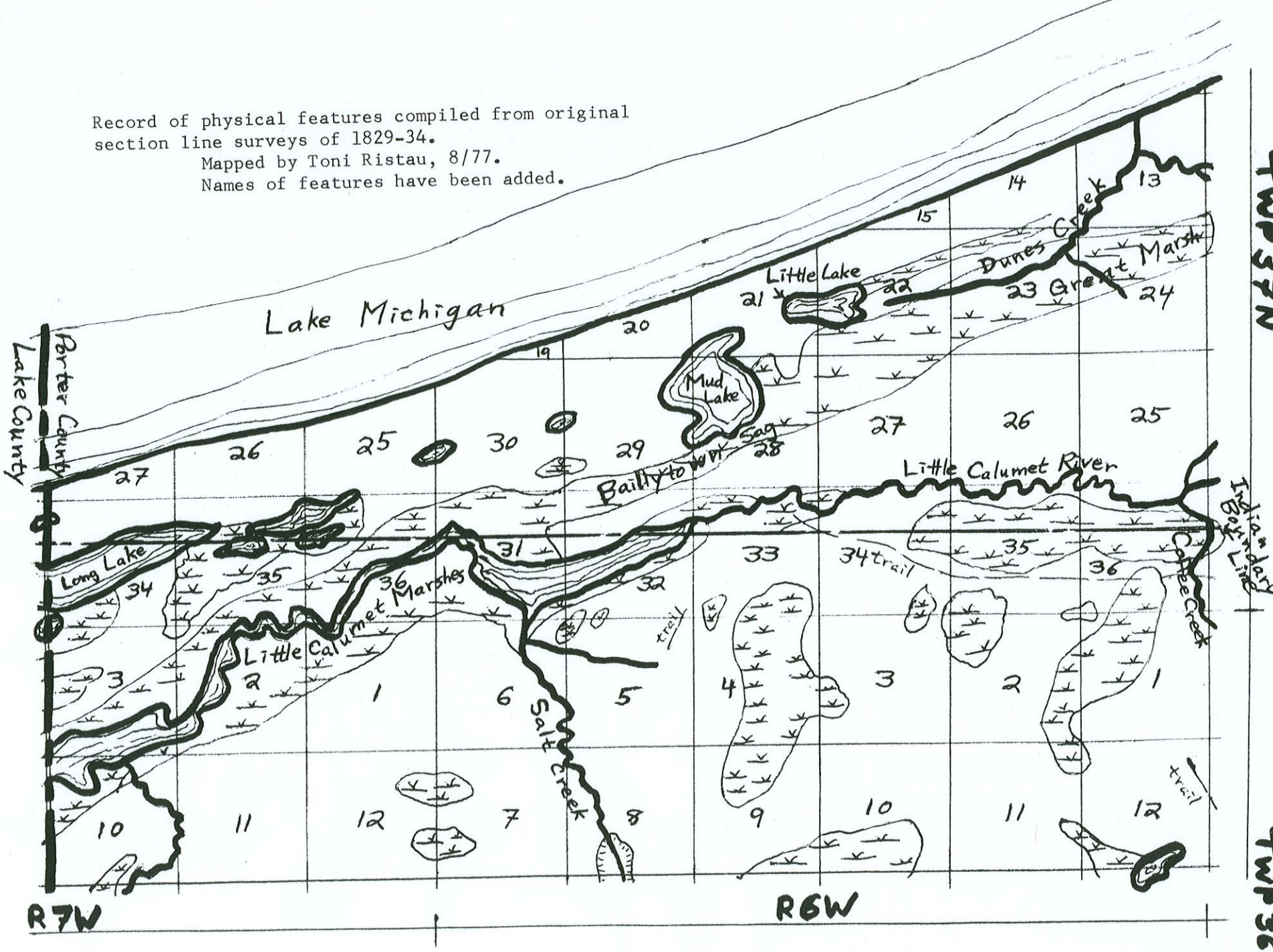
GRAMINOIDS TO CATTAIL

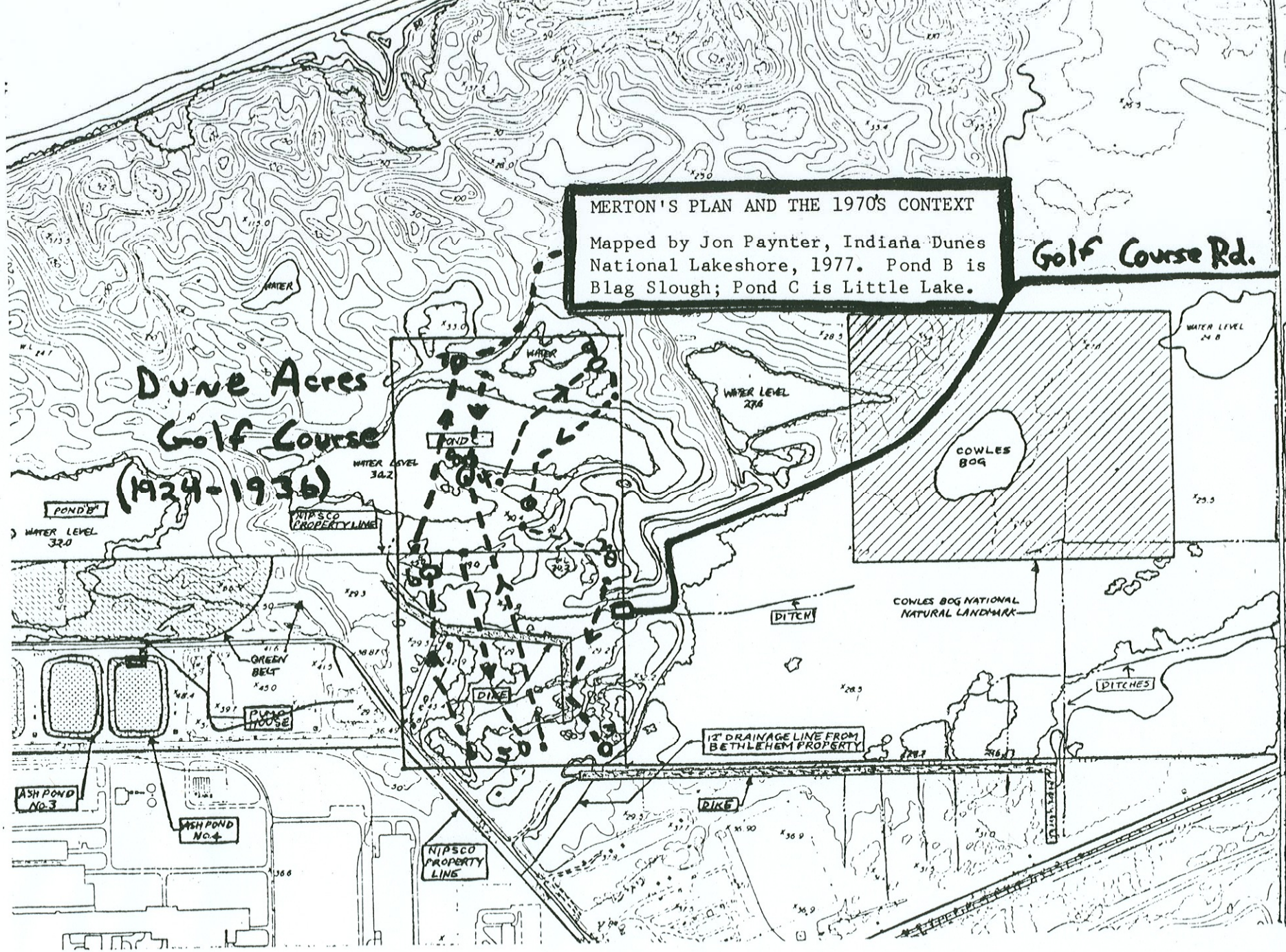
- Southwestern portion of CBWC represented a divide between east and west watersheds
- Early 1900's ditches facilitated grazing and haying of graminoid resource.
- Adrian Muck soils compressed lowing surface topography.

GRAMINOIDS TO CATTAIL

- Early 1970's beaver blocked water flow to the east and dike construction blocked flow to the west.
- Surface water levels increased killing graminoid resource and facilitating Cattail spread.
- Expansion of Adrian Muck soils in combination with development of a floating mat reduced surface water levels.

Record of physical features compiled from original section line surveys of 1829-34.
Mapped by Toni Ristau, 8/77.
Names of features have been added.

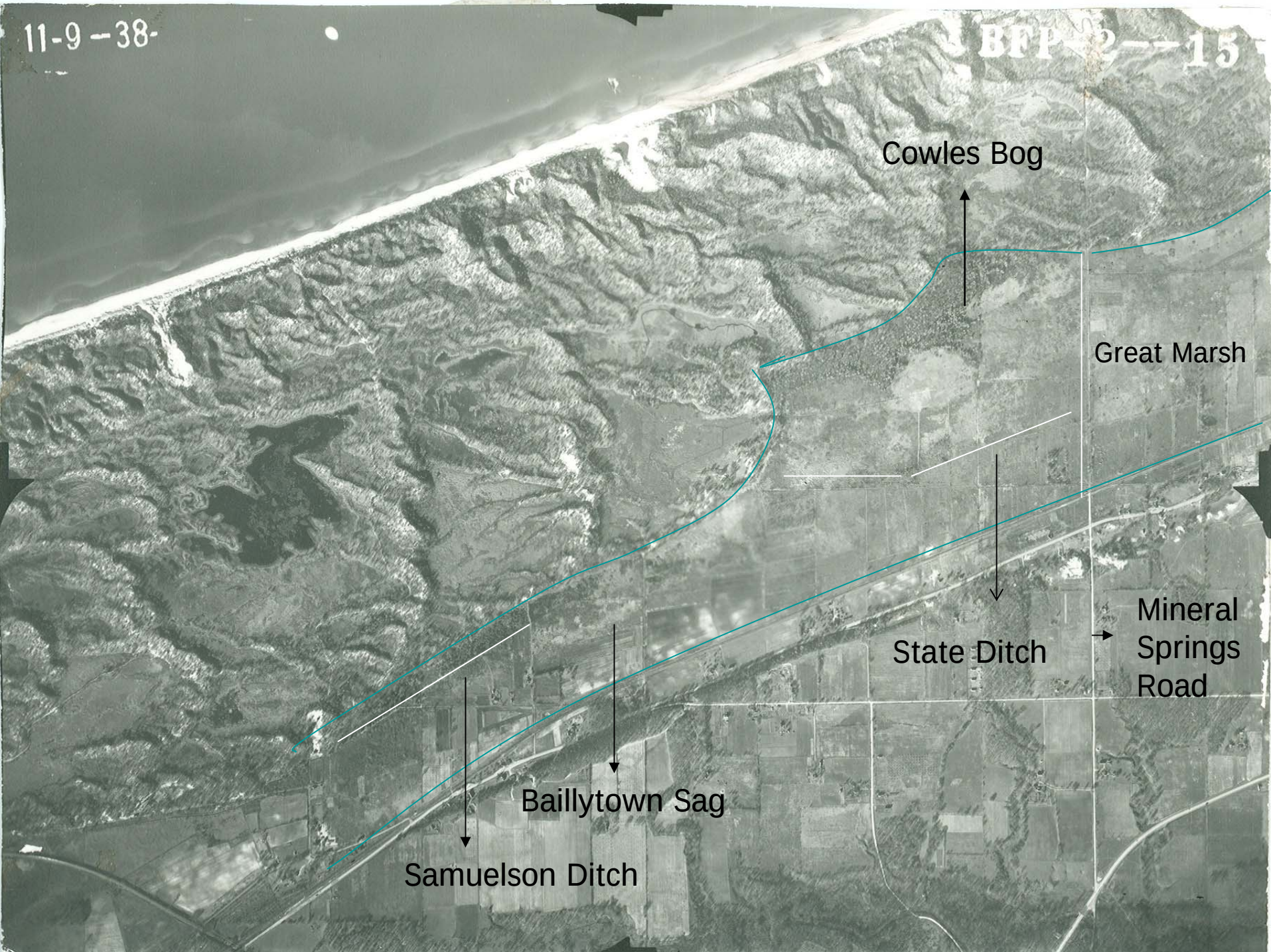




MERTON'S PLAN AND THE 1970'S CONTEXT

Mapped by Jon Paynter, Indiana Dunes National Lakeshore, 1977. Pond B is Blag Slough; Pond C is Little Lake.

Figure 11

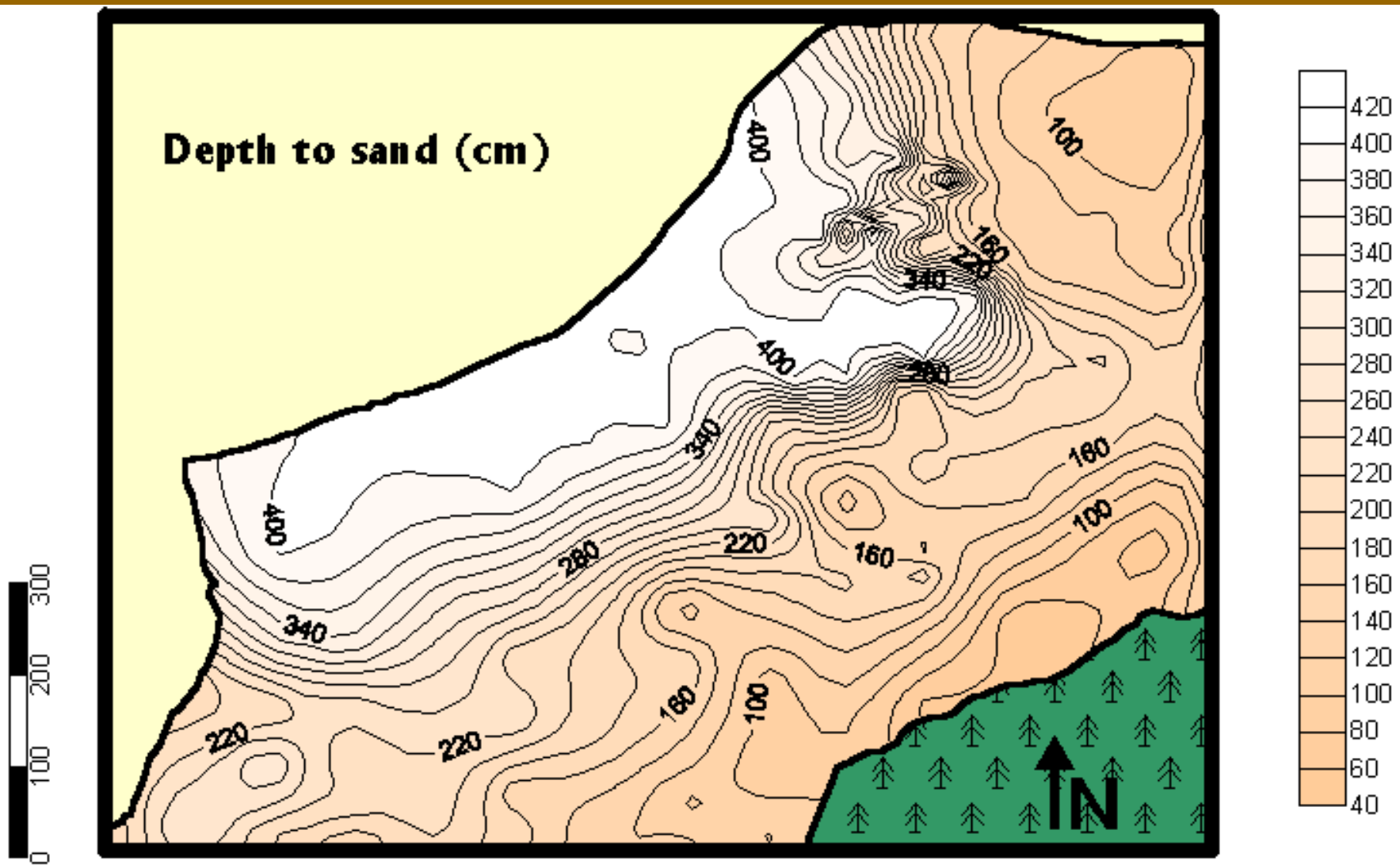

11-9-38-
Cowles Bog
Great Marsh
State Ditch
Mineral
Springs
Road
Baillytown Sag
Samuelson Ditch

7-8-54
BFR-1N-

Michigan Dunes N.L.

