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NYSDOT Living Snow Fence Training

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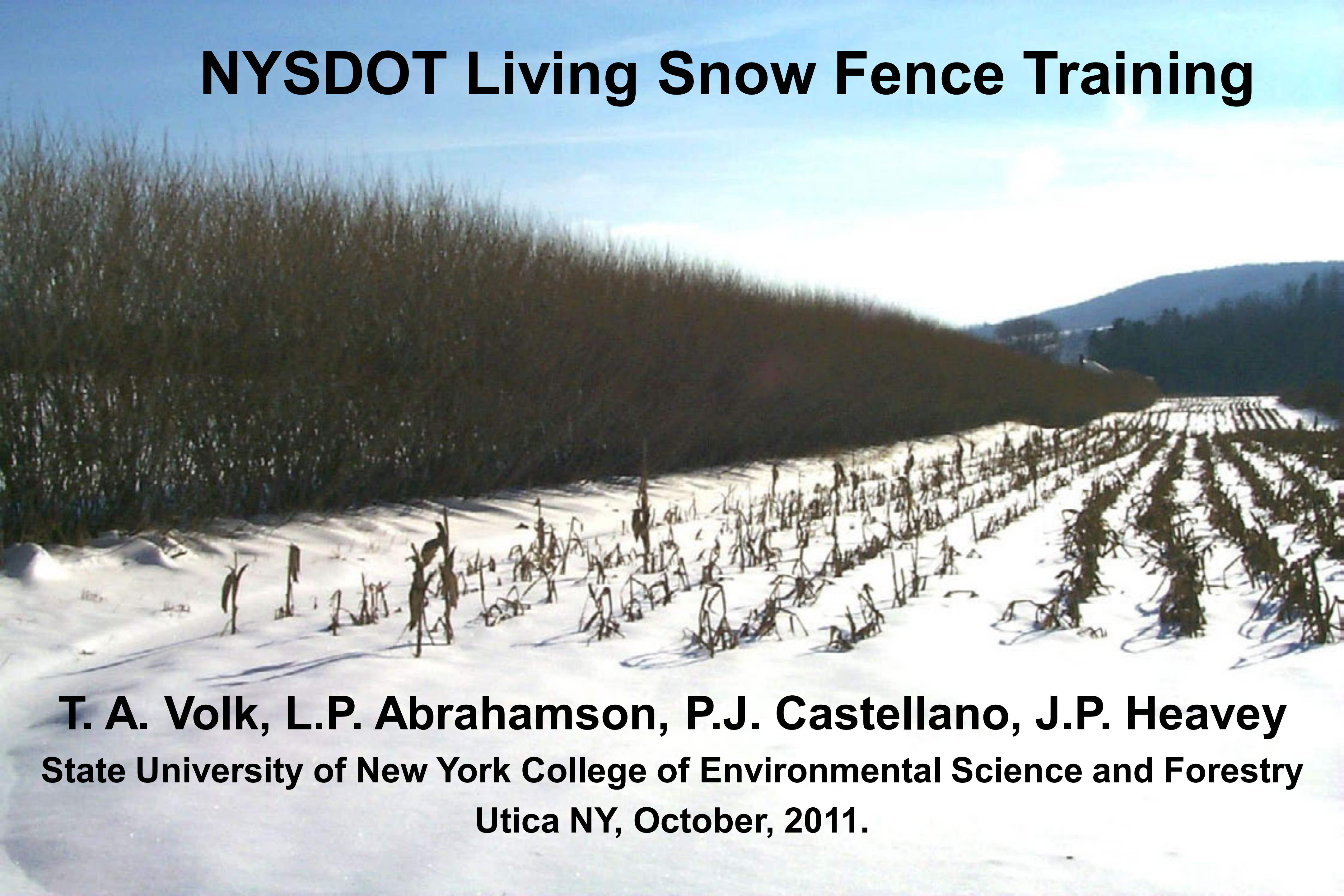

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Background

The Challenge

- Snow and ice removal and control costs over $2 billion annually in the US
- NYSDOT annual S&I costs are $252 million
  - $154 million labor
  - $38 million equipment
  - $60 million materials
- Blowing and drifting snow causes:
  - Reduced visibility
  - Impaired road conditions
  - Reduced road width
  - More frequent road closures
  - Increased number of accidents and injuries
  - Increased need for plowing and deicing materials

The Challenge

- Mechanical snow removal costs up to 100 times more than trapping snow with snow fences (SHRP 1991)
- Options
  - Wood, plastic or other structural snow fences
  - Living snow fences
  - Modify highway design

Historical Use of Snow Fences

The forest acts powerfully in checking the force of the winds because the elastic swaying of the twigs and branches is a very effective hindrance to the movement of air.

~Gifford Pinchot, 1905

Rock snow fences protecting a railroad cut in SEW Wyoming were probably built in 1868 (Tabler 2003)

Snow fences protecting the Union Pacific Railroad in 1901 (Tabler 2003)

Structural snow fences

- Less costly than snow removal
  - Snow removal costs about $3/ton (Tabler 2003)
  - A 4 ft high snow fence can trap up to 4.2 tons of snow per linear ft
  - That is >24,000 tons per mile
- Temporary or permanent
  - Wood or plastic composite
  - Cost varies with material and installation location
- Visually unappealing

Temporary Structural Snow Fences

- In areas with large snow transport loads, temporary structural snow fences can become buried and ineffective

A Solution – Larger Structural Fences

- Permanent structural snow fence being tested in the town of Scott

- Sometimes challenging to properly design and locate permanent snow fences with limited rights of way

A Solution – Larger Structural Fences

- Permanent structural snow fence in western NY

A Solution – Larger Structural Fences

Snow fences in Wyoming
(Tabler 2003)

Another Solution - Living snow fences

- Designed plantings of trees, shrubs, and/or native grasses that are strategically established short distances upwind of area of concern used to control drifting snow
- Key characteristics for suitable species
  - High density that extends to the ground
    - » Many deciduous trees do not have this form and are in effective for snow fences
    - » Woody shrubs and evergreens are most favorable
  - Rapid growth
  - Suited to local soil and climate conditions
  - Easy to establish and maintain

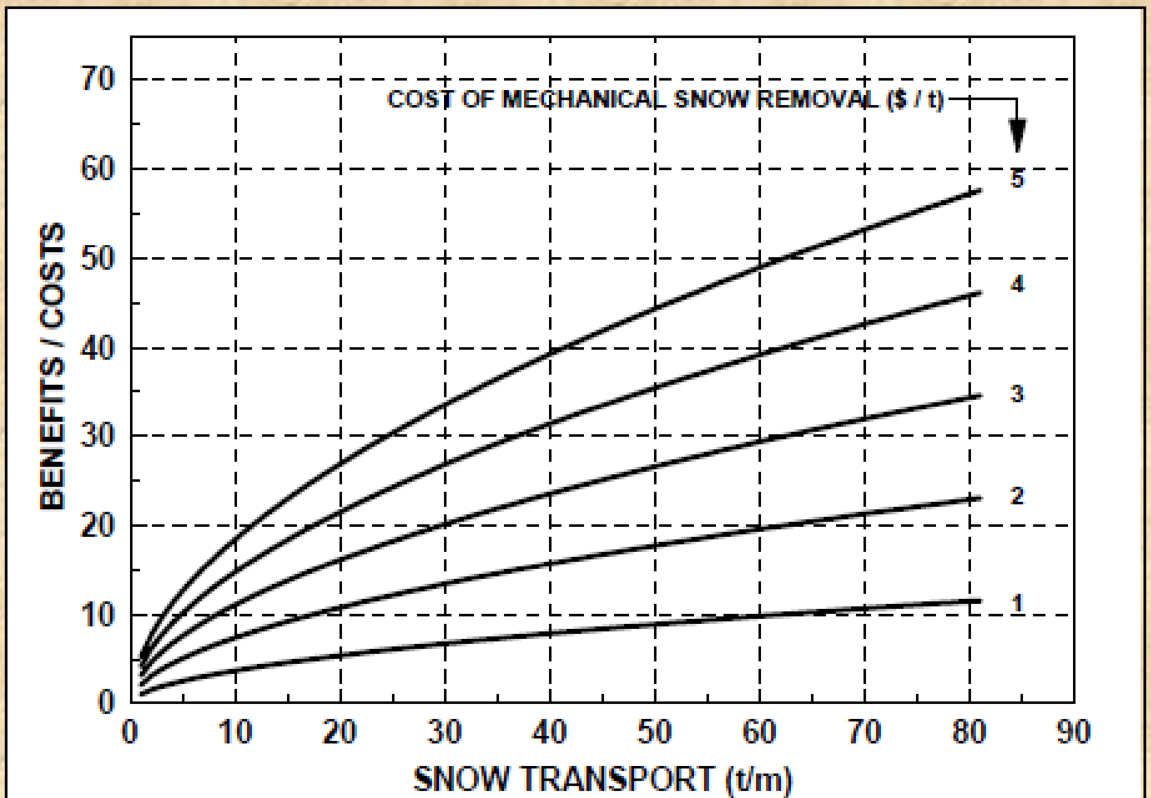
Living Snow Fences - Benefits

- Over the long term they can be cheaper than plastic or wood snow fences
- Effective in years with heavy snowfall once established
  - Challenge: young living snow fences can be damaged by heavy snow accumulation
- Potential to provide wildlife habitat
  - May be a benefit or limitation
- Potential for income generation for landowner from materials produced from shrubs and trees
- Opportunities for carbon sequestration
- Difficult to capture benefit of externalities at this time

Economic Benefit

- Cost benefit ratio of living snow fences in MN ranged from 2:1 to 36:1 (Gullickson et al. 1999)
  - Used average snowfall (32 inches)
  - $1/ton snow removal (it can be $3/ton or greater in severe storms)
  - Only benefits related to snow removal were used as benefits
  - Benefits would be higher if road closure and accident reductions were accounted for
  - Ratios may also be improved with more efficient installation & maintenance practices
- Will develop a benefit ~ cost model for conditions in NY as part of this project

Structural Snow Fences – Cost Benefit



- Benefit cost ratio for snow fences as a function of average annual snow transport and cost of snow removal (Tabler 2003)

- Benefit cost ratio will increase as the amount of snow transported increased and the cost of removal increases

Economics of Living snow fences

(Daigneault and Betters 2000)

	Three row living snow fence [1]	Double row slatted snow fence
Establishment ($/mi)	20,400	16,366
Maintenance ($/mi/yr)	1,000	8,700
Useful Life (yrs)	50	8
Total Net Benefits ($)	1,246,000	110,000
Benefit: Cost ratio	6:1	2:1

[1] Two conifer and one shrub row, requiring 20 years to be effective. Estimated establishment for one row willow snow fence in a corn field was $3,000/mi with annual maintenance cost of $250/mi. Can be effective in 2 – 3 years.

