The Association of State Wetland Managers Presents:

Improving Wetland Restoration Success 2014 — 2015 Webinar Series

Peatland Restoration

Presenters:

Marcia Spencer-Famous

Richard Weber

Norman Famous

Larry Urban

Moderators: Jeanne Christie & Marla Stelk

Supported by EPA Wetland Program Development Grant 83541601

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AGENDA

- **Welcome and Introductions** (5 minutes)
  - **Restoration Webinar Schedule & Future Recordings** (5 minutes)
- **Peat Land Restoration** (80 minutes)
  - Overview
  - Organic soils & HGM
  - 3 Case Studies
- **Question & Answer** (15 minutes)
- **Wrap up** (5 minutes)

WEBINAR MODERATORS

Jeanne Christie,
Executive Director

Marla Stelk,
Policy Analyst

WETLAND RESTORATION PROJECTS

- Convened interdisciplinary workgroup of 25 experts
- Developing monthly webinar series to run through September 2015
- Developing a white paper based on webinars and participant feedback
- To be continued through 2016 in an effort to pursue strategies that:
  - Maximize outcomes for watershed management
    - Ecosystem benefits
    - Climate change
  - Improve permit applications and review
  - Develop a national strategy for improving wetland restoration success

WEBINAR SCHEDULE & RECORDINGS

WEBINAR SCHEDULE & RECORDINGS

FUTURE SCHEDULE - 2015

- **August: No Webinar**
- **September 8th, 3pm eastern (tentative date):**
  - **Stream/Wet Meadow Restoration (Will Harmon, Stream Mechanics, Inc., +)**
- **October 13th, 3pm eastern (tentative date):**
  - **Restoration in Urban & Highly Disturbed Landscapes (Tom Ries, Ecosphere Restoration Institute, Inc., +)**
- **November 10th, 3pm eastern (tentative date):**
  - **Novel Ecosystems & Restoration (Marilyn Jordan, Retired, The Nature Conservancy, +)**

FOR FUTURE SCHEDULE & UPDATES, GO TO:
http://aswm.org/aswm/6774-future-webinars-improving-wetland-restoration-success-project

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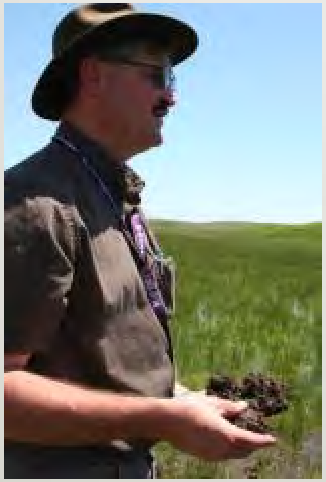
PRESENTERS

Marcia Spencer-Famous
Spencer-Famous Environmental Consultants



Rich Weber
NRCS Wetland Team

Norman Famous
Spencer-Famous Environmental Consultants

Larry Urban
Montana Dept. of Transportation

A "COOKBOOK" APPROACH TO WETLAND RESTORATION WON'T WORK

There are too many variables.

- *Ingredients are always different*
- *Reason for 'cooking' varies*
- *Recipe isn't always correct*
- *Inexperienced cooks*
- *Cooking time varies*
- *Poor inspection when "cooking"*
- *Additional ingredients may be needed*
- *Is it really done?*

WE NEED TO UNDERSTAND THE PLANNING PROCESS AND VARIABLES FROM SITE TO SITE THAT MUST BE STUDIED, UNDERSTOOD AND ADDRESSED

EACH WETLAND RESTORATION PROJECT IS UNIQUE:

- *Consider both historic and current landscape setting*
- *Analyze how water moves into and out of the site*
- *Evaluate soils present and identify any onsite drainage*
- *Focus first on hydrology and soil first, last on plants*
- *Develop a plan that is achievable for the site*
- *Develop comprehensive cost estimates*
- *Ensure plan is followed*
- *Hire experienced and knowledgeable contractors*
- *Adapt plan as needed during construction*
- *Determine if monitoring criteria will measure progress*
- *Keep good records and share with others*

Peatland Restoration

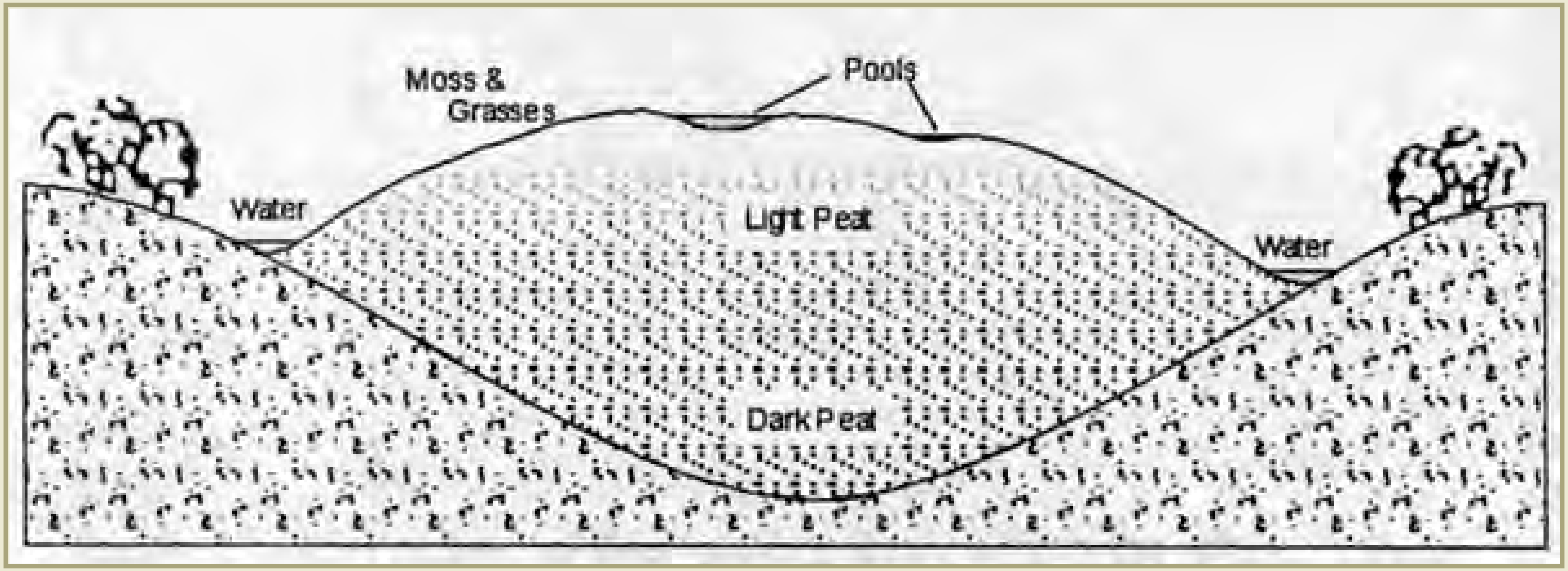
IT WILL TAKE US A FEW MOMENTS TO MAKE THE SWITCH…