INVENTORY

- Vegetation
- Seedbank
- Hydrology
- Water Chemistry
- Soil Chemistry
- Soil Classification


Depth to sand (cm)
400
100
160
220
340
400
280
340
160
100
400
280
220
160
340
220
220
160
100
N
0
100
200
300
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40

VEGETATION

- Herbaceous vegetation evaluated in 1115 meter square plots. (Spp list; cover est. cattail stem density)
- Trees ($\geq$ 7cm DBH; > 1m height) evaluated in 10x10m plots.
- Shrubs were evaluated in 5x5m plots

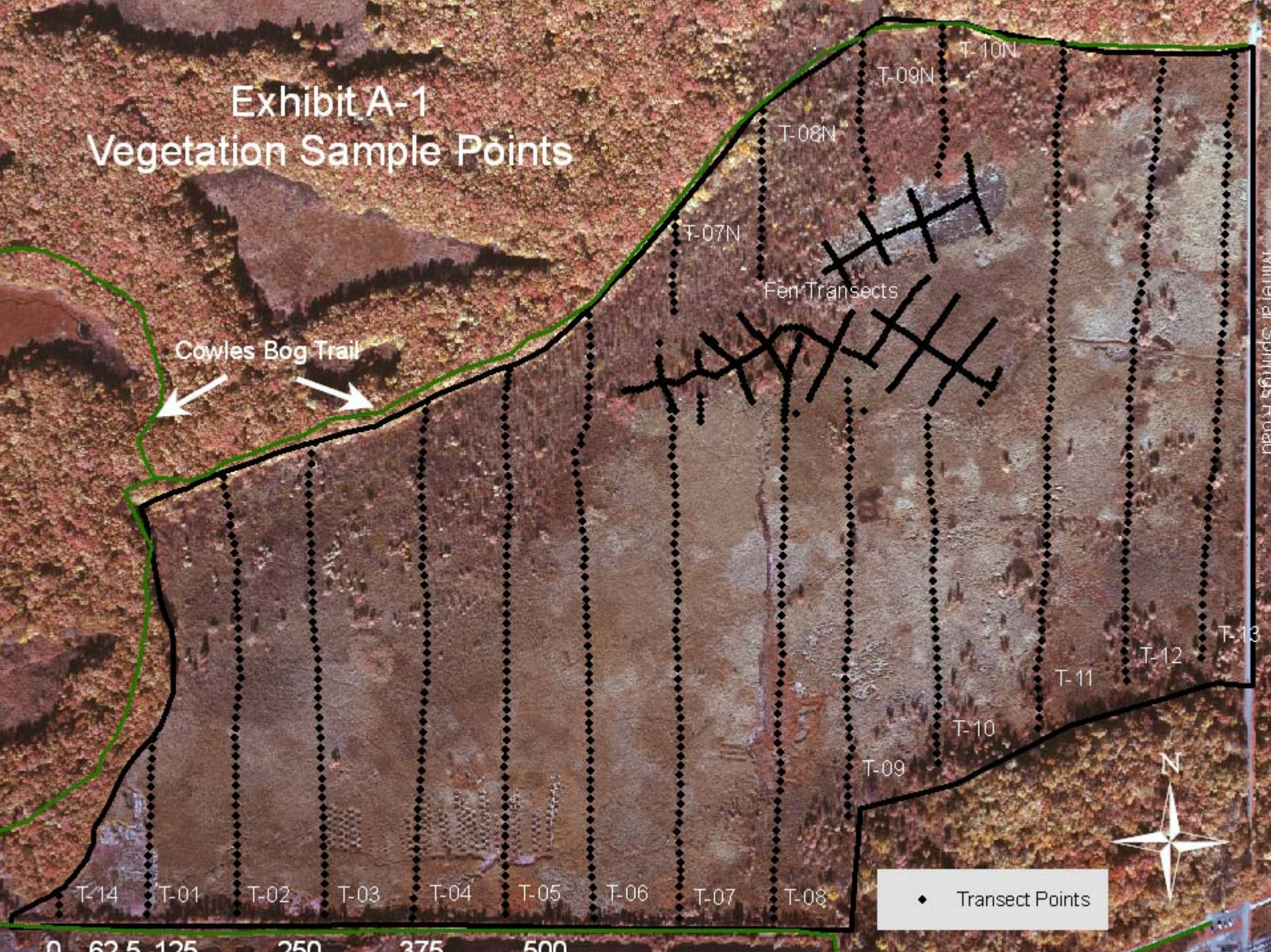
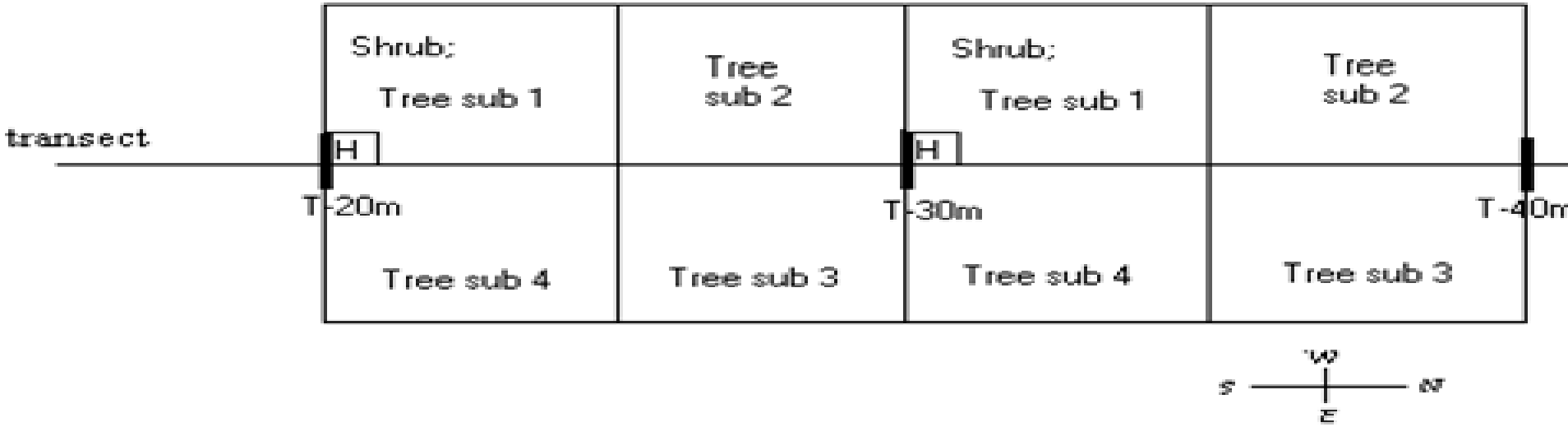


Exhibit A-1
Vegetation Sample Points
Cowles Bog Trail
Fen Transects
T-07N
T-08N
T-09N
T-10N
T-14
T-01
T-02
T-03
T-04
T-05
T-06
T-07
T-08
T-09
T-10
T-11
T-12
T-13
N
Transect Points
0 62.5 125 250 375 500


Shrub;
Tree sub 1
Tree sub 2
Shrub;
Tree sub 1
Tree sub 2
transect
H
H
T-20m
T-30m
T-40m
Tree sub 4
Tree sub 3
Tree sub 4
Tree sub 3
W
S
N
E

VEGETATION ANALYSES

- Hierarchical agglomerative cluster analyses (relative Sorenson / Wards)
- Contours of similar cattail stem densities generated using Surfer V. 8 (Kriging algorithm).
- The 12 identified woody plant assemblages were adaptively field mapped.

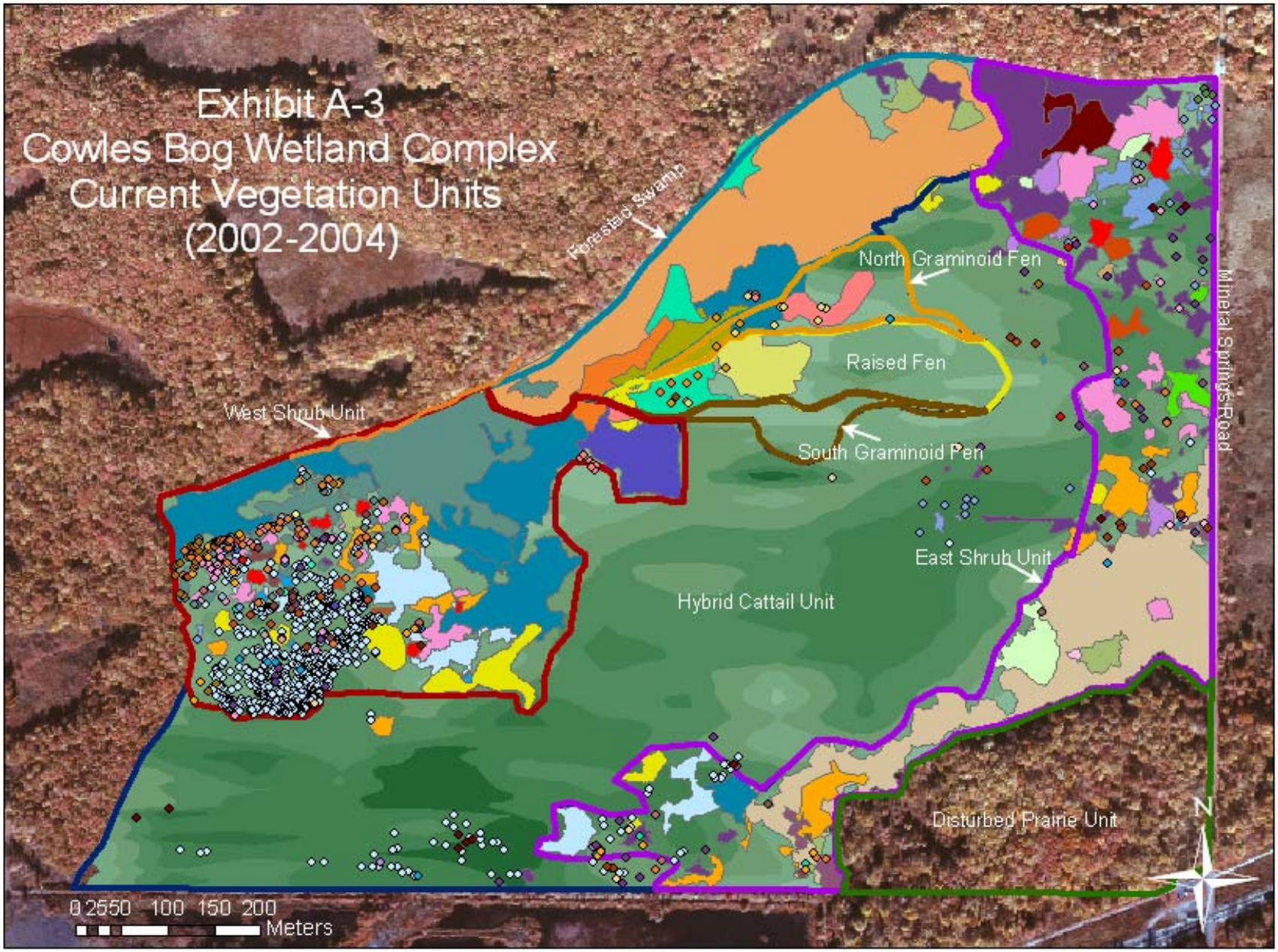


Exhibit A-3
Cowles Bog Wetland Complex
Current Vegetation Units
(2002-2004)
Forestad Swamp
North Graminoid Fen
Raised Fen
West Shrub Unit
South Graminoid Fen
East Shrub Unit
Hybrid Cattail Unit
Disturbed Prairie Unit
Mineral Springs Road
N
0 2550 100 150 200
Meters

Realized Vegetation Units	Area	Hybrid Cattail (stems per m square)	Area
West Shrub Unit	13.2	0 - 10	18.3
East Shrub Unit	16.9	11 – 20	15.5
Forested Swamp Unit	7.3	21 – 30	12.5
Raised Fen	2.9	31 – 40	14.1
South Graminoid Fen	0.9	41 – 50	10.4
North Graminoid Fen	1.4	51 – 60	0.4
Hybrid Cattail Unit	31.1	61 – 70	1.5
Disturbed prairie Unit	7.3	**Total Area**	**72.7 HA**
Total Area	**81 HA**		

Table 1: Summary of Characteristics of Species Observed in the Cowles Bog Wetland Complex (Three growth forms of graminoids are provided).

Total Species	**Quantity**	**Wetland Status**	**Quantity**	**Growth Form**	**Quantity**
Native species	268	OBL-FAC	253	Fern	8
Non-native species	26	FAC- to UPL	41	Fern Ally	1
Total	294			Forb	146
		Class	**Quantity**	Graminoid	63
Life Cycle	**Quantity**	Dicot	201	grass	32
Annual	15	Equisetinae	1	rush	11
biennial	2	Filicinae	8	sedge	20
perennial	277	Gymnosperm	3	Shrub	39
		Monocot	81	Tree	30
				Vine	7

Scientific Name	CBWC	West Shrub	Forested Swamp	Raised Fen
Acer rubrum	3305	1127	2779	121
Alnus rugosa*	188	61	200	0
Betula alleghaniensis	1665	690	1330	36
Betula papyrifera*	277	345	0	0

Table xx: Dominant Species Present in the Cowles Bog Wetland Complex

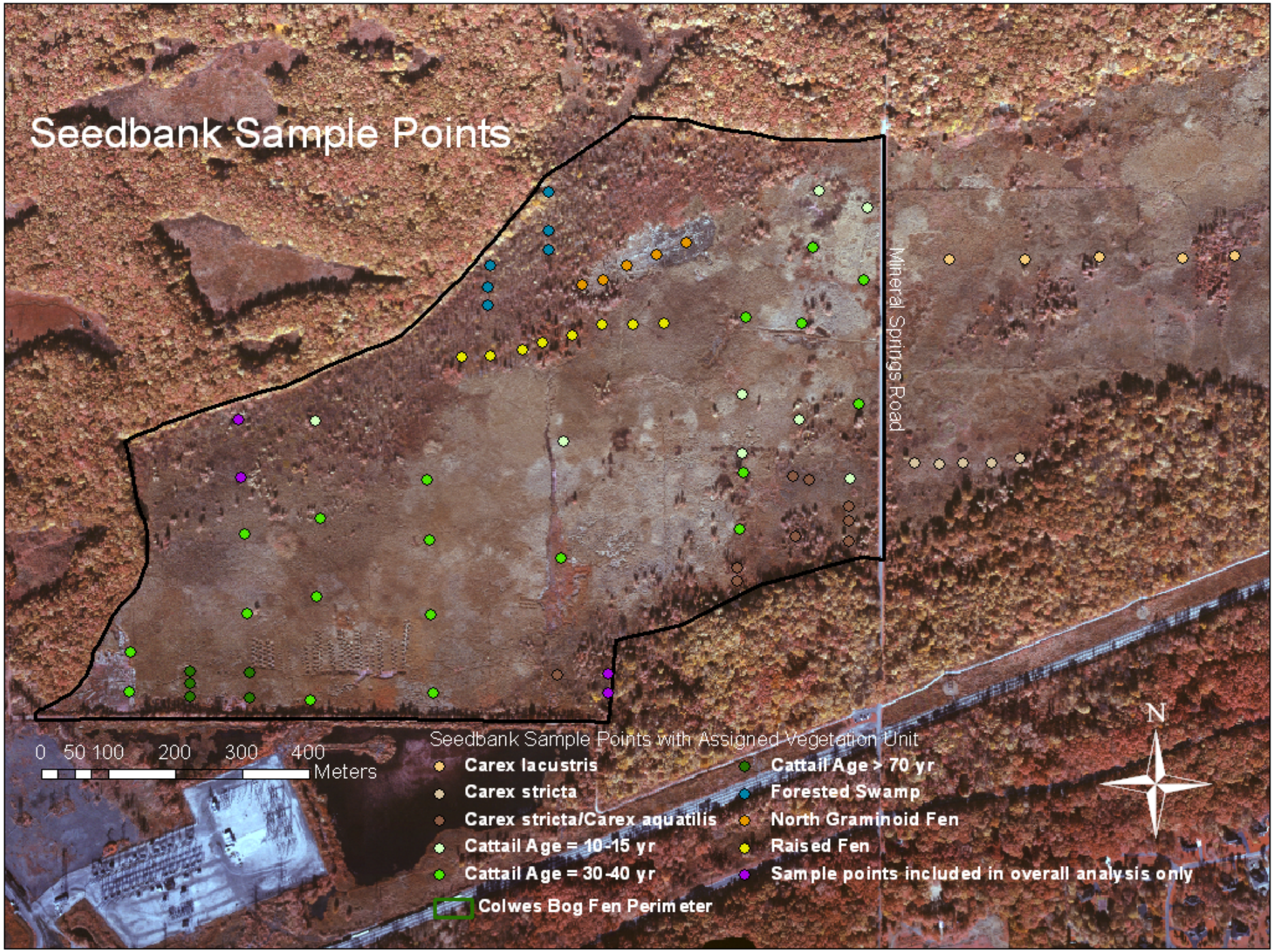
TREES				
Scientific Name	**Density**	**Basal area**	**Cover**	**Importance**
Acer rubrum	0.45	103.52	3.742	112.40
Betula alleghaniensis	0.23	32.71	1.664	47.52
Total	**1.21**	**286.7**	**9.5**	

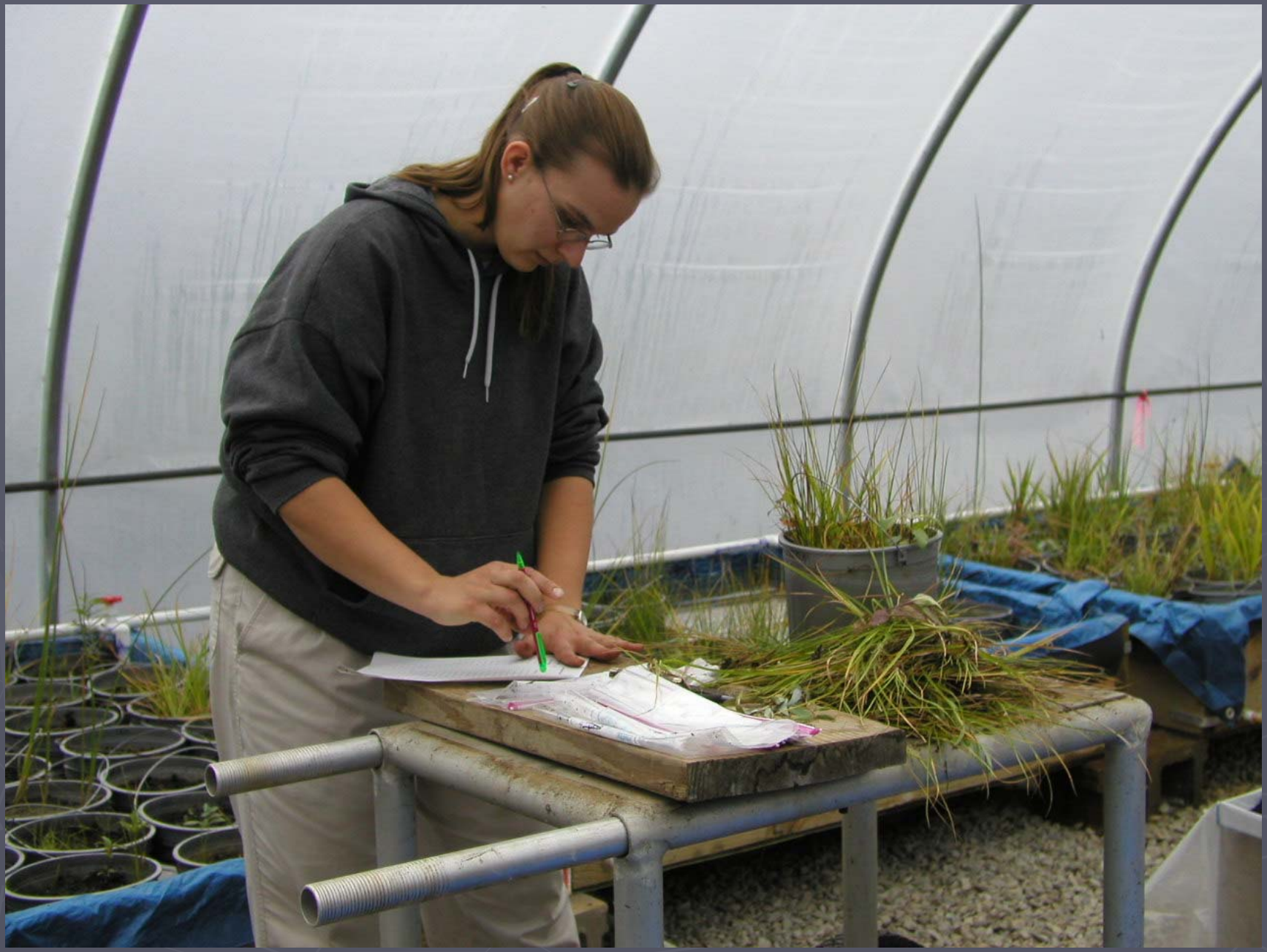
SHRUBS & WOODY VINES			
Scientific Name	**Cover**	**Frequency**	**Importance**
Ilex verticillata	2.51	11.29	23.33
Lindera benzoin	2.33	11.62	22.43
Rhus vernix	1.17	19.52	20.69
Alnus rugosa	1.66	7.24	15.27
Cornus stolonifera	1.03	12.06	14.73
Rosa palustris	0.92	11.84	13.87
Total	**16.1**		

