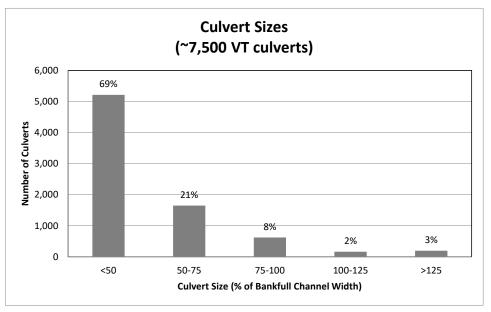
# The Geomorphic-Engineering Approach to Designing Bridges and Culverts

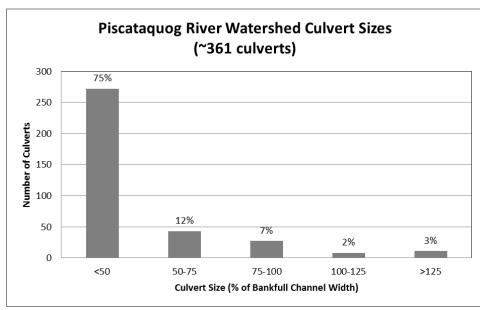
**Presented By** 

**Roy Schiff** 

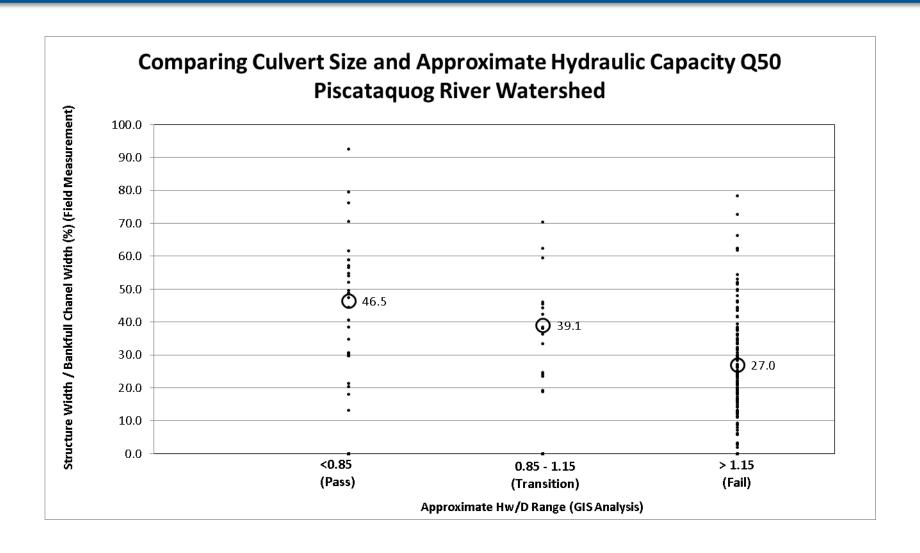


#### **Undersized Culverts**

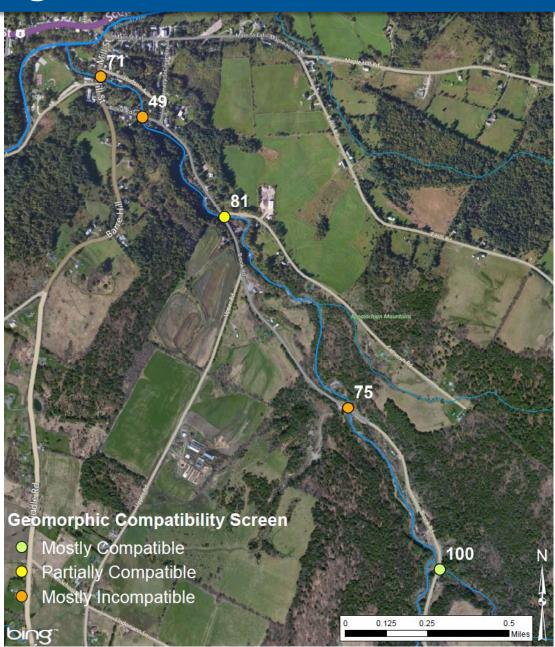




#### **Undersized Culverts**



### **Undersized Bridges**



### Geomorphic-Engineering Design

#### Start with the Vermont GP Design Requirement

 $W_{\text{structure}} = 1.0 \text{ x } W_{\text{bankfull channel}}$ 

 $\mathbf{H}_{\text{opening}} = 4 \times \mathbf{D}_{\text{bankfull channel}}$ 

 $D_{embed} = 30\% H_{opening}$  or  $D_{84}$  for boulder bed, whichever larger (min 1.5 feet, max 4.0 feet)

**Solve for initial Hw for clear-flow hydraulic capacity** Qdesign and AHW requirement from Hydraulics Manual

#### Check 1

Select Q, AHW, and % block to evaluate risk of structure failure due to material deposition.