Peatland Restoration

Marcia Spencer-Famous
July 14, 2015

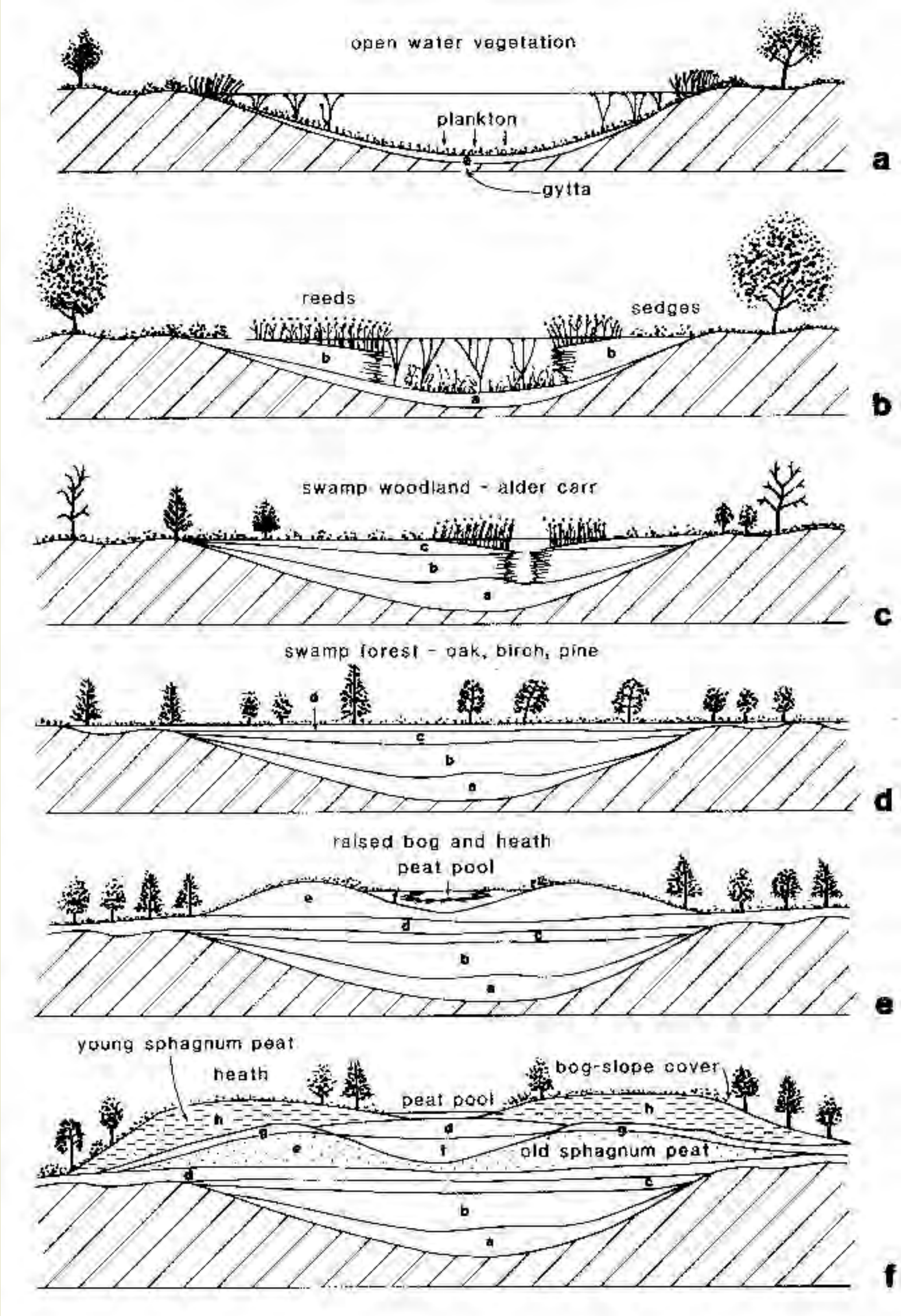
What is a peatland?

- Peatland - A wetland with a thick organic soil layer
- Bog - Ombrotrophic ["rain-water fed"] peatland
  - domed bog, coastal plateau bog, blanket bog, aapa mire
- Fen – Minerotrophic ["nutrient-rich"] peatland
  - acidic fen, patterned fen, circumneutral fen, rich fen, pocosin
- How do they form? Peat accumulation over time.
- Where? In ponds, along streams, in shallow depressions, on moist slopes, even on mountain tops
- Usually have a perched water table, but not always.
- Usually sphagnum dominated, but not always.



Typical lake-fill domed bog

- Perched water table
- Secondary pools on top
- Sphagnum and ericaceous shrubs, stunted trees
- Peat at bottom more decomposed, peat at top less decomposed
- Lagg at upland/bog interface



Typical lake-fill domed bog formation

a and b - Pond with sediment accumulating, floating bog mat around edges, bottom fills in

c and d - Shrub/forested fen, pond filled in but upland runoff and groundwater still control nutrient levels, minerotrophic

e - Peat continues to accumulate, dome starts, sphagnum takes over, shift to ombrotrophic as peat accumulates, secondary pool forms

f - Fully domed bog, sphagnum dominant, peat layers at different stages of decomposition

Rock Dam South, T16 MD, Hancock Co., Maine

Secondary Pool, Lower Beddington Bog, Maine

Jonesport Heath, Jonesport, Maine

Sunkhaze Bog, Milford, Penobscot Co., Maine

Can you restore a peatland?

Three things needed for a wetland

- Hydric soil? The peat is now in bags in the store. What is the growing surface?
- Hydrology? Block or fill drainage ditches? Is there just a shallow pond left? What if there is little or no watershed?
- Hydrophytes? Not all hydrophytes are peatland plants.
  - Re-seed? Which species to start? Natural re-colonization?

Can you ever get a raised bog back?

- Primary succession - No seed bank, long distance to seed sources, pioneer species recolonized disturbed areas first
- Sphagnum – How long will it take to re-colonize, if at all?
  - Other peat producing species?
- Time for peat to accumulate – Varies, but always long
- What is the best stage of peatland development to restore to?
  - Fen? Swamp? Pond with floating mat?
  - Depends on remaining peat type and thickness, nutrient availability, hydrology
- Climate change

Other peatland restoration problems

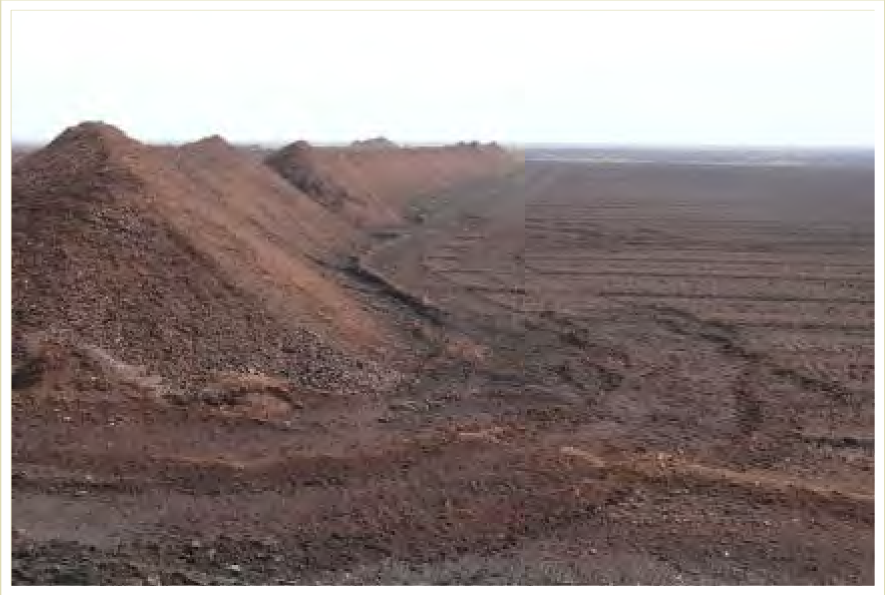
- Huge areas - Drained, may be dug up and hauled away
- Harsh growing conditions – Too dry, too wet, too acidic, little or no peat left, frost heaving, crusting
- Erosion – Water, but wind especially
- Watershed – Sometimes little or none
- If peat is removed completely – Ponds, cattail swamps, areas where little will grow, upland islands