HERBACEOUS			
Typha hybrid	23.800	82.10	42.16
Impatiens capensis	5.817	54.37	14.48
Symplocarpus foetidus	8.219	26.29	14.31
Pilea fontana	4.927	58.52	13.79

SEEDBANK

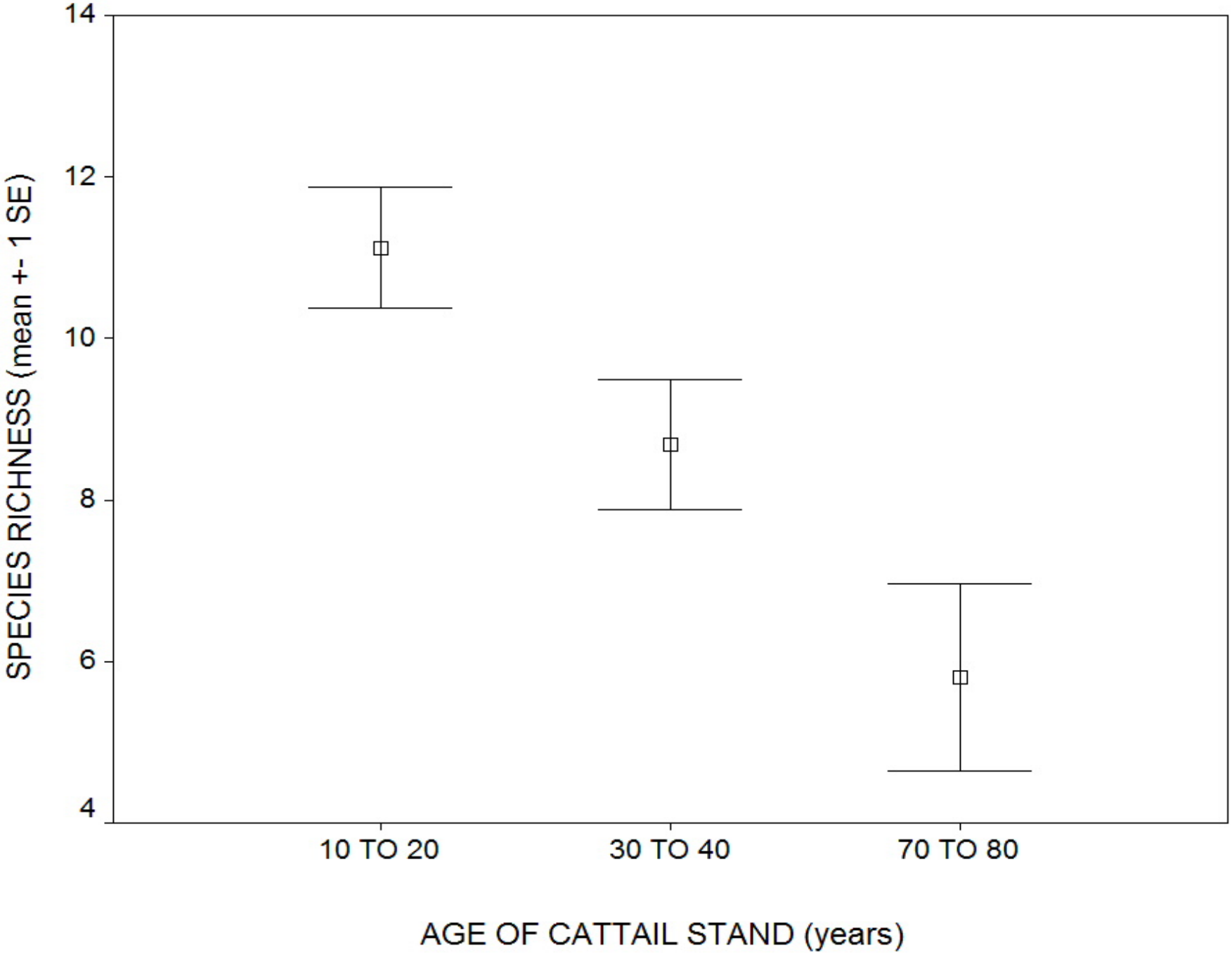
- Seedling emergence method
- 74 sample points representing 7 vegetation types
- At each point, 12 cores acquired with a golf-hole cutter
- Samples from each point homogenized and placed in 6 buckets: 3 saturated & 3 inundated

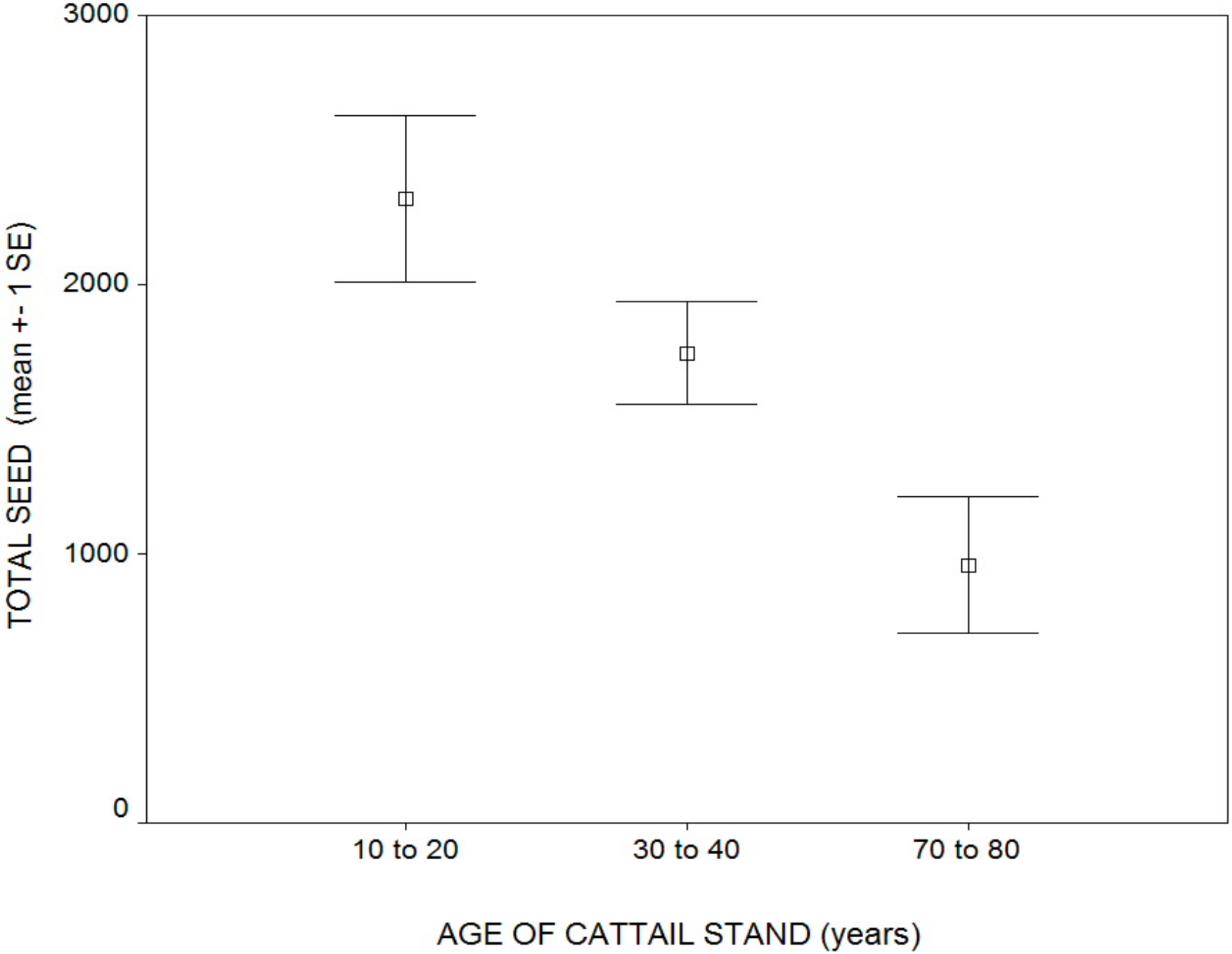

Seedbank Sample Points
Mineral Springs Road
0 50 100 200 300 400
Meters
Seedbank Sample Points with Assigned Vegetation Unit
Carex lacustris
Carex stricta
Carex stricta/Carex aquatilis
Cattail Age = 10-15 yr
Cattail Age = 30-40 yr
Colwes Bog Fen Perimeter
Cattail Age > 70 yr
Forested Swamp
North Graminoid Fen
Raised Fen
Sample points included in overall analysis only
N



DOMINANT SPECIES OF THE SEEDBANK (74 sample points)			
Scientific Name	Quantity	Frequency	Importance
Typha spp.	896	100	71.6
Scirpus cyperinus	133	89	18.2
Juncus effusus	105	34	10.7

SEEDBANK				
Plant Grouping	Spp. Richness	Total Seed	Cattail Seed	Seed no Cattail
Carex lacustris	15	2160	382	1778
Carex stricta	9	377	148	229
Raised Fen	8	717	432	285
N. Graminoid	5	1251	1047	204
Sedge Meadow	13	1375	440	935
Forested Swamp	11	1104	311	793
Hybrid Cattail	9	1735	1307	428


14
12
10
8
6
4
SPECIES RICHNESS (mean +- 1 SE)
10 TO 20
30 TO 40
70 TO 80
AGE OF CATTAIL STAND (years)


3000
2000
1000
0
TOTAL SEED (mean +- 1 SE)
10 to 20
30 to 40
70 to 80
AGE OF CATTAIL STAND (years)

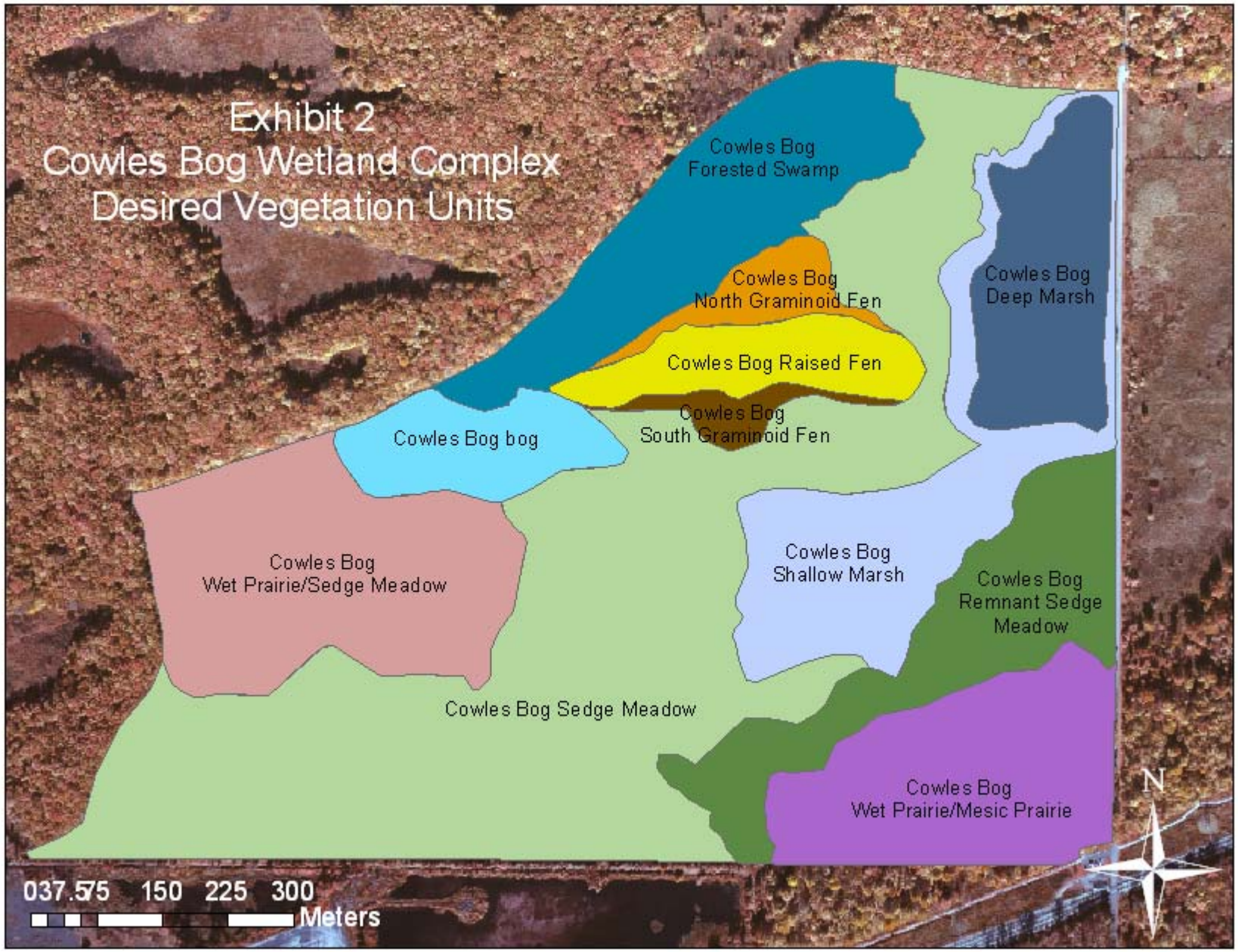


Exhibit 2
Cowles Bog Wetland Complex
Desired Vegetation Units
Cowles Bog
Forested Swamp
Cowles Bog
North Graminoid Fen
Cowles Bog Raised Fen
Cowles Bog
South Graminoid Fen
Cowles Bog
Deep Marsh
Cowles Bog bog
Cowles Bog
Wet Prairie/Sedge Meadow
Cowles Bog
Shallow Marsh
Cowles Bog
Remnant Sedge
Meadow
Cowles Bog Sedge Meadow
Cowles Bog
Wet Prairie/Mesic Prairie
N
037.575 150 225 300
Meters

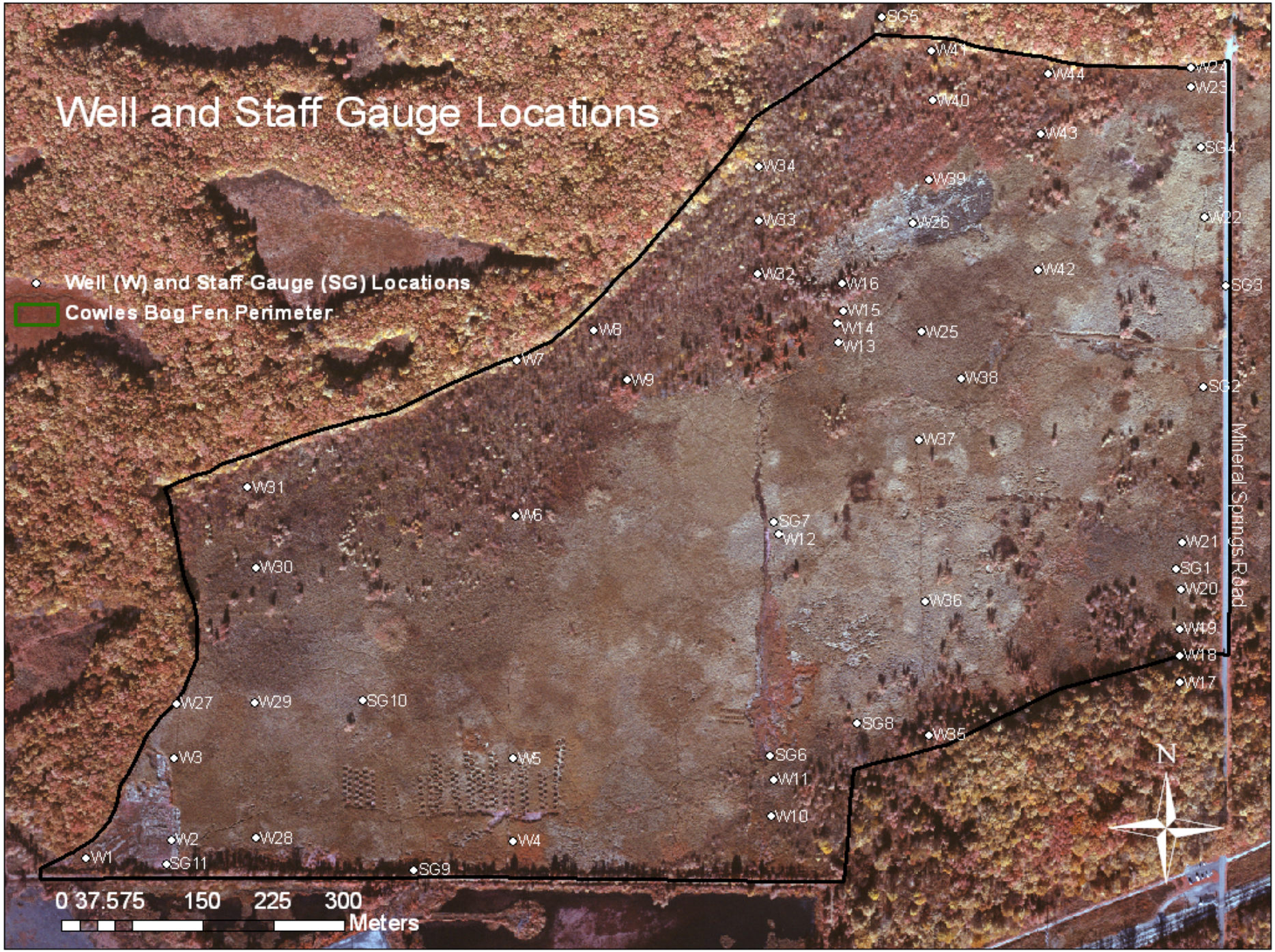
HYDROLOGY

- Thirty-three shallow groundwater wells & 11 staff gauges
- Weekly measurements Apr-Dec 2002&2003
- Six surface water measurement events at each vegetation quadrat.

