Effects of Northern Climates on Performance of Porous Pavements and Filtration Systems

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Dedicated to the protection of water resources through effective stormwater management

- Research and development of stormwater treatment systems

- To provide resources to stormwater communities currently involved in design and implementation of Phase II requirements

Cold Climate Issues

Hypothesis

Frozen, open-graded systems may maintain porosity and infiltration capacity

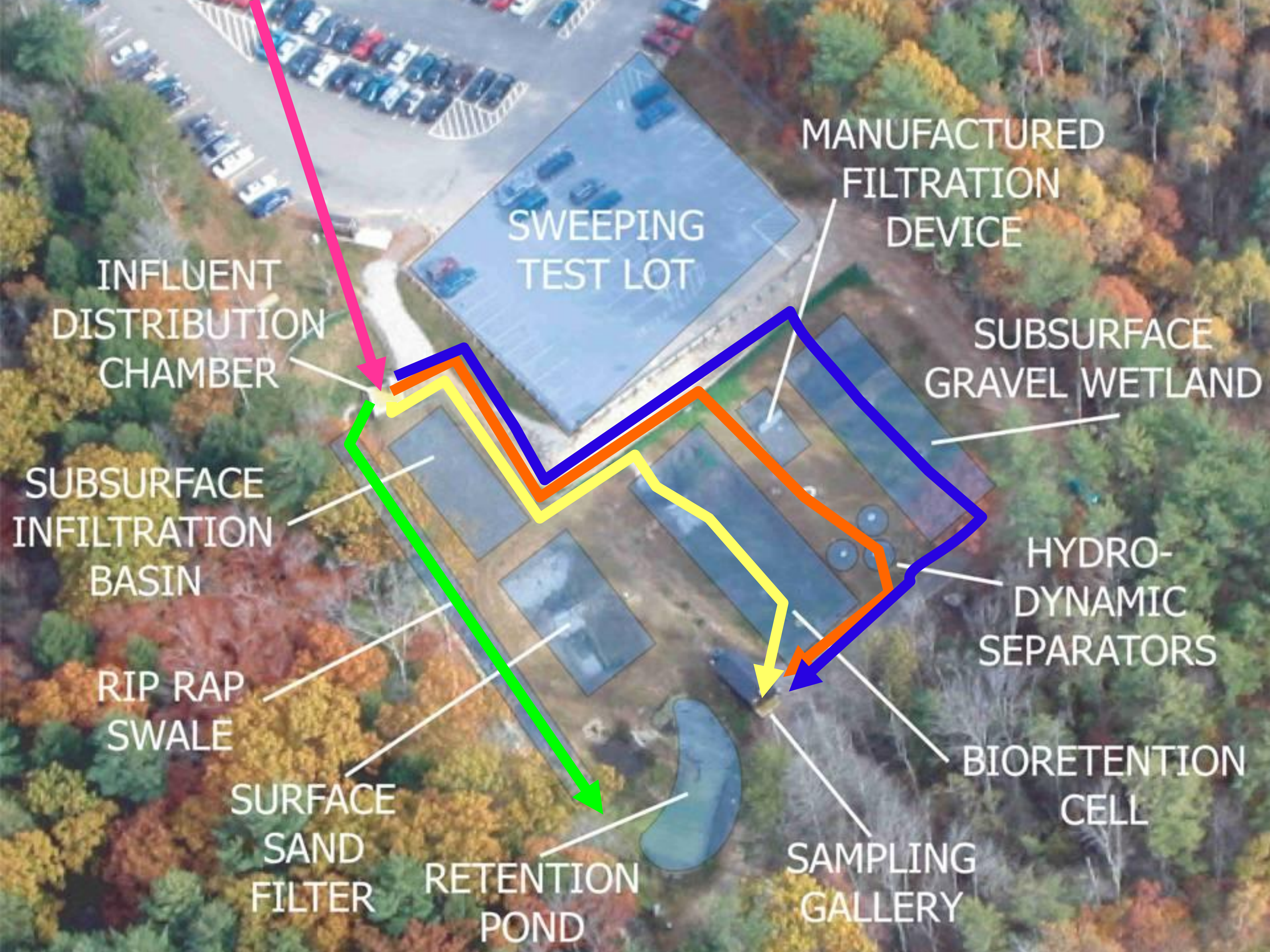
Background

- Annual precipitation= 44 in, average monthly precipitation = 3.7 in +/- 0.5 in
- Mean annual air temperature = 48°F, average low in January = 15.8°F, average high in July = 82°F
- 5 months of below freezing temperature
- Design frost depth is 48 inches