#### Check 2

Select Q and AHW to evaluate risk of structure failure due to <u>channel</u> incision and scour.

Solve for Hw to verify adequate structure size considering deposition and scour. Analyze and compare results to clear-flow capacity. Consider:

- Flood level and velocity;
- · Clogging potential;
- · Incision and scour potential;
- · Geomorphic compatibility;
- · Aquatic organism passage (AOP); and
- · Wildlife passage.

1. Adequate capacity and structure not likely to fail due to clogging or scour during flood.

- · Inlet/outlet design, headwall
- · Footing, scour analysis

2. 'Modified Stream Type' OR excess capacity AND structure not likely to fail due to clogging or scour\*\* More capacity needed OR structure likely to clog or scour

#### Larger structure width required

Evaluate  $W_{structure} \ge 1.2 x$ 

 $\mathbf{W}_{\mathrm{bankfull\ channel}}$  such as  $\mathbf{W}_{\mathrm{structure}} = \mathbf{W}_{\mathrm{floodprone}}$ 

- Sediment transport dominated reaches with large volume of coarse bedload.
- Actively incising sediment production reaches with or without slope failures.
- Confinement of floodplain flows in the structure leading to high velocity and shear.
- Channel/structure with long damage history.
- Structure located near breaks in valley slope that is prone to clogging with sediment, woody debris, or ice.
- Wandering, braided, or fan stream types with frequently adjusting channel alignment.
- Channels with wide floodplain flow that would impact improved property if conveyance area blocked.

\*\*The proposed structure must meet the Equilibrium and Connectivity Performance Standards and requires approval from the Secretary of the Vermont Agency of Natural Resources for a General Permit or an application for an Individual Permit.

#### $W_{\text{structure}} \leq 1.0 \text{ x } W_{\text{bankfull channel}}$ if:

- Vertically stable channel designated by the River Management Engineer as being a 'Modified Stream Type' (VTANR, 2009):
  - Confined or constrained by unmovable public infrastructure;
  - Confined or constrained by unmovable habitable structures; and
  - Functioning as a sediment transport reach due to a pre-existing channelized condition (i.e., moderately entrenched and having a steeper slope).
  - Confined valley setting with or without unmovable property making the use of bankfull width structures impractical.

#### $\mathbf{H}_{\text{opening}} < 4 \times \mathbf{D}_{\text{bankfull channel}}$ if:

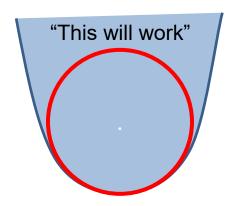
- Low risk of impeding design flows and the passage of sediment and debris.
- Aquatic organism passage can be achieved.
- Larger streams.

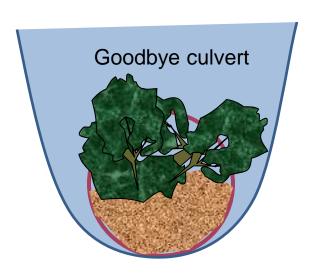
#### $D_{embed} \le 30\% H_{structure}$ if:

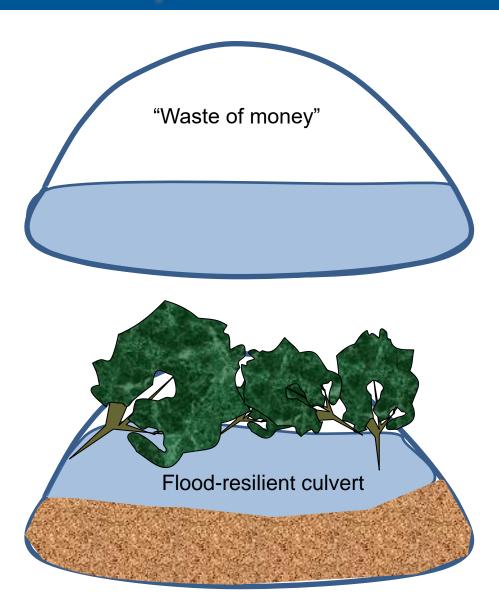
- Channel slope < 0.5%.</li>
- Structure under outlet control, or backwatered.
- No sediment retention sills