Drainage ditches first

Vegetation gone

Pokesudie Bog, New Brunswick, Canada

Vacuum harvesting

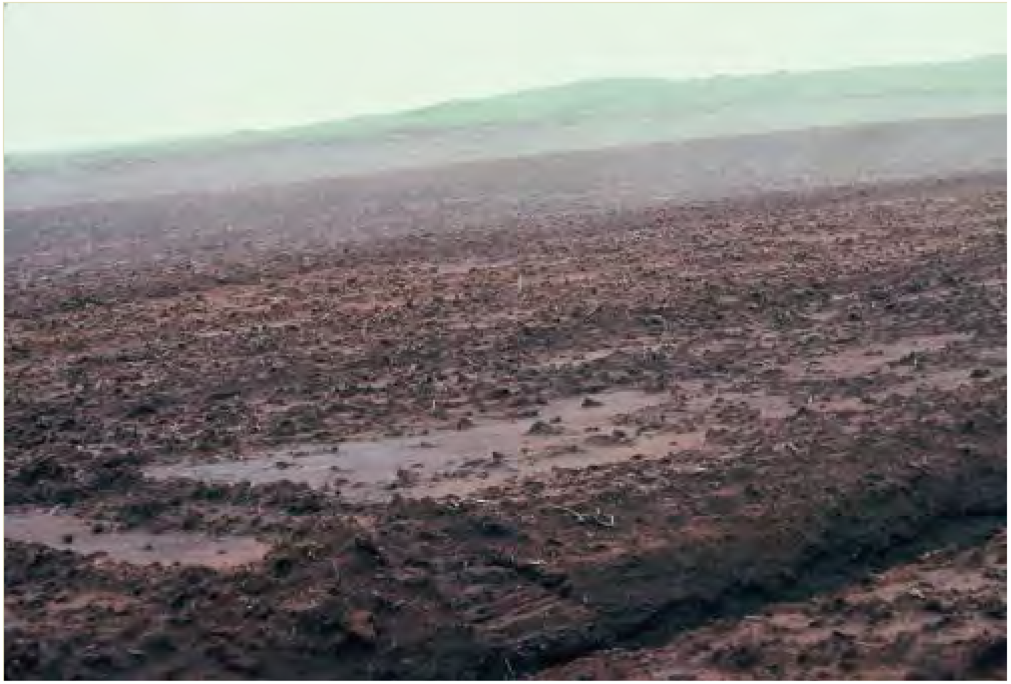


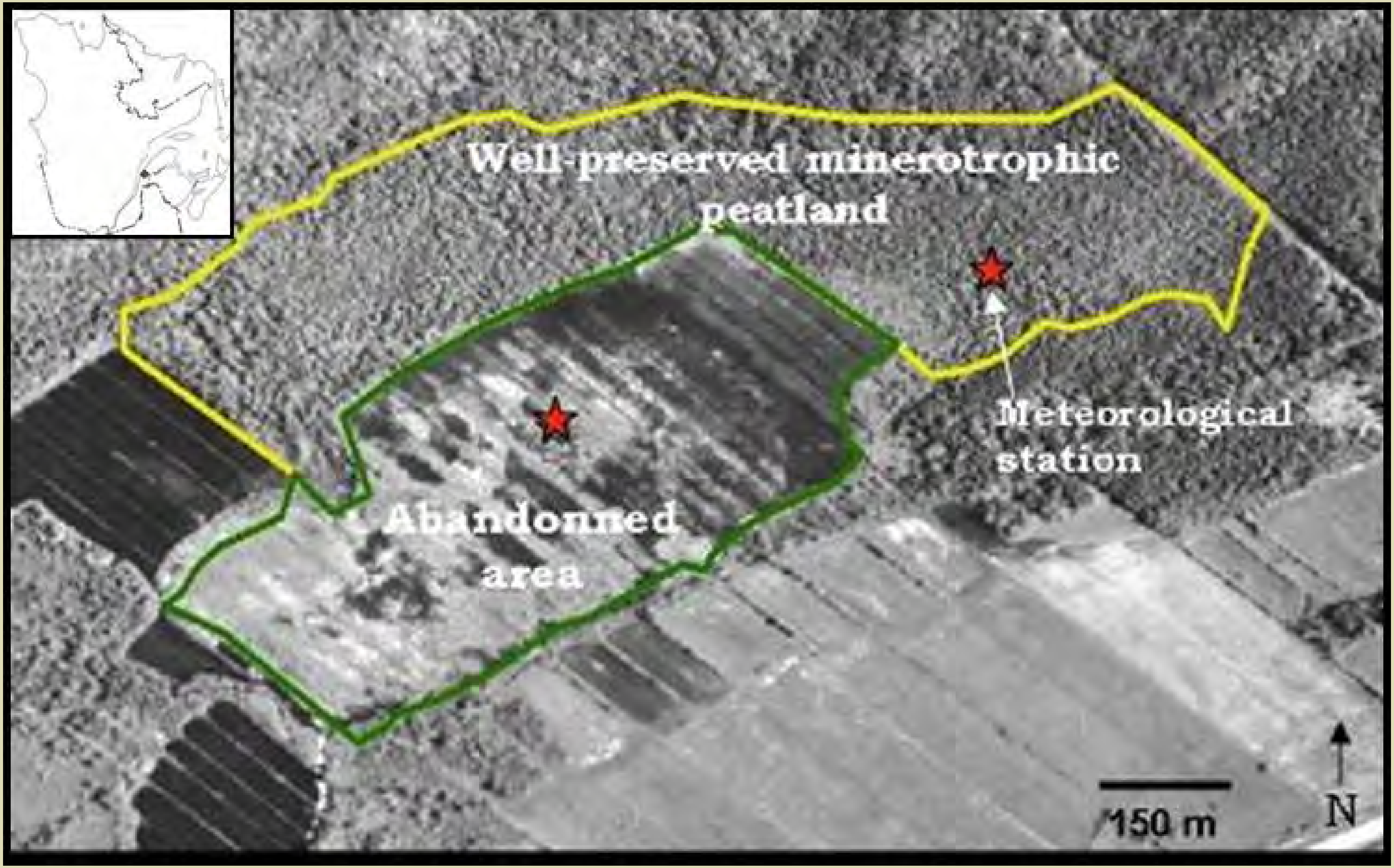
Windrow method

Can you ever get a developing bog back?

Can you even get a wetland back?

Newly abandoned mined peatlands





Areas at the edge of mined bogs abandoned first

- Less acidic areas with some nutrient input become re-colonized faster; may recolonize with species not found on undisturbed peatlands – is this ok?
- Early successional species such as *Eriophorum vaginatum var. spissum*, or the moss *Polytrichum commune* may recolonize the bare peat surface.
  - “Companion species”
- Protected niches help seedlings and sphagnum recolonize.
- Will sphagnum become a dominant eventually?
  - How long will it take to restore a “growing” peatland?

Recolonizing mined peat surfaces with mineral soil/nutrient influence




Eriophorum vaginatum, an early successional species

Recolonizing block-cut areas

Farnham Bog, Quebec

Dredged 100+ years ago, up to 20 feet deep

<< Sphagnum in an undisturbed bog

Recolonizing sphagnum spread on bare peat at restoration site >>

Factors to consider when preparing a peatland restoration plan

Disturbance history

- Peat extraction method
- Other use
- Compaction
- Ditching
- Mineral soil influence
- Time since disturbance

Existing conditions

- Peat depth, type
- Decomposition level
- Available hydrology
- pH and nutrient availability (soil and water)
- Plant propagule options
- On-going disturbance
  - Erosion – wind and water
  - Frost heaving
  - Crusting
  - Periodic flooding

Factors to address in a peatland restoration plan

- Realistic time frame for the restoration process
- Stage of peatland development being restored initially
- Re-seeding/re-planting or natural recolonization
  - Re-establishment of *Sphagnum*
- Addition of nutrients to jump start recolonization
  - Establish cover to stabilize growing surface
- Adjust hydrology - Block or fill ditches, drain ponds, etc.
- Create protected niches
- Monitoring

Reference materials

- Quinty, F. and L. Rochefort, 2003. *Peatland Restoration Guide*, second edition. Canadian Sphagnum Peat Moss Association and New Brunswick Department of Natural Resources and Energy. Québec, Québec.
- Wheeler, B.D. and S. C. Shaw, 1995. *Restoration of Damaged Peatlands*, Environmental Consultancy, University of Sheffield, 343 Fulwood Road, Sheffield, UK
- Wheeler, B.D. and S.C. Shaw, 1995. *A focus on fens. Restoration of Temperate Wetlands* (eds. B.D. Wheeler, S.C. Shaw, W.J. Fojt and R.A. Robertson). Wiley, Chichester, UK.

Organic Soils & HGM

Richard Weber, Wetland Hydraulic Engineer

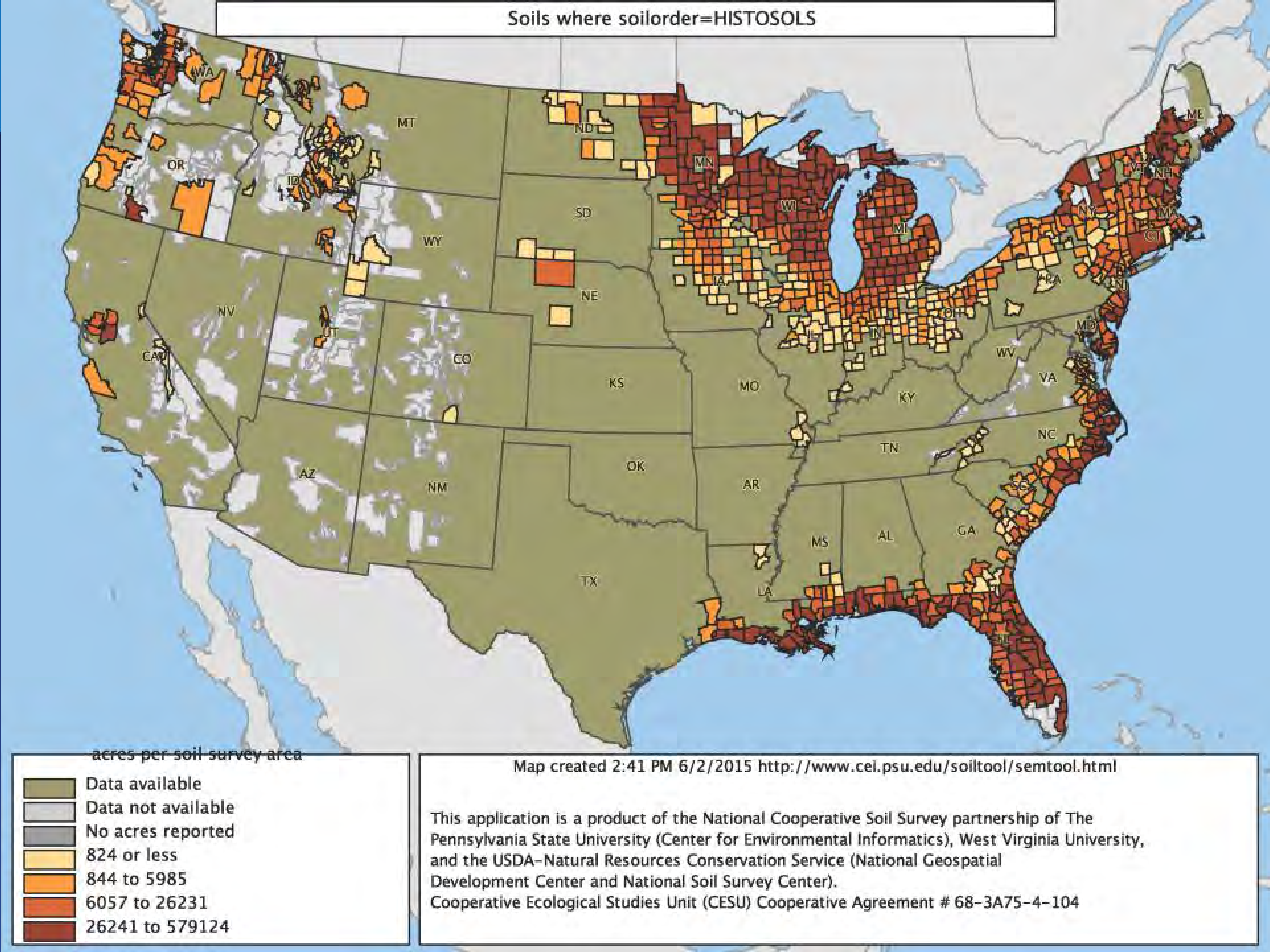
NRCS Wetland Team
CNTSC, Ft. Worth, TX

Organic Soils - Histosols

- Histosols have a high content of organic matter and no perma-frost. Most are saturated year round, but a few are freely drained. Histosols are commonly called bogs, moors, peats, and mucks.