Living Snow Fences - Limitations

- Traditional living snow fences require 6 – 20 years to become effective (Tabler 1994)
  - Address with choice and size of plants and design of system
- Require more space than structural snow fences because they often require more than one row of plants
- Biological systems – more care need to establish, potential for damage from pests and diseases
- They are permanent installations so sometimes it is harder to get landowner cooperation

Potential Solution – Willow Snow Fences

Mature single row willow snow fence in central NY

- A single or double row of densely planted shrub willows
  - Easier and cheaper to establish
  - Rapid growth
  - Dense canopy and lots of stem near the ground
- May not meet expectations of landowners and community
  - Mix with other species if desired
- Shrub willow research at SUNY ESF since 1986
  - Excellent knowledge base of willow growth, development and management
- Numerous crossbred varieties have been developed that are ideal for roadside applications

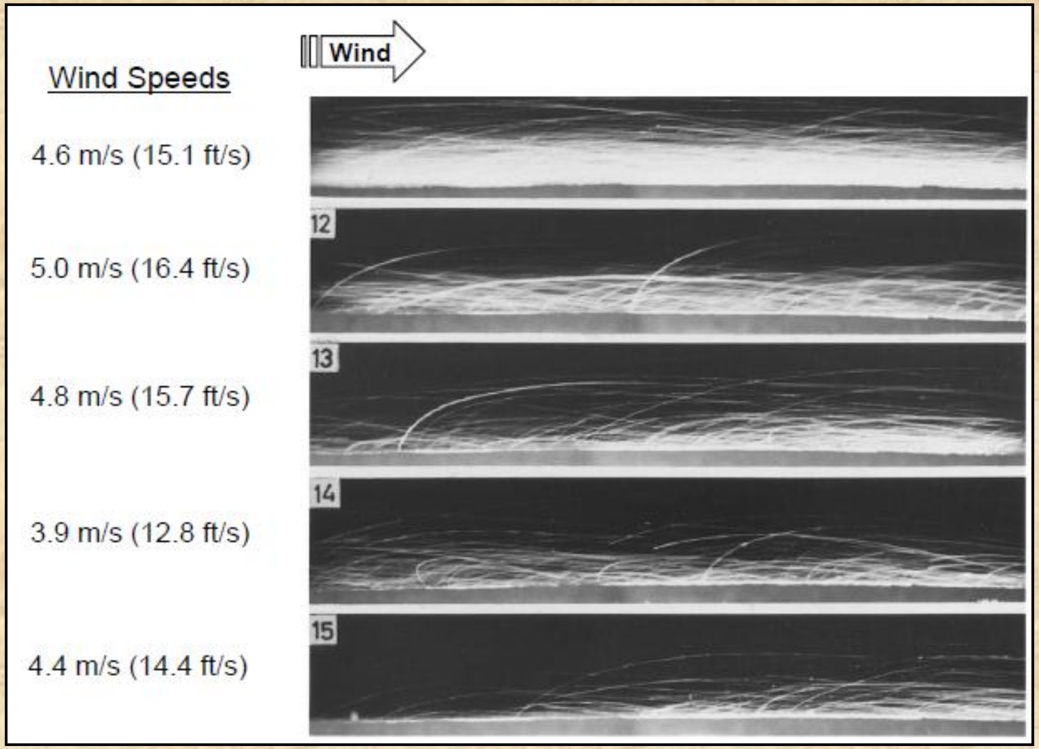
Keys for Success

Willow snow fence two years after coppicing

- Collaboration with multiple agencies and landowners
- Planning and design in advance
- Proper site preparation
- Careful planting and maintenance


Principles of Blowing and Drifting Snow
and Effect of Snow Fences

Snow Transport



Saltating snow particles (Tabler 2003)

- Snow particles range in size from very small up to about 0.5 mm
- Main methods of movement are creep, saltation and turbulent diffusion
- Fluffy snow begins to move at ~15 mph
- Hardened snow may not move at 55 mph
- Most snow no longer moves below 15 mph

Snow Transport

Snow waves formed by creeping snow (Tabler 2003)

- Creep
  - Particles too large to be lifted by the wind roll across the surface forming snow waves
  - Snow waves largely disappear when winds are over (?) 35 mph because snow is picked up and moved
  - Accounts for about ¼ of snow movement at lower wind speeds
  - Easily trapped by snow fences or topographic features

Snow Transport

Snow shadow created by 1.2m wide cylindrical shed (Tabler 2003)

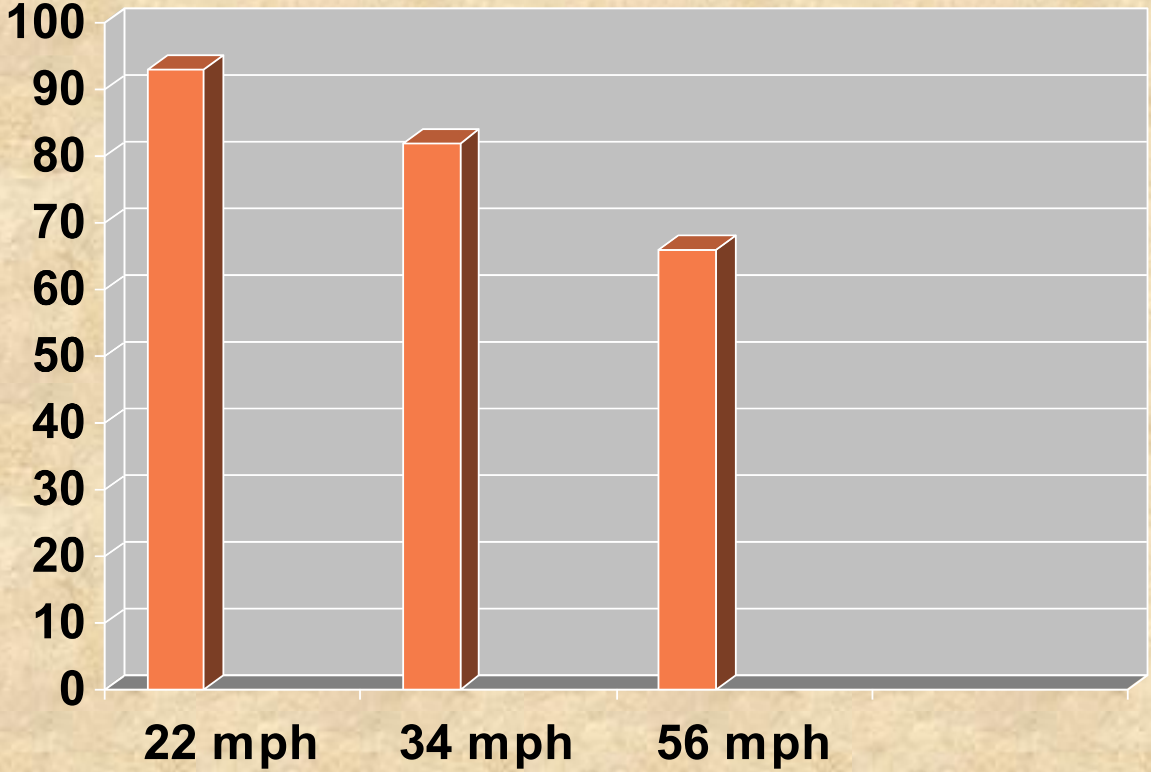
- Saltation
  - Lighter particles jumping across the surface but too heavy to remain suspended in the air
  - Most particles remain within a few inches of the surface
  - Can dislodge other particles when they land
  - Form snow streams in topographic depressions
  - Snow shadows form behind fixed features on the landscape because they deflect and disrupt the flow of particles

Snow Transport

Turbulent diffusion of snow particles (Tabler 2003)

- Turbulent Diffusion
  - Snow particles are suspended in the air without contact with the surface
  - Smaller particles than saltation
  - Most blowing snow is moved by turbulent diffusion
  - Greatest proportion of total suspended snow is contained about 3 ft above the surface
  - Significant transport ceases at 16 ft above ground level

Effect of Wind Speed



Proportion of snow in first 4.5 ft out of the total snow moved in the first 16 ft

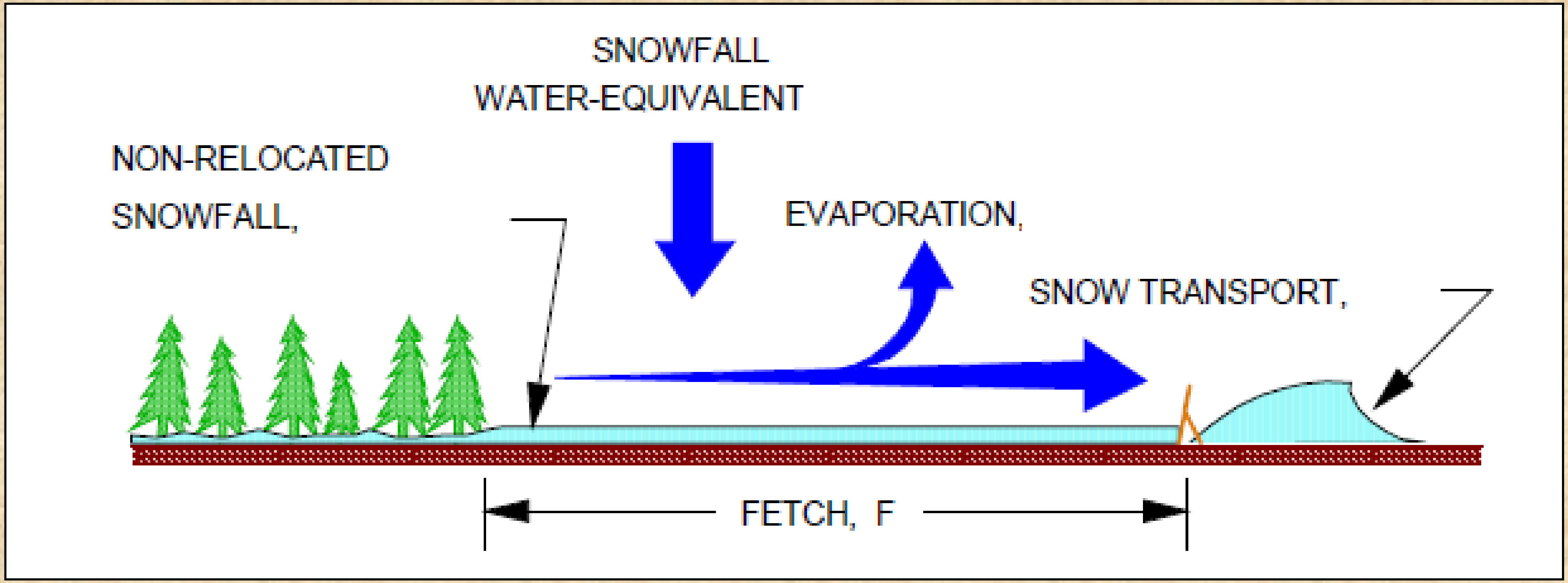
- Majority of blowing snow moves relatively close to the ground
- Opportunity to stop and trap blowing snow
- As snow is trapped this height increases

Evaporation of Snow

- Ice cubes evaporate in the freezer
- Snow particles have a large surface area to mass ratio so evaporation can be significant
- Relative humidity is a key driving factor
- Areas with high relative humidity (e.g. area prone to lake effect snows) have less evaporation and potential for more blowing snow

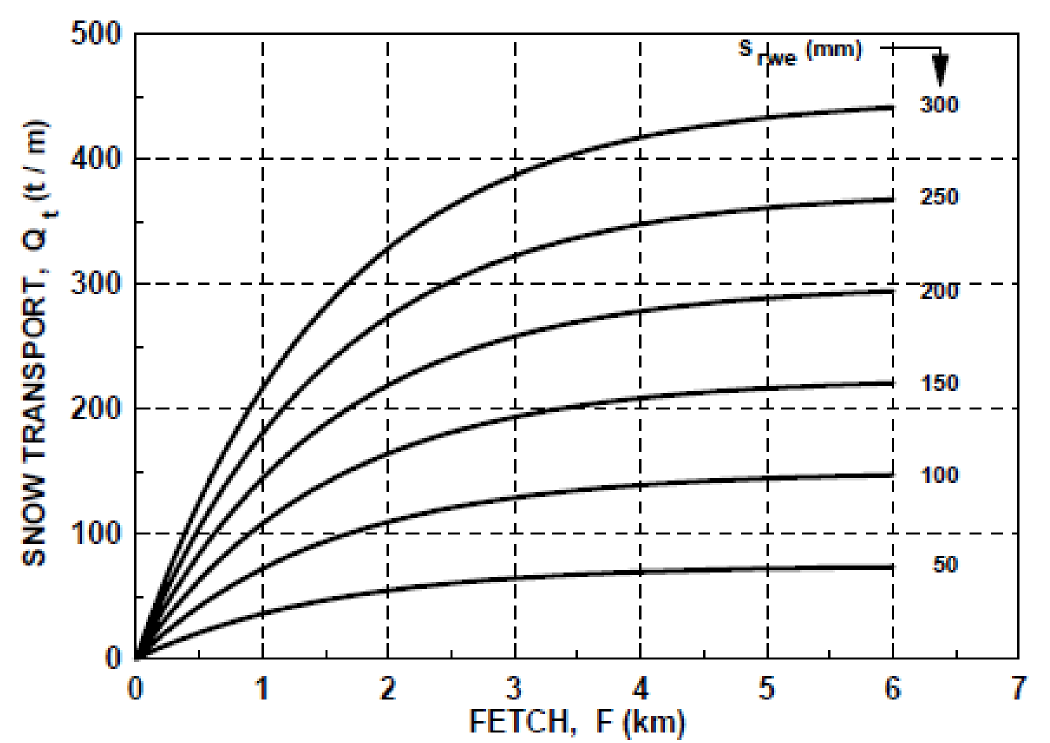
Snow Transport

- Factors influencing the amount of snow that could be transported – fetch, wind speed, snow fall
- Important to determine snow fence storage capacity



(Tabler 2003)