RE-EVALUTE

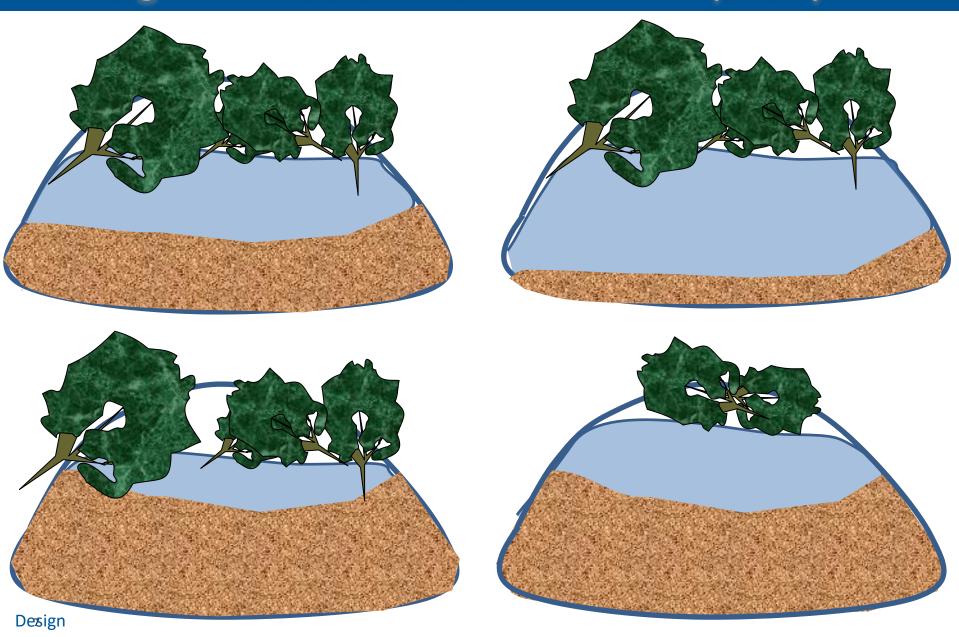
### Design – Clear Flow v Reality



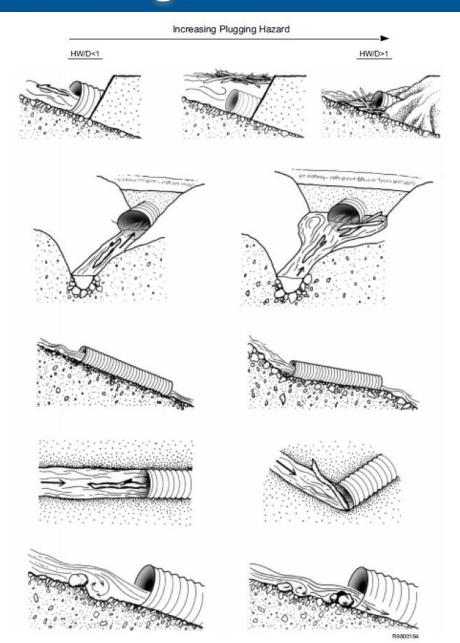




# Design – What is true structure capacity?



### Assessment – Large Wood



# Large Wood at Bridges



Great Brook Brook Road in Plainfield, VT 7/19/2015 Photo taken by B. Towbin

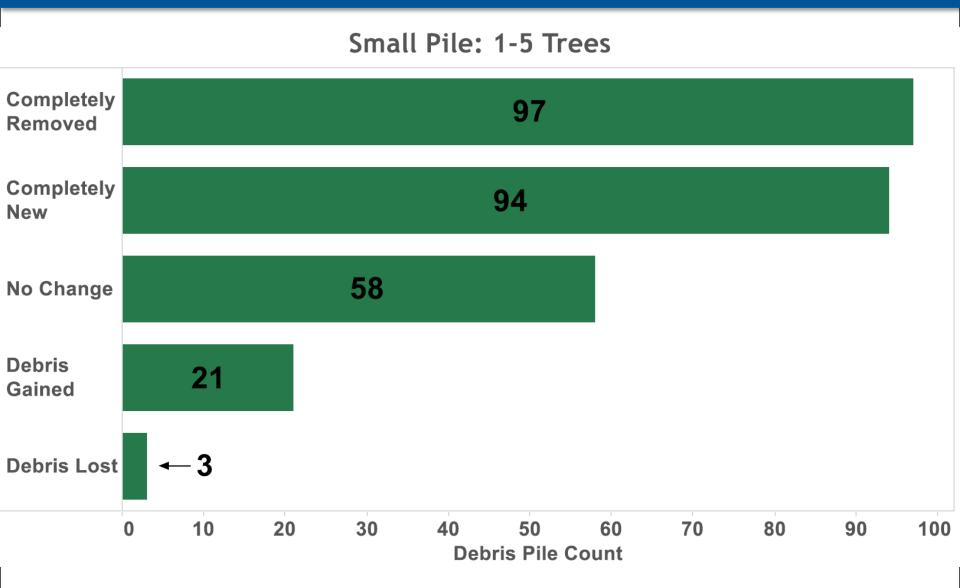
Great Brook Brook Road in Plainfield, VT 5/27/2011 Photo taken by G. Springston



# **UVM Large Woody Debris Study**



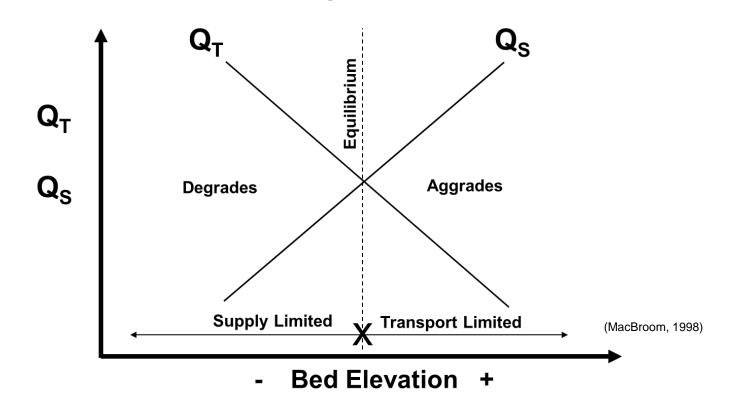
# **UVM Large Woody Debris Study**



(O'Neil-Dunne and Ahles, 2015)

### Sediment Transport

- Equilibrium: Load ≅ Transport
- Deposition: Supply > Transport
- Erosion: Transport > Supply
- Local Scour: Bridges, bends, contractions



# **Identify Sediment Sources**



Fulmer Creek German Flatts, NY (M. Carabetta, 2013)

Roaring Branch Bennington, VT (MMI, 2011)



# Assessment and Design Overview

#### **Independent Variables** (Assessment )

- **Physical Site Constraints**
- Valley / Channel Slope
- **Existing Channel and** Floodplain Dimensions
- Confinement
- Flow
- Stream Power ( $\Omega$ = $\gamma$ QS)
- Channel Pattern, Alignment,

- Sediment and Large Wood
- **Channel Evolution**

#### **Dependent Variables** (Design)

- Structure Slope / Channel **Profile**
- Structure Width and Height / Capacity
- **Hydraulics**
- Scour