- Histosols form in decomposed plant remains that accumulate in water, forest litter, or moss faster than they decay. If these soils are drained and exposed to air, microbial decomposition is accelerated, and the soils may subside dramatically.

- Histosols make up about 1% of the world's ice-free land surface


Soils where soilorder=HISTOSOLS
WA
OR
CA
NV
ID
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WY
UT
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SC
PA
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NJ
CT
MA
VT
NH
ME
acres per soil survey area
Data available
Data not available
No acres reported
824 or less
844 to 5985
6057 to 26231
26241 to 579124
Map created 2:41 PM 6/2/2015 http://www.cei.psu.edu/soiltool/semtool.html
This application is a product of the National Cooperative Soil Survey partnership of The Pennsylvania State University (Center for Environmental Informatics), West Virginia University, and the USDA-Natural Resources Conservation Service (National Geospatial Development Center and National Soil Survey Center).
Cooperative Ecological Studies Unit (CESU) Cooperative Agreement # 68-3A75-4-104

Organic Soil Sub-Orders

- Fibrists
  - Peat
  - Plant material relatively un-decomposed
- Saprists
  - Muck
  - Well decomposed plant material
- Hemists
  - Mucky Peat
  - Intermediate between Fibrists and Saprists

Organic Soils in Wetlands

- Organic Soils are proof of wetland hydrology
  - Except for Folists
  - Surface saturation required to form and maintain wetland organic soils
  - Anaerobic conditions prevent oxidation
  - Dominant Water Source is either:
    - Groundwater discharge
    - Direct Precipitation

Discharge Wetlands

- These receive groundwater discharge from adjacent recharge zones in the local watershed
- If recharge zone is high in minerals, the wetlands are Mineraltrophic
- Includes Discharge Depressions and Fens
- Fens low in dissolved minerals are referred to as “Poor Fens”.

Prairie Potholes

- Not all Prairie Potholes are Discharge!
- Must have near continuous groundwater discharge

DEPRESSION HGM CLASS
Discharge sub-class

Large Headwaters

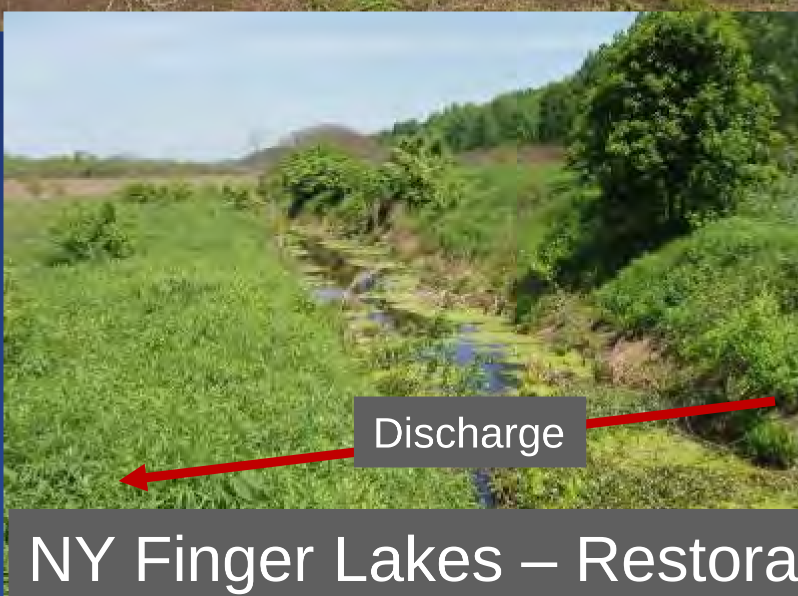
- Upstream of Riverine reaches
- Strong recharge zone
- Surface Saturated, not ponded

Boundary County, ID
SLOPE HGM Class

Large Headwaters

NY Finger Lakes – Drained "Muck Farm"

NY Finger Lakes - Intact



NY Finger Lakes – Restoration: Plug the Perimeter Ditch

Smaller Headwaters

Kansas “Gyp Hills”
- Histic Epipedon

Near Pinedale, Wyoming

Palouse, ID

Recharge Organic Soil Wetlands

- Dominant Water Source – Precipitation
- Ombotrophic
- Acidic
- Bogs
- Organic Flat HGM Class

Organic Flats

- Interfluves
- Glacial Lake Plains
- AND: Within Depressions……..Bogs within Fens

Pocosins

- Atlantic Coastal Plain
- Rain Fed
- Nutrient Poor
- Interfluves

Overview of Minerotrophic Fen Restoration and Creation: Two Case Histories

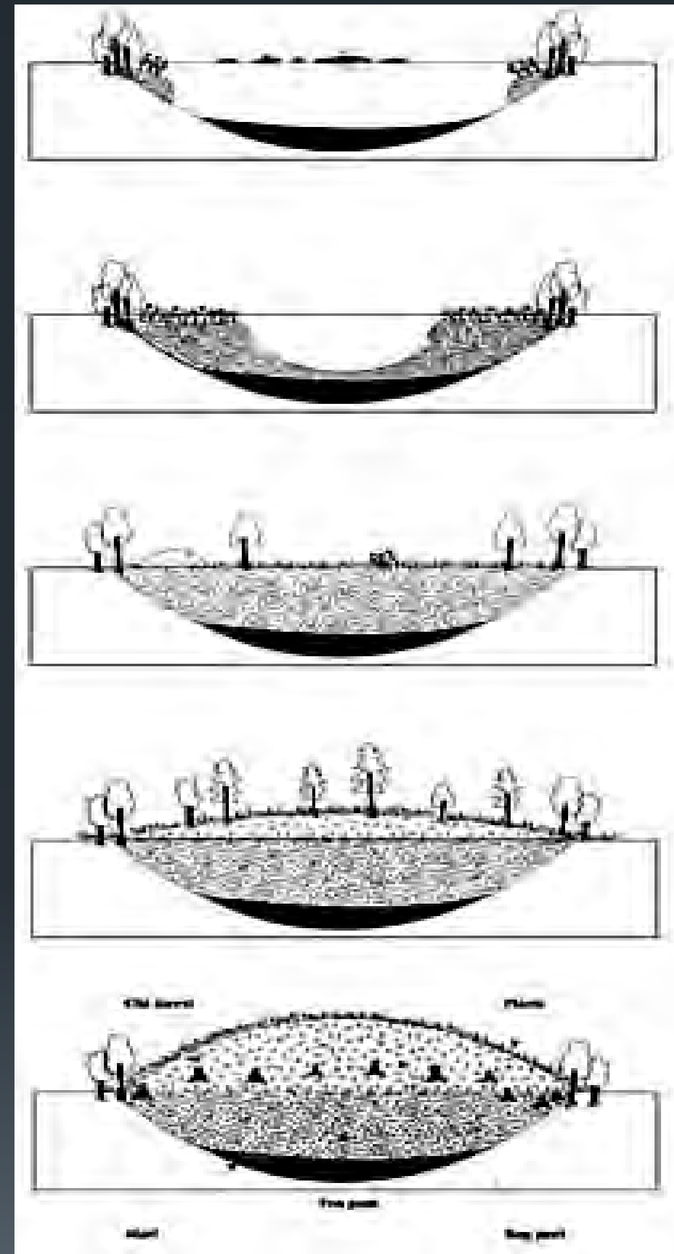
Norman C. Famous

July 14, 2015

What are Fens?

Fen Development
(Drawings 1 to 3)

Raised Bog Development
(Drawings 4 & 5)



1

2

3

4

5

Now let's look at a few fens

A combination of bog and fen (above)

Fen portion - Light vegetation along upland Edge, and left and lower-left side.

Extends out to the forested area in the middle where the bog begins.

This peatland is located on Great Wass Island in Maine.