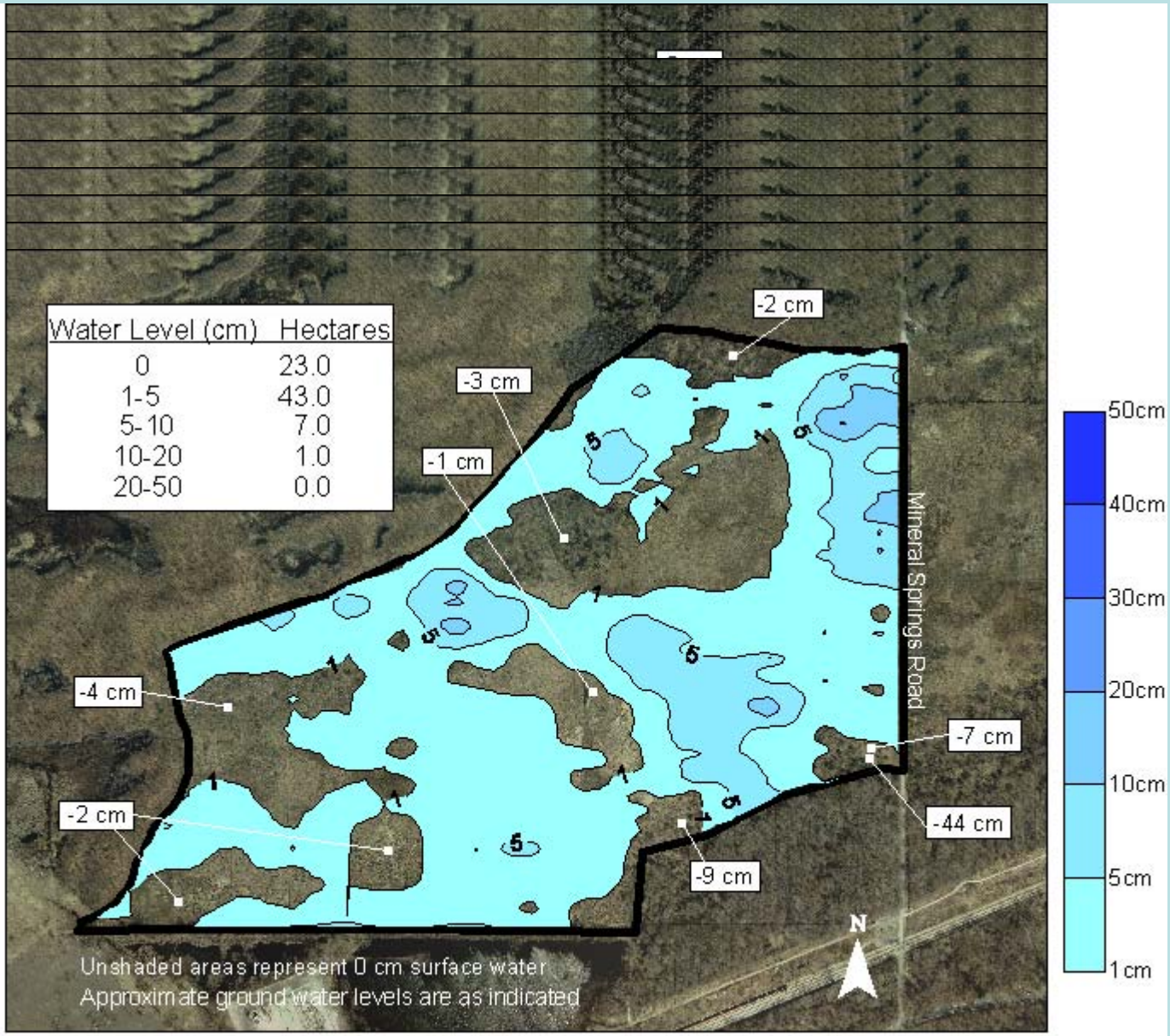
HYDROLOGY

- Regression equations were generated for each quadrat that identified well data that best predicted surface water depth.

- Contours of similar surface water depth generated using Surfer V. 8 (Kriging algorithm).


Well and Staff Gauge Locations
Well (W) and Staff Gauge (SG) Locations
Cowles Bog Fen Perimeter
SG5
W41
W44
W24
W23
W40
W43
SG4
W34
W39
W33
W26
W22
W42
W32
W16
SG3
W15
W14
W13
W8
W25
W7
W9
W38
SG2
W37
Mineral Springs Road
W31
W6
SG7
W12
W21
W30
SG1
W20
W36
W19
W18
W17
W27
W29
SG10
SG8
W35
W3
W5
SG6
W11
W10
W2
W28
W4
W1
SG11
SG9
N
0 37.575 150 225 300
Meters

NATIONAL PARK SERVICE



Surface Water Depths (cm)
9 December 2003

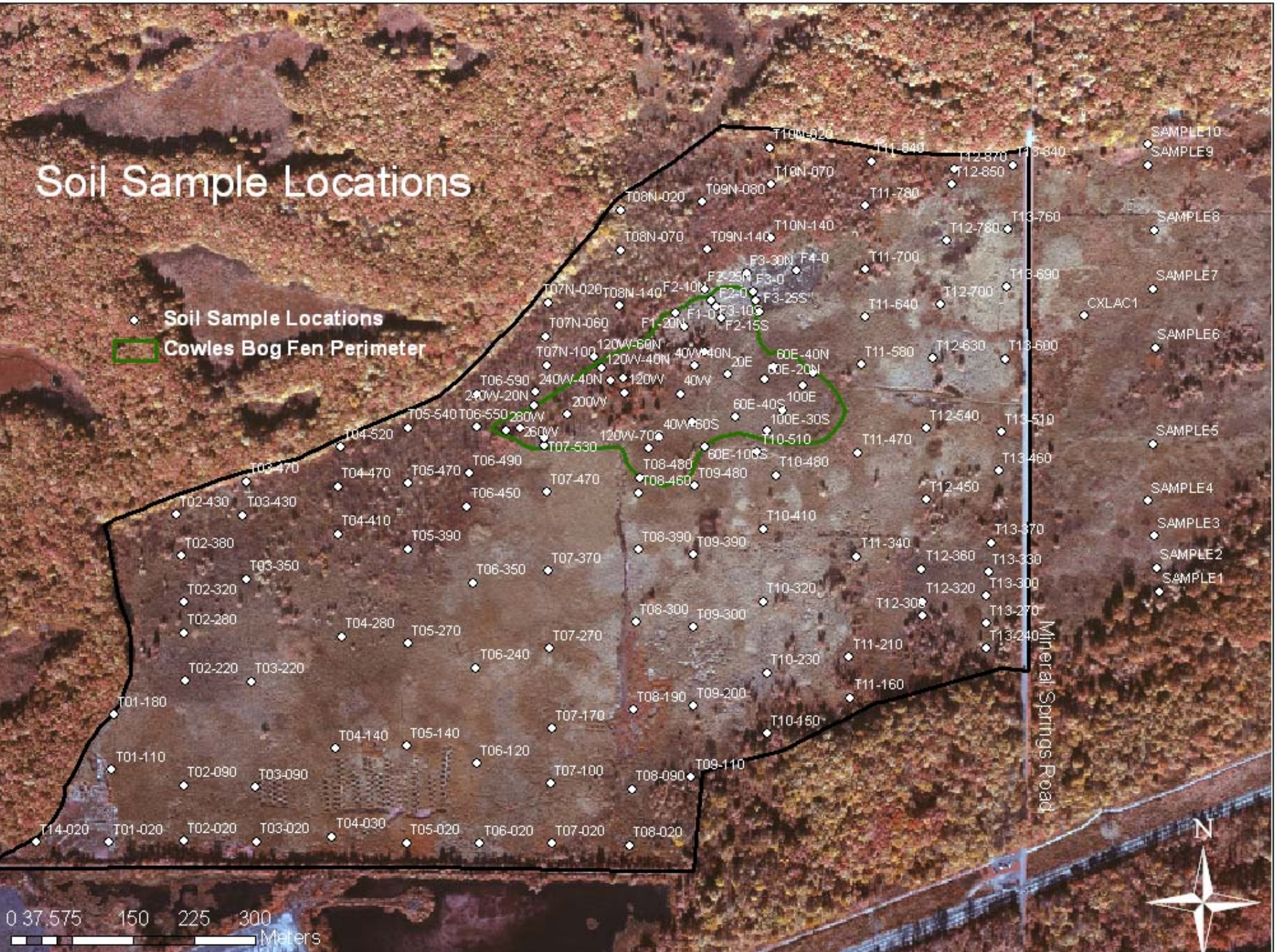
0m 250m 500m

Soil Chemistry

- Soils were sampled at 160 points between October 10 an November 7, 2002.
- Soils were sampled to 20cm using a using a golf-hole cutter; 3 to 5 samples were taken at each point.
- Samples were air dried, pulverized and sifted through a #10 sieve.

SOIL CHEMISTRY

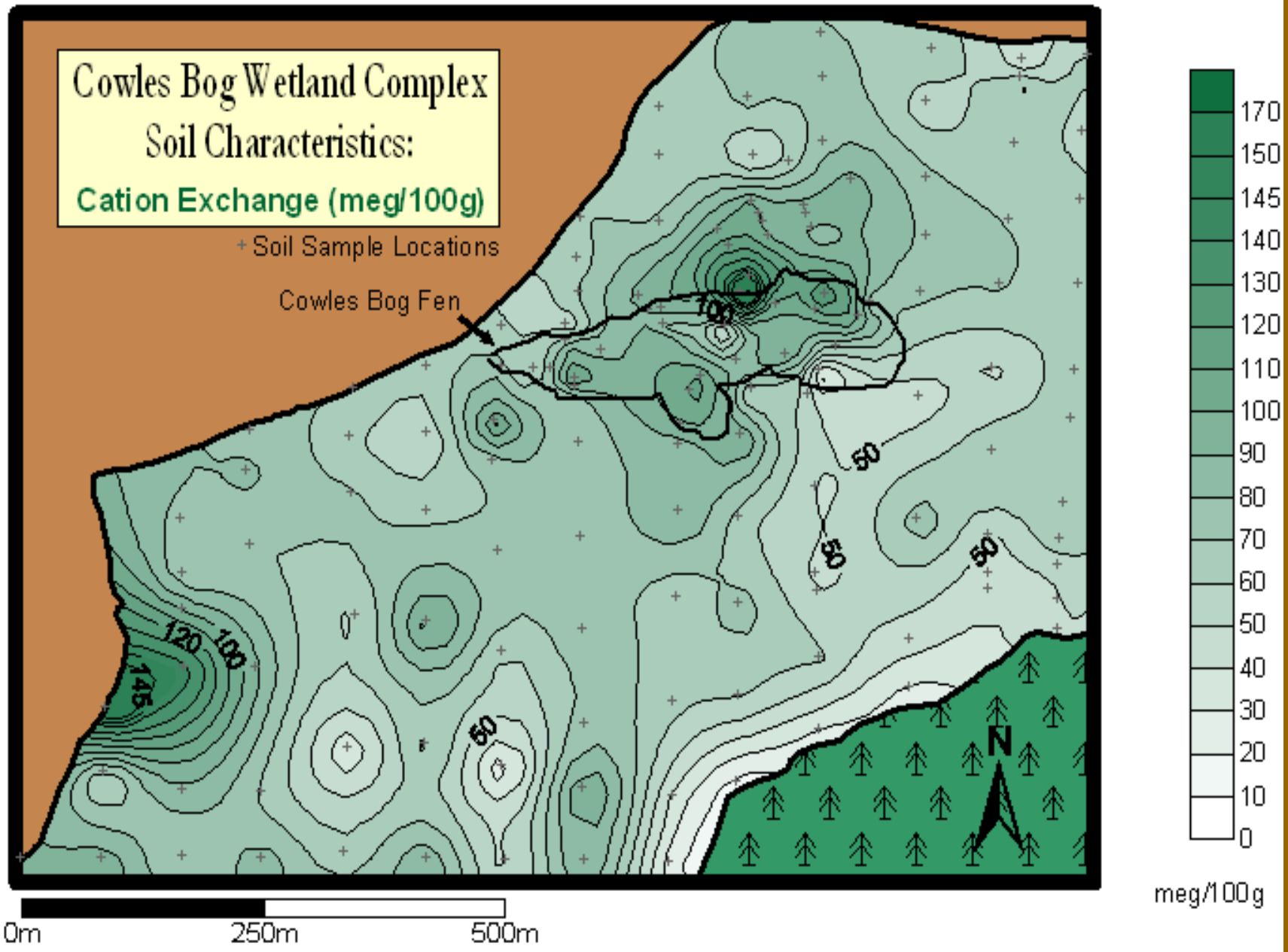
- Each sample was placed in three labeled sample bags
- One set of bags was sent to Key Agricultural Labs, Macomb, IL
- One set of bags was sent to Dr. Stephen Broome, North Carolina State University.
- One set of bags remained at Indiana Dunes National Lakeshore.

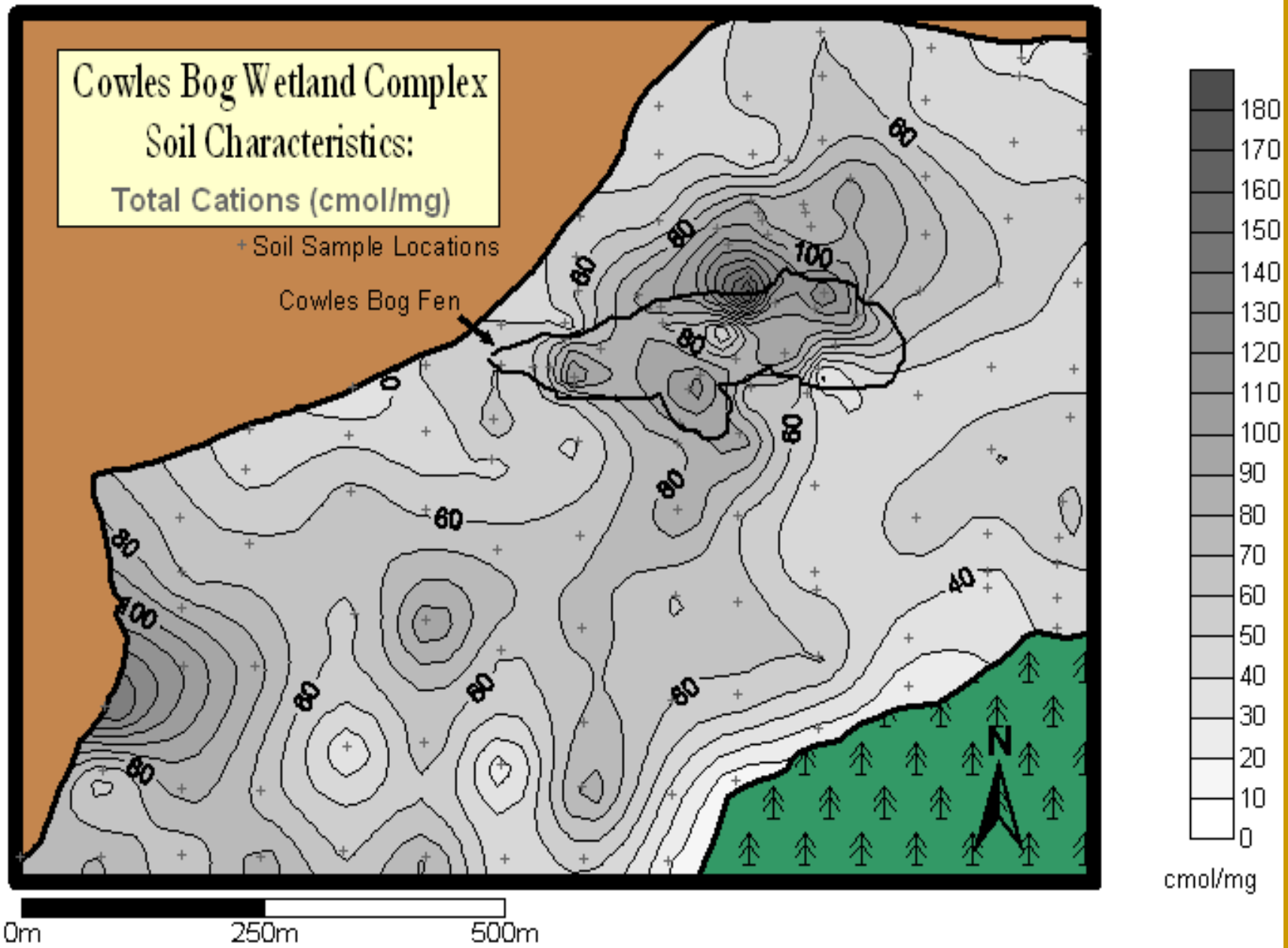

Soil Sample Locations
Soil Sample Locations
Cowles Bog Fen Perimeter
Mineral Springs Road
N
0 37.575 150 225 300
Meters
T10N-020
T11-840
T12-870
T13-840
SAMPLE10
SAMPLE9
T10N-070
T12-850
T08N-020
T09N-080
T11-780
T13-760
SAMPLE8
T08N-070
T09N-140
T10N-140
T12-780
T11-700
T13-690
SAMPLE7
T07N-020
T08N-140
T12-700
CXLAC1
T11-640
T07N-060
T07N-100
T11-580
T12-630
T13-600
SAMPLE6
T06-590
T05-540
T06-550
T04-520
T12-540
T13-510
SAMPLE5
T11-470
T03-470
T04-470
T05-470
T06-490
T07-470
T13-460
T02-430
T03-430
T06-450
T12-450
SAMPLE4
T04-410
T10-410
T05-390
T13-370
SAMPLE3
T02-380
T08-390
T09-390
T11-340
T12-360
T13-330
SAMPLE2
T03-350
T07-370
T06-350
T12-320
T13-300
SAMPLE1
T02-320
T10-320
T12-300
T13-270
T02-280
T08-300
T09-300
T04-280
T05-270
T07-270
T13-240
T11-210
T06-240
T10-230
T02-220
T03-220
T11-160
T01-180
T08-190
T09-200
T07-170
T10-150
T04-140
T05-140
T06-120
T01-110
T09-110
T02-090
T03-090
T07-100
T08-090
T14-020
T01-020
T02-020
T03-020
T04-030
T05-020
T06-020
T07-020
T08-020