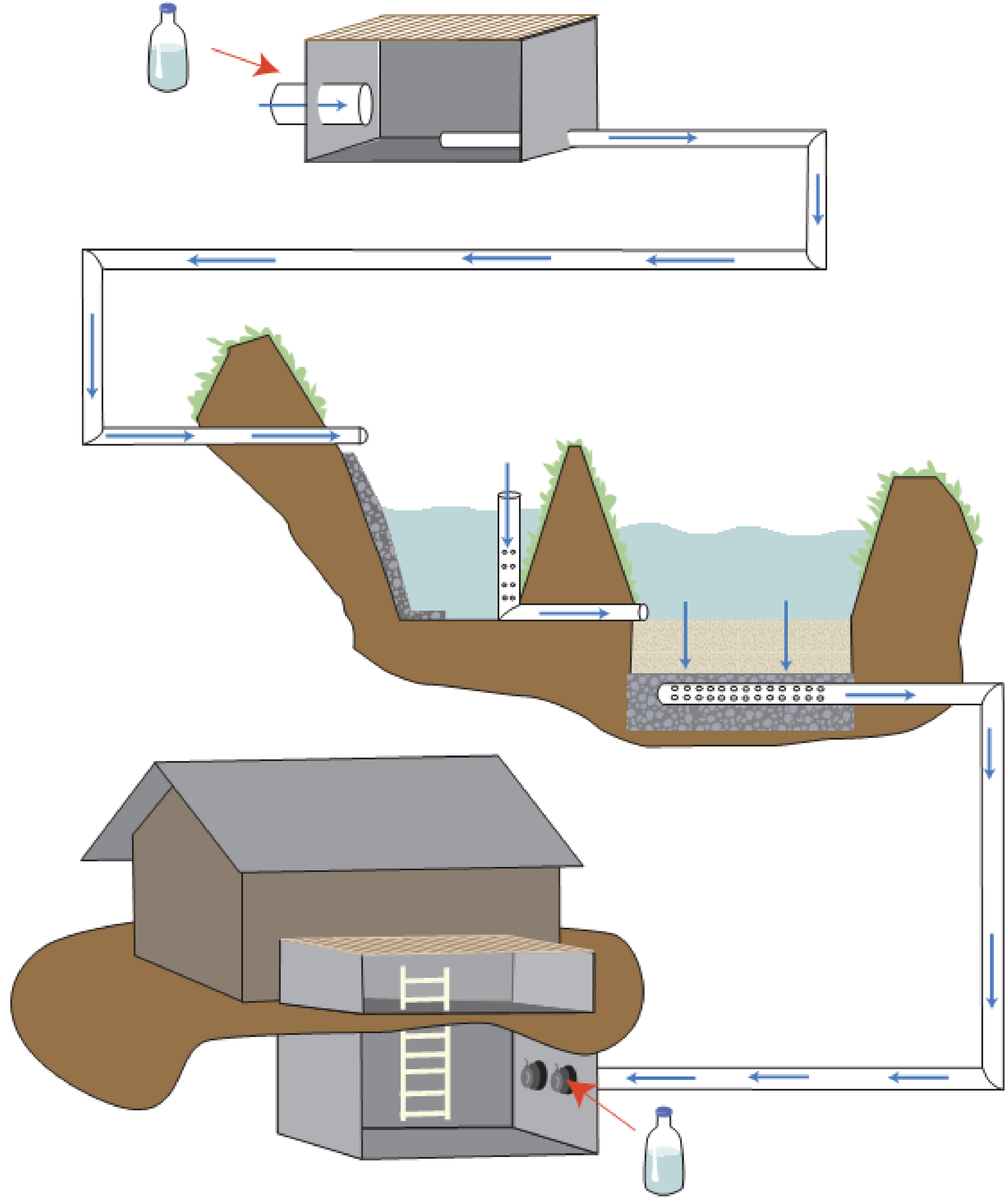
Cold Climate Concerns

- Potential for increased runoff due to rain on snow events and limited infiltration capacity;
- Reduced or no infiltration capacity;
- Change in roughness characteristics due to snow and ice cover;
- Obstruction by freezing of piping or hydraulic control structures;
- Chloride toxicity related to deicing practices;
- Reduced particle settling velocities due to low temperature, high viscosity, and high chloride content runoff;
- Dormant vegetation;
- Required depth of design for infiltration 48-52+” from coast to inland.
- High rate of cycling between freeze and thaw

Study Locations


MANUFACTURED FILTRATION DEVICE
SWEEPING TEST LOT
INFLUENT DISTRIBUTION CHAMBER
SUBSURFACE GRAVEL WETLAND
SUBSURFACE INFILTRATION BASIN
HYDRO-DYNAMIC SEPARATORS
RIP RAP SWALE
BIORETENTION CELL
SURFACE SAND FILTER
RETENTION POND
SAMPLING GALLERY

Performance Evaluation



Hydrodynamic Separator

Isolator Row

Subsurface Infiltration

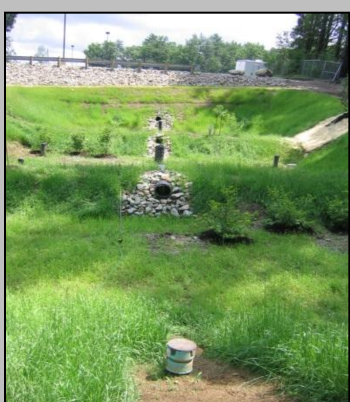
Filter Unit

Porous Asphalt

Pervious Concrete

Retention Pond

Rip Rap Swale



Gravel Wetland

Sand Filter

Bioretention Unit

Tree Filter

Cold Climate Performance Results

Research Topics

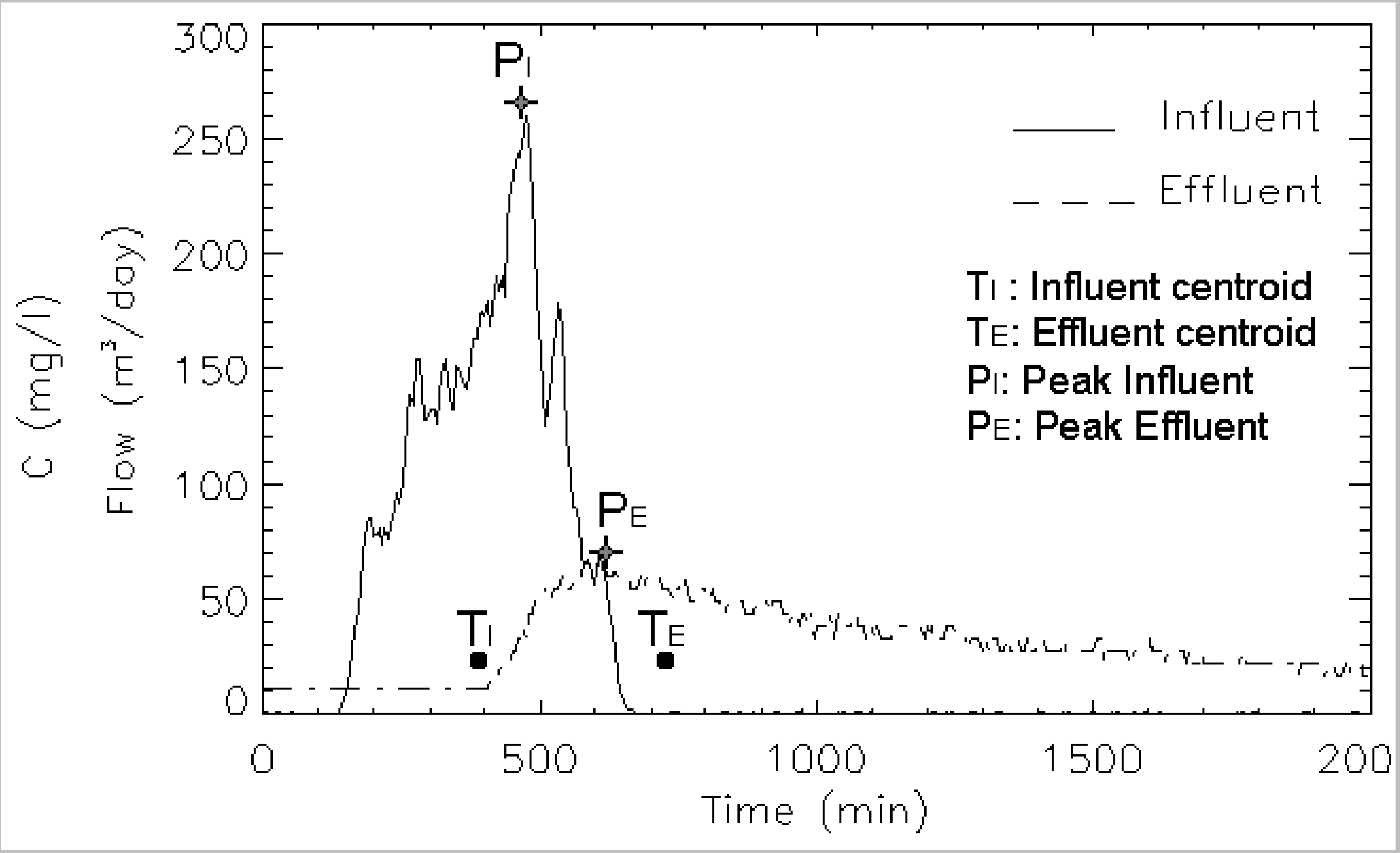
- Hydrology
- Water Quality
- Frost Depth
- Surface Infiltration Capacity
- Maintenance & Salt Reduction