Small Fen Creation/ Restoration

Case study in Northern Maine

Fen Construction Procedure

- Add wetland soil (mixture of 12% organics by volume)
- Add 10% cover of dead logs & woody debris
- Disperse graminoid seed mixture
- Allow the wetland soil to become saturated
- Add additional graminoid mixture
- Start planting herbaceous and woody plants during the third growing season
- Monitor water table and plant establishment rates –

10% dead wood cover over 12 inches of soil mix

***Sphagnum* moss mound-building with companion plants 7 years post-construction (exceptional rate)**

Large *Sphagnum* mounds at Farnham Bog in Quebec, PC excavated over 100 years ago

Moose and deer eat most non-ericaceous woody plants

Woody debris and moose footprints protect *Sphagnum* moss clumps and small shrubs. Plants are wool grass seedlings (*Scirpus cyperinus*)

Graminoid Seed Mixture

Common Name	Scientific Name	Wetland Status
▪ Wool-grasses	*Scirpus cyperinus*	FACW
▪ Woolgrass	*S. pedicellatus*	OBL
▪ Red-stemmed bulrush	*S. microdiscus*	OBL
▪ Broom sedge	*Carex scoparia*	FACW
▪ Fringed sedge	*C. crinita*	OBL
▪ Gray sedge	*C. canescans*	OBL
▪ Crowded sedge	*C. stipata*	OBL
▪ Nodding sedge	*C. gynandra*	OBL

Graminoid Seed Mixture

Common Name	Scientific Name	Wetland Status
Spiny sedge	*C. echinata*	OBL
Manna grass	*Glyceria striata*	OBL
Soft rush	*Juncus effuses*	FACW
Canada rush	*Juncus canadensis*	OBL
Blunt spike-rush	*Eleocharis obtusa*	OBL
Rushes	*Juncus* spp.	OBL & FACW
Manna grasses	*Glyceria* spp.	OBL

Lessons Learned
Vegetation Management

- **Allow water levels to stabilize for 2-3 years before planting most wetland species including Ericaceous shrubs.**
- **Woody debris and moose footprints protect *Sphagnum* moss clumps and small shrubs.**
- ***Sphagnum* moss propagules should not be dispersed until a full companion plant cover is established.**
- **Match *Sphagnum* with each species preferred nutrient regime and hydrology.**

Post-Construction Monitoring

Post-Construction Monitoring

- **Target wetland functions and values**
  - **Vegetation: percent cover, cover types, plant establishment rates**
  - **Companion plants / *Sphagnum* establishment**
  - **Ericaceous shrub growth and reproduction**
  - **Water levels**
  - **Peat and water chemistry which varied little from year-to-year (suspended after 3 years)**
- **Invasive species colonization and control**
- **Bird populations (breeding season and migration observations) & amphibian #'s**

***Sphagnum* mosses colonize a log**

Round-leaved sundews (*Drosera rotundifolia*) growing on top of log

Ericaceous Shrub Monitoring

Ericaceous shrubs spreading - Leatherleaf (*Rhododendron groenlandicum*)

Large cranberries in lower- center, below Leatherleaf (*Vaccinium macrocarpon*)

Amphibian Breeding Pool

Minden Bog
Michigan
Case Study:
Restoration of a
Mined Raised Bog to a Fen

Minden Bog
Undisturbed Condition

Minden Bog showing active production cells in the fore-ground

Minden Bog showing abandoned production cells in the foreground

Minden Bog, Michigan: Case Study

- Prepared an in-kind restoration plan for a raised bog mined down to fen peat layers
- Mined by vacuum harvesting and bulldozing
- Heavily ditched, some very deep (14 feet)
- Special problems
  - Ditches penetrated underlying calcareous lake substrate
  - Large areas of non-restorable invasive species - monocultures of *Phragmites*
  - Located next to a state game preserve and deer wintering area

Pre-Restoration Plan Sampling

- Sampled existing vegetation to create a cover type map
- Mapped abandoned mineral-contaminated mined fields & invasive species cover
  - Included the ditch system
- Compiled a list of potential restoration plant species and their preferred microhabitats
- Probed to determine peat thickness to create a bottom topo map (used existing data)
- Sampled peat chemistry and water chemistry

Partially flooded abandoned production cells with *Phragmites australis* and open water

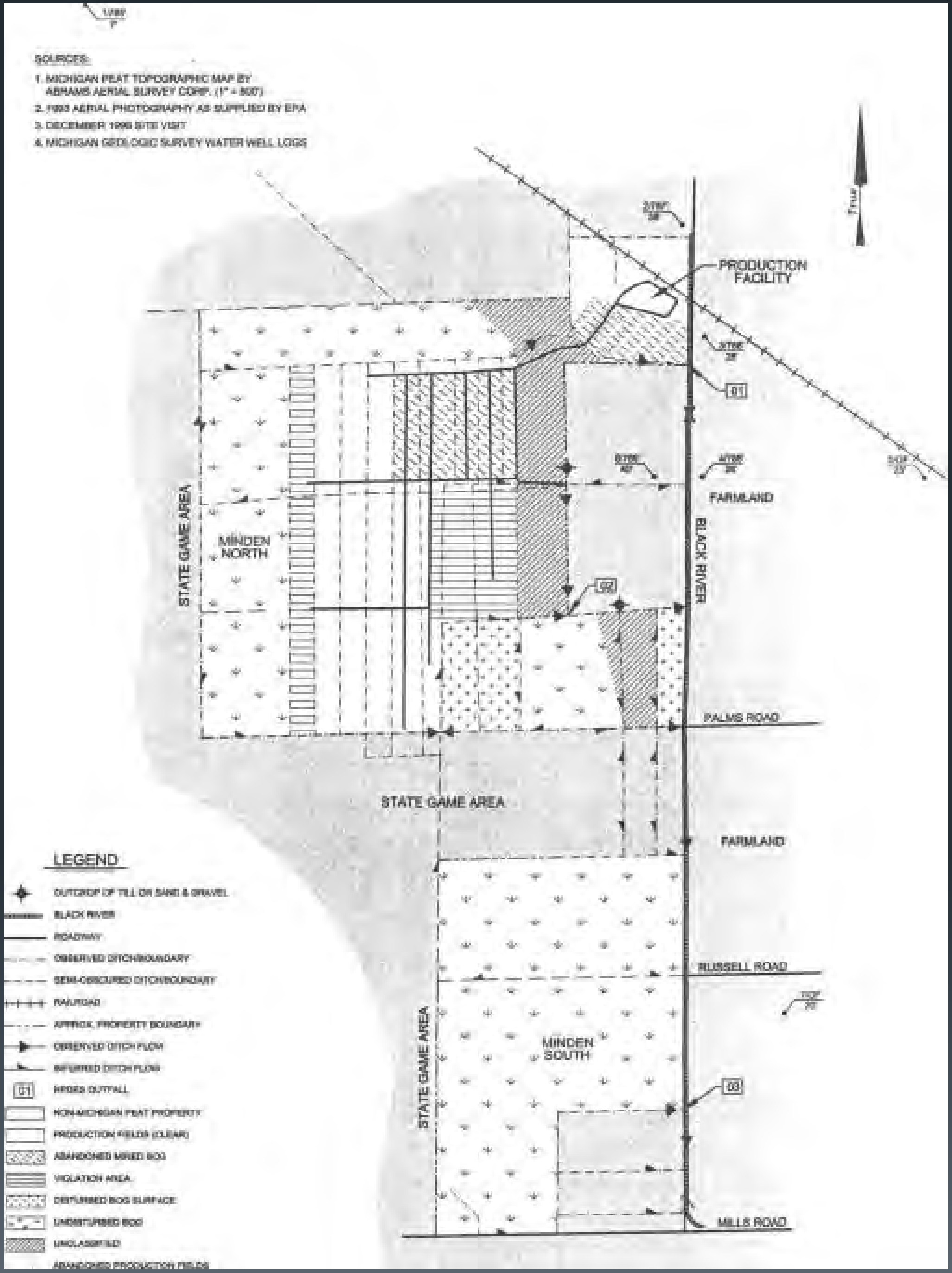
Ditch system penetrated the underlying calcareous substrate.