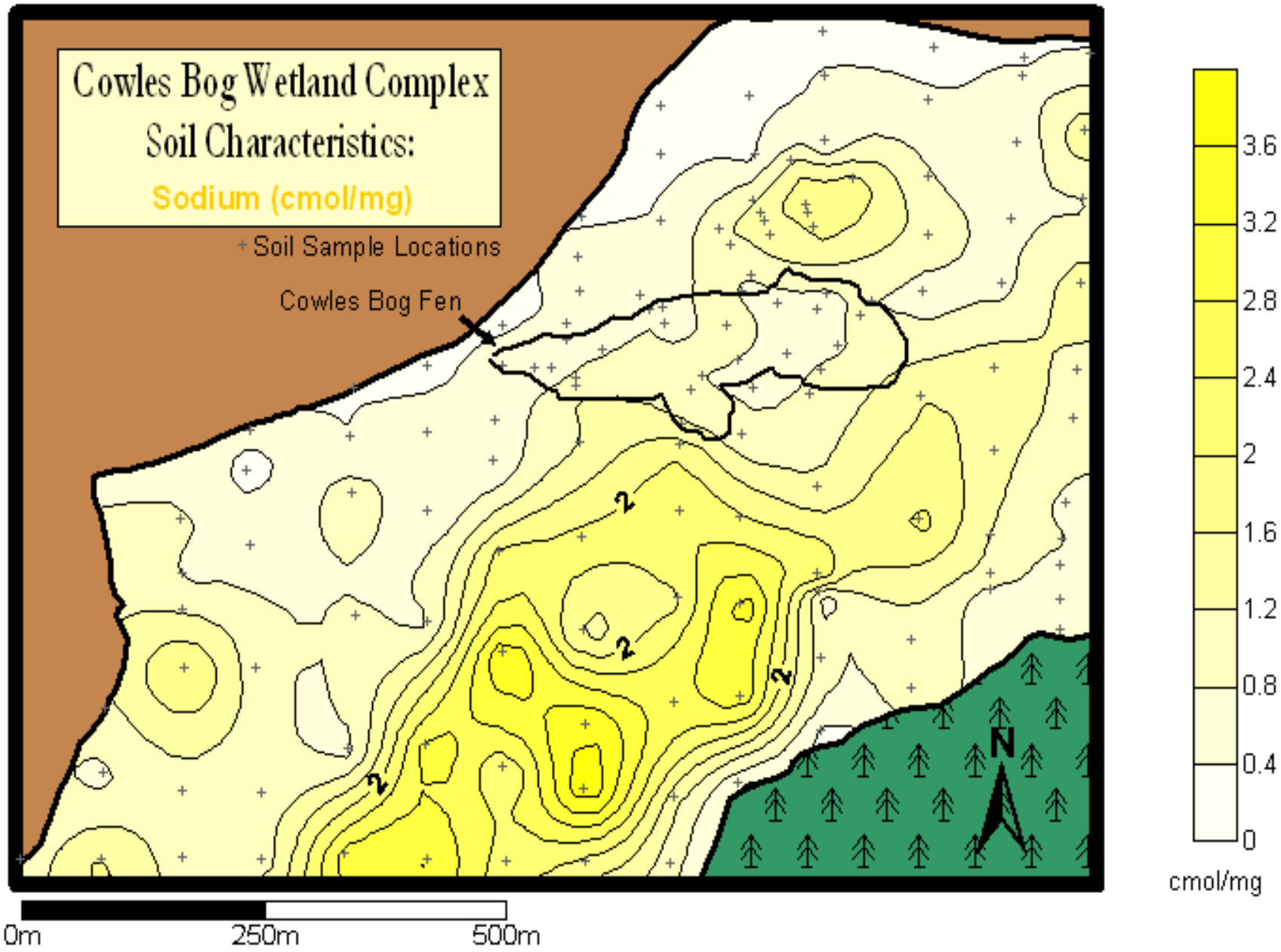
5QUART

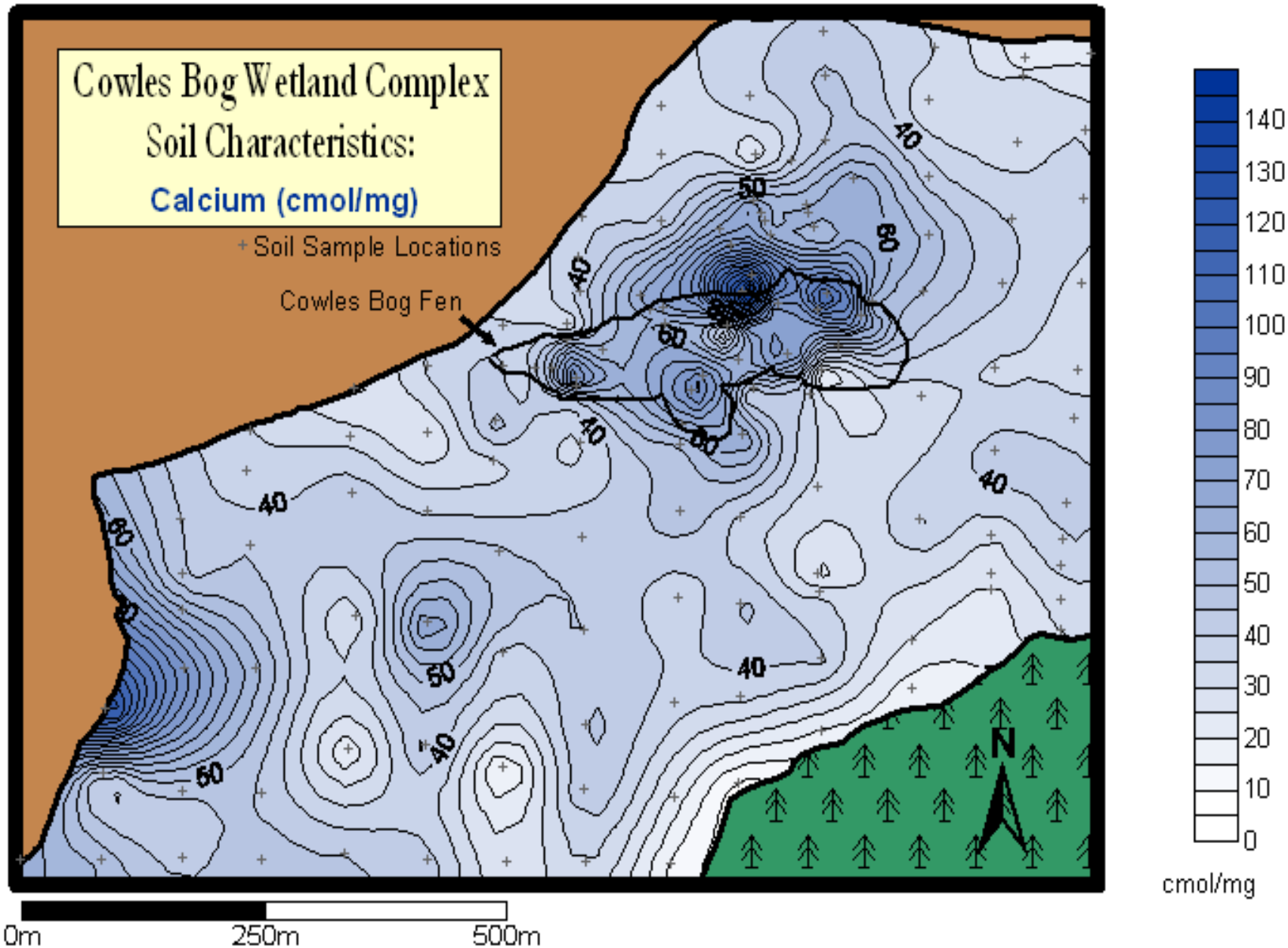
Soil Chemistry

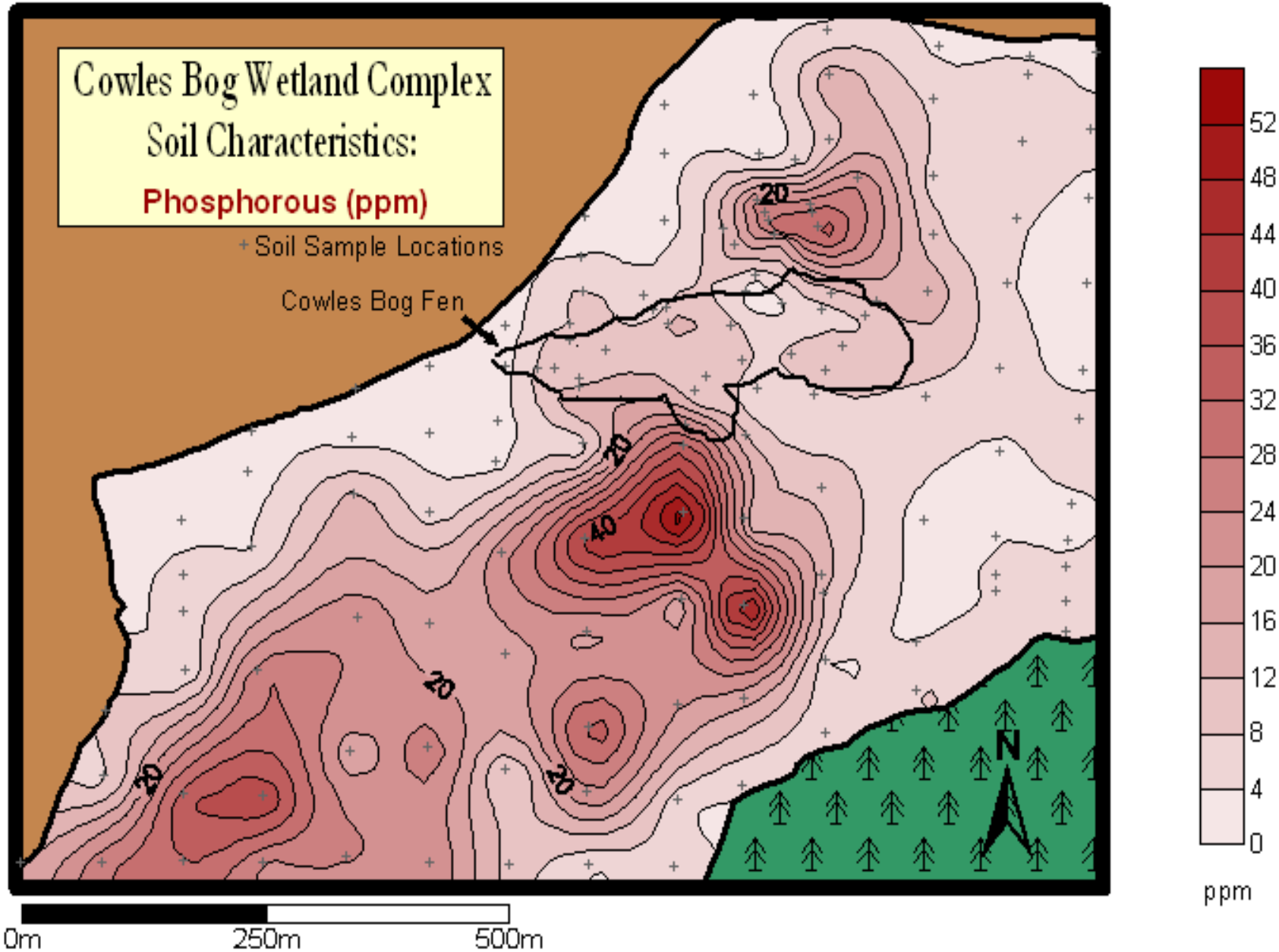
- Total cations
- Cation exchange
- Sodium
- Potassium
- Magnesium
- Calcium
- Density
- Percent Carbon
- Phosphorous
- Percent Nitrogen
- Nitrate
- Hydrogen saturation
- pH
- Ammonium

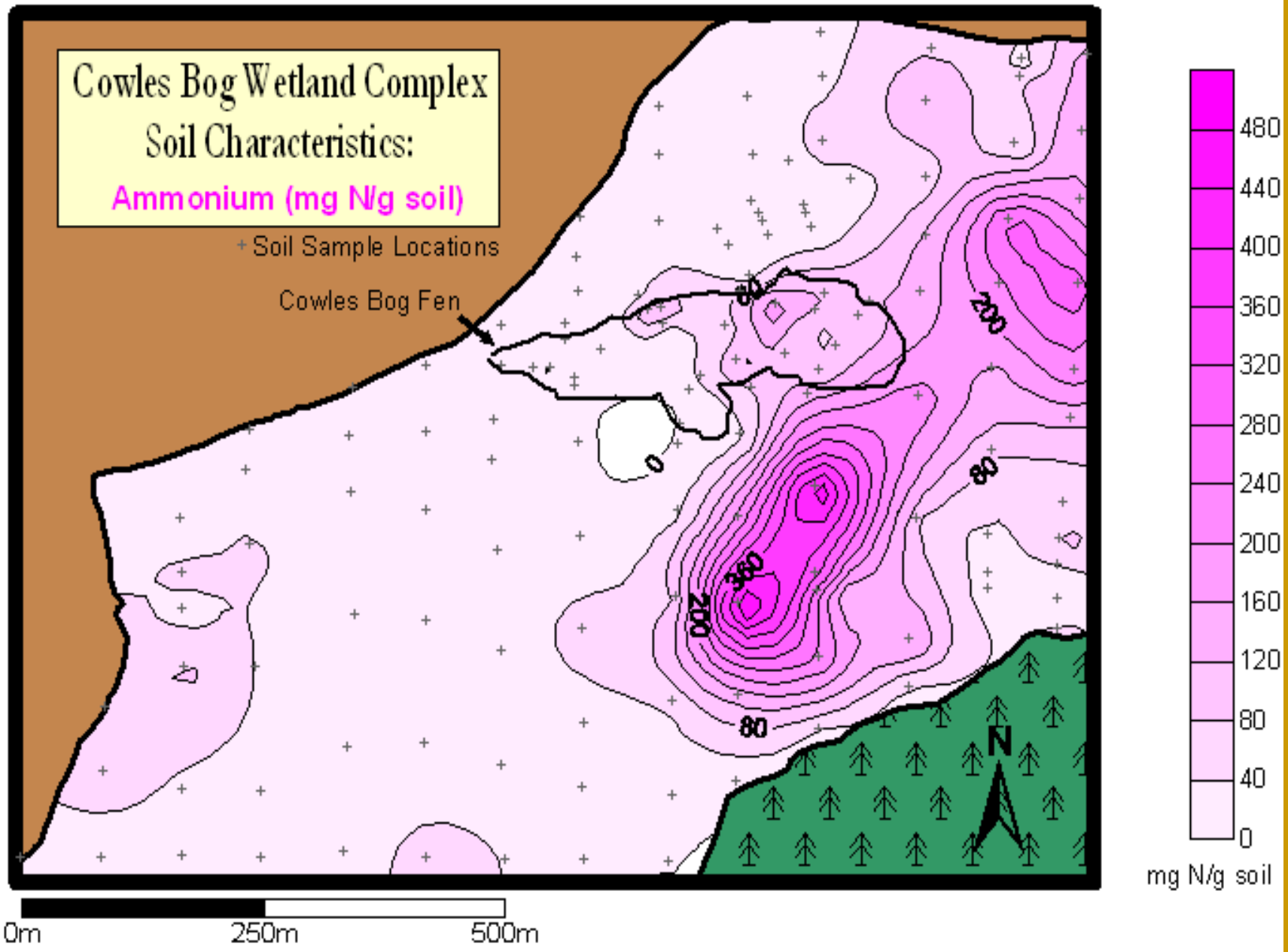

Cowles Bog Wetland Complex
Soil Characteristics:
Cation Exchange (meg/100g)
Soil Sample Locations
Cowles Bog Fen
100
50
50
50
120
100
145
50
N
170
150
145
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
meg/100g
0m
250m
500m

