Rainfall, Flood Magnitude, and Geomorphic Impacts of Tropical Storm Irene on the White River Watershed, East-central Vermont

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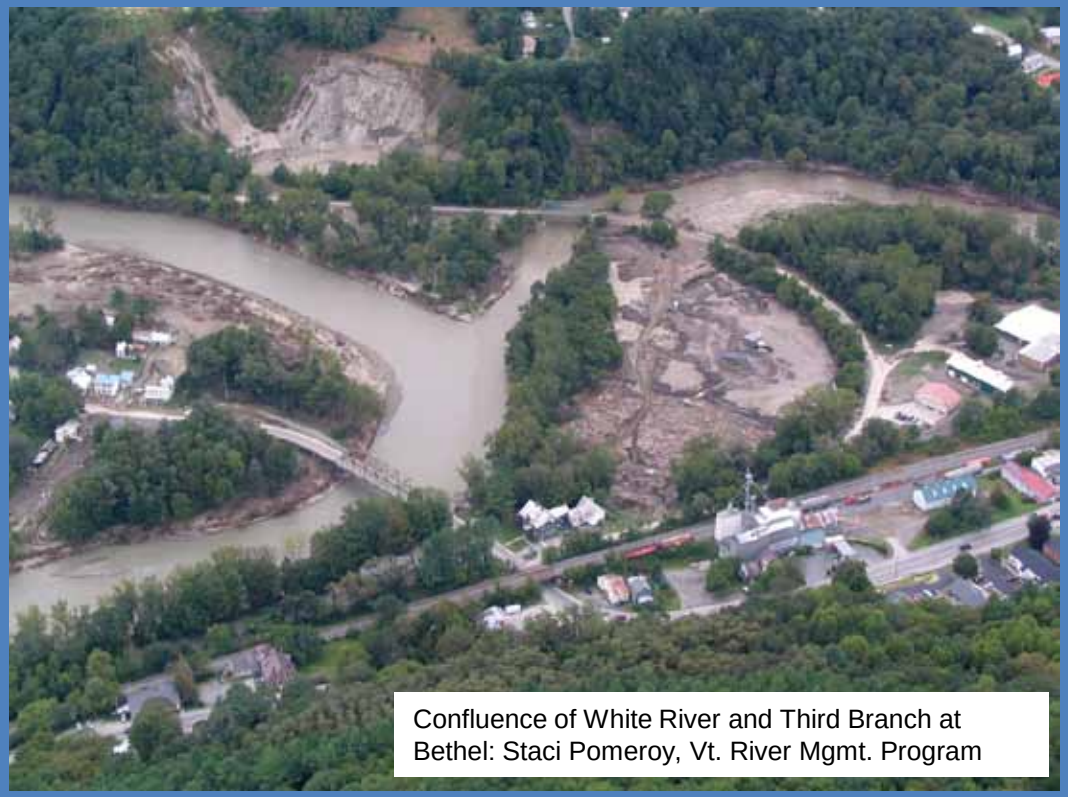