Snow Transport

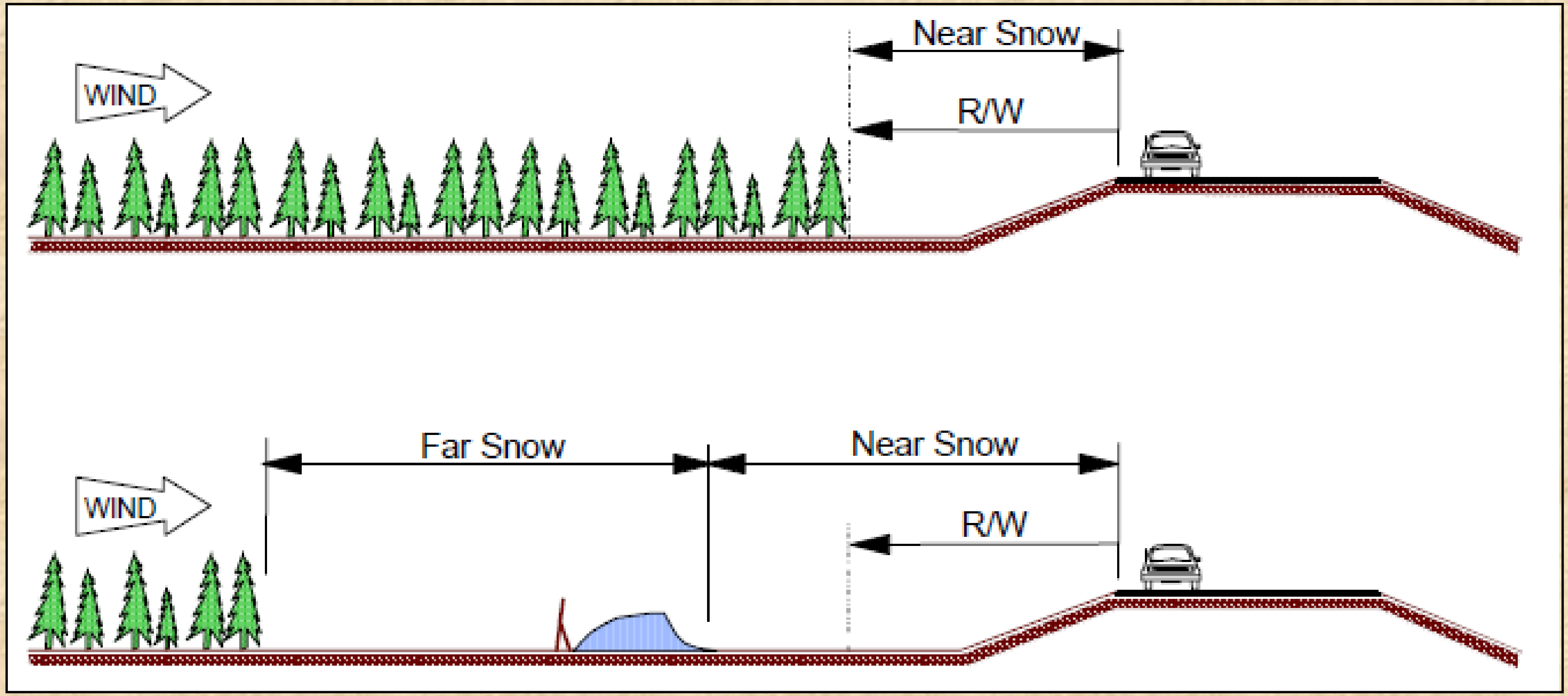


The amount of snow transported varies with the length of the fetch and the amount of snow relocated (Tabler 2003)

- Fetch can be described as the length of an area that is contributing to blowing snow at a downwind location (Tabler 1994)
- Relocated snow, *Srwe*,
  - that portion of the winter's snowfall relocated by the wind, and excludes snow retained by vegetation and topographic features, or snow that hardens or melts in place
  - Reported as a water equivalent to standardize measurements

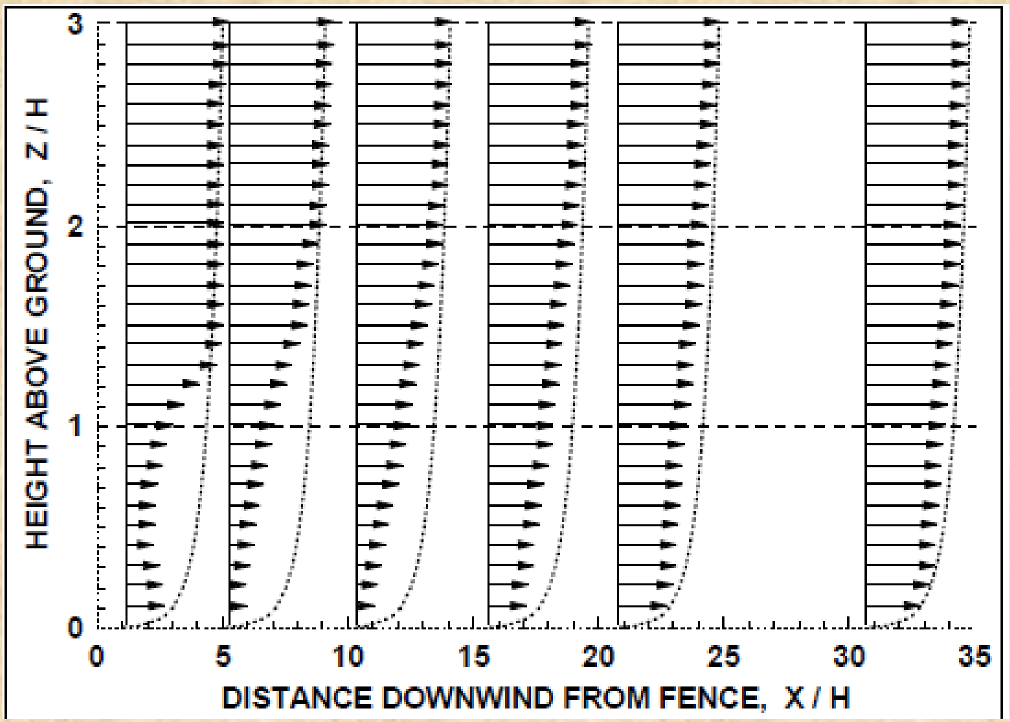
Near Snow and Far Snow

- Different designs and approaches are needed to address near and far snow problems.



Near snow and far snow often require different solutions (Tabler 2003)

Effect of Snow Fences on Wind Speed



Wind speed profiles at different distances downwind from a 50% porous snow fence. Z is height above ground. H is fence height (Tabler 2003)

- Reduction in wind speed near the surface allows creeping and saltating particles to come to a rest
- Some of these particles are deposited upwind
- Suspended particles are deposited as wind speed reduces downwind from the snow fence (Tabler 2003)

How Snow Fences Work

- Snow fences redirect and change wind speed
  - Wind speed increases over the top and around the sides of the barrier
  - Wind speed is reduced below the top of the barrier and downwind, from the snow fence

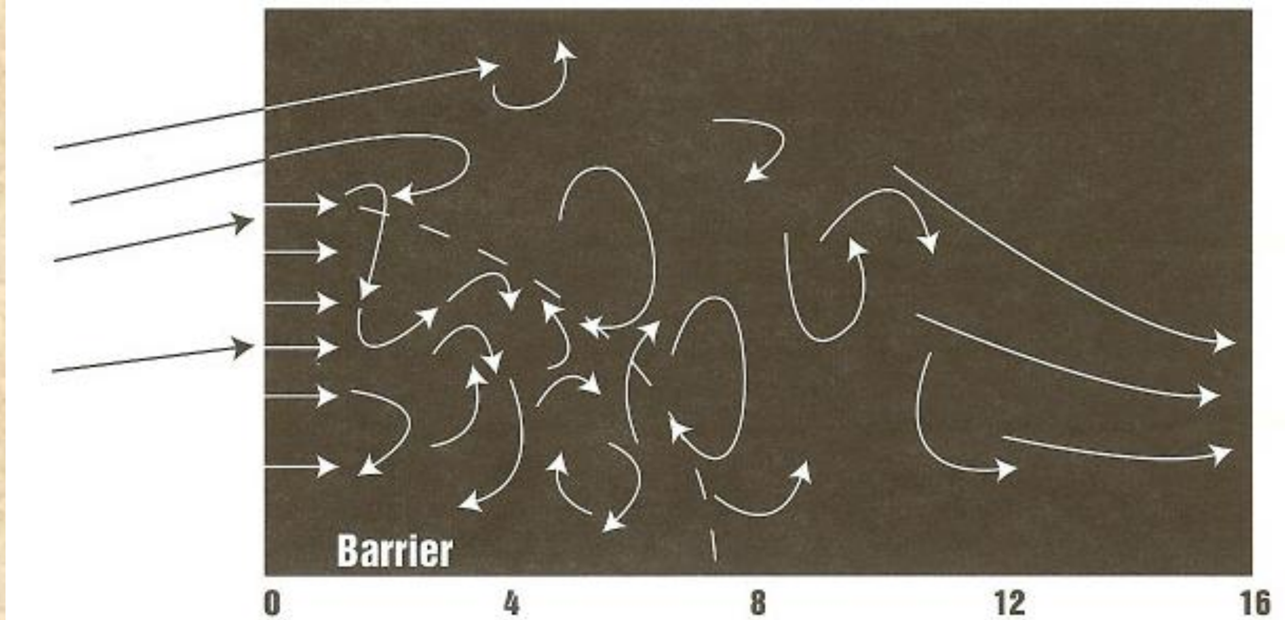
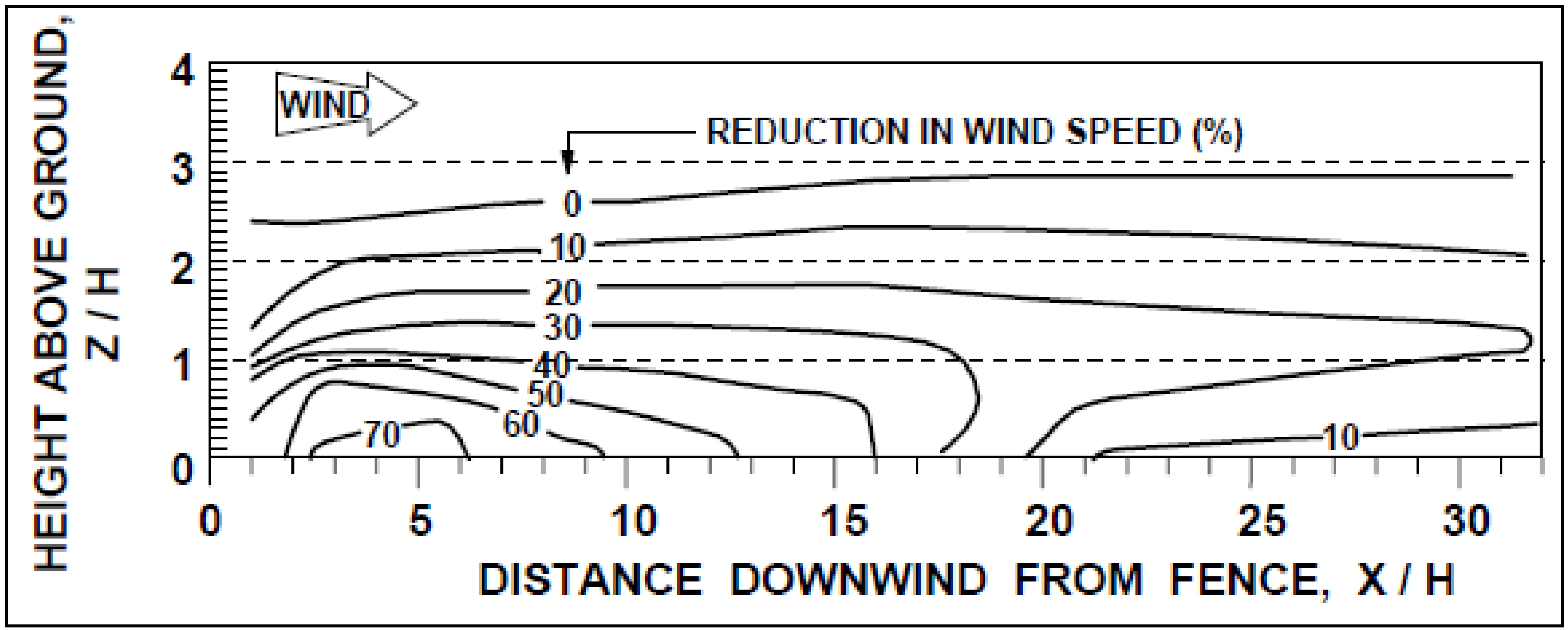


Figure 3.3.
Schematic representation of turbulence in the wake and in the quiet zone behind a model windbreak.