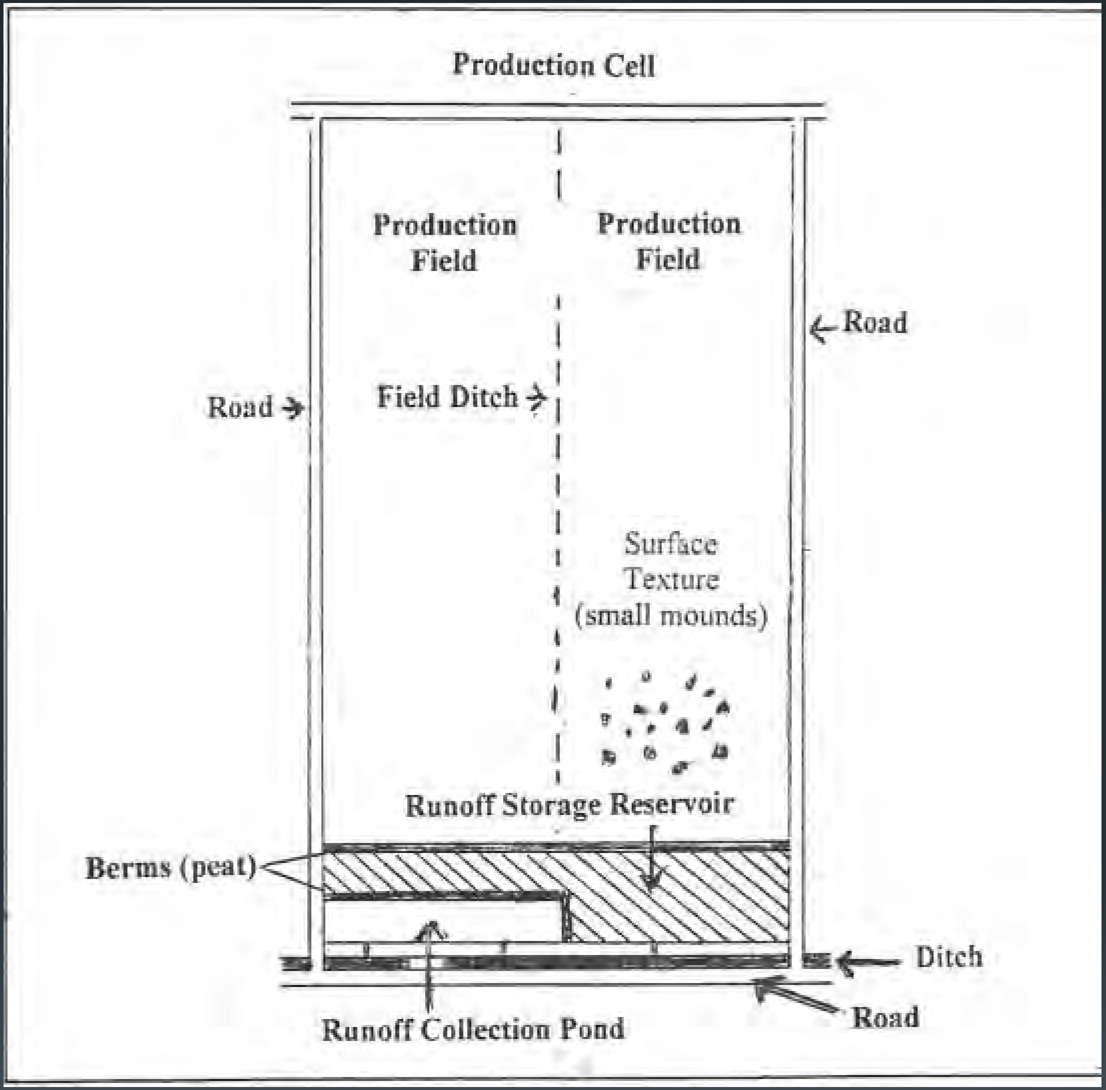
Create an interspersed patchwork of vegetation and water to attract waterfowl, American bitterns and herons.

Minden Bog Site Plan

- **Active production fields (clear)**
- **Abandoned fields (diagonal lines)**
- **Disturbed surfaces (+)**
- **Undisturbed surfaces (wetland symbols)**
- **Violation areas (horizontal lines)**

Ditch flow direction is shown with truncated arrows





Conceptual plan view of a production cell water reservoir system

Wide perimeter ditch with calcareous sediments thrown up onto the bog surface by ditch maintenance

Abandoned production field with a *Phragmites australis* monoculture

Recommendations Made for Minden Bog

- Isolate uncontaminated remaining fen peat from mineral-contaminated water and calcareous bottom substrate
  - Leave 2-meters of unmined peat to separate the mining surface from the calcareous bottom substrate
  - Stop mining in sections where ditches have started penetrating the bottom substrate
  - Ditch liners are needed for sections already penetrating the bottom substrate
  - Start restoration within 2 years after a production cell has been abandoned
- Block ditches in abandoned areas to rewet peat
- Monitor the ditch system each time it is lowered
- Monitor restoration plan implementation annually for ten years and every other year for the next 10

Peatlands Restoration

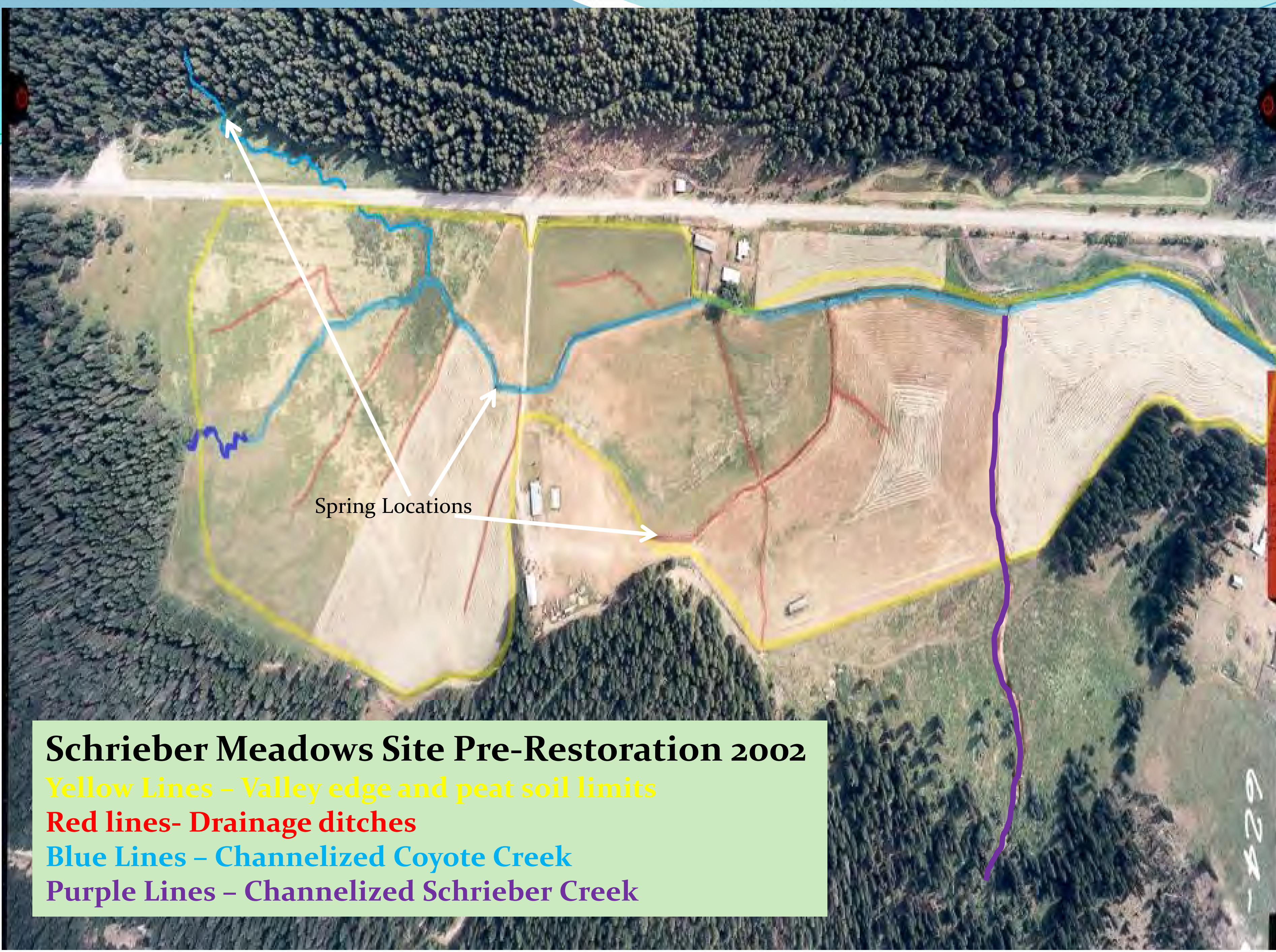
The Montana Experience

Schrieber Meadows Restoration

- Investigated mitigation opportunities in cooperation with Kootenai National Forest on a 57-acre drained fen in northwestern Montana beginning in 2000.
- Ephemeral and groundwater fed spring creek (Coyote) through site was moved and channelized along eastern edge of property in early 1900's.
- Schrieber Creek channelized to prevent spring flooding of barns and calf rearing areas.
- Additional ditches installed at various locations to further drain site in order to promote hay production in the 1920's and 1940's.