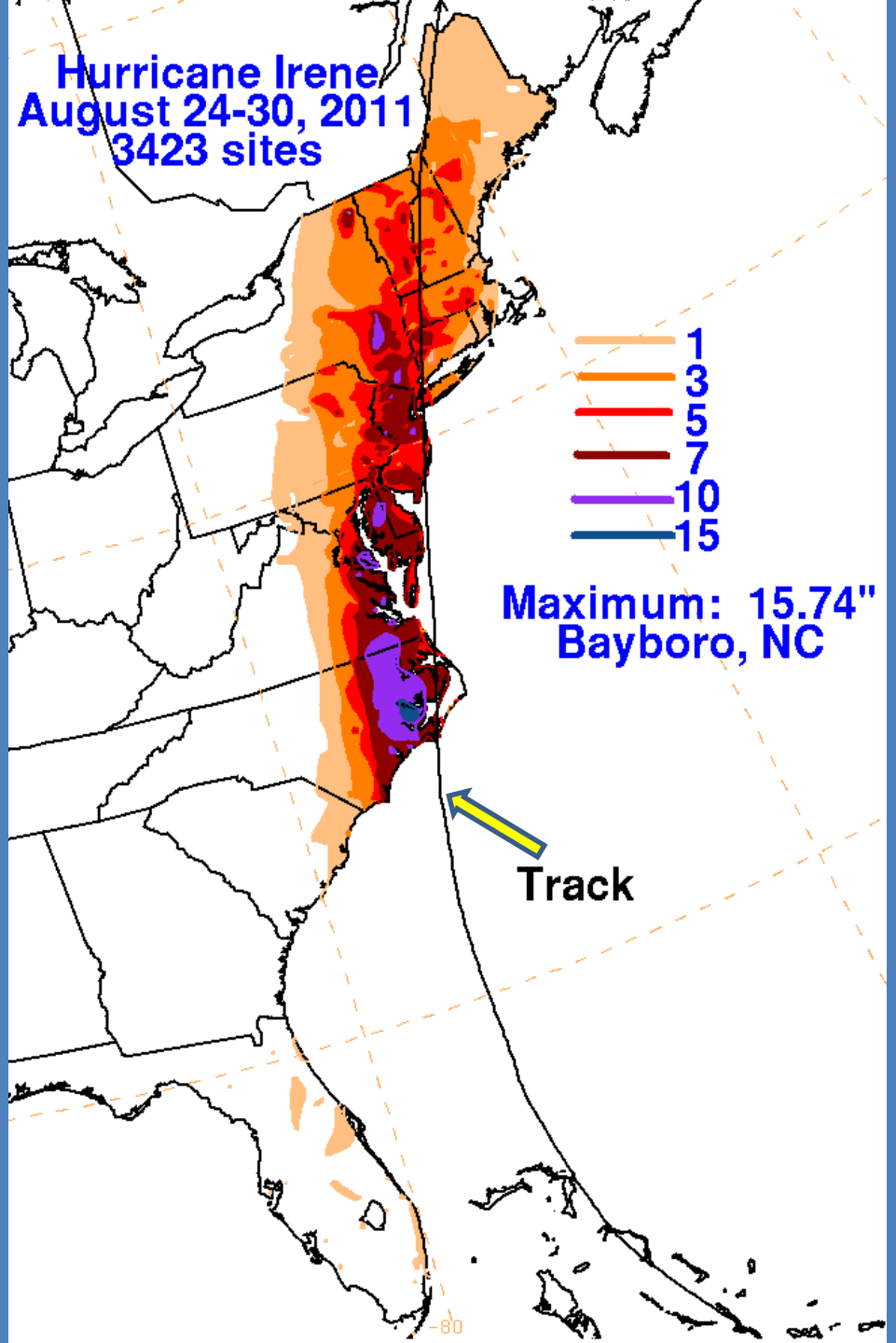
Confluence of White River and Third Branch at Bethel: Staci Pomeroy, Vt. River Mgmt. Program