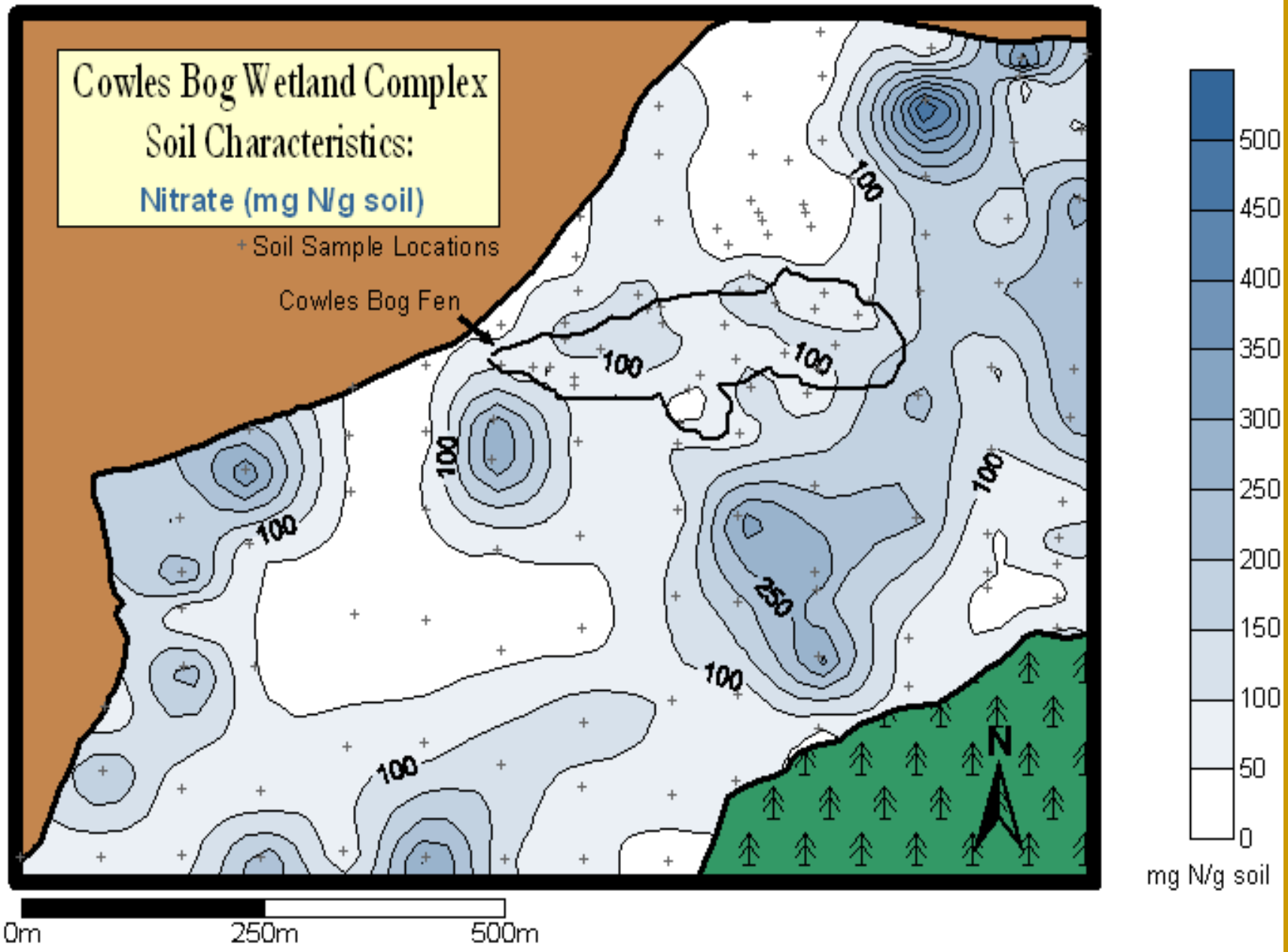

Cowles Bog Wetland Complex
Soil Characteristics:
Total Cations (cmol/mg)
Soil Sample Locations
Cowles Bog Fen
60
80
100
40
N
0m
250m
500m
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
cmol/mg

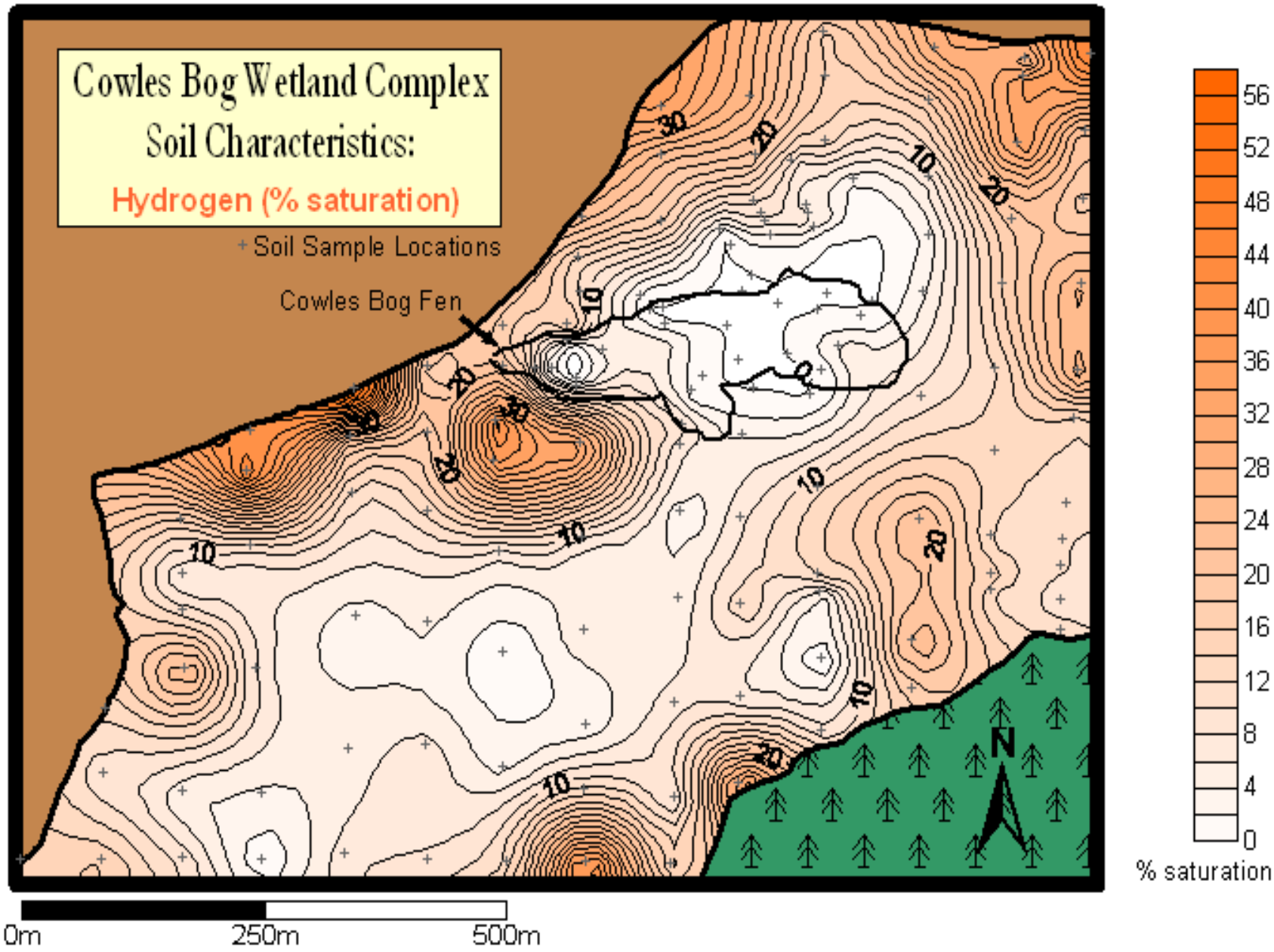

Cowles Bog Wetland Complex
Soil Characteristics:
Sodium (cmol/mg)
Soil Sample Locations
Cowles Bog Fen
2
2
2
2
N
3.6
3.2
2.8
2.4
2
1.6
1.2
0.8
0.4
0
cmol/mg
0m
250m
500m

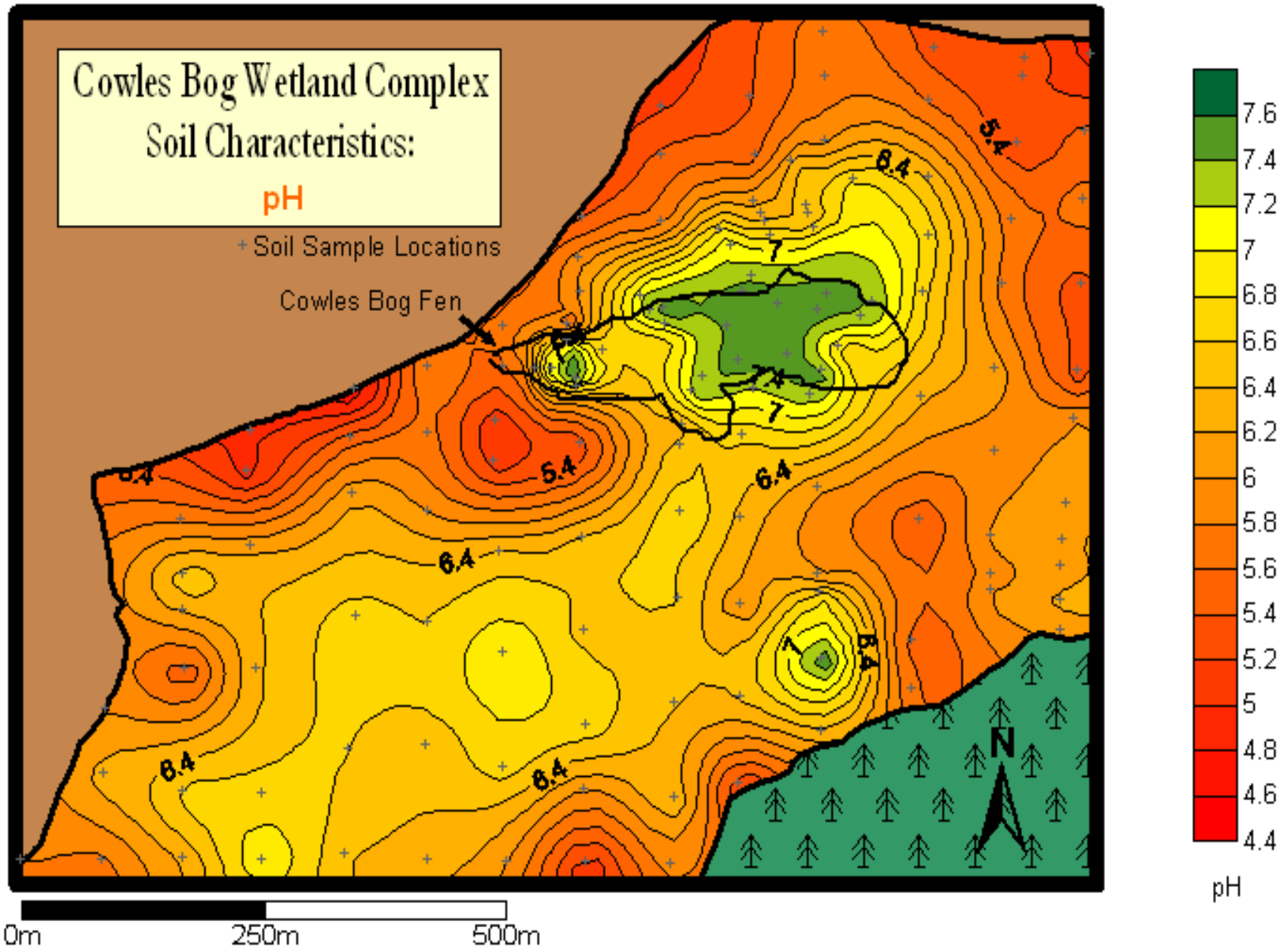

Cowles Bog Wetland Complex
Soil Characteristics:
Calcium (cmol/mg)
Soil Sample Locations
Cowles Bog Fen
40
50
60
N
0m
250m
500m
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
cmol/mg

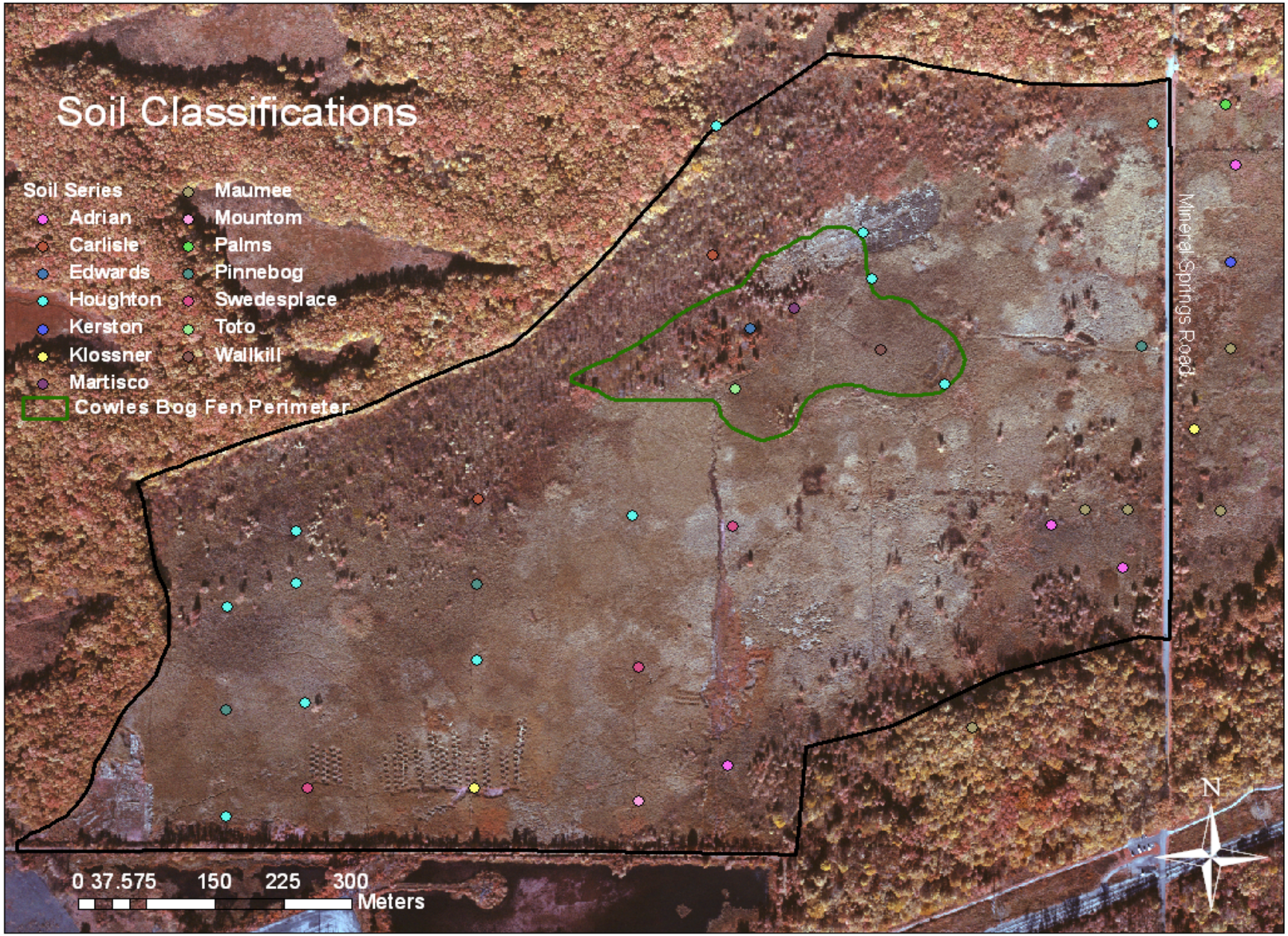

Cowles Bog Wetland Complex
Soil Characteristics:
Phosphorous (ppm)
Soil Sample Locations
Cowles Bog Fen
20
20
40
20
20
20
N
52
48
44
40
36
32
28
24
20
16
12
8
4
0
ppm
0m
250m
500m


Cowles Bog Wetland Complex
Soil Characteristics:
Ammonium (mg N/g soil)
Soil Sample Locations
Cowles Bog Fen
80
200
0
80
360
200
80
N
480
440
400
360
320
280
240
200
160
120
80
40
0
mg N/g soil
0m
250m
500m


Cowles Bog Wetland Complex
Soil Characteristics:
Nitrate (mg N/g soil)
Soil Sample Locations
Cowles Bog Fen
100
250
N
0m
250m
500m
500
450
400
350
300
250
200
150
100
50
0
mg N/g soil

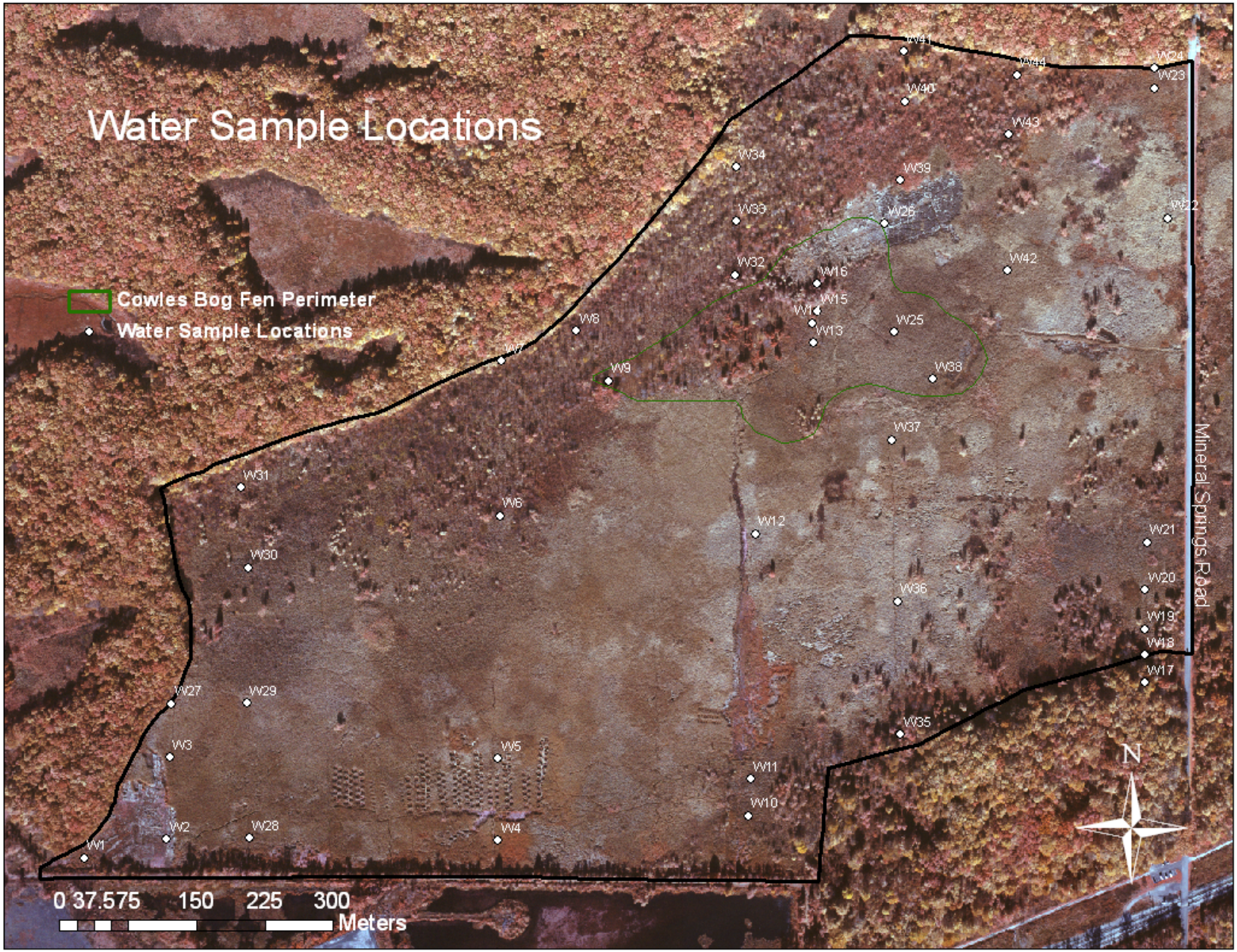

Cowles Bog Wetland Complex
Soil Characteristics:
Hydrogen (% saturation)
Soil Sample Locations
Cowles Bog Fen
N
0m
250m
500m
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
% saturation