(Gullickson et al. 1999)

Effect of 50% Porous Snow Fence on Wind Speed



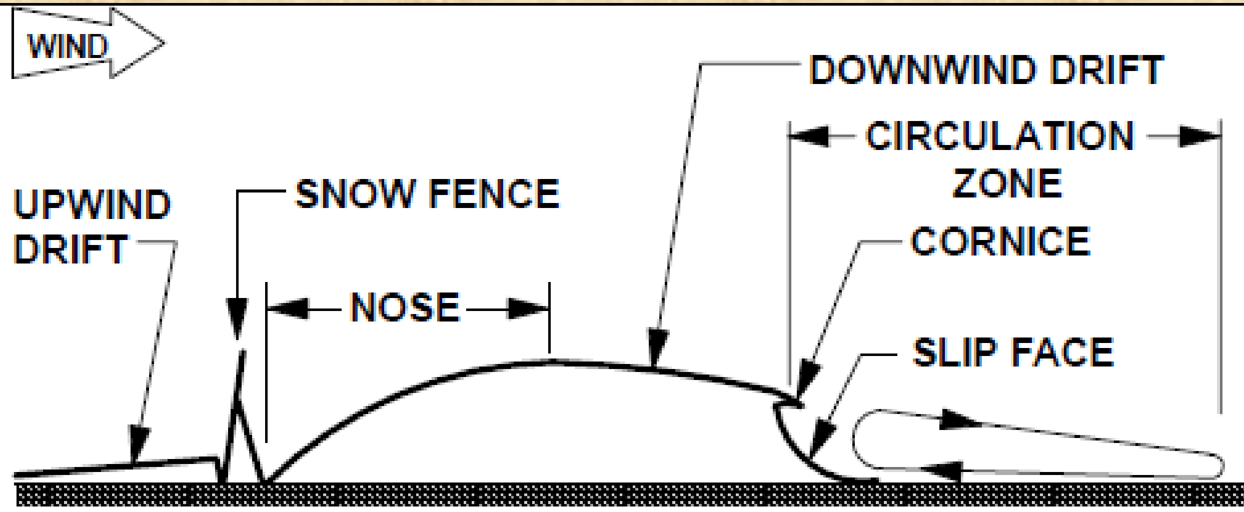
(Tabler 2003)

- Wind speed reduction is roughly scaled with height
- When snow first begins to accumulate, the effect of the snow fence on wind speed controls how snow is deposited
- This changes as the snow drift develops and begins to influence air flow behind the snow fence

Snow Drift Development

- Snow drifts develop in stages over time
- Main components of snow drifts are shown below
- Equilibrium slope is reached only when snow fence is full

Figure 3.31. Slip-face and circulation region formed by a 50%-porous snow fence during the intermediate stages of growth (Tabler and Jairell 1993).

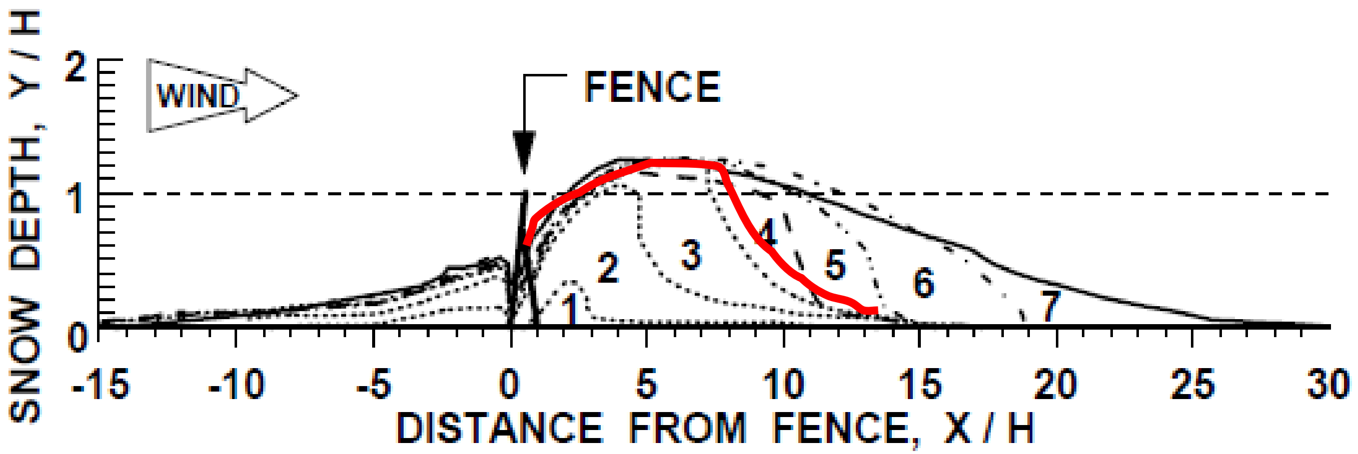


(Tabler 2003)

Snow Drift Development

- Initial stage – wind speed reduced and snow falls to about 7H
- Forms lens shaped drift that becomes thicker extending the effective sheltered region to 12 – 15H until fence is ~75% full
- Slip face and circulation zone develop, which extends 6 – 7H
- With light winds, trapping efficiency is still good
- With newly fallen snow the particles can adhere and form a cornice

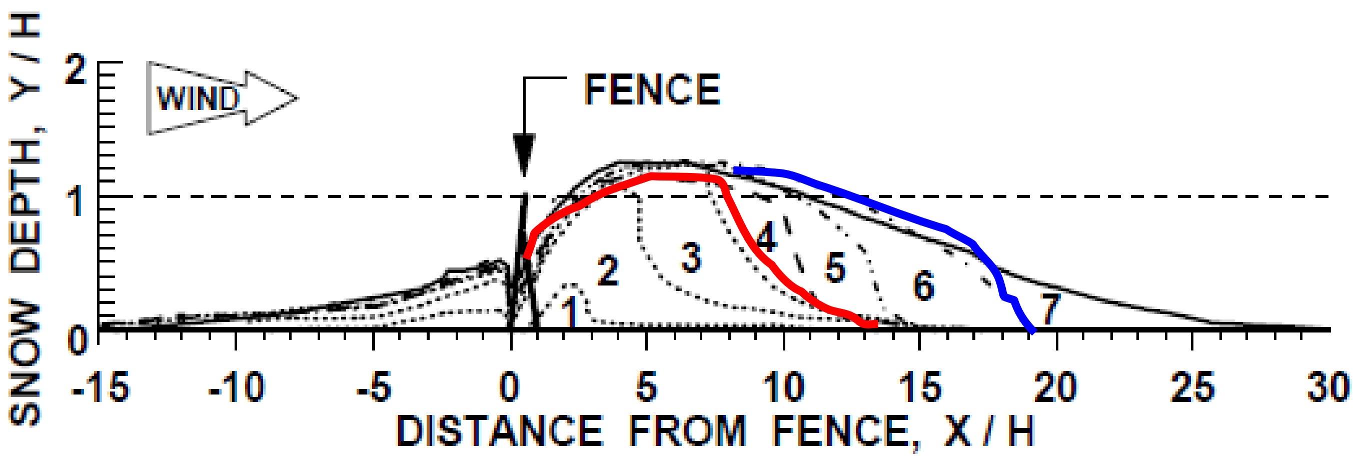
Figure 3.33. Cross-section of snowdrift formed by a 3.8-m (12.4-ft) 50% porous horizontal-board fence on seven dates (Tabler 1986).



Snow Drift Development – Stage 3

- As snow drift depth reaches its maximum (1.0 – 1.2H for 50% porous snow fences) snow begins to fill the circulation zone and drift lengthens downward (measurements 4- 6)
- As long as slip face is present, trapping efficiency is fairly high

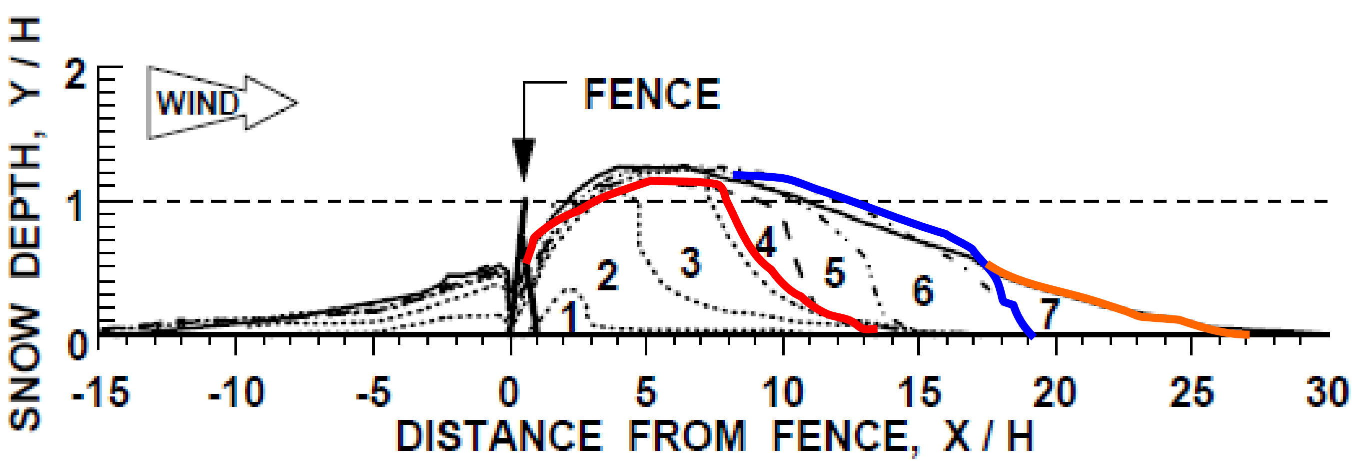
Figure 3.33. Cross-section of snowdrift formed by a 3.8-m (12.4-ft) 50% porous horizontal-board fence on seven dates (Tabler 1986).



Snow Drift Development – Stage 4

- Drift develops a smooth surface with no slip face or circulation zone
- Drift extends to about 20H
- Trapping efficiency declines and only creeping and saltating particles are trapped
- Growth is slow but can extend out to 30 – 35H
- Equilibrium drift is streamlined and zero trapping efficiency

Figure 3.33. Cross-section of snowdrift formed by a 3.8-m (12.4-ft) 50% porous horizontal-board fence on seven dates (Tabler 1986).



Snow Drift Development in NY

- Hypothesis: Lower relocation coefficients, denser snow, shorter accumulation seasons, smaller fetches, more obstructions limit the amount of potential snow transport in the Northeast
  - Fences in New York may never reach equilibrium
  - Very tall willow and evergreen fences with high densities are therefore probably “oversized” in terms of storage capacity
  - If correct, this indicates fences can be sited closer to roadways than the standard equations and trends would dictate because earlier drifts stages and larger windward drifts have enough capacity to handle potential transport
  - Will test this by measuring snow drifts behind living snow fences in NY

Snow Drift Development
(Double Row of Shrub Willow Two years after Coppicing)

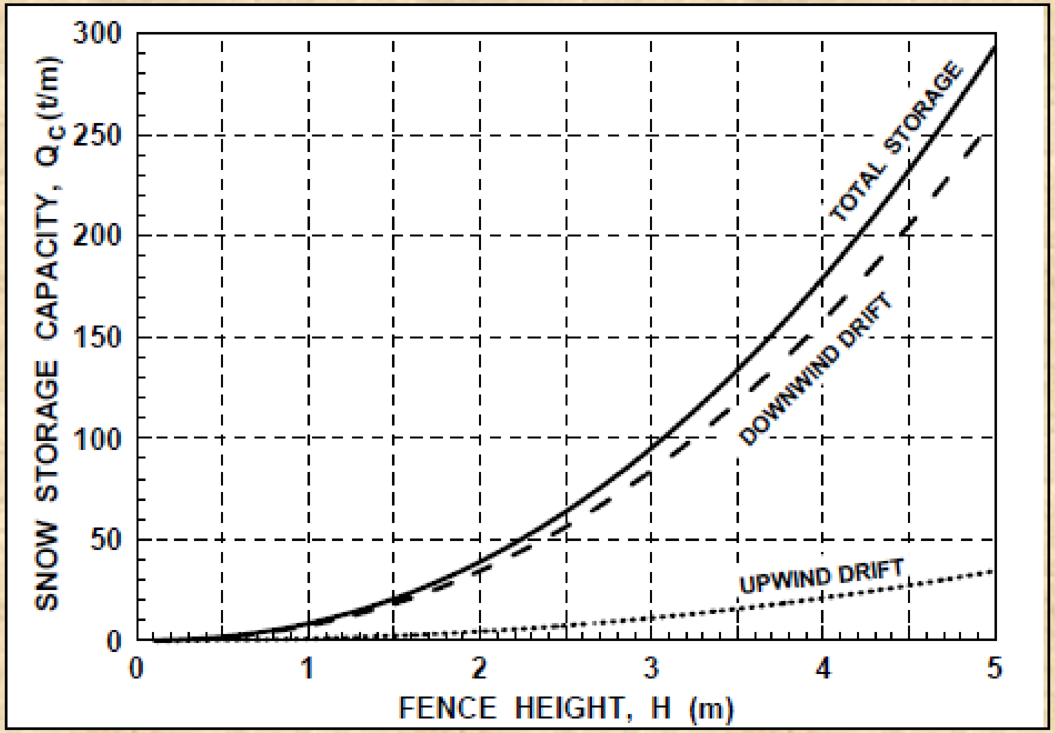
Snow Drift Development

Snow storage capacity of structural snow fences can become filled making them ineffective