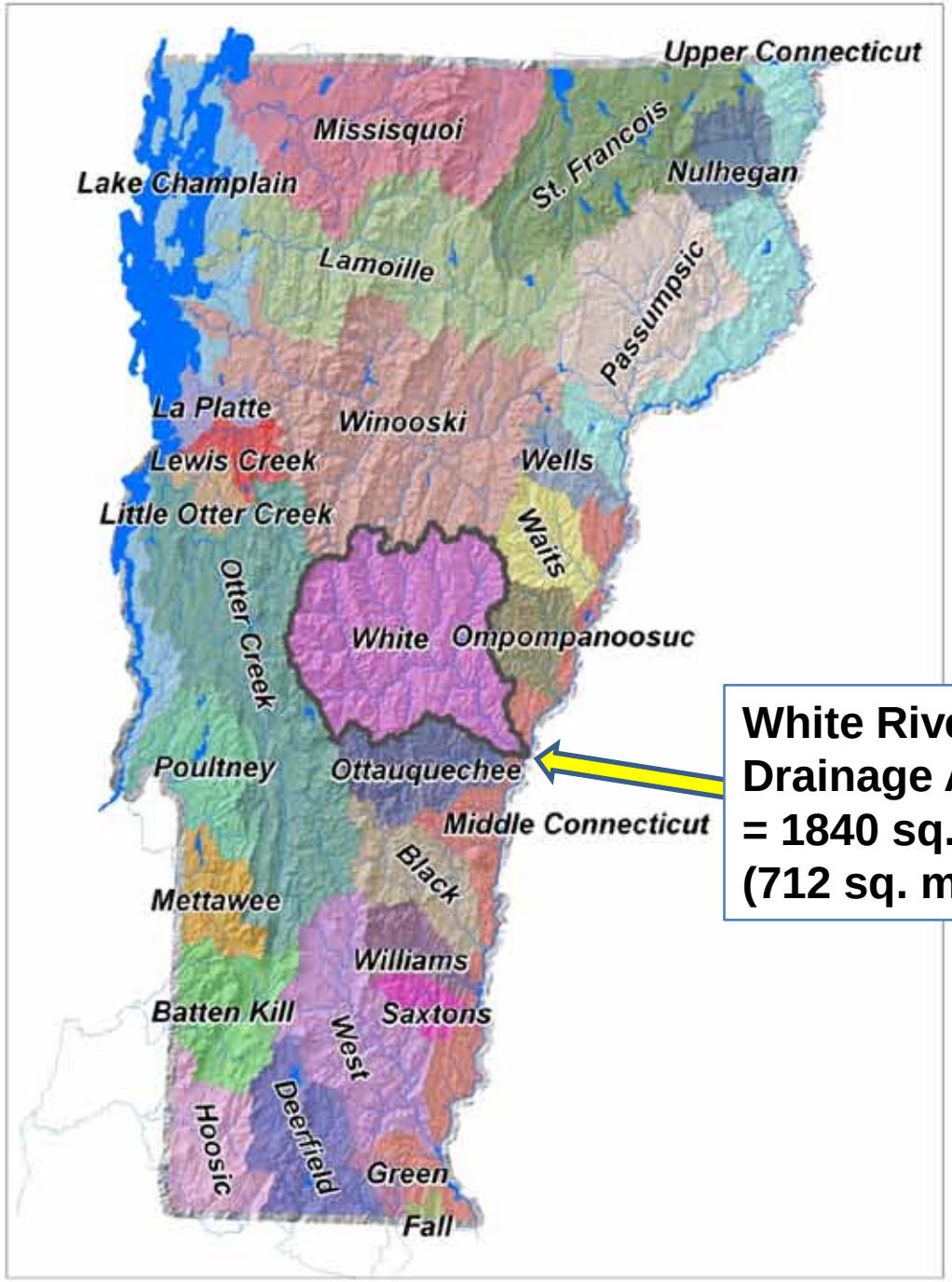
USGS science for a changing world

NORWICH UNIVERSITY 1819 Expect Challenge. Achieve Distinction.

Outline

- Statewide patterns of rainfall, stream runoff, and road damage
- Rainfall versus runoff in and near the White River watershed
- Geomorphic impacts
  - Tributaries
  - Upper Mainstem
  - Lower Mainstem





White River Drainage Area = 1840 sq. km. (712 sq. miles)

Streams

Water Bodies

White River Watershed

Streams and watersheds downloaded from Vermont Center For Geographic Information at http://www.vcgi.org. Subwatersheds modified from HUC8 watersheds in original VCGI data.