variables that may drop out of

Increasing complexity and

basic a

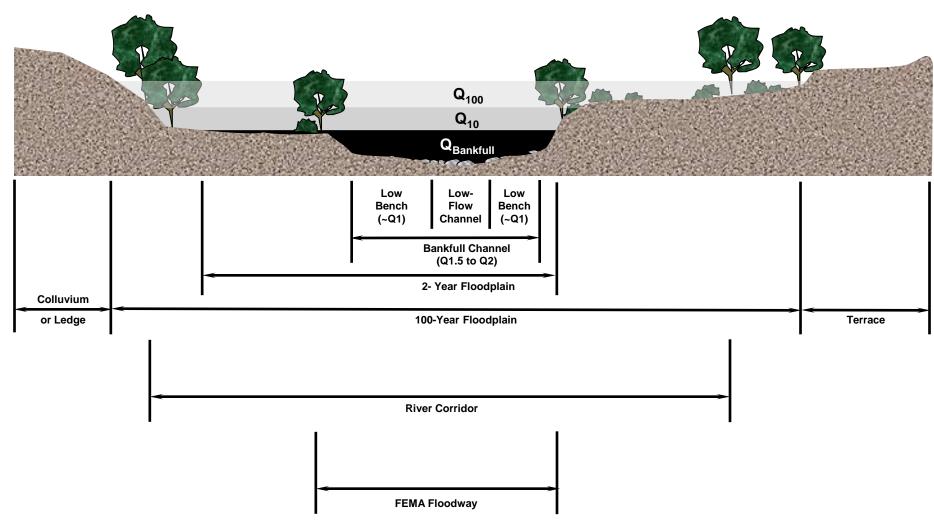
assessment during quick emergency repairs.

- Sediment in Structure
  - **Natural**
  - **Embedded**
  - Streambed Fill in Structure
- **AOP**
- Structure Design

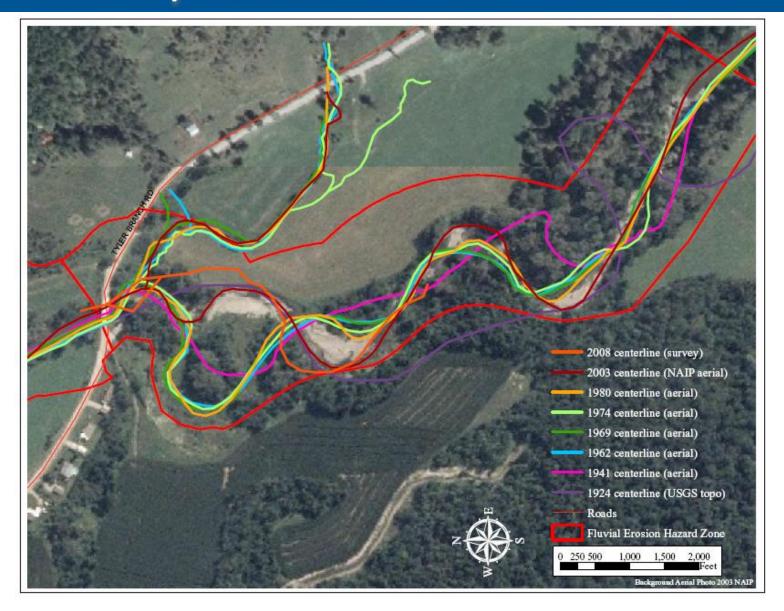
and Dynamics Floodplain Connectivity **Entrenchment** Incision

Design Assessment &

# Floodplain Dimensions



# **Channel Dynamics**



Assessment (MMI, 2009)

#### NH Draft Screen Results Legend Dustin Tayern Pd ond PenshawRo **STR** GC Geomorphic Aquatic Organism **AOP** Forest Rd Risk Score uelen Dearborn Variable Score Hillside **Getting ahead** Brook of the storm... Streams (thickness by order) **Developing a tool that helps** road officials prioritize culvert repair or replacement Waterbody NH DOT Roads School & Principal Arterial Collector Piscataquog River Watershed Boundary Town Boundaries