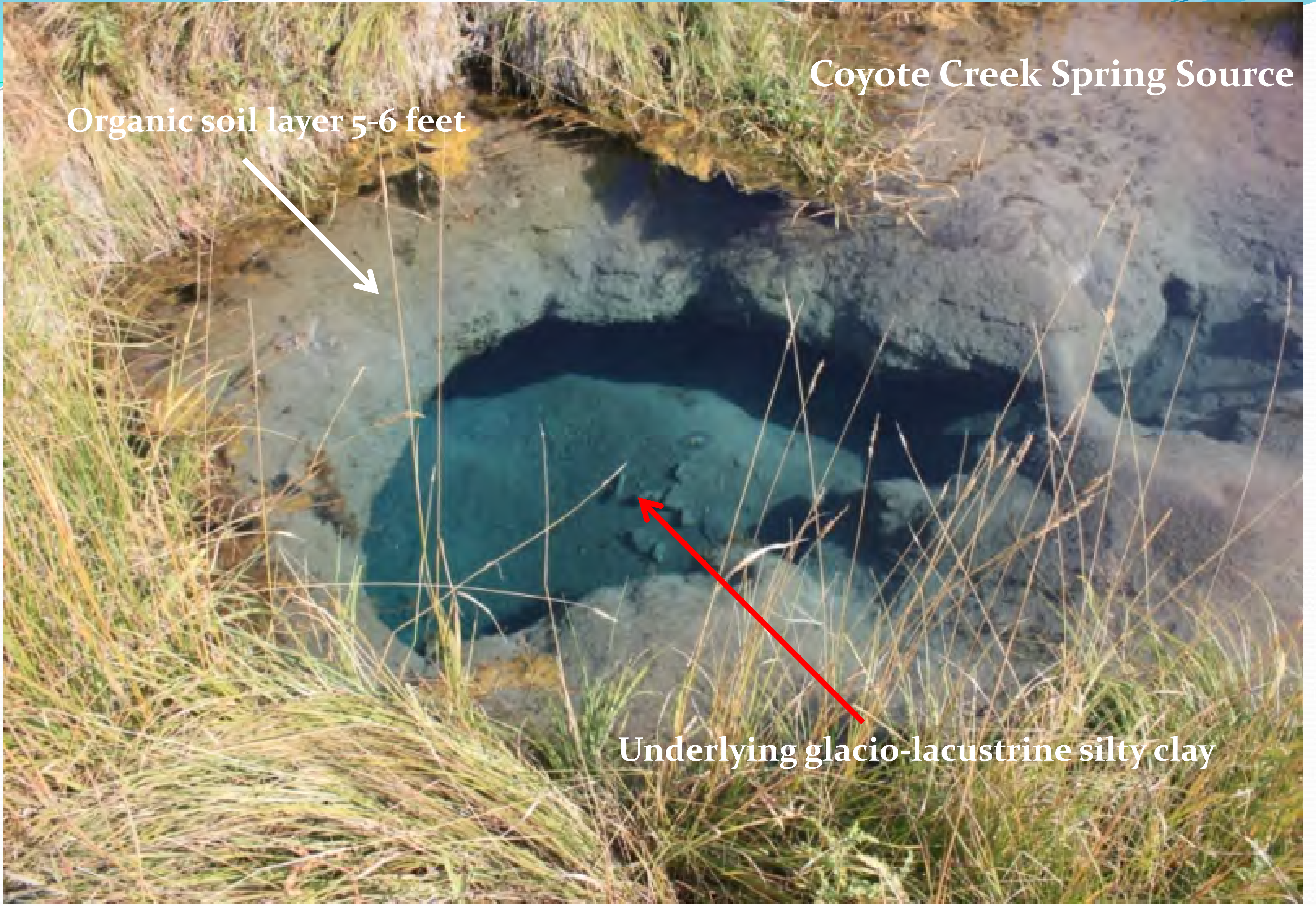
Schrieber Meadows /Lake area 1999

Schrieber Meadows Site Pre-Restoration 2002



Feasibility Studies

- Installed a series of 12 monitoring wells across the entire 57-acre site on both MDT and USFS properties.
- Conducted topographic surveys of the entire area at 1-foot contours.
- Hydrologic evaluation of stream flows on Coyote & Schrieber Creek, drainage ditches and a very large spring found within site.
- Baseline evaluations of soils, vegetation, wetlands, geotechnical, hydraulic, etc. over a 3 year period.
- Developed Conceptual designs incorporating stream restoration and shallow wetland development within site.
- Evaluated constructability issues when working on organic soils.


Coyote Creek Spring Source
Organic soil layer 5-6 feet
Underlying glacio-lacustrine silty clay

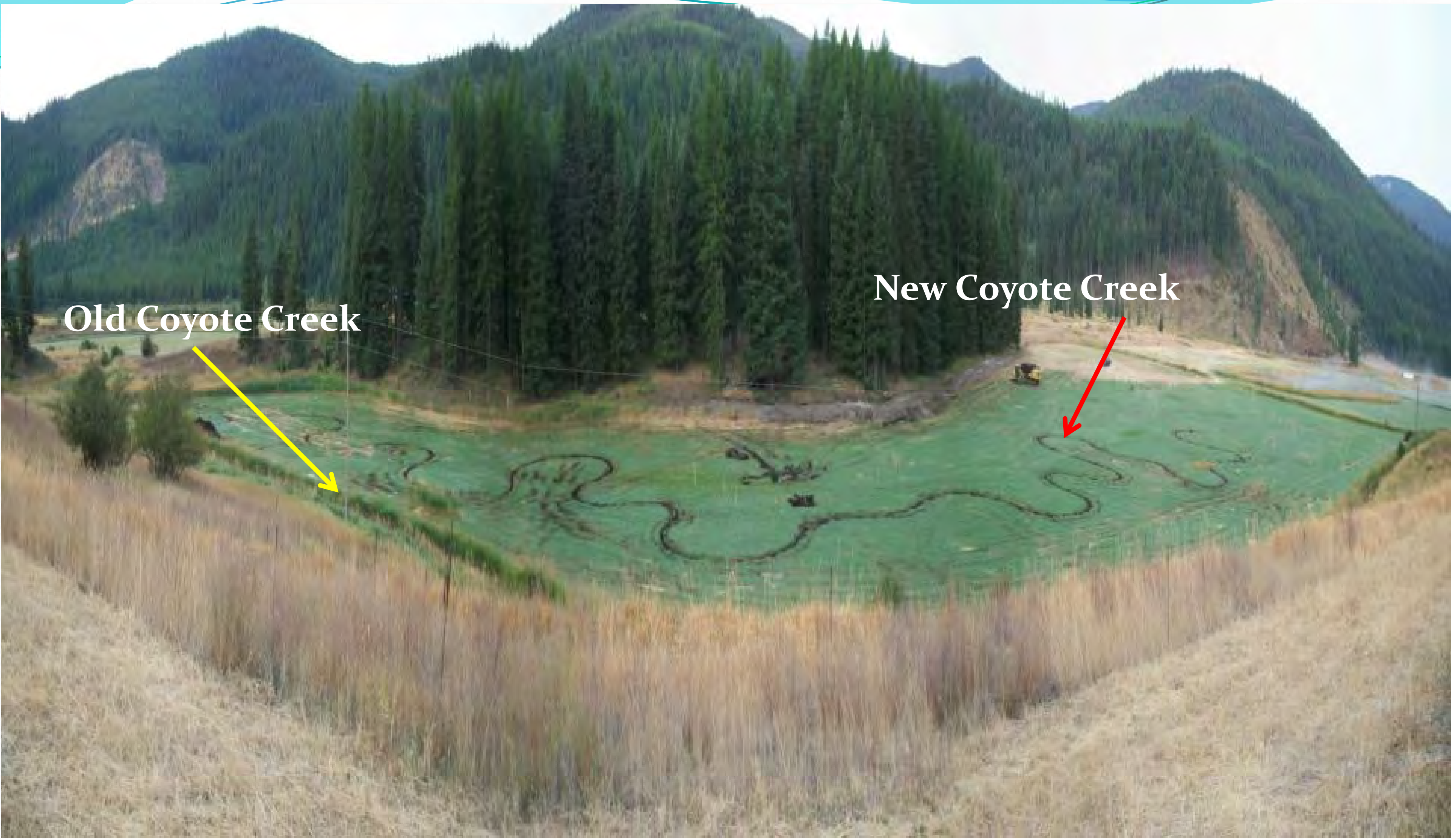
Feasibility Study Findings:

- Geotechnical core samples indicated organic soils ranging in thickness from 2 feet to 20+ feet in depth across site from north to south. Thickness of organics increased as topography sloped down valley to the south.
- All peat soils underlain by Glacio-lacustrine sediments consisting of silty clays.
- Also found an ash layer of Mount Mazama volcanic ash ranging in thickness from 2 inches to 2 feet in depth in some cores.
- Groundwater depths ranged from 6 inches to 2 feet below the surface at well locations. Greater depths at northern end of site to a depth of 3+ feet.
- Existing Coyote Creek channel 10-15 feet wide, and 4 to 5 feet deep. Number of drainage ditches across site to drain natural springs and high groundwater 5-8 feet wide and 3 to 4 feet deep.

Mount Mazama ash deposit in cut for the Schrieber Creek channel restoration with peat soils on top & below ash layer.

Proposed Restoration Actions:

- Plug Existing drainage ditches and the channelized reach of Coyote Creek at various locations within site.
- Construct a new Coyote Creek channel with a narrower channel width (1-3 ft.) and shallower depth (1-2 ft.).
- Excavate a series of shallow wetland cells to bisect the existing groundwater in an effort to diversify the landscape and change existing plant communities (i.e. drown the reed canary grass).
- Preserve existing springs at various locations within site.
- Allow groundwater to rise to normal levels and to store water longer within the system for downstream water rights users.