N

Kilometers

0 20 40

Vermont Watersheds

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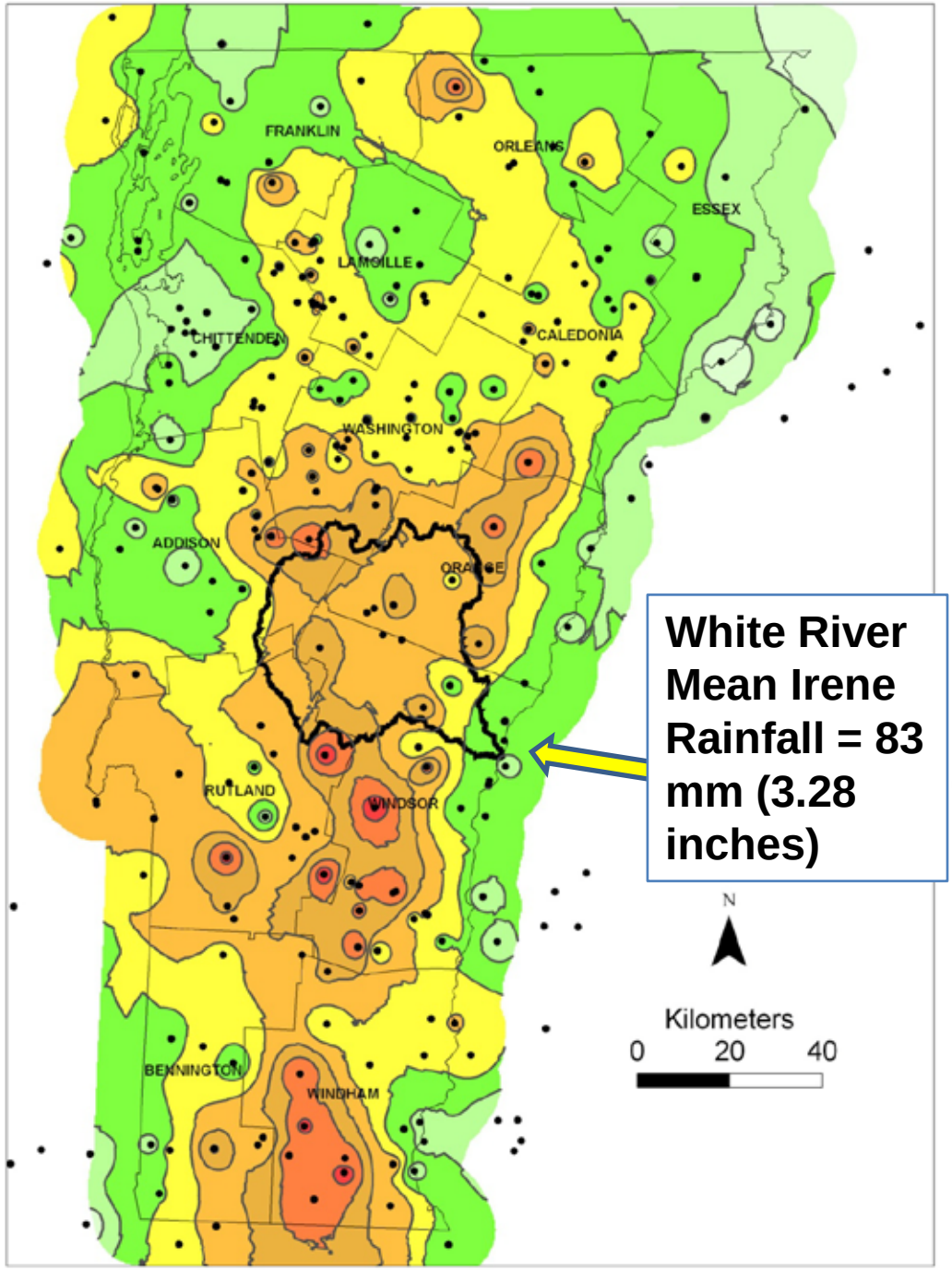
2/10/2012



White River Mean Irene Rainfall = 83 mm (3.28 inches)

- Stations

Rainfall (mm)

- 201 - 214
- 181 - 200
- 161 - 180
- 141 - 160
- 121 - 140
- 101 - 120
- 80.1 - 100
- 65 - 80
- Rainfall (20 mm)
- WhiteRiverWatershed

The original rainfall data from the National Weather Service compilation of September 2011 has been supplemented by data from the MesoWest network, the National Climatic Data Center, the CoCoRaHS network of observers, and additional data fromsewage treatment plant operators and private citizens.