Hydrology

Seasonal Hydraulic Efficiency

Equation 1: Peak reduction coefficient $$k_p = \frac{P_E}{P_I} \leq 1$$

Equation 2: Lag coefficient $$k_L = \frac{T_E}{T_I} \geq 1$$



Device	Measure	Annual	Winter	Summer
Subsurface Infiltration	K_l	1.6	1.7	1.5
	K_p	0.13	0.15	0.12
Surface Sand Filter	K_l	1.5	1.5	1.3
	K_p	0.27	0.27	0.26
Retention Pond	K_l	1.8	1.9	1.8
	K_p	0.13	0.16	0.10
Bioretention	K_l	1.7	2.0	1.3
	K_p	0.20	0.23	0.17
Gravel Wetland	K_l	1.6	1.6	1.6
	K_p	0.13	0.14	0.11
Swale	K_l	1.0	1.0	1.0
	K_p	0.56	0.77	0.39
Porous Asphalt	K_l	4.6	5.07	3.76
	K_p	0.12	0.10	0.13
Street Tree/ Tree Filter	K_l	1.2	1.2	1.1
	K_p	0.80	0.86	0.72

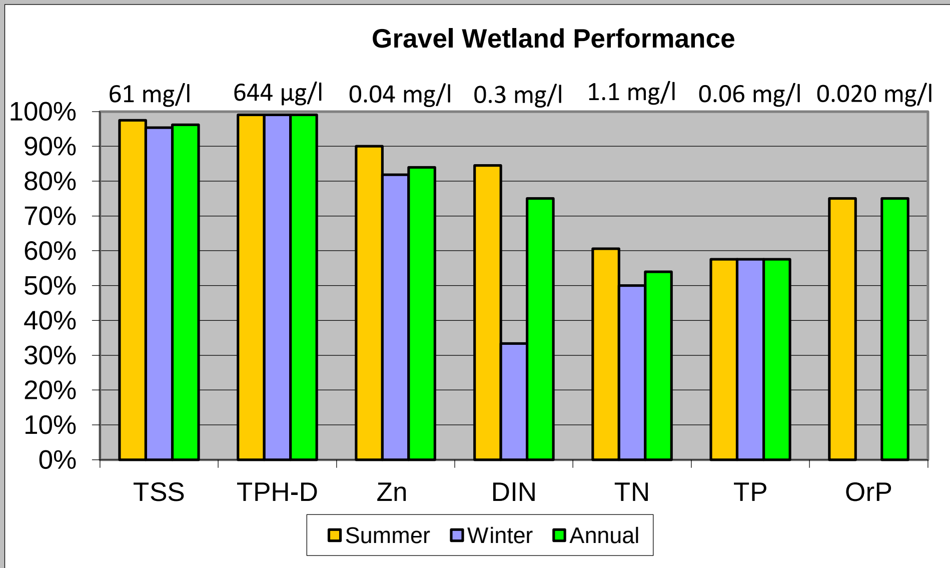
REFERENCE

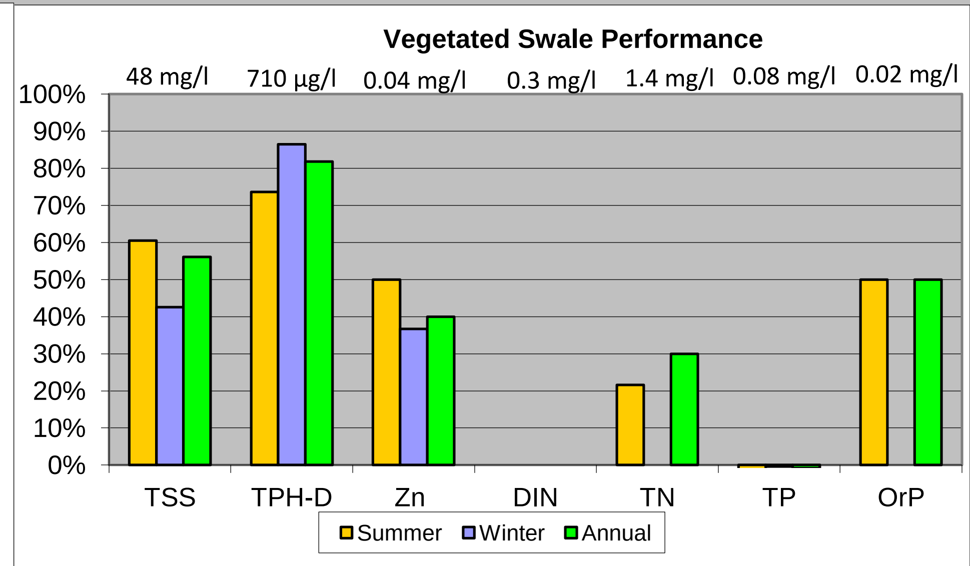
MIN EFFECT

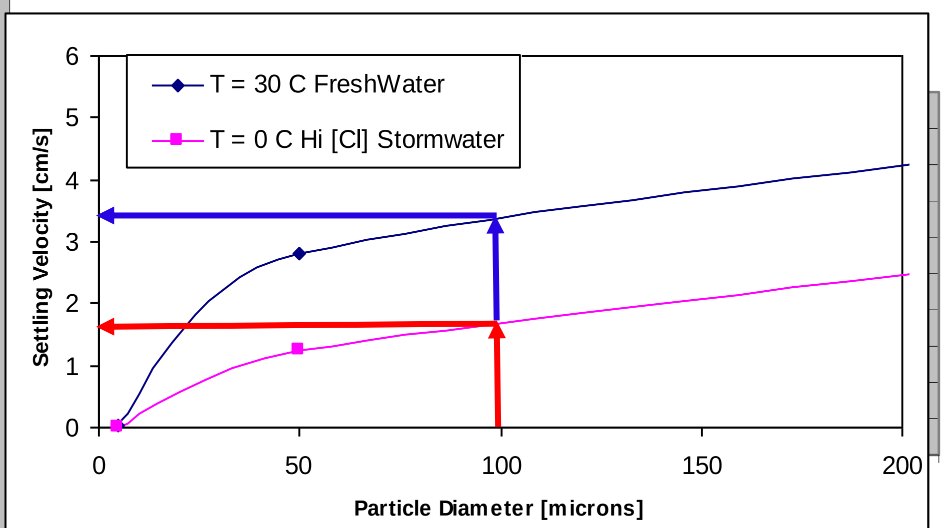
GREATEST EFFECT

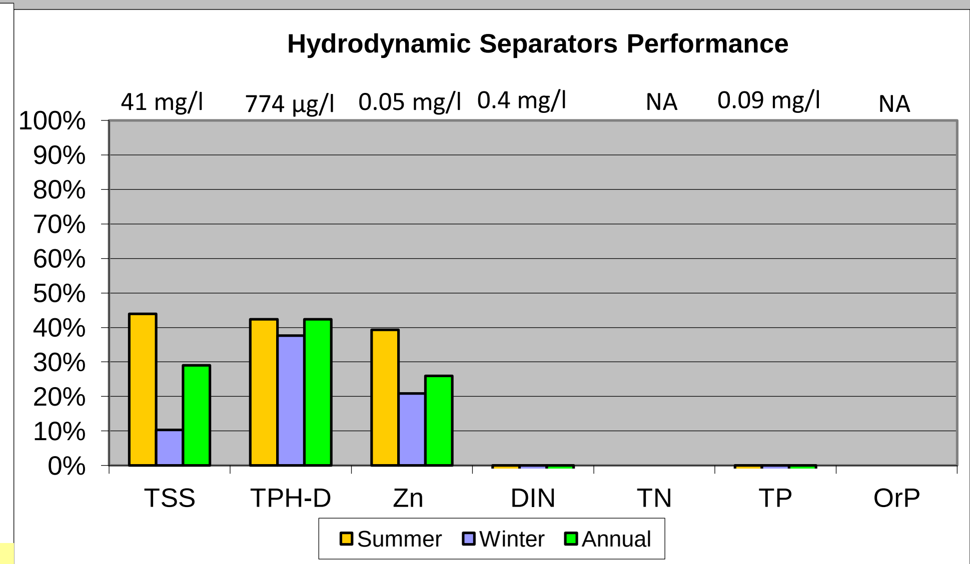
Water Quality

Seasonal Variations in Performance









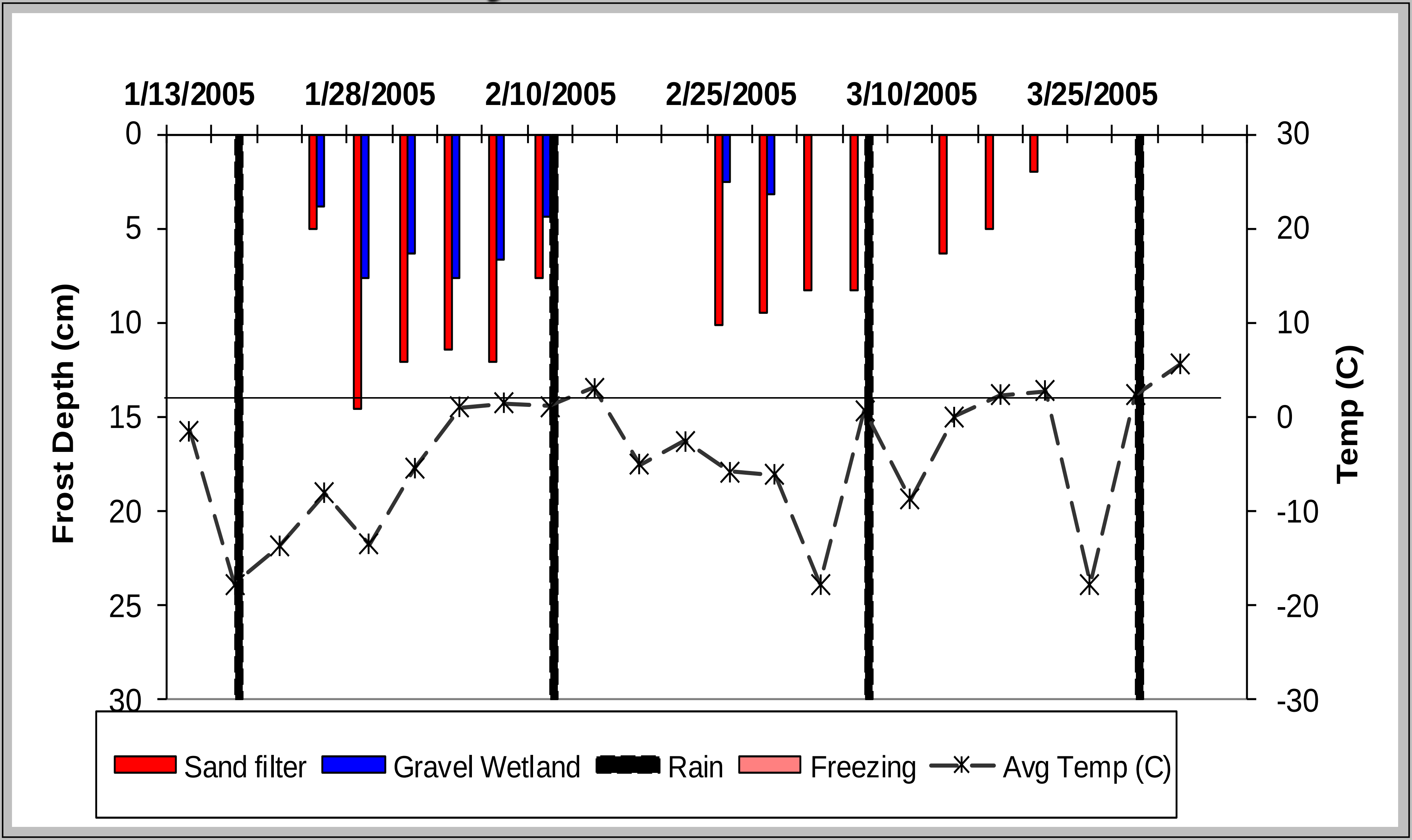
The effect of T and [Cl$^-$] is to nearly double the settling time from 1.6 to 3.4 cm/sec