#### THANK YOU.



Former culvert

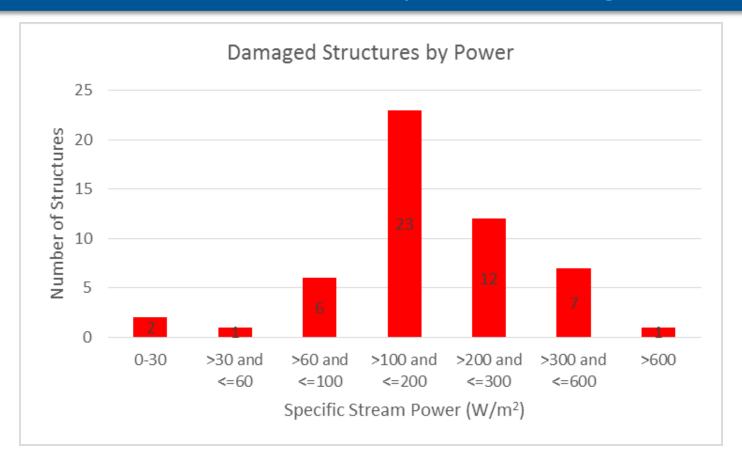


New culvert→

HIGH RESILIENCY = HIGH CONNECTIVITY

### EXTRA SLIDES.

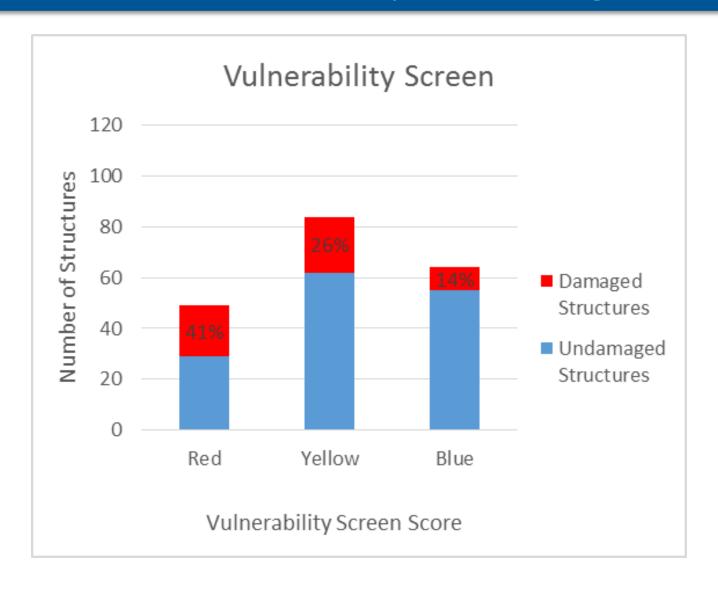
### MA Culvert Vulnerability Screening



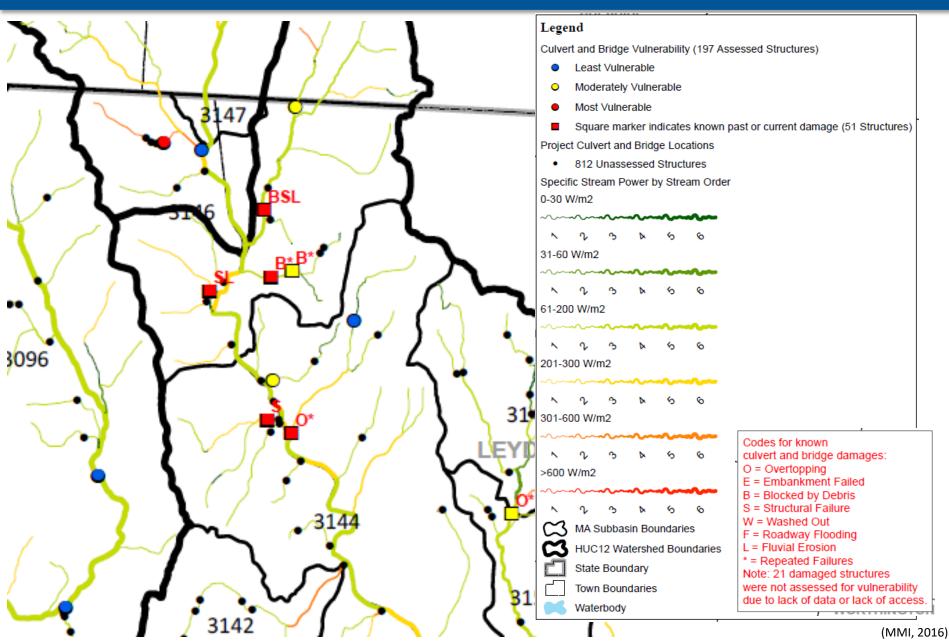
#### **Specific Stream Power versus Bed Resistance**

		Dominant Particle Size (Bed Resistance)					
		Silt	Sand	Gravel	Cobble	Boulder	Bedrock
Specific Stream Power (W/m²)	0-60	3	3	2	3	4	4
	60-100	3	3	0	1	3	3
	100-300	3	2	0	0	2	2
	300+	2	1	0	0	1	2

### MA Culvert Vulnerability Screening



#### MA Culvert Vulnerability Screening



# Poor Bridge Alignment

Roaring Brook US Route 4 in Killington, VT Photo by Lars Gange & Mansfield Heliflight, August 31, 2011)