Rainfall From Tropical Storm Irene

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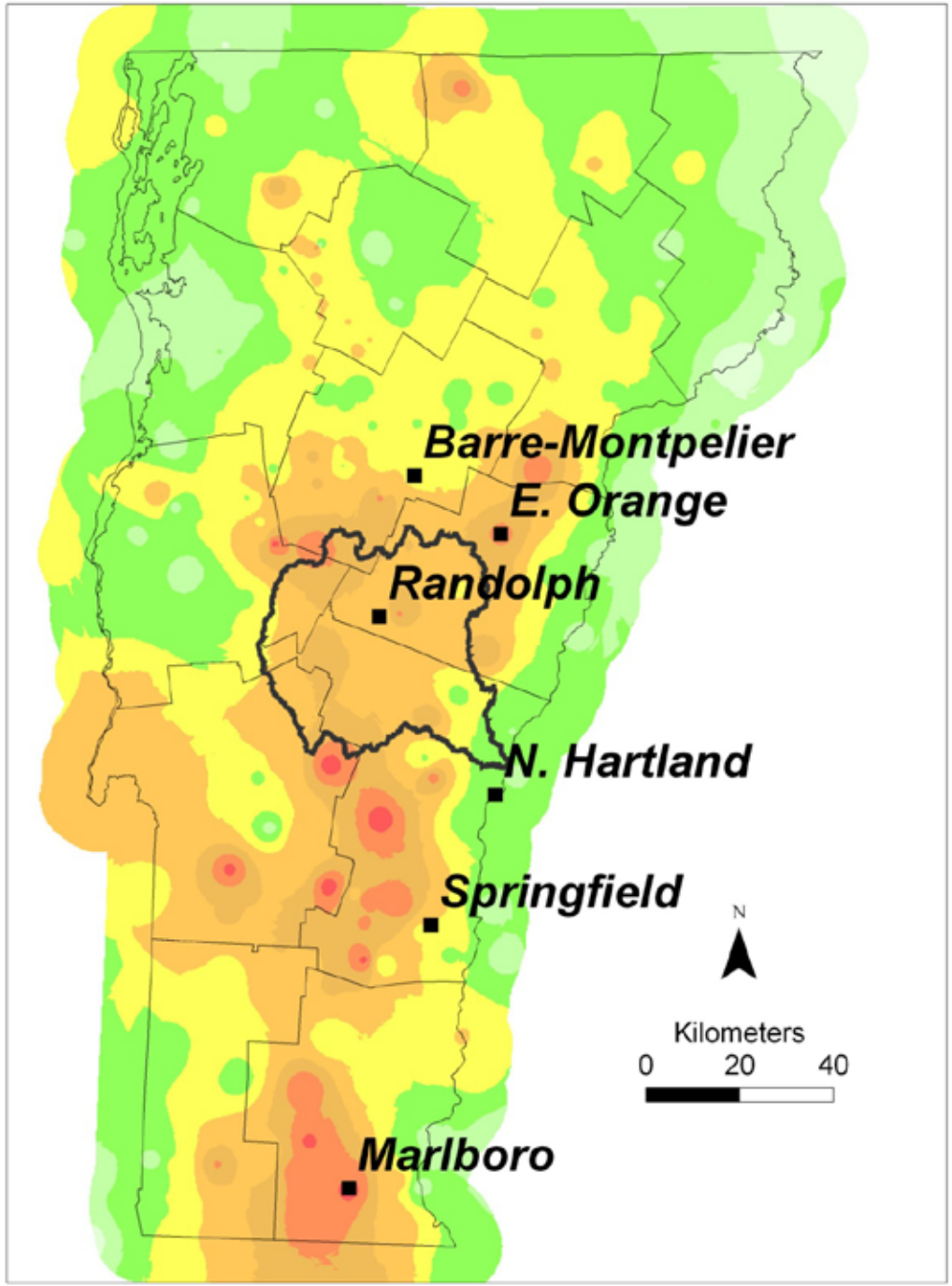

Rainfall (mm)

- 201 - 214
- 181 - 200
- 161 - 180
- 141 - 160
- 121 - 140
- 101 - 120
- 80.1 - 100
- 65 - 80
- WhiteRiverWatershed
- Recording Rain Gauges

The original rainfall data from the National Weather Service compilation of September 2011 has been supplemented by data from the MesoWest network, the National Climatic Data Center, the CoCoRaHS network of observers, and additional data fromsewage treatment plant operators and private citizens.