Frost Penetration

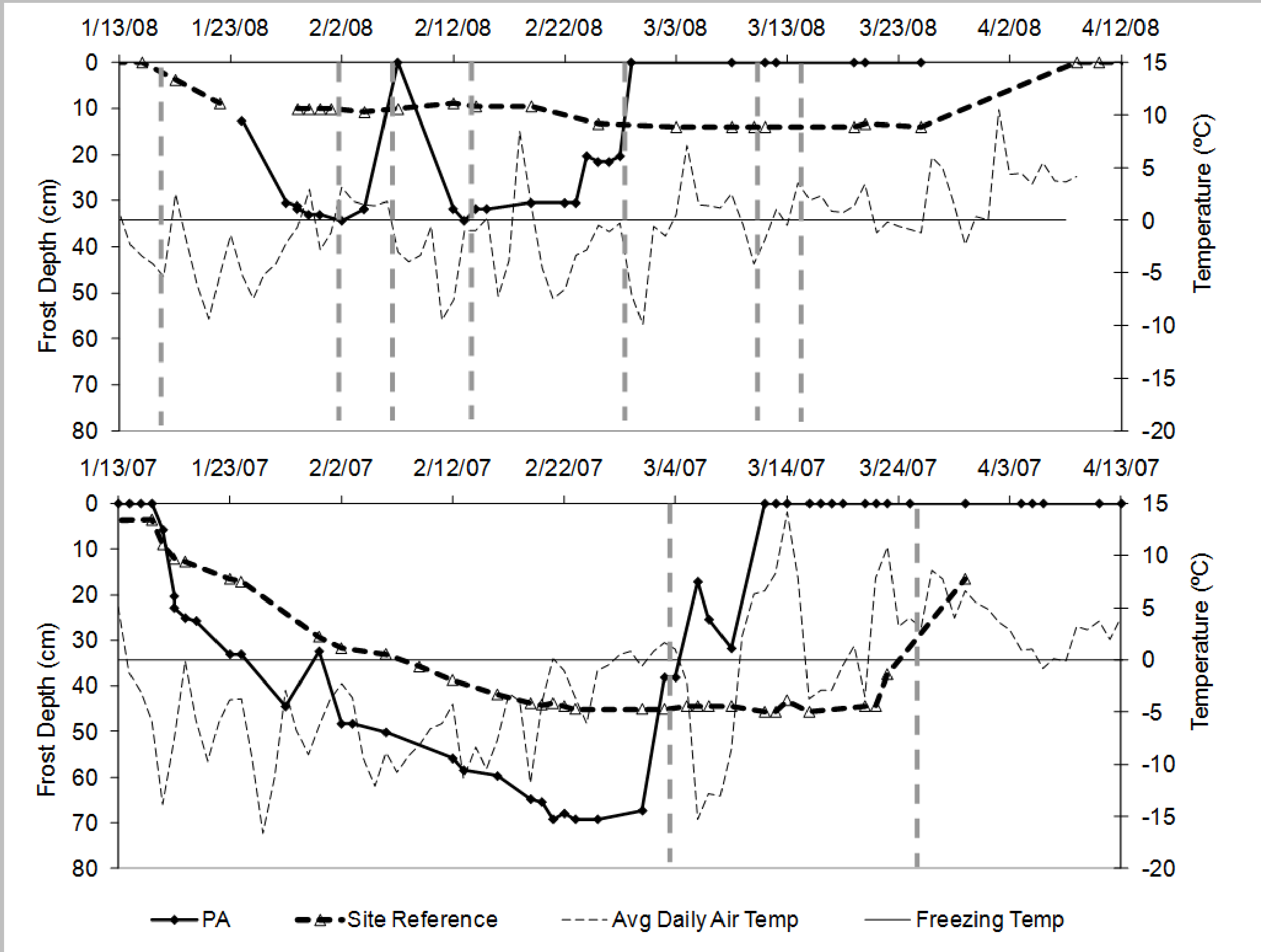
Frost Penetration

- Measured with a 'field-assembled' frost gauge (Ricard et al., 1976)
- Show relationships between pavements or system media and surrounding soils