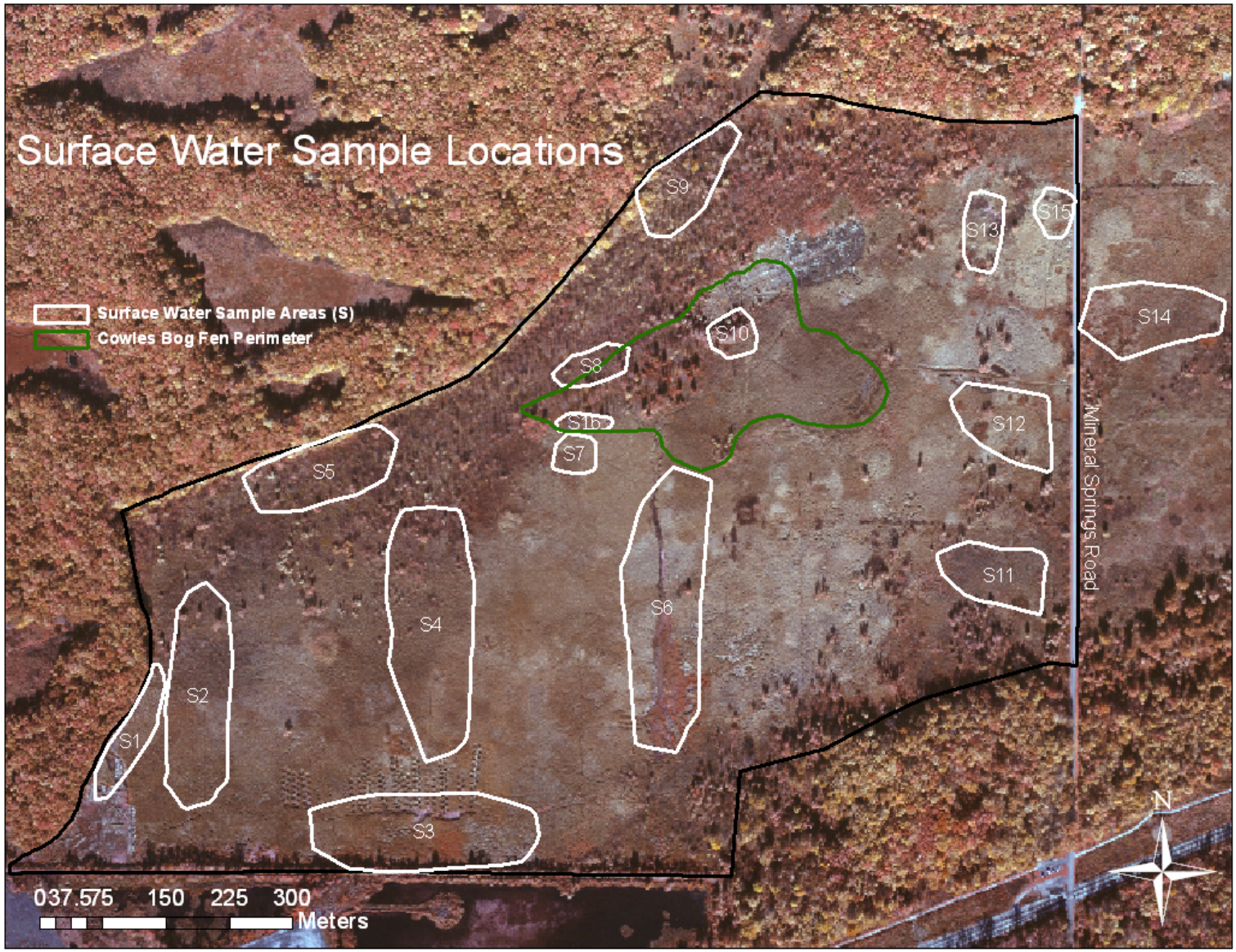

Cowles Bog Wetland Complex
Soil Characteristics:
pH
Soil Sample Locations
Cowles Bog Fen
5.4
6.4
7
N
0m
250m
500m
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
pH


Soil Classifications
Soil Series
Adrian
Carlisle
Edwards
Houghton
Kerston
Klossner
Martisco
Maumee
Mountom
Palms
Pinnebog
Swedesplace
Toto
Wallkill
Cowles Bog Fen Perimeter
Mineral Springs Road
N
0 37.575 150 225 300
Meters

Ground Water Chemistry

- Nitrate (mg/l)
- Total Nitrogen (mg/l)
- Total phosphorus (ppb)
- Spring-summer-fall of 2003
- 72 samples
- William Crumpton Iowa State U.
- pH
- Total Hardness (mg/l)
- Calcium (mg/l)
- Alkalinity (mg/l)
- Conductivity (ohms)
- 166 samples with analyses conducted at INDU.


Water Sample Locations
Cowles Bog Fen Perimeter
Water Sample Locations
W41
W44
W24
W23
W40
W43
W34
W39
W33
W26
W22
W32
W16
W42
W15
W14
W13
W25
W8
W7
W9
W38
W37
W31
W6
W12
W21
W30
W20
W36
W19
W18
W17
W27
W29
W35
W3
W5
W11
W10
W2
W28
W4
W1
Mineral Springs Road
N
0 37.575 150 225 300
Meters

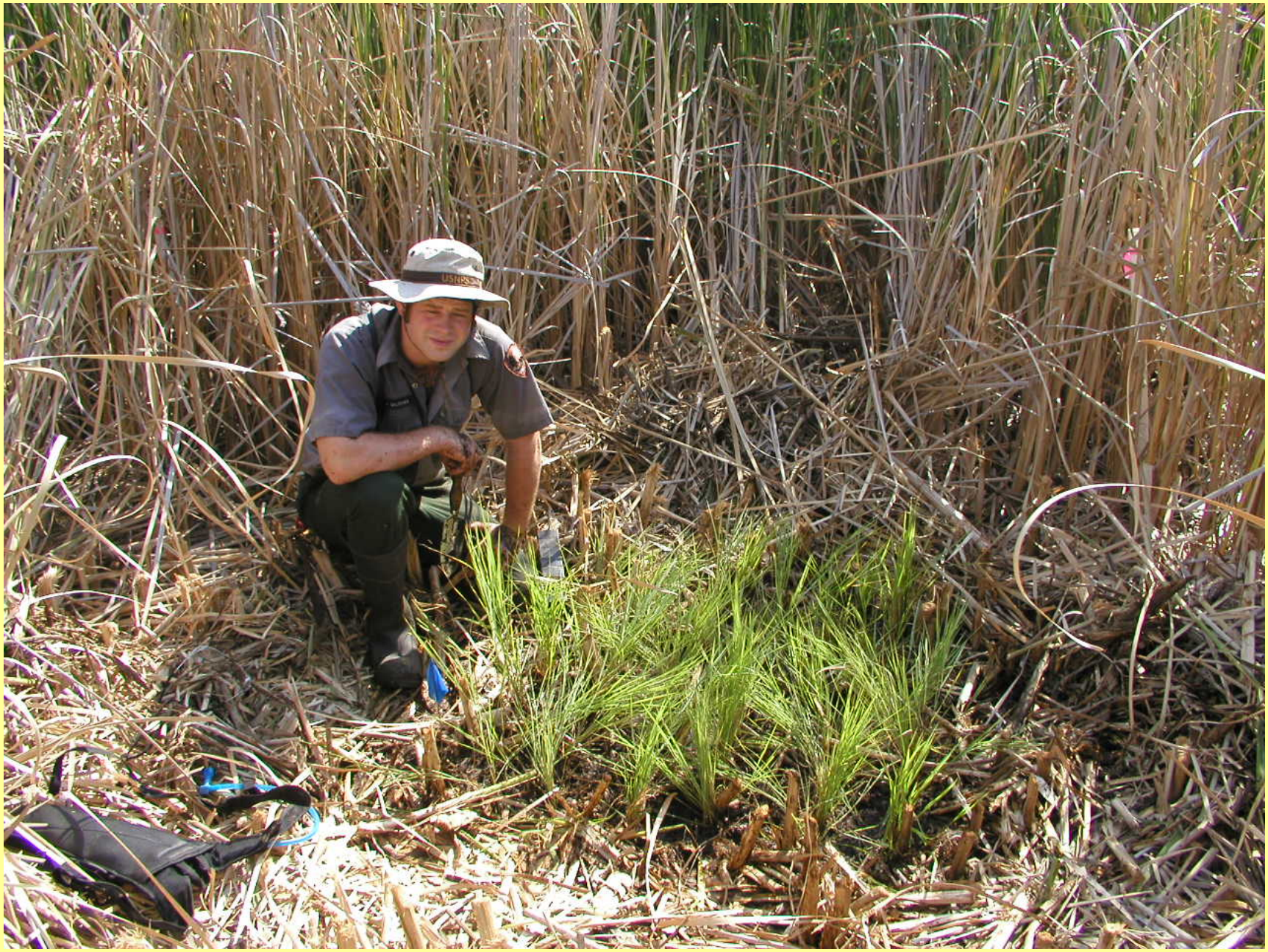

Surface Water Sample Locations
Surface Water Sample Areas (S)
Cowles Bog Fen Perimeter
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
S14
S15
Mineral Springs Road
N
037.575 150 225 300
Meters

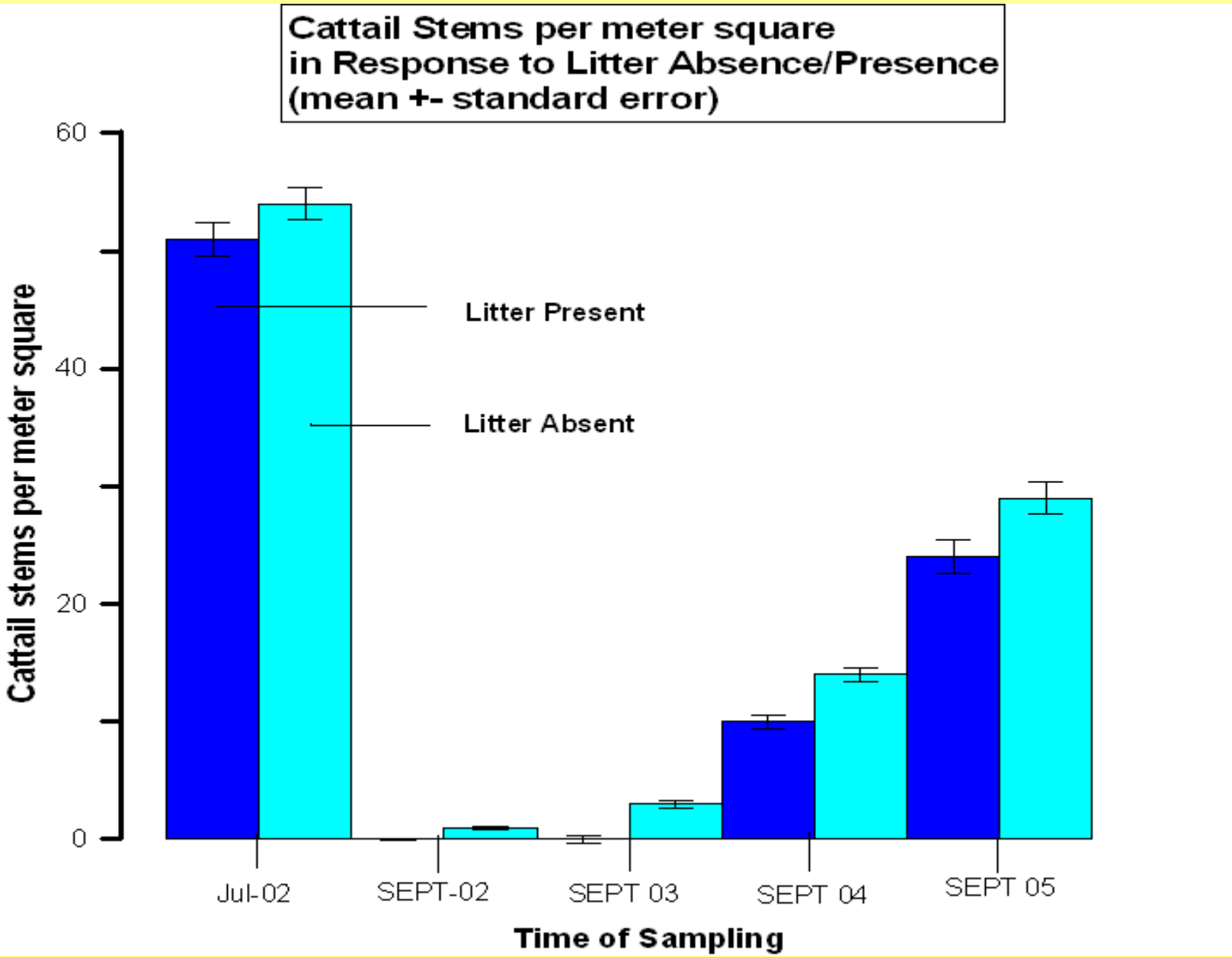
GROUNDWATER CHEMISTRY			
Unit	Nitrate	Total Nitrogen	Total Phosphorus
Hybrid Cattail	0.37	0.78	310
West Shrub	0.40	0.57	267
Forested Swamp	0.37	1.12	534
Fen	0.31	0.42	54
Sedge Meadow	0.12	0.42	329

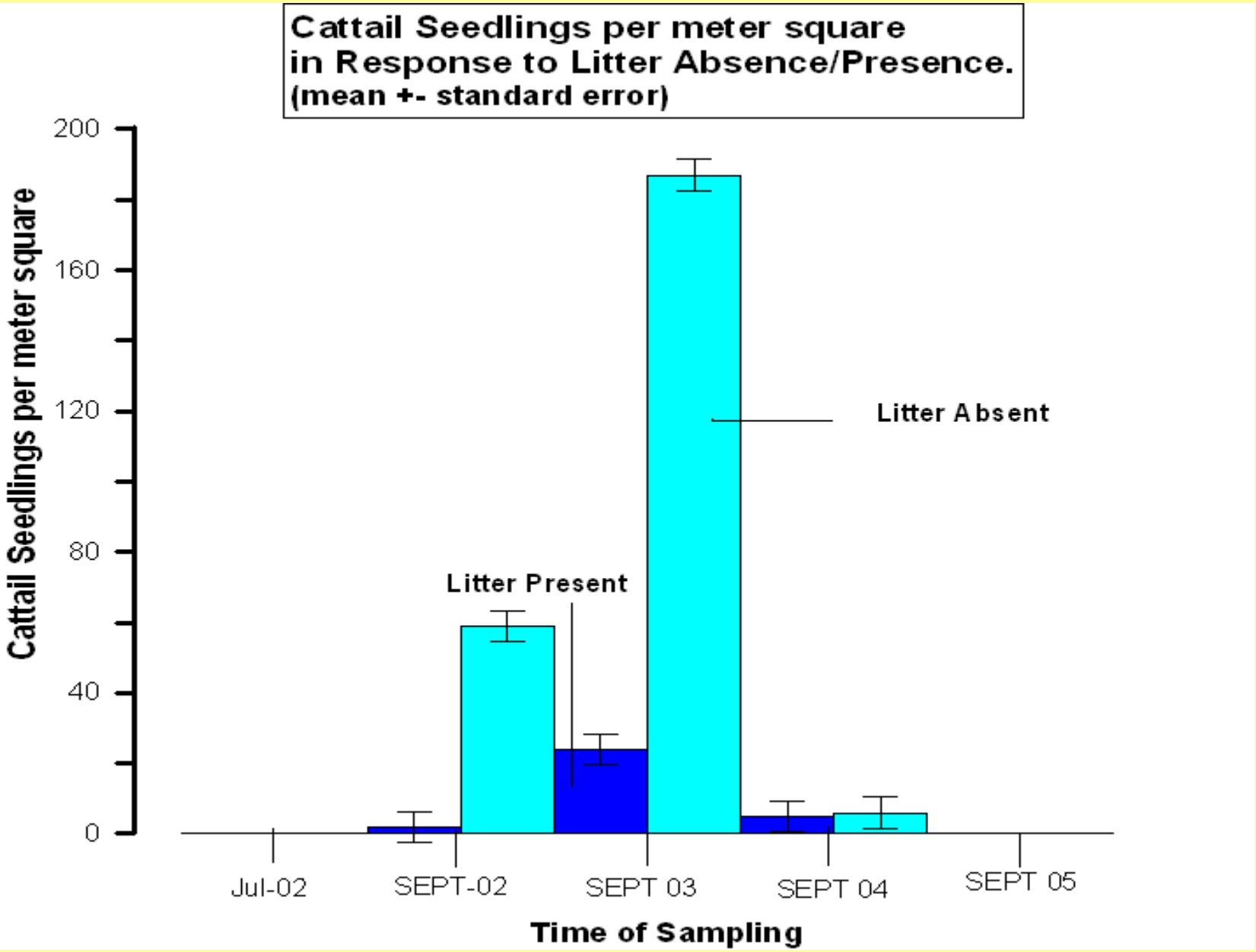
GROUNDWATER CHEMISTRY					
Unit	pH	Ca	Alk	Total Hardness	Conduct
Hybrid Cattail	7.0	185.1	246.1	291.4	499.9
West Shrub	6.7	158.5	193.0	321.0	449.9
Forested Swamp	6.8	135.3	156.0	208.8	309.5
Fen	7.4	230.0	324.1	384.9	605.8
Sedge Meadow	7.0	200.7	220.5	331.9	549.5