Locations of Recording Rain Gauges Analyzed

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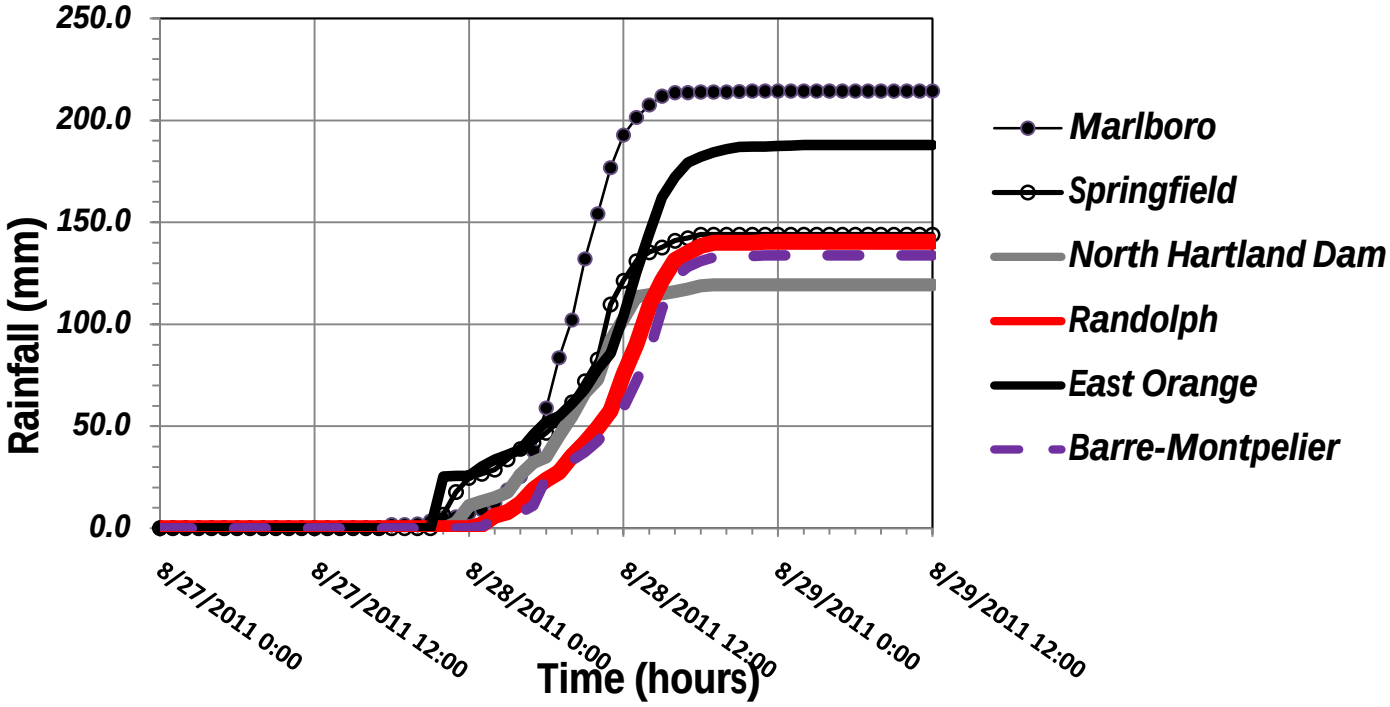
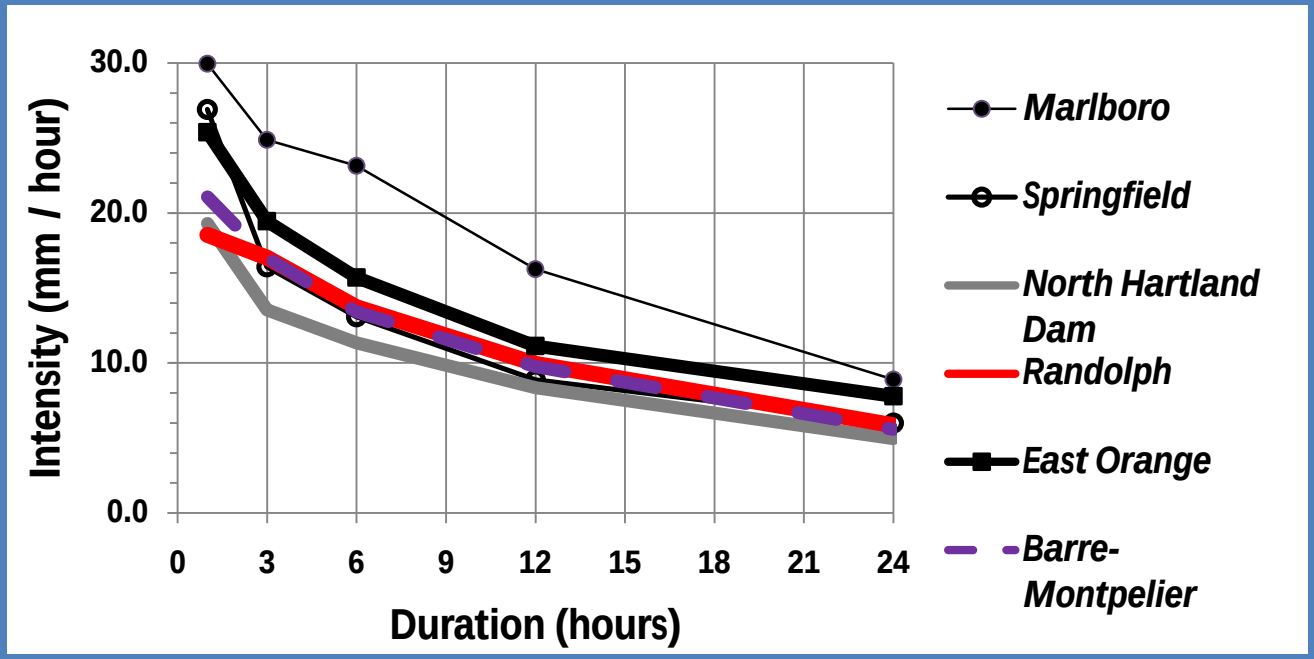
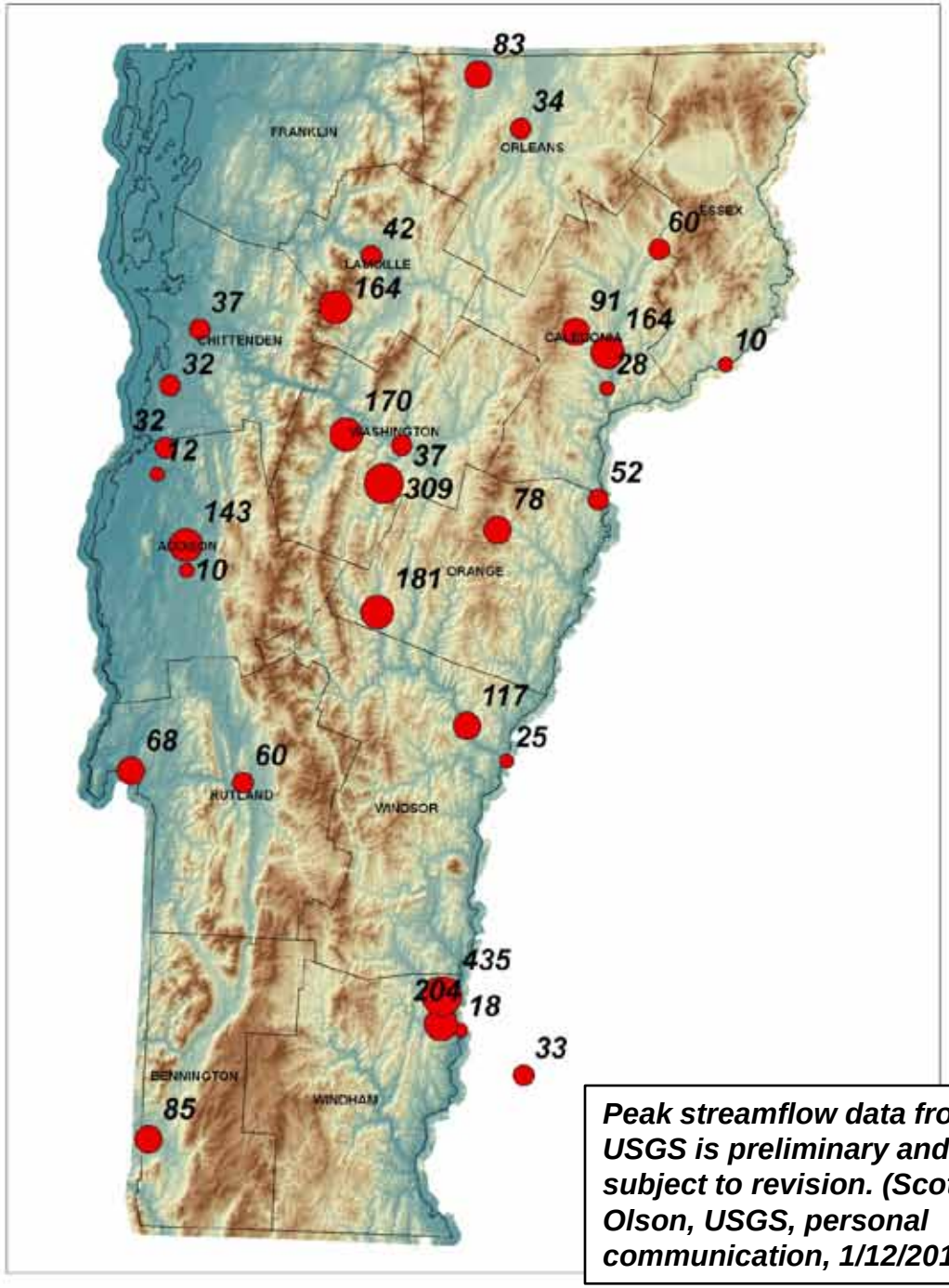