Coyote Creek Channel reconstruction Fall of 2011 – small narrow sinuous channel

Wetland Cell excavated to reach groundwater in area exposing peat soils.

Spring 2012 water inundating the entire site. USFS Photo.

Shallow wetland cell beginning to fill with groundwater – September 26, 2011

Same wetland cell one week later – October 3, 2011

View looking north from the bottom end of Schrieber Meadows in spring 2012 after the completion of restoration work completed by MDT in 2011. Note areas of inundation.

Close up view of areas of inundation across site, and decline in reed canary grass and non-native pasture grasses.

Schrieber Meadows area spring 2014

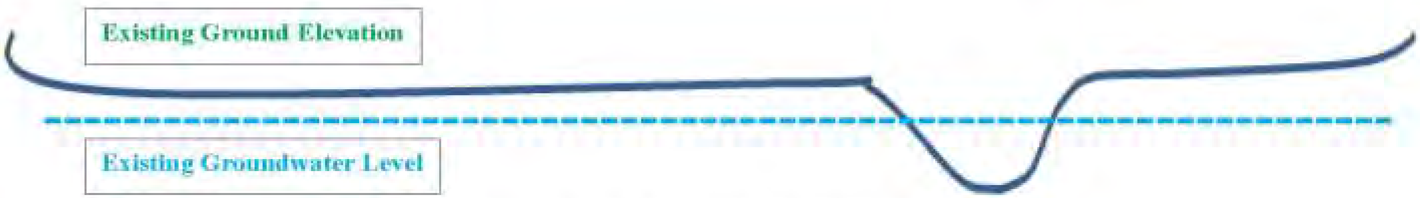
Lessons Learned

- Organic soils within fen/bog areas that have been exposed to aerobic conditions and been drained for agriculture, eventually subside and compact over time.
- Construction techniques and equipment utilized must be capable of working in unstable organic and saturated soil conditions.
- Groundwater levels although evaluated for almost 5 years reached equilibrium between 2 inches and 2 feet above existing ground surfaces across a majority of the site upon completion. ***Expect the unexpected.***
- Surface water across the site appears to be at the historical ground water elevation.
- **Positive** - Reed canary grass is beginning to disappear from the wetter portions of the site and is being replaced by *Carex* and *Calamagrostis* species.
- **Positive** – Utilized lessons learned here on restoration activities on adjacent Schrieber Lake property.
- **Negative** – Proposed scrub/shrub habitat will be difficult to achieve as a mitigation objective due to high surface water levels.

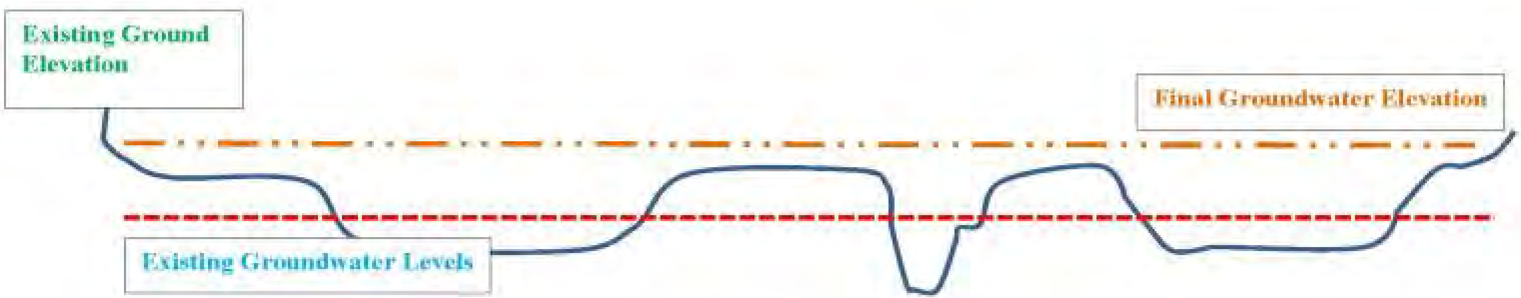
Close up view of the compacted organic soil layers after years of agricultural practices and draining. Soil contained leaves, bark, twigs, vegetation, etc. and each distinct layer was between 2.5 mm to 1 cm in width.

Cross-section typical of Schrieber Meadows site:

Schrieber Meadows Groundwater Elevations -



PRE-EXISTING SITE CONDITIONS – Groundwater 2 inches to 2 feet below ground surface



FINAL CONSTRUCTED WETLAND CONDITIONS – After restoration activities, groundwater 6 inches to 2 feet above ground elevation.

Aerial Photograph from July 2014. Note dark colored water in areas of organic soils.

Recommendations

The Peat Field, by Vincent Van Gogh (1883)

Marcia Spencer-Famous' Recommendations

Cause of Failure	Recommendation	Selected Measures
Peatland not restored to pre-disturbance condition.	Re-assess what is possible at the site, the stage of recolonization, and time frame for achieving the target peatland community. "Adaptive management"	Develop a plan to "jump start" or guide/correct recolonization: *i.e.,* addition of nutrients, seeding with target species, removal of invasive plants, adjust hydrology if possible. Adjust expectations.
Early recolonizing plant community is a sparse sedge monoculture, may include mosses such as *Polytrichum commune*, but not a sphagnum-dominated community.	Monitor to determine if the recolonizing species are "companion species" providing protected niches for sphagnum to recolonize. *Eriophorum vaginatum var. spissum* is desirable.	Monitor for several years for recolonization by sphagnum. Search areas such as along ditches sides and in small protected areas, as well as under companion plants. Consider re-seeding with live sphagnum fragments. Sphagnum recolonizes a site slowly.
Recolonizing peat surface is subject to wind erosion, frost heaving and desiccation.	Stabilize the peat surface to improve growing conditions.	If plants are not yet re-established, consider ways to create micro-topography. Seed with an early re-colonizer such as *Eriophorum vaginatum var. spissum*. Add nutrients to jump start growth. Protect the peat surface by spreading straw over newly re-seeded areas, especially when sphagnum is spread.

Richard Weber's Recommendations

Cause of Failure	Recommendation	Selected Measures
Soil Saturation not restored due to inadequate water supply.	Account for lost groundwater inputs.	Disable surface ditches or subsurface drainage which is intercepting groundwater inputs at the wetland boundary (discharge).
Soil Saturation not restored due to excessive removal of groundwater	Account for excessive groundwater drawdown from interior channels, ditches, or open excavations	On watercourses, match interior channel water surface profile to groundwater level targets. Minimize open excavations that draw down groundwater levels.
Deep ponding is in excess of restoration targets	Assess the potential for subsidence that has caused land surface to be below existing local surface outlets	Adjust restoration goals to account for local infrastructure grades (roads, culverts). Modify existing outlets to match subsided land surface.

Norman Famous' Recommendations

Cause of Failure	Recommendation	Selected Measures
High pH and excess nutrient levels (surface water, groundwater and calcareous soils)	• Change restoration goals from a low-nutrient fen to a nutrient-rich non-peatland wetland	• Adjust groundwater levels to control the height and plant composition of the new target wetland types
Excess of weedy non-wetland species including invasives	• Account for low groundwater levels (e.g., excessive drawdown, shallow initial excavation) • Remediate by flooding or saturating dry sections to control weedy species	• Lower surface elevation to saturate or flood the surface • Adjust level of outlet structure • Construct water control weirs
Lack of Sphagnum moss establishment	• Wait 2-3 years for water levels to stabilize • Establish companion plants and 10% cover of dead woody debris • 'Give it time'	• Delay Sphagnum moss applications until ground and surface water levels are determined and companion plants are well established • Match Sphagnum species with surface and subsurface water levels • Adjust restoration goals

Larry Urban’s Recommendations

Cause of Failure	Recommendation	Selected Measures
Evaluation of the subsidence of ground surface due to de-composition and compression of organic soils.	Evaluate soils by conducting detailed geotechnical evaluations.	Geotechnical evaluations must understand the complexity of organic soil types such as Saprists, Fibrists and Hemists. Rates of decompositions within Saprist soils is an unknown in the Rocky Mountain region and should be considered in restoring fen/carr systems.
Higher than anticipated groundwater tables.	Installation of piezometers to evaluate groundwater prior to construction.	Five years of groundwater data and hydraulic analysis/modeling did not predict groundwater elevations would be higher than existing ground surface. Water elevations are at their historical levels now that the site has equilibrated to normalcy. Non-native grasses are disappearing from the site and native grasses /sedges/rushes are establishing.
Drowned shrub and tree plantings. Scrub/Shrub credit development unlikely due to high water table and will require adaptive management efforts.	Await the development of hydrology within site possibly 2 to 3 years dependent upon weather cycles.	Schedule supplemental plantings of woody plants after water levels have equilibrated to the site conditions. Also to change the woody species to be planted based upon the new site conditions.

Questions?

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Thank you for your participation!
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