- Potential snow storage is related to the height of the snow fence
- Doubling the height of the snow fence increases snow storage potential by 4x assuming all other factors are equal

Snow Storage vs. Height

50% Density Structural Snow Fence



- Snow storage capacity in upwind and downwind drifts formed by a Wyoming snow fence (Tabler 2003)

- Snow can be stored upwind and down wind from snow fences
- For 50% density shown here the amount of snow stored upwind is relatively small
- As density increases the amount of upwind snow stored increases

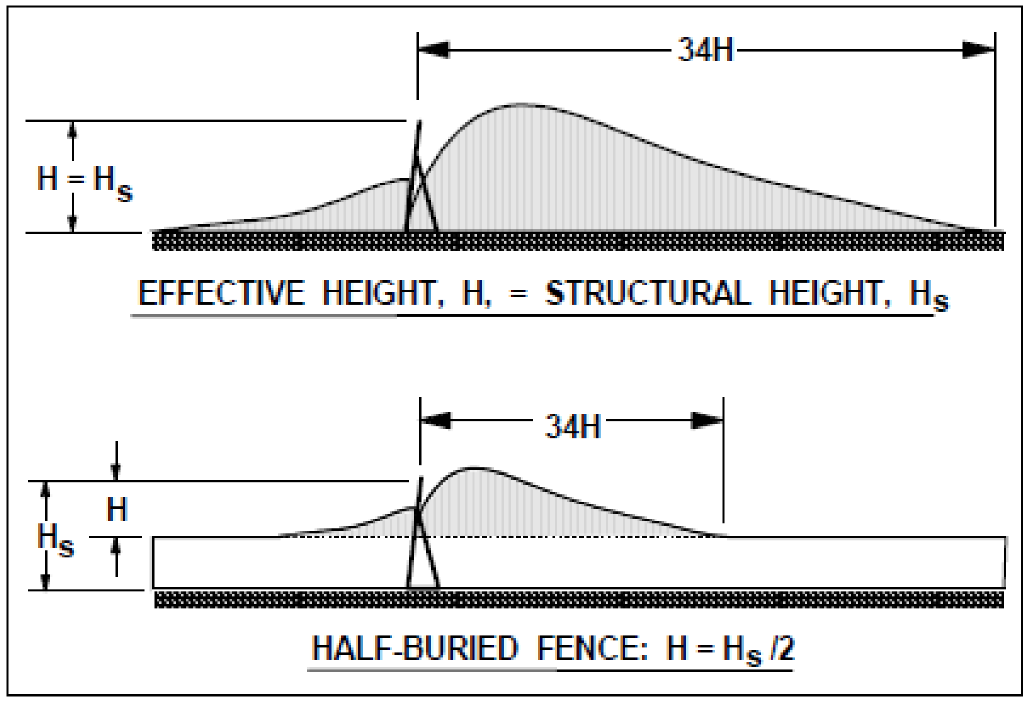
Snow Storage vs. Height

50% Density Structural Snow Fence

Fence Height (ft)	Tons of snow/linear ft.
4.0	4.4
4.5	5.7
6.75	14.0
8.0	20.3
10.0	33.1
12.0	49.5
15.0	79.0

(Tabler 2004)

Snow Fence Height



Effective height (H) of a snow fence is important in determining the size of the drift and the amount of snow stored (Tabler 2003)

- All other things being equal, the equilibrium snow drift dimensions are proportional to the effective height of the snow fence
  - e.g. a drift behind a 8 ft fence is twice as long and twice as deep as a 4 ft fence
- Effective height is the height of the snow fence above the surrounding snow cover

Snow Drift Development

(Double Row of Shrub Willow Two years after Coppicing)

Edge or End Effect

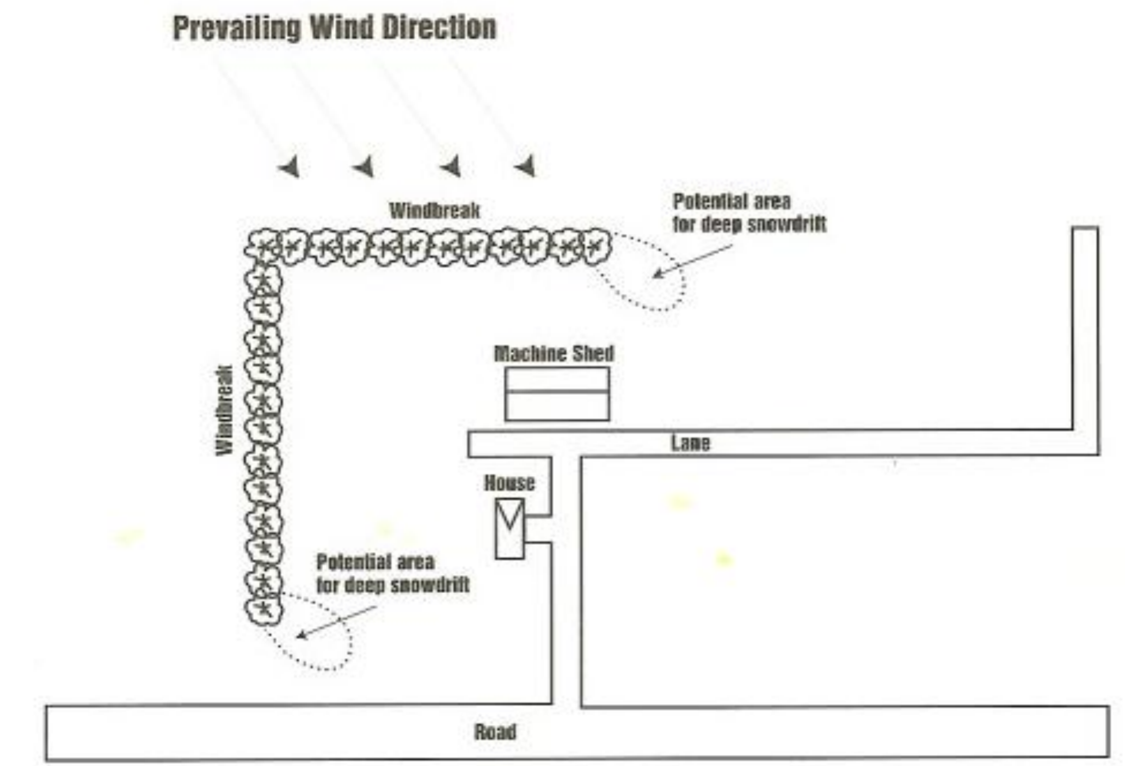


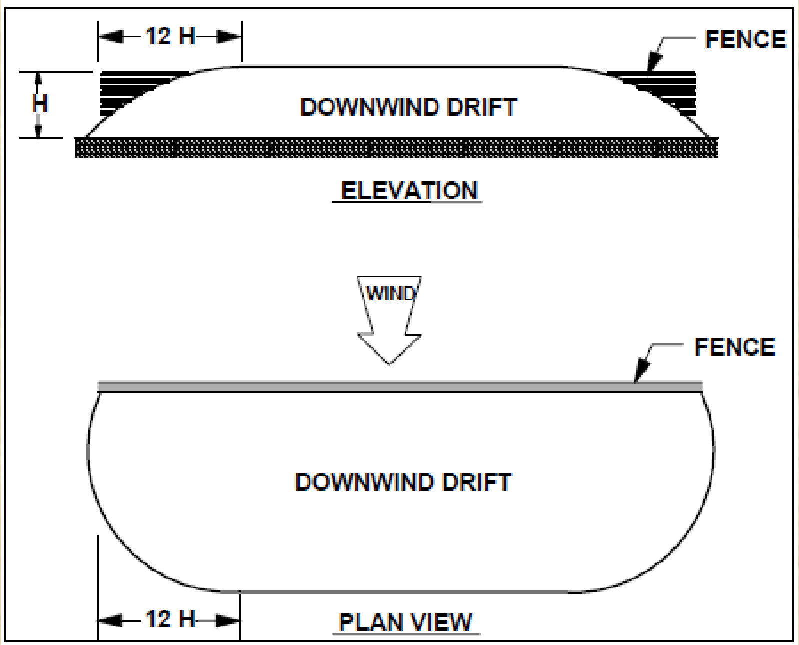
Figure 3.4.
Locating of lanes and roads adjacent to windbreaks. Typical snow drift pattern near end of windbreaks.

- Areas of turbulence are created around the ends of snow fences creating areas for potential snow drifts

Edge or End Effect

- Areas of turbulence are created around the ends of snow fences creating areas for potential snow drifts
- Length of drift is reduced by rounding effect at the ends of snow fences
  - reduces storage capacity and snow trapping efficiency
- Extend snow fence beyond the area that needs to be protected

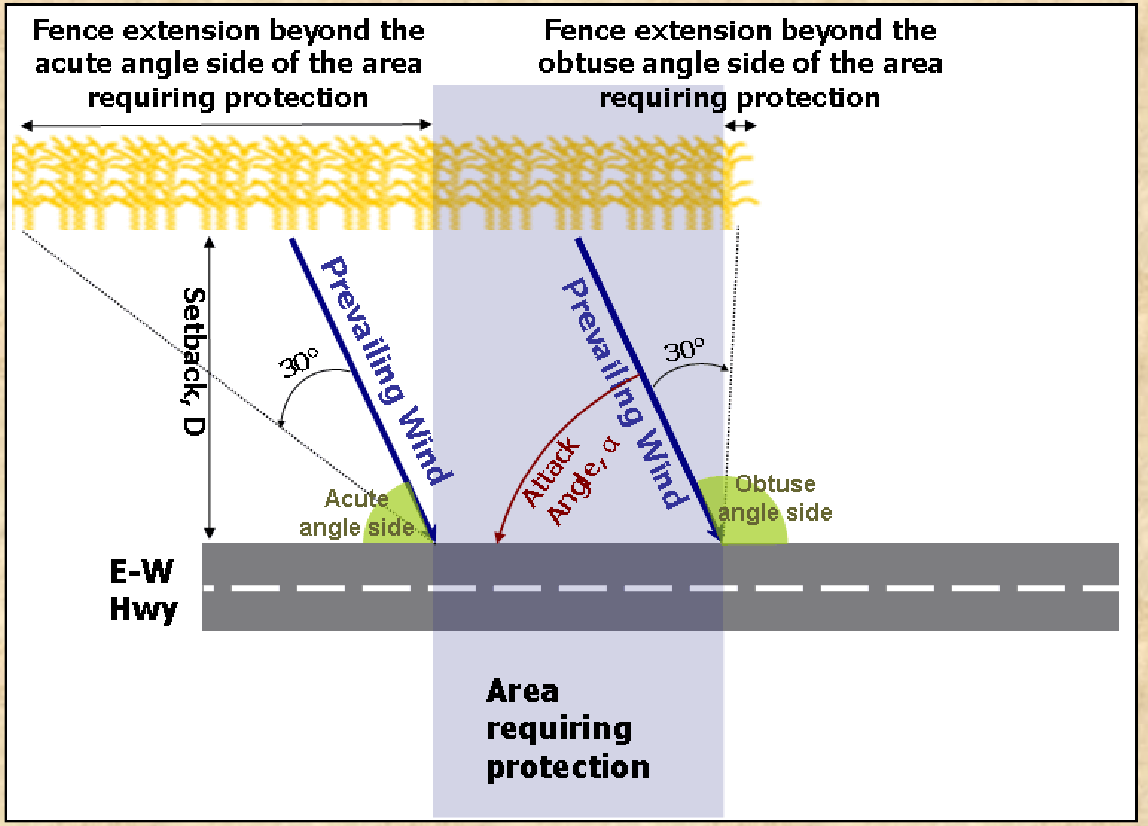
(Tabler 2003)