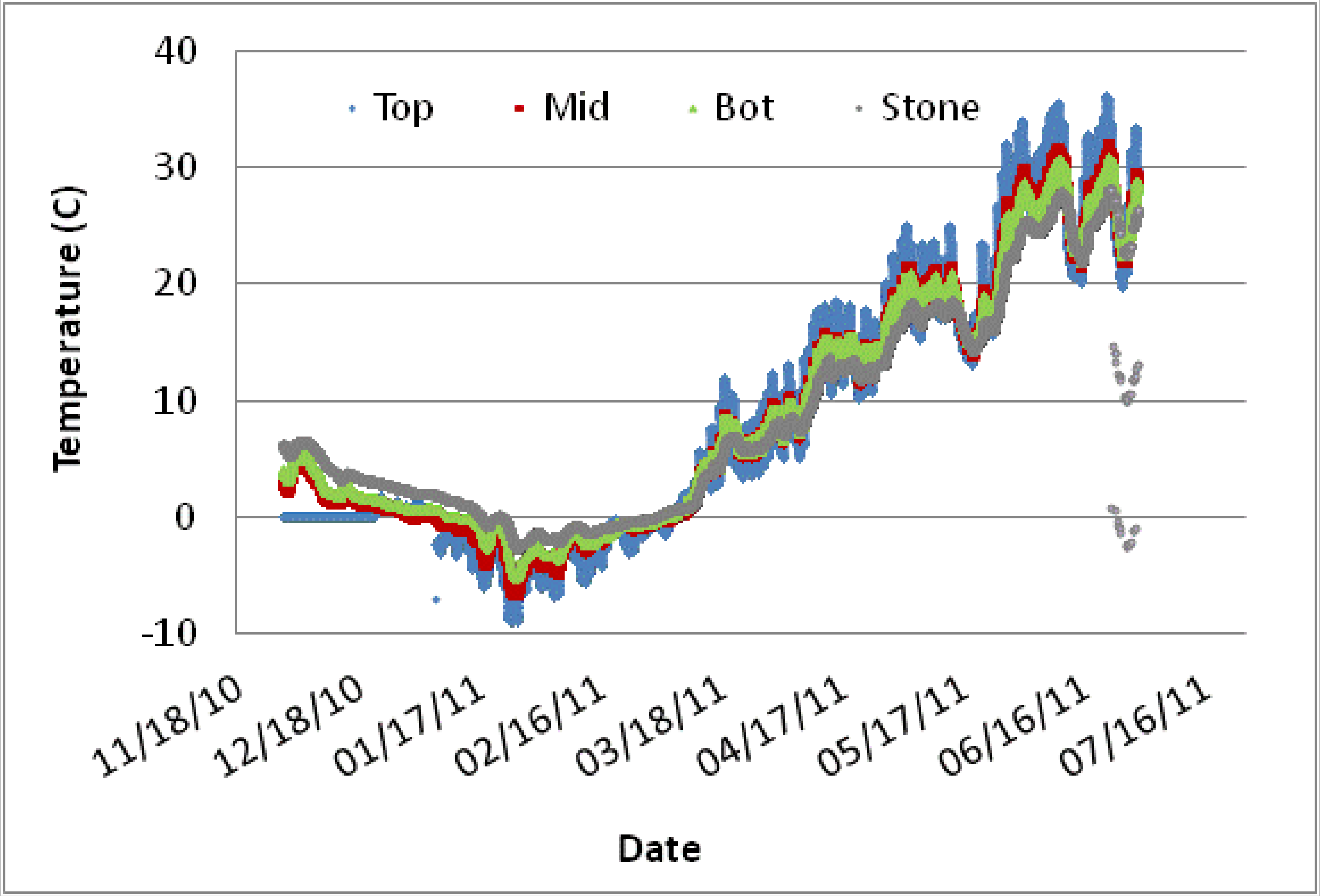
Filtration Systems Frost Penetration



Porous Asphalt Frost Penetration



Temperature – PA Base

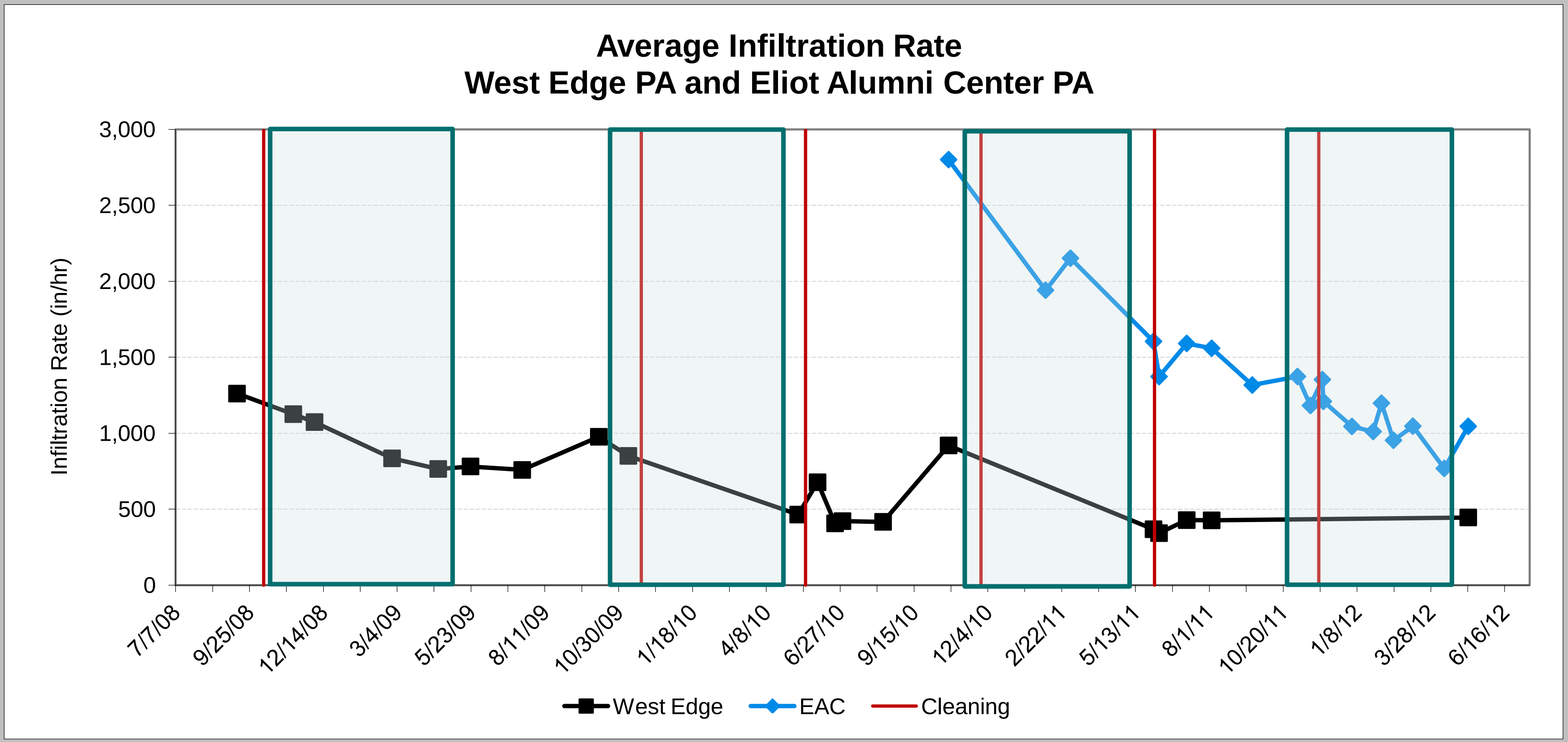


Surface Infiltration Capacity

Surface Infiltration Capacity

- Tests ability of pavement to infiltrate water
- Measured with two devices
  - Surface Inundation (SI) test (Bean, 2004)
    - Falling head test
  - Double-Ring Infiltrometer (ASTM D3385-03)
    - Constant head test

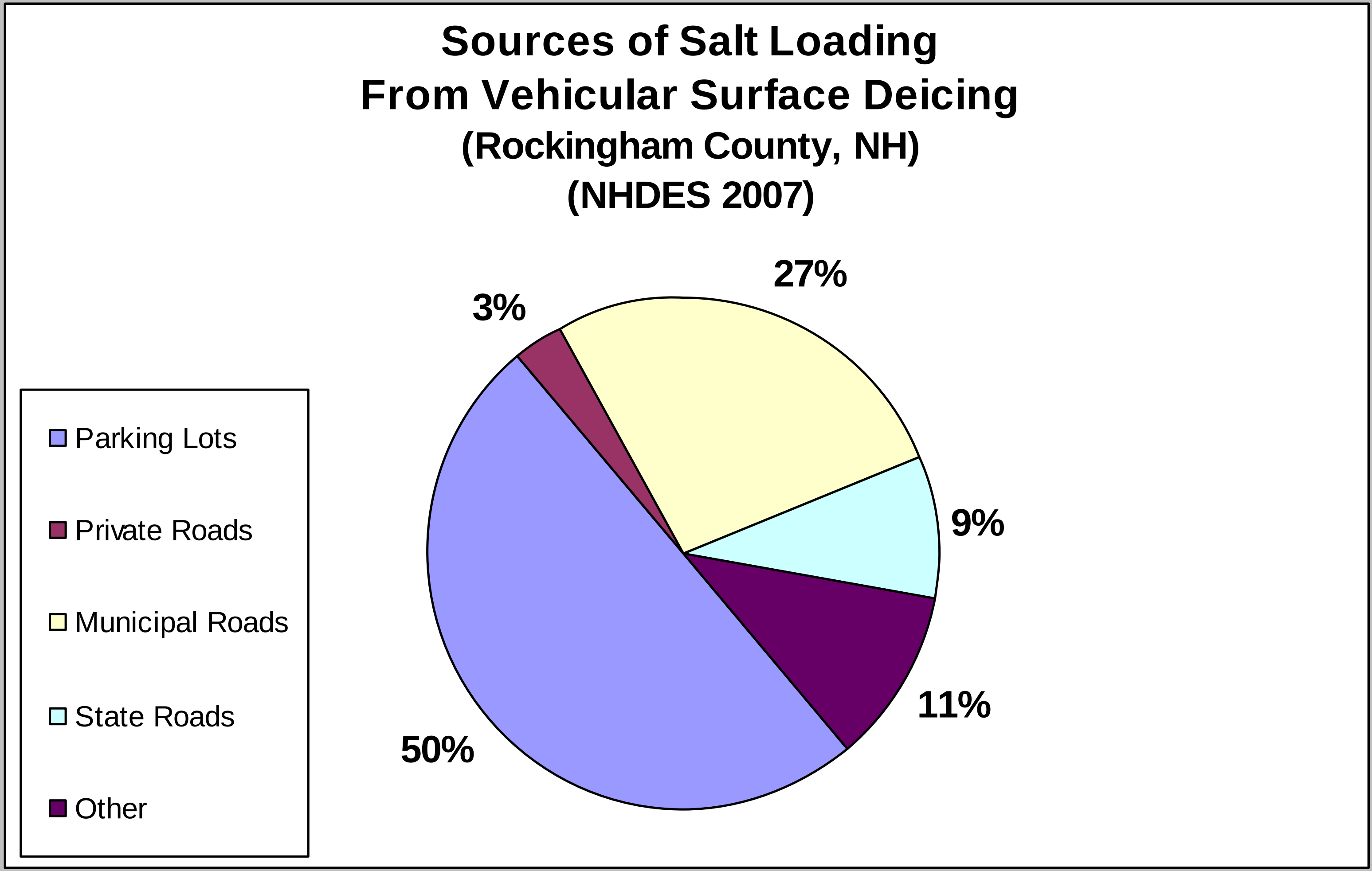
Porous Asphalt Surface Infiltration Capacity