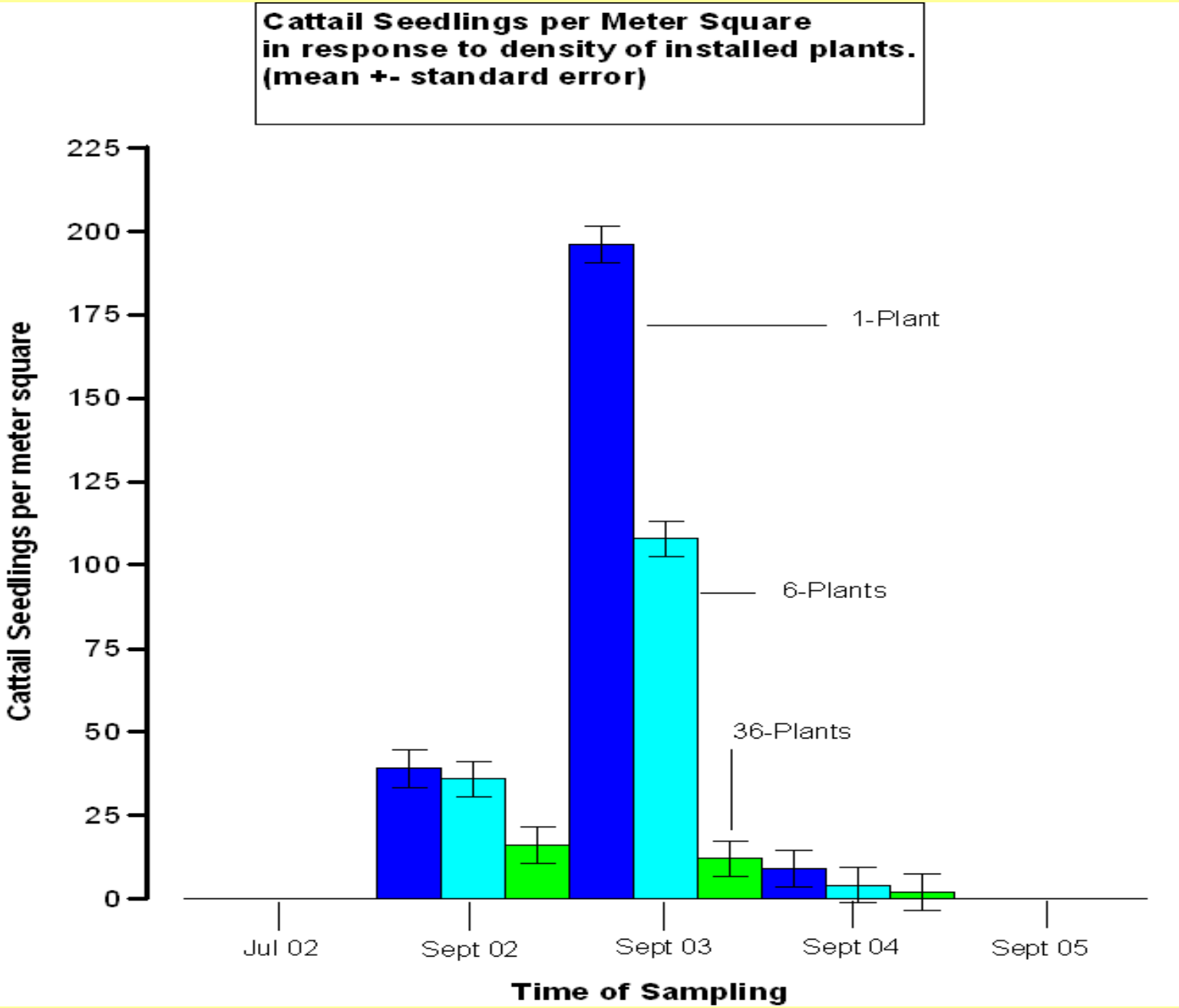
MANAGEMENT EXPERIMENTS

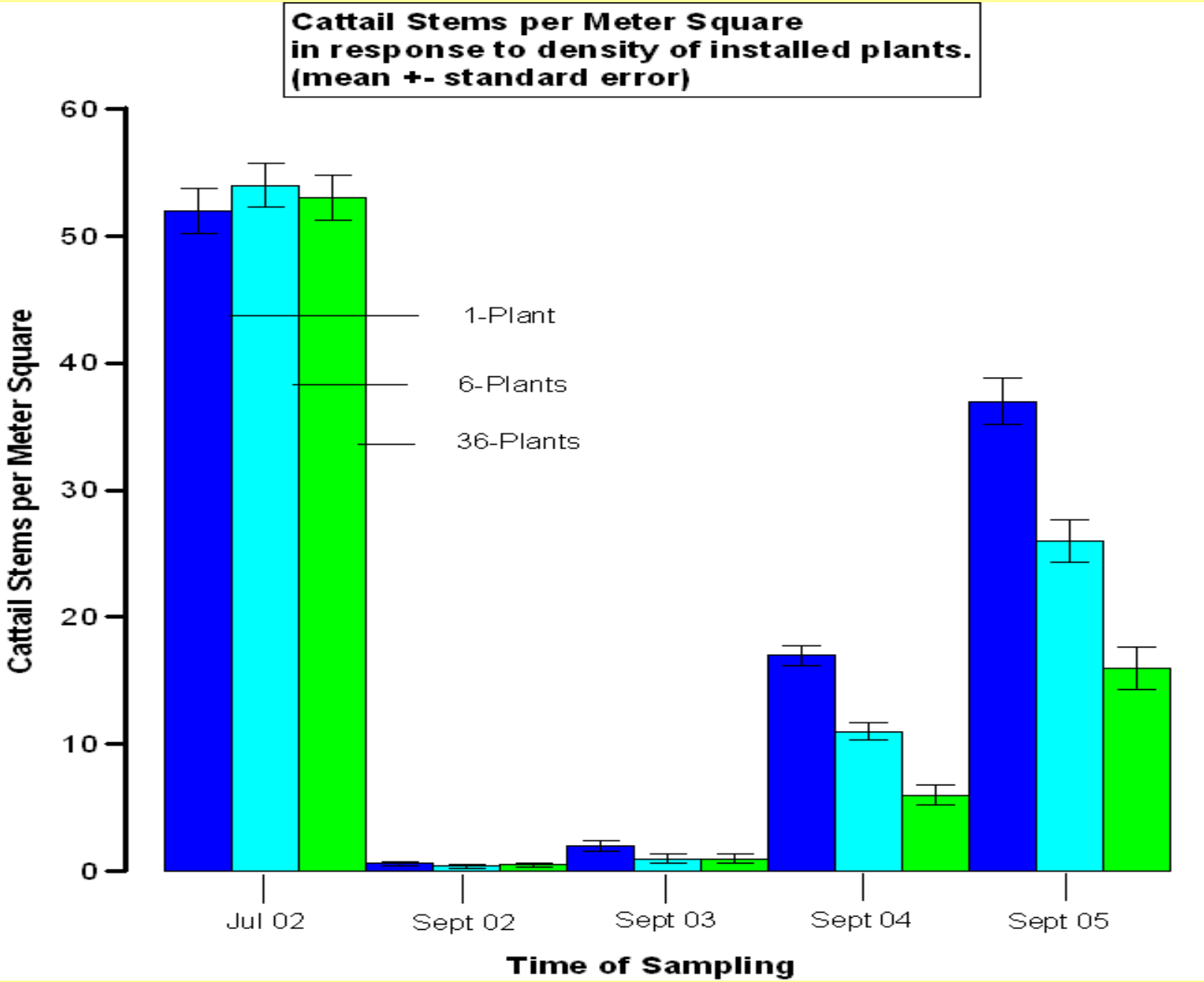
- Cattail seedbank response to removal of cattail dominated vegetation.
- Seedbank depletion.
- Seedbank suppression.

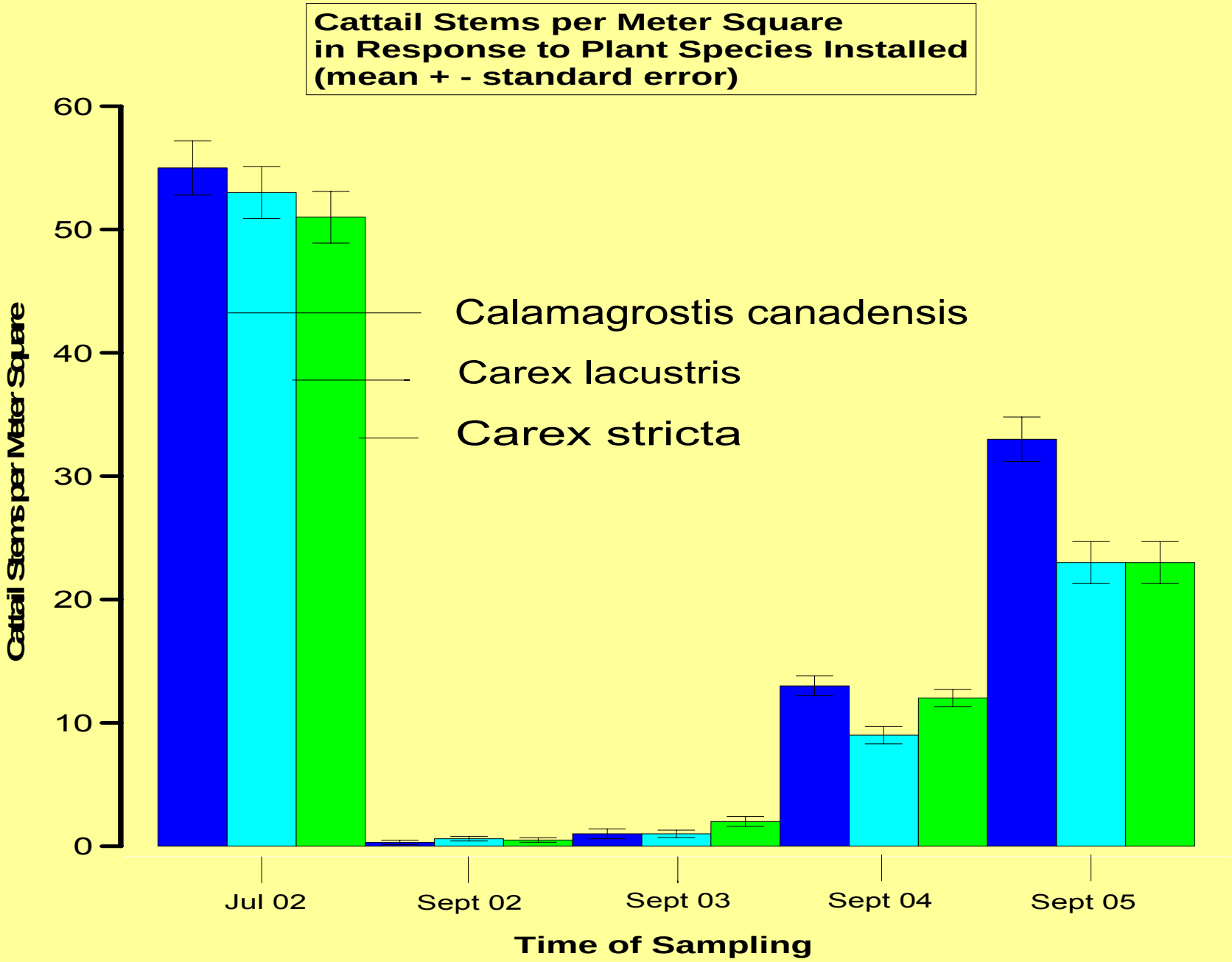

USGS


Cattail Stems per meter square
in Response to Litter Absence/Presence
(mean +- standard error)
Cattail stems per meter square
60
40
20
0
Litter Present
Litter Absent
Jul-02
SEPT-02
SEPT 03
SEPT 04
SEPT 05
Time of Sampling


Cattail Seedlings per meter square
in Response to Litter Absence/Presence.
(mean +- standard error)
Cattail Seedlings per meter square
200
160
120
80
40
0
Litter Absent
Litter Present
Jul-02
SEPT-02
SEPT 03
SEPT 04
SEPT 05
Time of Sampling


Cattail Seedlings per Meter Square
in response to density of installed plants.
(mean +- standard error)
Cattail Seedlings per meter square
225
200
175
150
125
100
75
50
25
0
1-Plant
6-Plants
36-Plants
Jul 02
Sept 02
Sept 03
Sept 04
Sept 05
Time of Sampling


Cattail Stems per Meter Square
in response to density of installed plants.
(mean +- standard error)
Cattail Stems per Meter Square
60
50
40
30
20
10
0
1-Plant
6-Plants
36-Plants
Jul 02
Sept 02
Sept 03
Sept 04
Sept 05
Time of Sampling


Cattail Stems per Meter Square
in Response to Plant Species Installed
(mean + - standard error)
Cattail Stems per Meter Square
60
50
40
30
20
10
0
Calamagrostis canadensis
Carex lacustris
Carex stricta
Jul 02
Sept 02
Sept 03
Sept 04
Sept 05
Time of Sampling

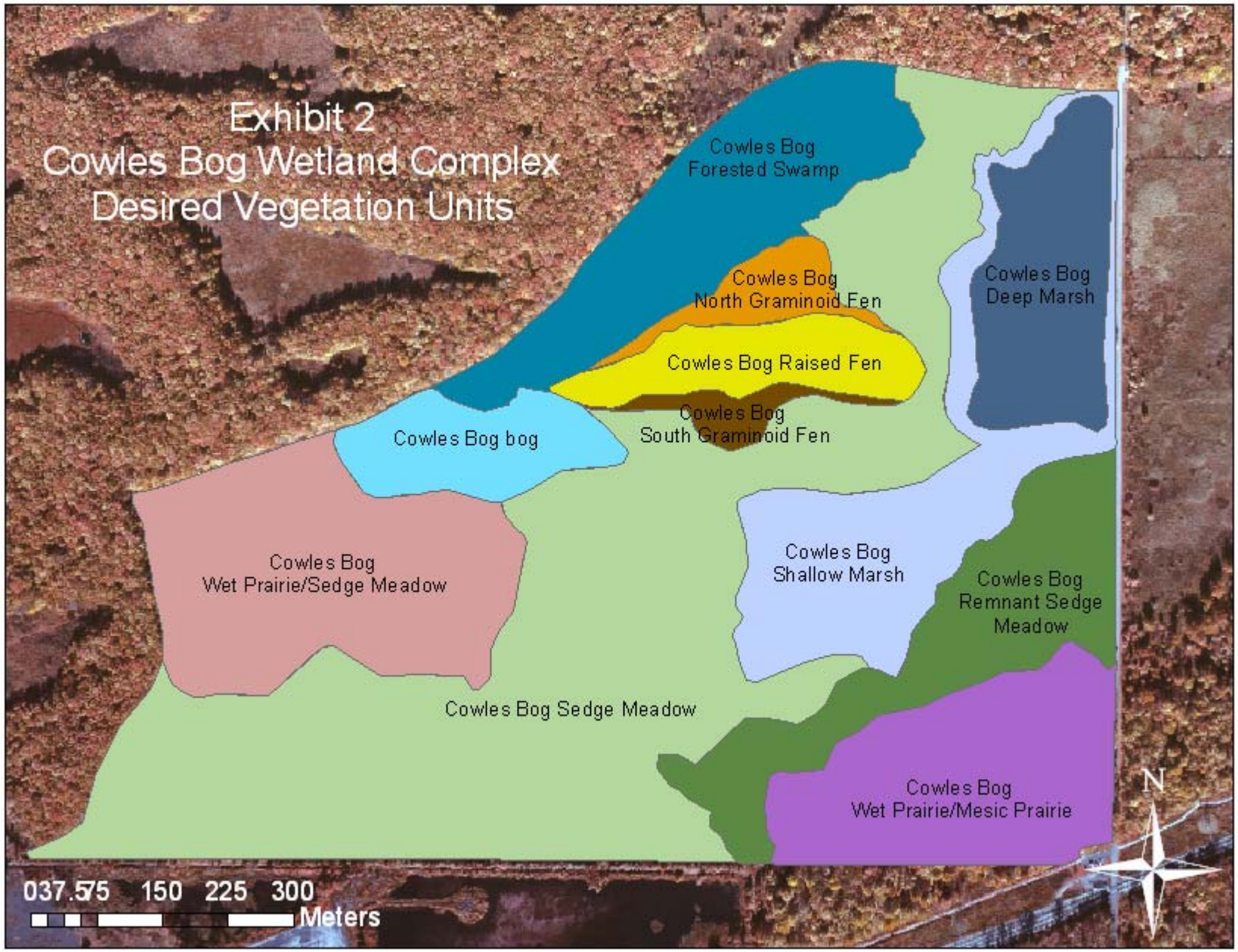


Exhibit 2
Cowles Bog Wetland Complex
Desired Vegetation Units
Cowles Bog
Forested Swamp
Cowles Bog
North Graminoid Fen
Cowles Bog Raised Fen
Cowles Bog
South Graminoid Fen
Cowles Bog
Deep Marsh
Cowles Bog bog
Cowles Bog
Wet Prairie/Sedge Meadow
Cowles Bog
Shallow Marsh
Cowles Bog
Remnant Sedge
Meadow
Cowles Bog Sedge Meadow
Cowles Bog
Wet Prairie/Mesic Prairie
N
037.575 150 225 300
Meters

COWLES BOG RESTORATION

- Phase I – Inventory (2002 – 2006)

- Phase II – Fen, Sedge Meadow/Wet Prairie, Deep Marsh, Remnant Sedge Meadow Recovery (2008 – 2010)

COWLES BOG RESTORATION

- Phase III – Bog Recovery, 1/3 of Sedge Meadow and Wet Prairie/Mesic Prairie, adaptive Management to Phase II units (2011-2013)
- Phase IV – Recovery of 2/3 of Sedge Meadow and Wet Prairie/Mesic Prairie, adaptive management to Phase II and III (2014-2016).

COWLES BOG RESTORATION

- Phase V – Adaptive management to Phases II, III, and IV (2017-2019).

STIHL