(Tabler 2003)

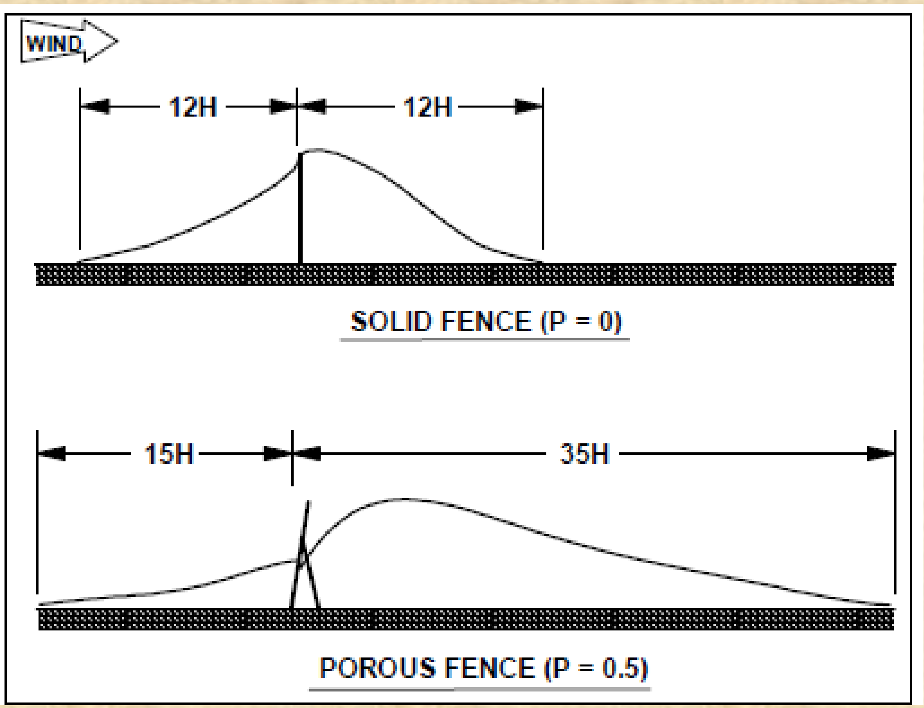
Edge or End Effect

- Fences can be parallel to the road if the prevailing wind is within 35° of being perpendicular (attack angle >55°)
  - Living snow fences are 3D so they may be effective at a smaller attack angle
- Proper extension of the snow fence is more important than the orientation



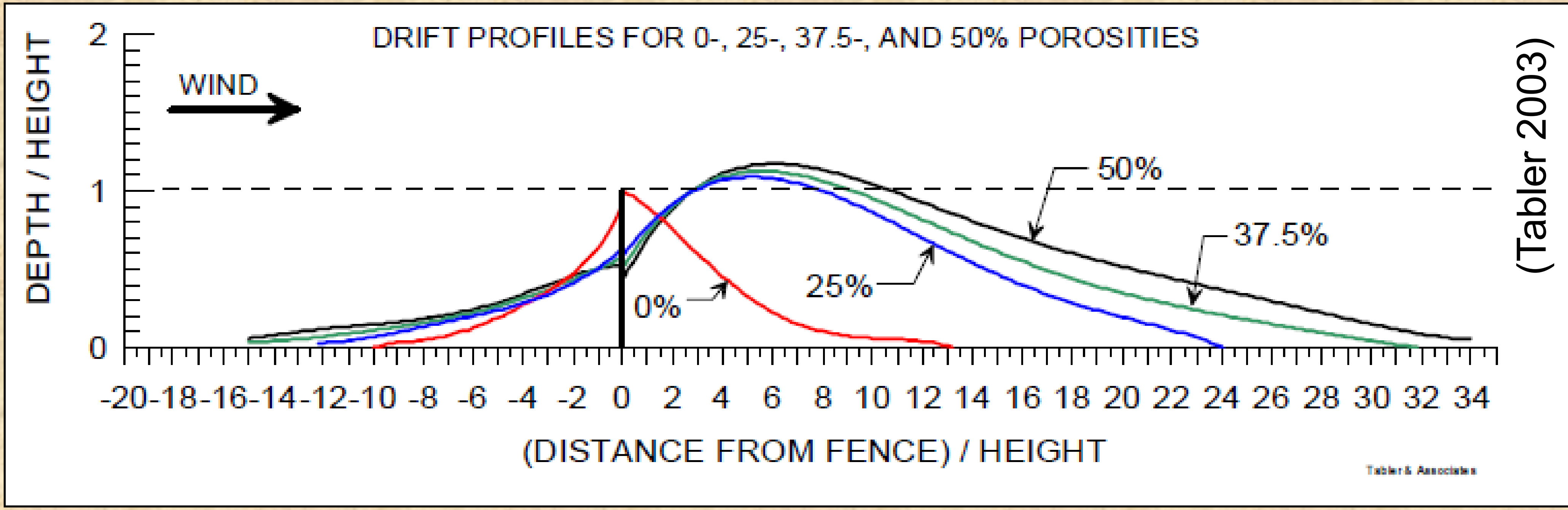
(Gullickson et al. 1999)

Snow Fence Density / Porosity



- Snow fence porosity affects ability to trap snow and the shape and size of an equilibrium snow drift change
  - Solid fence has larger drifts on the upwind side and smaller drift down wind
  - Snow fence density of 50 – 60% (porosity of 50 – 40%) has the greatest storage capacity

Snow Fence Density / Porosity



- Changes in porosity has an effect on the size and length of the equilibrium snow fence
- Challenge for living snow fences because porosity changes as the plants develop

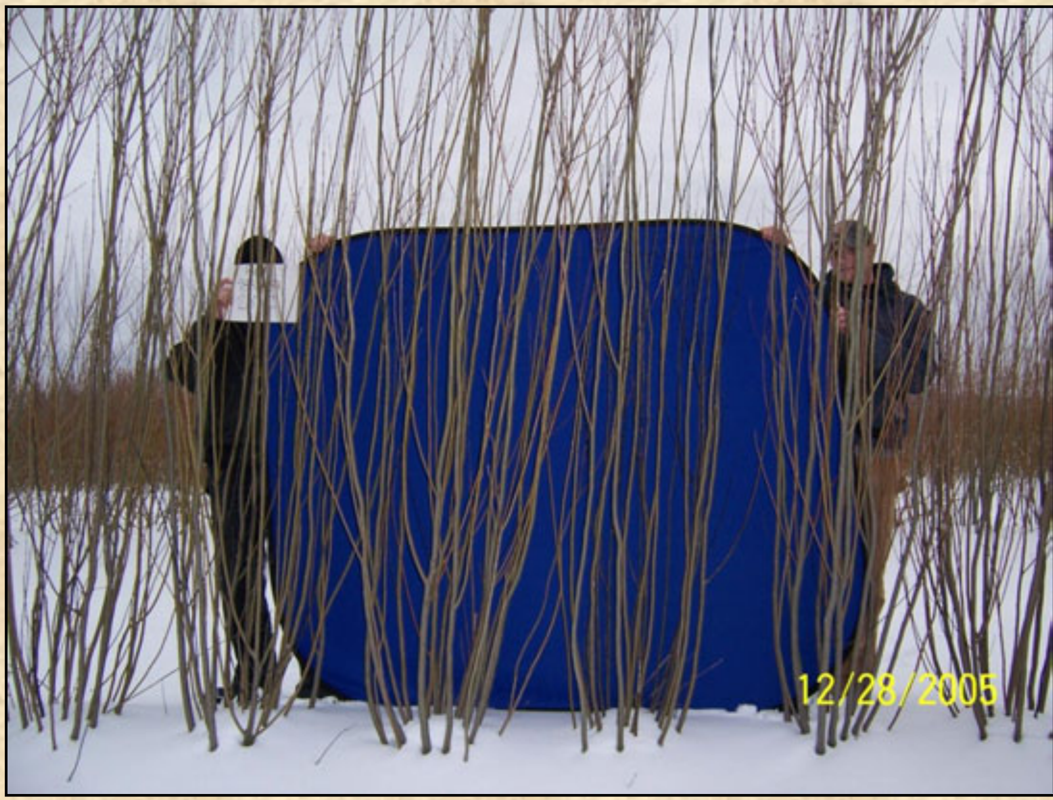
First Year Growth of Shrub Willow Double Row Living Snow Fence

One Year Old Coppice Growth on a Two Year Old Root System

Fish Creek - Density – 47.5%

SV1 - Density – 23.7%

Two Year Old Coppice Growth on a Three Year Old Root System



Fish Creek - Density – 50%

SV1 - Density – 53%

Snow Fence Design

Identifying the Problem

- The first step is to identify the problem
  - Drift encroachment on the road
  - Poor visibility for drivers
  - Slush and ice formation
  - Combination of problems
- What impact does this have on accidents, crew requirements, duty cycles, road closures etc.
- What are the benefits from addressing the problem, which will help to prioritize sites
  - Improved safety
  - Free up equipment and crews for other locations
- On site visits and discussions with local and regional staff are essential

Source of Blowing Snow Problem

- Is the problem associated with near or far snow or both?
  - Amount of snow transported as near snow may be small but can be a dominant cause of icy roads and accidents especially where there are high embankments with no vegetation

Sources of Problem

- There are a number of potential issues with blowing snow and the solutions will vary
  - Cross cut geometry
    - Drifts in cuts can encroach on roads
    - High embankments with steep slopes create problems areas
  - Horizontal alignment
    - Road alignment parallel to wind direction reduces drifting but may increase visibility and icing problems
  - Vertical alignment
    - On upgrades with slower truck speeds, berms may be higher and closer to the road
  - Roadside structures, safety barriers and vegetation can cause drifts

Snow Fence Design

- Snow fences- either structural or living – are only some of the options to address blowing and drifting snow
- The situation needs to be addressed properly so that the best solution is implemented
- Other possible solutions may include
  - Modification of cross sections
  - Changes in snow removal practices
  - Modification of safety barriers
  - Management of roadside vegetation or structures including signs

Controlling Far Snow with Snow Fences

- Keys for a successful installation:
  - Adequate storage capacity
    - Factors such as height, porosity and location are important
  - Durable so that it lasts
    - Benefits associated with initial investment increase over time
  - Proper coverage of problem area
    - Long fences without openings and gaps

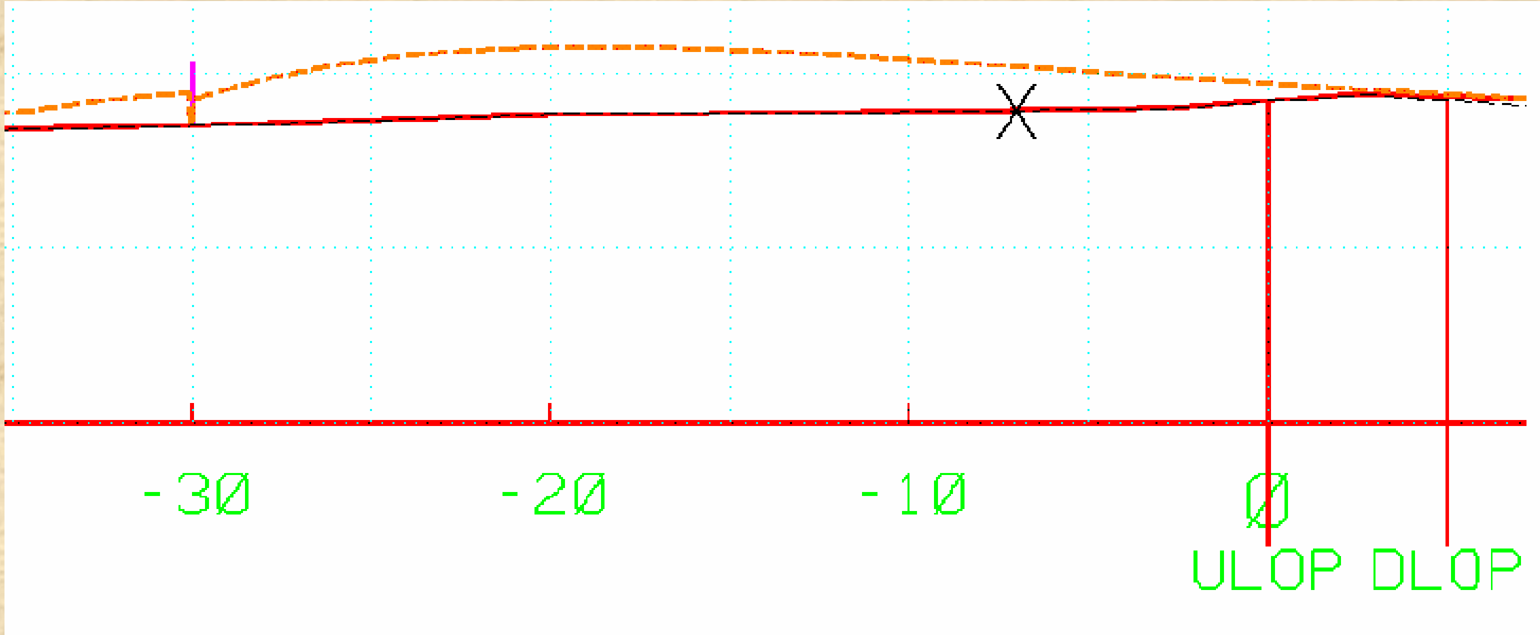
Snow Fence Design

- Several important factors associated with proper design and placement of snow fences
- Calculating snow transport (i.e. the amount of snow transported by the wind over a given period of time and distance) or capacity needed
  - » Identify the snowfall over the snow accumulation season
  - » Identify the snowfall water equivalent
  - » Identify the relocation coefficient
  - » Determine the prevailing direction of greatest snow transport
    - Measure orientation of snow drifts formed by large objects late in the snow season
    - Analyze historical wind records
  - » Determine the fetch distance for your location