Winter = Nov. – April; Summer = May – Oct.

Winter Maintenance & Salt Reduction

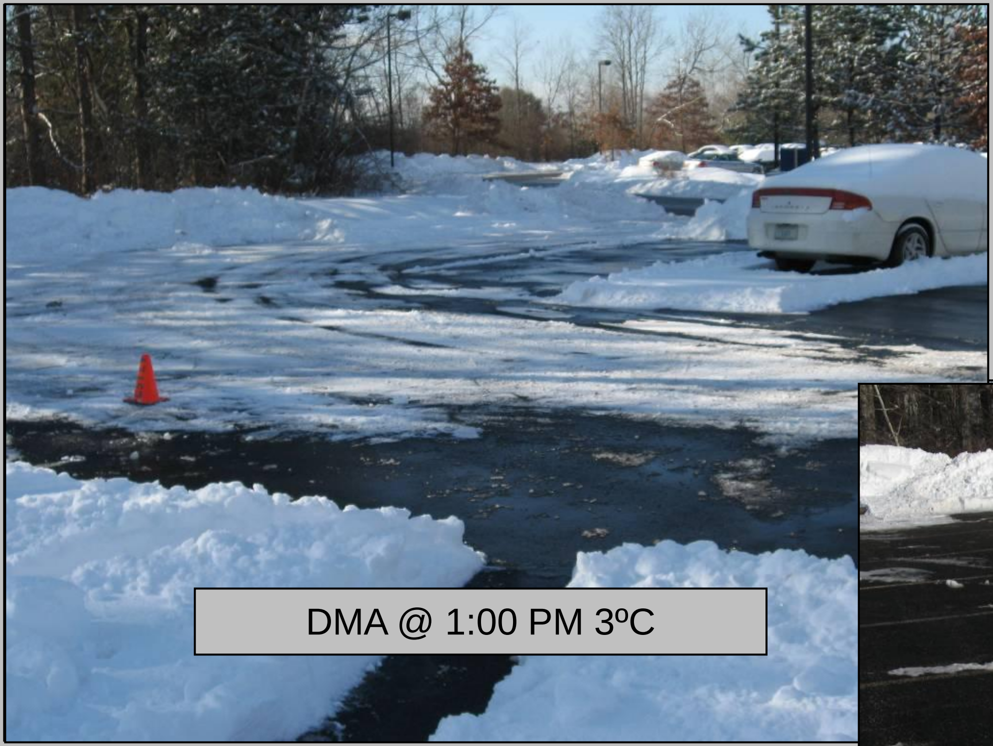
Where should reductions occur?

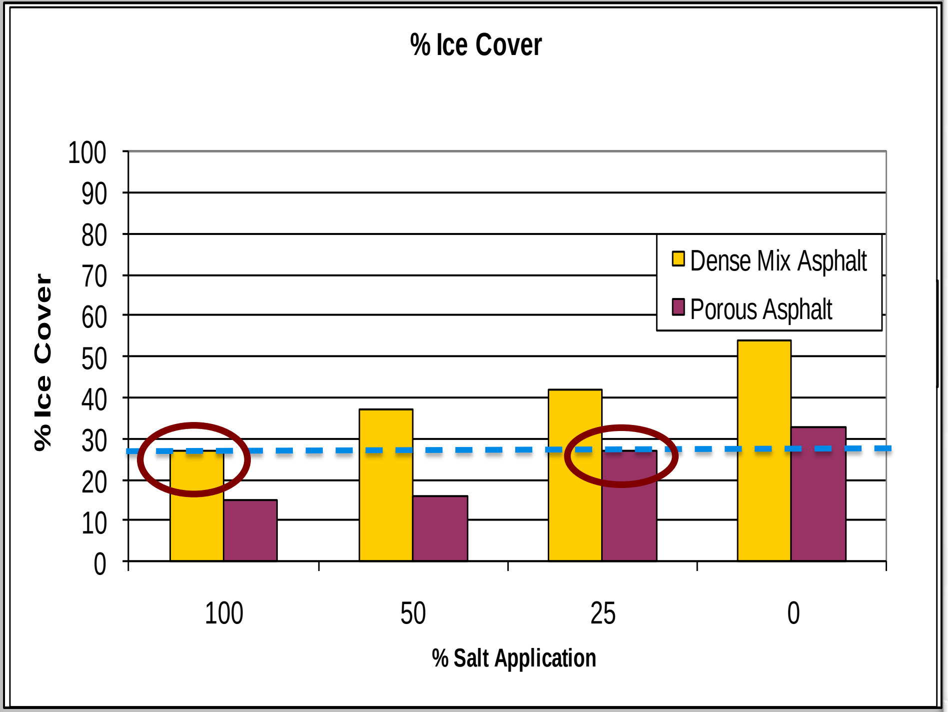


PA/DMA Snow & Ice Cover

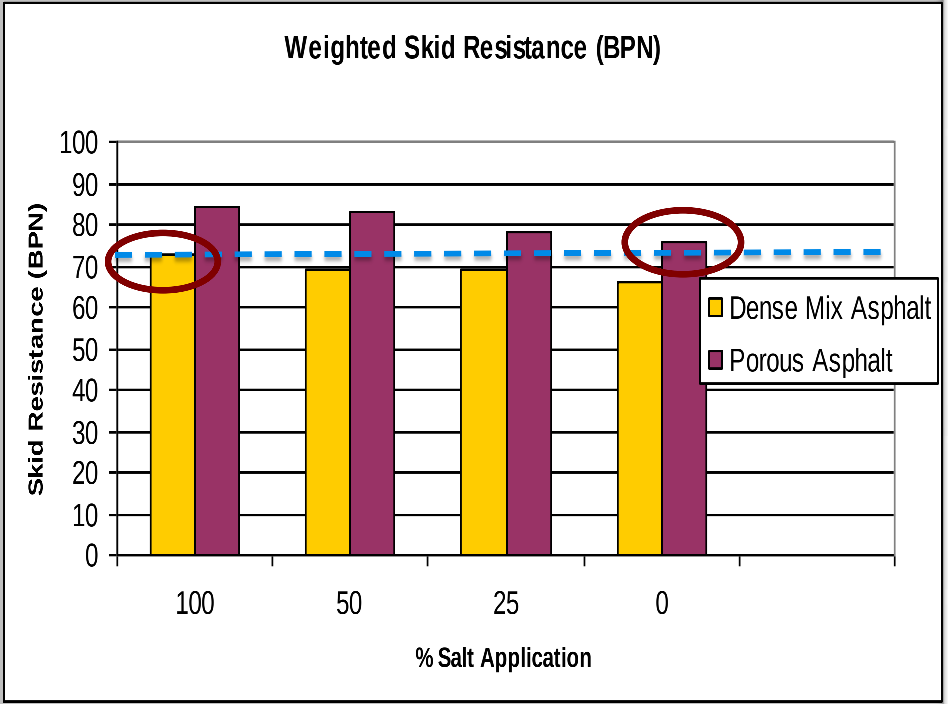
PC Snow & Ice Cover

Snow & Ice Cover
(12/14/07)




% Ice Cover
100
90
80
70
60
50
40
30
20
10
0
% Ice Cover
Dense Mix Asphalt
Porous Asphalt
100
50
25
0
% Salt Application


DMA after spring rain on snow event


Weighted Skid Resistance (BPN)
100
90
80
70
60
50
40
30
20
10
0
Skid Resistance (BPN)
Dense Mix Asphalt
Porous Asphalt
100
50
25
0
% Salt Application


PA after spring rain on snow event

Pervious Concrete Spalling


28D N83
U.S. MARINES

The PC Verdict

There are 3 main curing requirements for PC:

- 7 day cure for structural load
- 28 day cure to protect against freeze-thaw damage,
- 12 month cure prior to aggressive chloride deicing applications.

Cold Climate Considerations

Thickness of sub-base materials is determined based on various factors

1. Penetration of frost design

   Total system thickness $\geq 0.65 * D_{max}$ frost depth

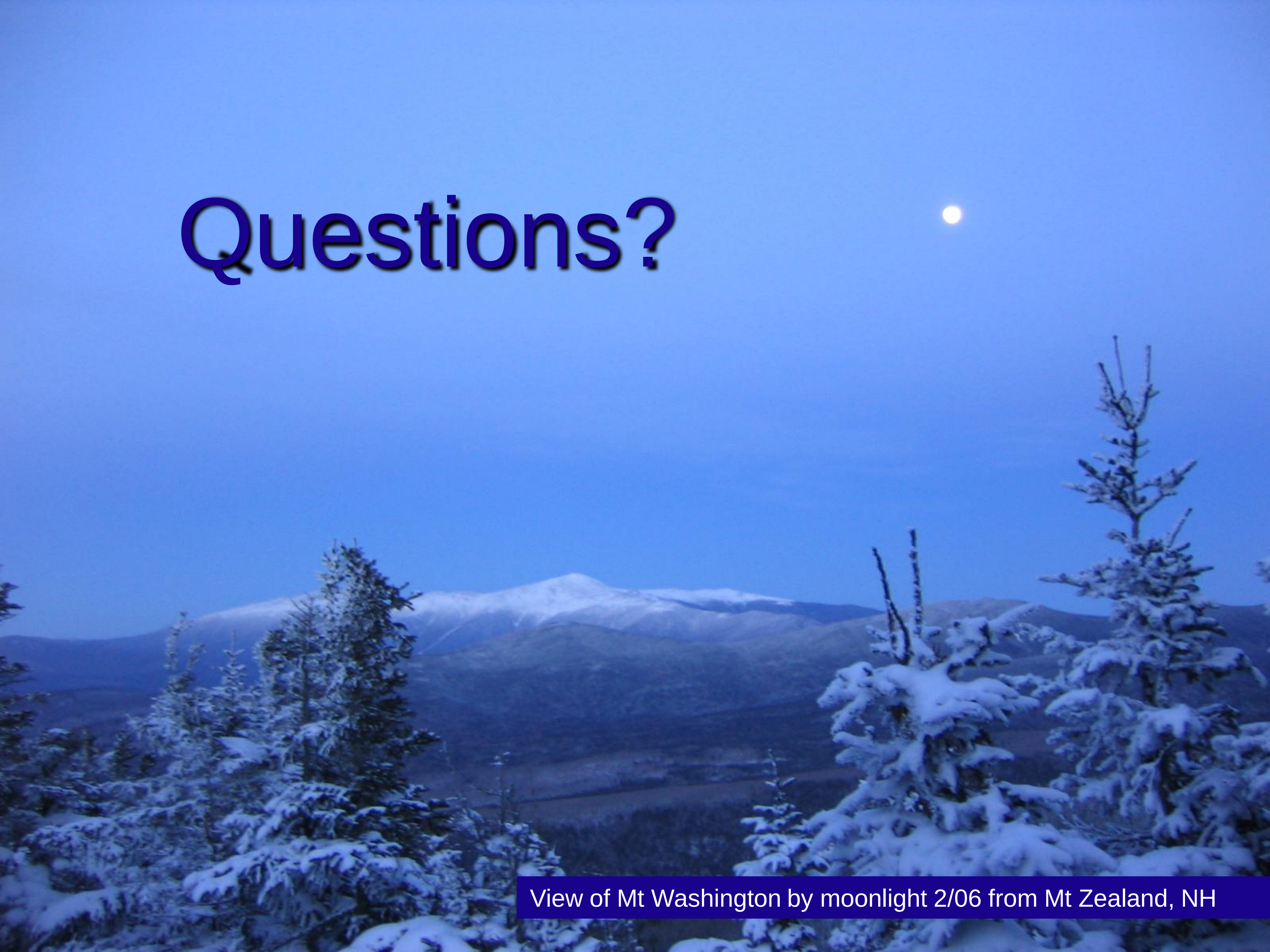
   Ex. if D_{max} = 48” sub-base depth = 32”

2. The high voids content of the reservoir course creates a capillary barrier to prevent wicking of moisture in subbase minimizing winter freeze-thaw and heaving

Funding

Funding is provided by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) whose mission is to support the scientific development of innovative technologies for understanding and reversing the impacts of coastal and estuarine contamination and degradation.

Questions?



View of Mt Washington by moonlight 2/06 from Mt Zealand, NH