Snow Fence Design

- Determine required snow fence height
  - Distance from the road
- Determine required set back for snow fence
  - Key factors are
    - Amount of transported snow
    - Porosity of snow fence
    - Height of snow fence
- Length fence should extend from either side of the problem area is calculated

Snow Fence Design - Snowman



- Tool can be used to develop specific parameters for snow fence design based on site specific conditions
- Precise site specific data is required from a survey and weather data bases

Assessing Site Conditions for Plants

Assessing Site Specific Conditions

- Living snow fence is permanent, compared to temporary snow fence.
- More permanent characteristics of living snow fences offers unique challenges/opportunities in working with landowners
- Landowner objectives
  - Clearly identify and discuss the landowner's short and longer term plans and intentions for the area being considered
  - Design will have to fit with the landowner's plans and preferences for the area
    - Location of living snow fence may not be ideal
    - Planting design and species selection may have to be adjusted to accommodate landowner
    - Site preparation and maintenance may have to be modified

Landowner Involvement is Essential

Assessing Site Specific Conditions

- Successful living snow fences start with proper site assessment
- Proper site evaluation will help to avoid many establishment and long term growth and survival problems
  - Site limitations such as wet areas, excessive slopes, stones, fence line removal/trimming
  - Soil conditions
  - Current and previous land use history
  - Existing vegetation
    - Woody plants
    - herbaceous annual or perennials
    - agricultural crop

Site Limitations

- Walk the site, to see if there are any barriers to preparing, planting or maintaining the site
- If limitations exist, work with landowner and create a plan to modify them if possible
  - Physically modify the site
  - Adapt equipment to suit the site
  - Change the snow fence design to avoid limitations

Site Assessment – Soil Conditions

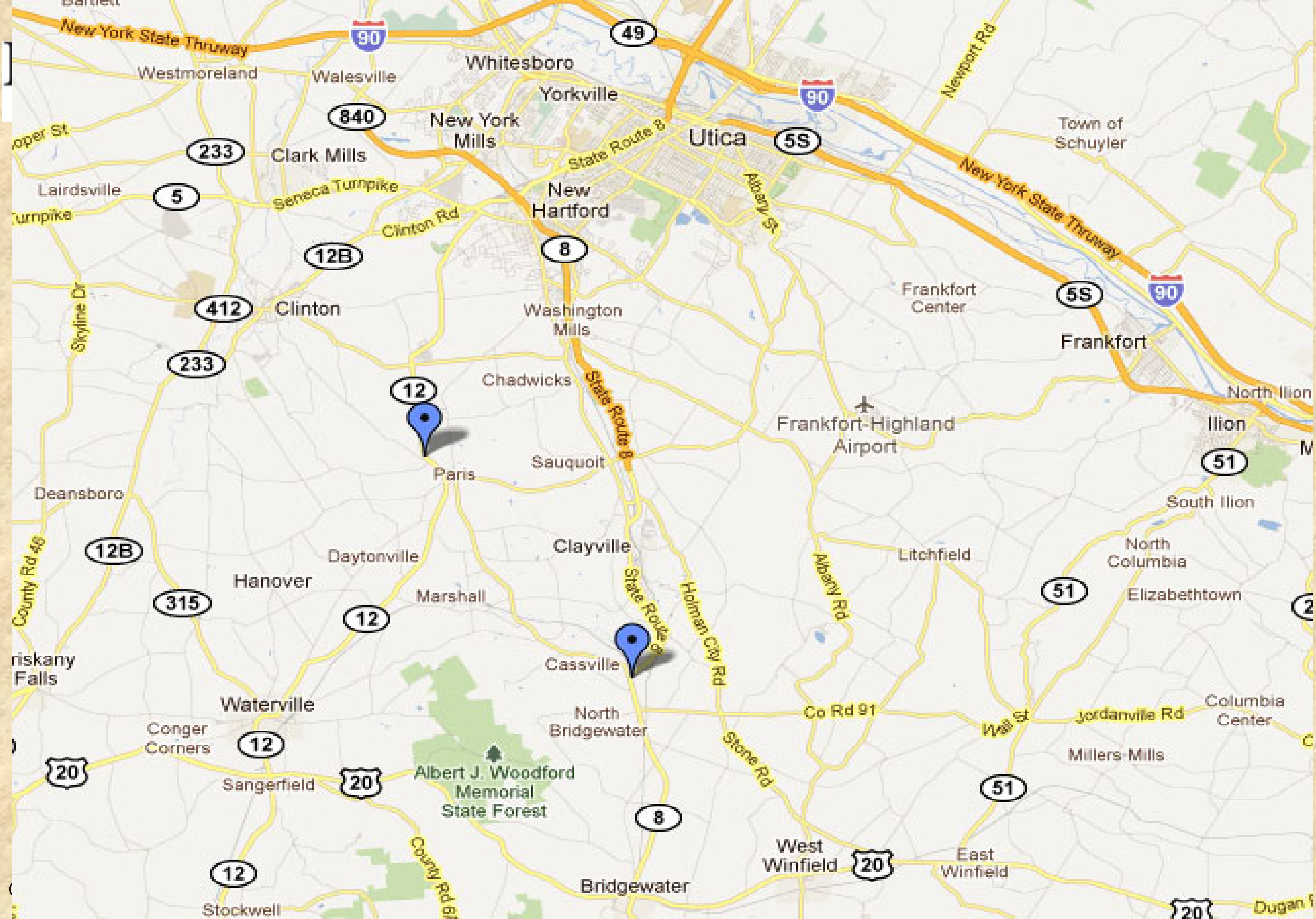
- Soil survey
- Soil samples and testing
- Site specific assessments
  - Drainage problems
  - Bulk density or root growth restrictions from hardpans or fill material

Assessing Site Specific Conditions

- Soil type and conditions
  - » USDA soil survey information for fields or areas away from the right of way
  - » Specific soil conditions should be assessed, especially on right of ways
    - Soil samples and testing
    - Identify other potential limitations such as wet or seasonally flooded areas, rocks, fence lines, other barriers
  - » Collect soil samples, assess rooting depth and potential barriers to successful growth

Soil Sampling

- Make use of Cornell Cooperative Extension sampling protocol and testing lab
- For woody plants use recommended sampling depths of 0 – 8 inches and 8 – 24 inches


New York State Thruway
90
49
Whitesboro
Westmoreland
Walesville
Yorkville
840
New York Mills
Utica
5S
Town of Schuyler
Newport Rd
State Route 8
233
Clark Mills
Lairdsville
5
Seneca Turnpike
Clinton Rd
New Hartford
Albany St
New York State Thruway
12B
8
412
Clinton
Skyline Dr
Washington Mills
Frankfort Center
5S
90
Frankfort
233
12
Chadwicks
State Route 8
North Ilion
Frankfort-Highland Airport
Ilion
Sauquoit
Paris
51
Deansboro
South Ilion
Clayville
Daytonville
Litchfield
North Columbia
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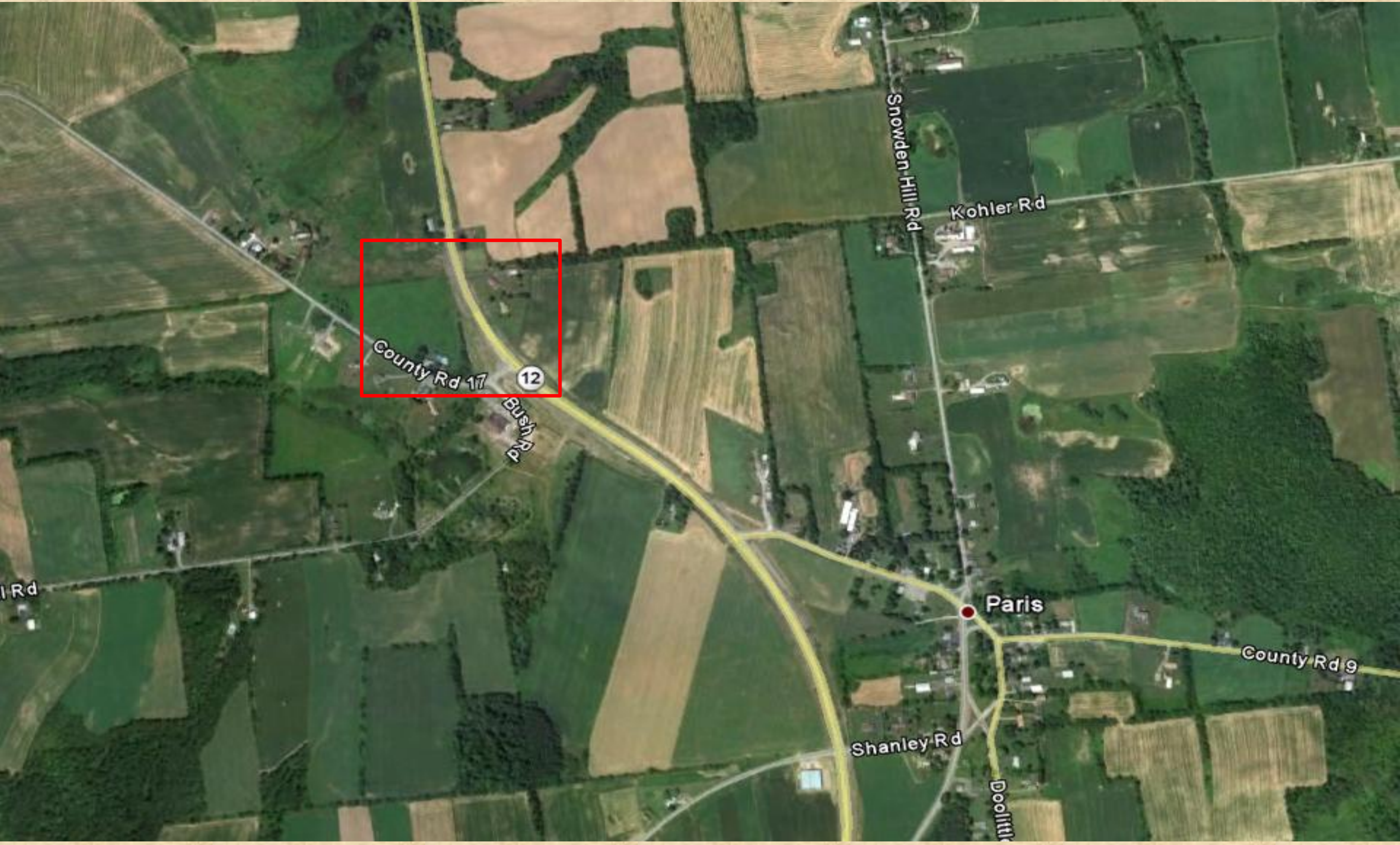
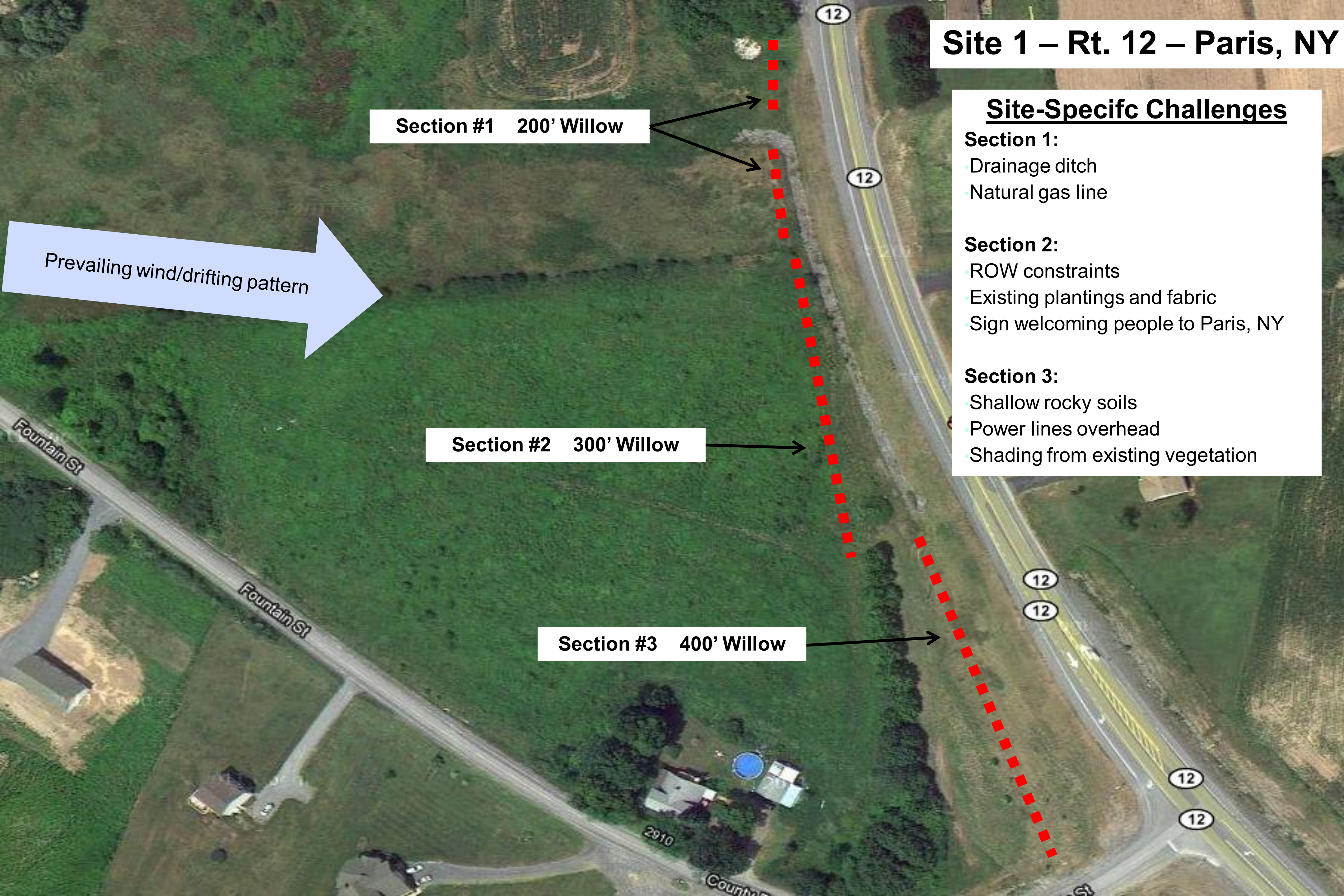
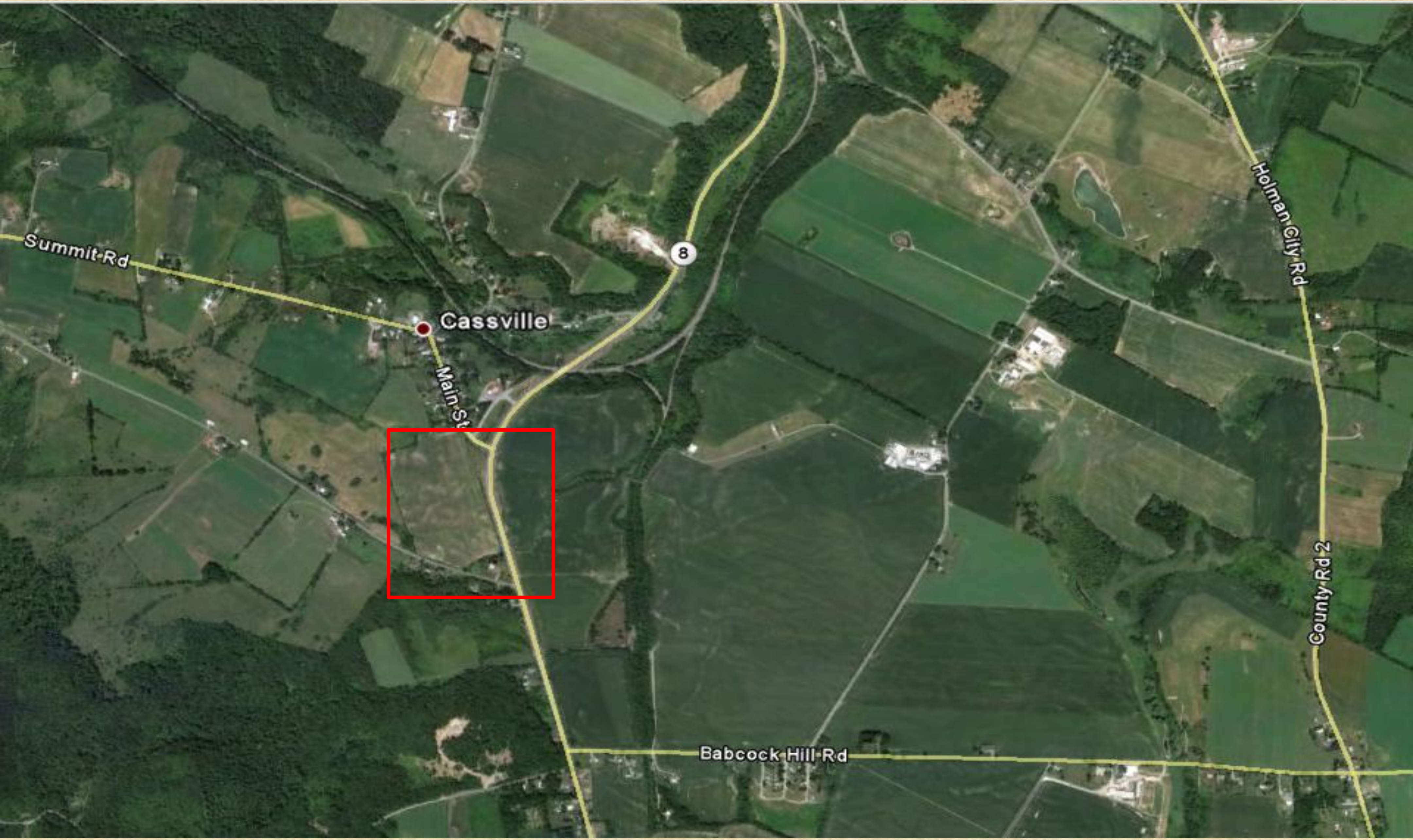
Hanover
Albany Rd
Holman City Rd
315
Marshall
12
State Route 8
51
Elizabethtown
Cassville
Waterville
North Bridgewater
Co Rd 91
Wall St
Jordanville Rd
Columbia Center
Conger Corners
12
20
Sangerfield
20
Albert J. Woodford Memorial State Forest
Stone Rd
Millers Mills
51
8
12
West Winfield
20
East Winfield
Bridgewater
Stockwell
Dugan Rd
20

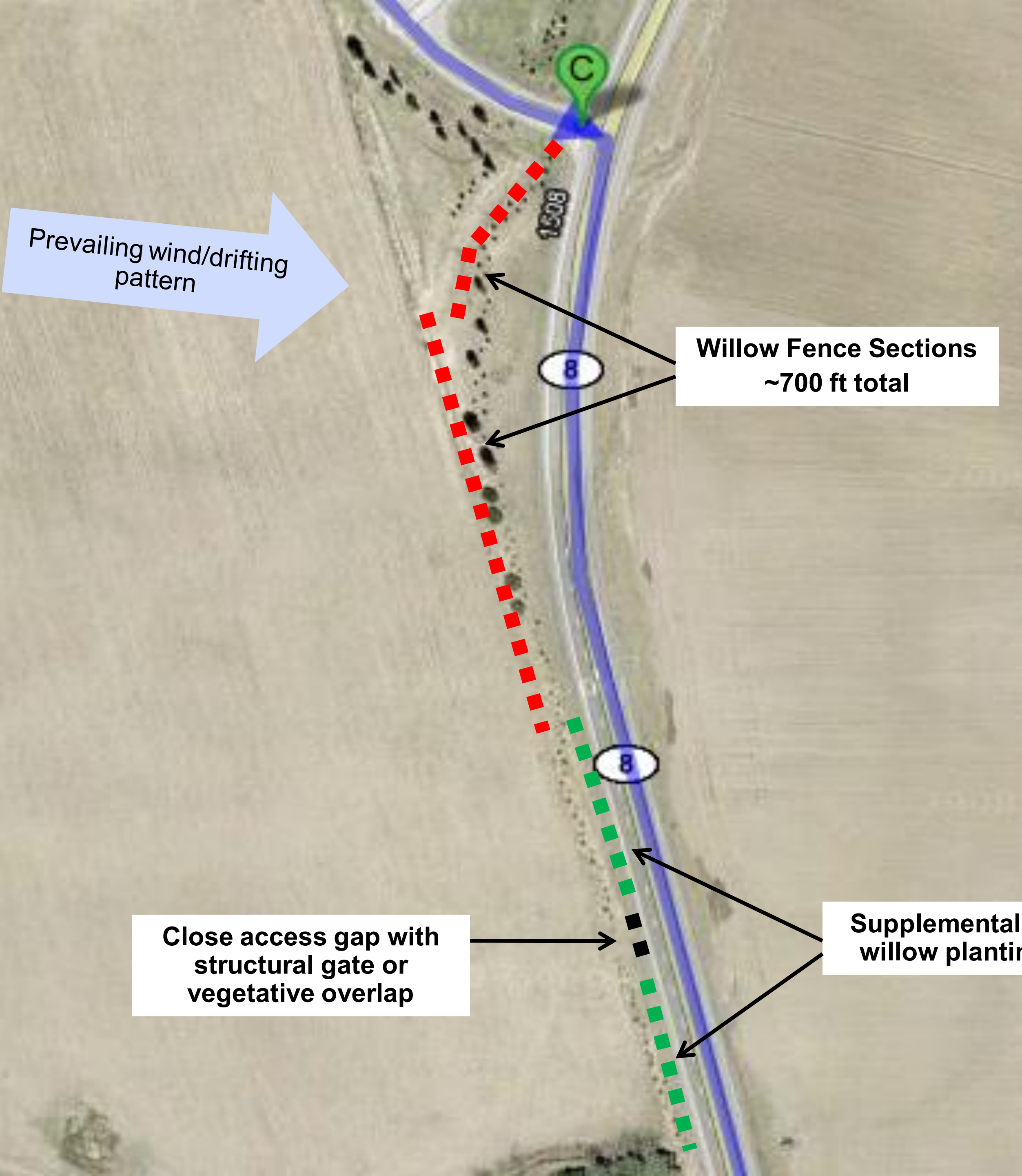

Snowden Hill Rd
Kohler Rd
County Rd 17
12
Bush Rd
Paris
County Rd 9
Shanley Rd
Rd



Site 1 – Rt. 12 – Paris, NY
Site-Specifc Challenges
Section 1:
Drainage ditch
Natural gas line
Section 2:
ROW constraints
Existing plantings and fabric
Sign welcoming people to Paris, NY
Section 3:
Shallow rocky soils
Power lines overhead
Shading from existing vegetation
Section #1 200’ Willow
Section #2 300’ Willow
Section #3 400’ Willow
Prevailing wind/drifting pattern
Fountain St
Fountain St
12
2910


Summit Rd
Cassville
8
Main St
Holman City Rd
County Rd 2
Babcock Hill Rd

Site 2 – Rt. 8 – Cassville, NY



Site-Specifc Challenges

- Large gaps in existing plantings
- Use various methods to improve functionality…
  - 2-3 willow fence sections where possible
  - Fill in smaller gaps with evergreens
  - Close access gap without restricting farm or snowmobile access

Additional Challenges

- Varying degrees of functionality up and down the site
- ROW constraints
- Rocky soil in spots
- Power lines
- Shading and competition from existing vegetation

Questions and Discussion

"We cannot keep it from snowing, but we can influence the wind that carries tons of blowing and drifting snow" – Gullickson et al. 1999.