Cumulative precipitation from Tropical Storm Irene for selected stations in Vermont.



Intensity versus duration plot for Tropical Storm Irene at selected stations in Vermont



Peak Streamflow from Irene
cfs / square mile

- 10 - 28
- 29 - 61
- 62 - 117
- 118 - 204
- 205 - 435

Precipitation data from National Weather Service. Dowloaded from Vermont Center For Geographic Information at http://www.vcgi.org/Irene/ on 9/29/2011. Streamflow data downloaded from USGS website.

N

Kilometers
0 20 40

Peak streamflow data from USGS is preliminary and subject to revision. (Scott Olson, USGS, personal communication, 1/12/2012.)

Peak Streamflows at USGS Gage Sites From Tropical Storm Irene

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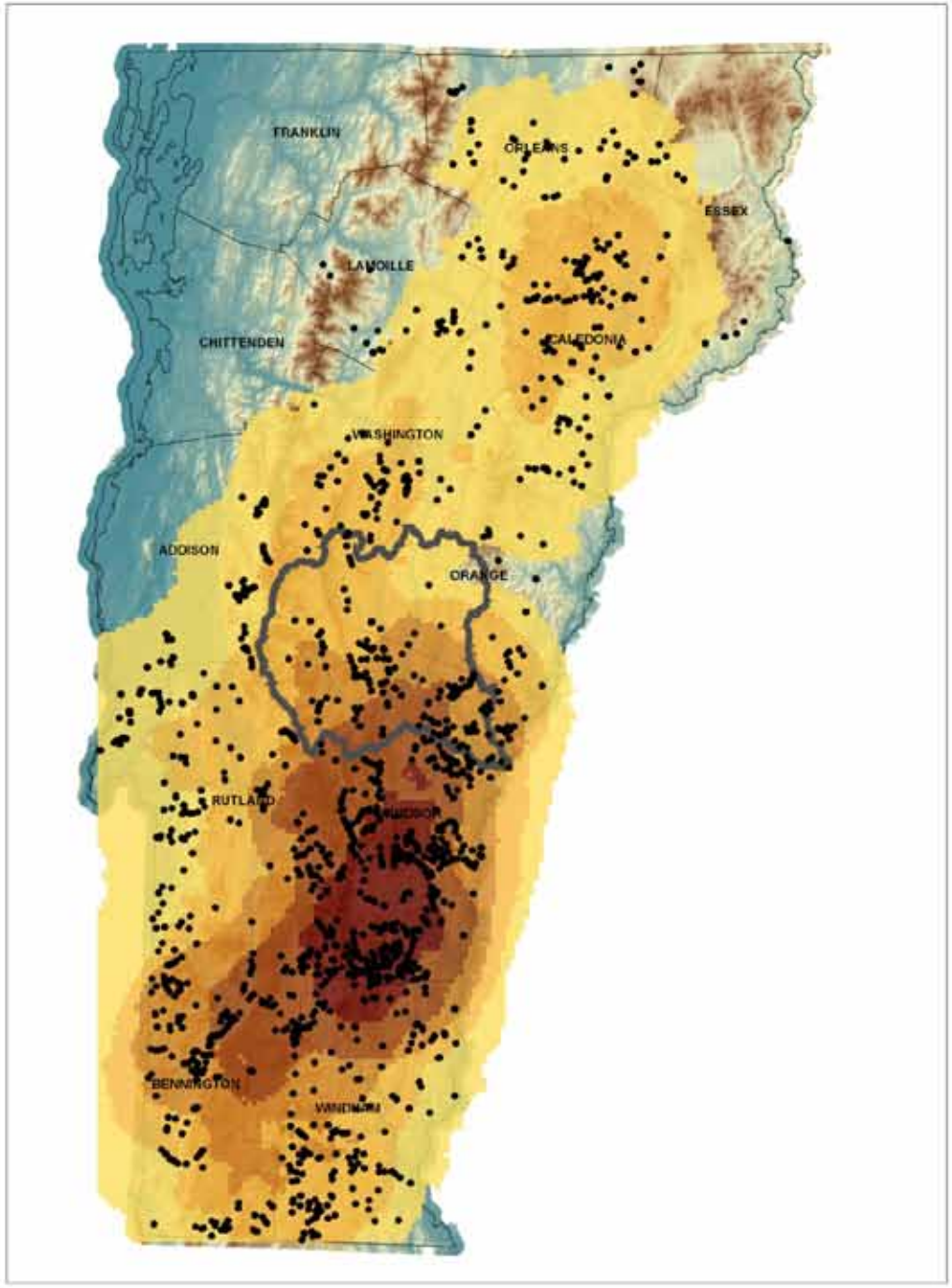
1/19/2012



Density of Damage Value

- 0 - 0.025
- 0.026 - 0.072
- 0.073 - 0.13
- 0.14 - 0.21
- 0.22 - 0.31
- 0.32 - 0.5
- Damage Sites
- WhiteRiverWatershed

State road and bridge data (draft products) is from Johnathan Croft, VTrans, 1/4/2011. Local road data (draft products) is from Pam Brangan, CCRPC, 1/11/2012.

N

Kilometers

0 20 40

Density of Damage to Bridges and Culverts From Tropical Storm Irene

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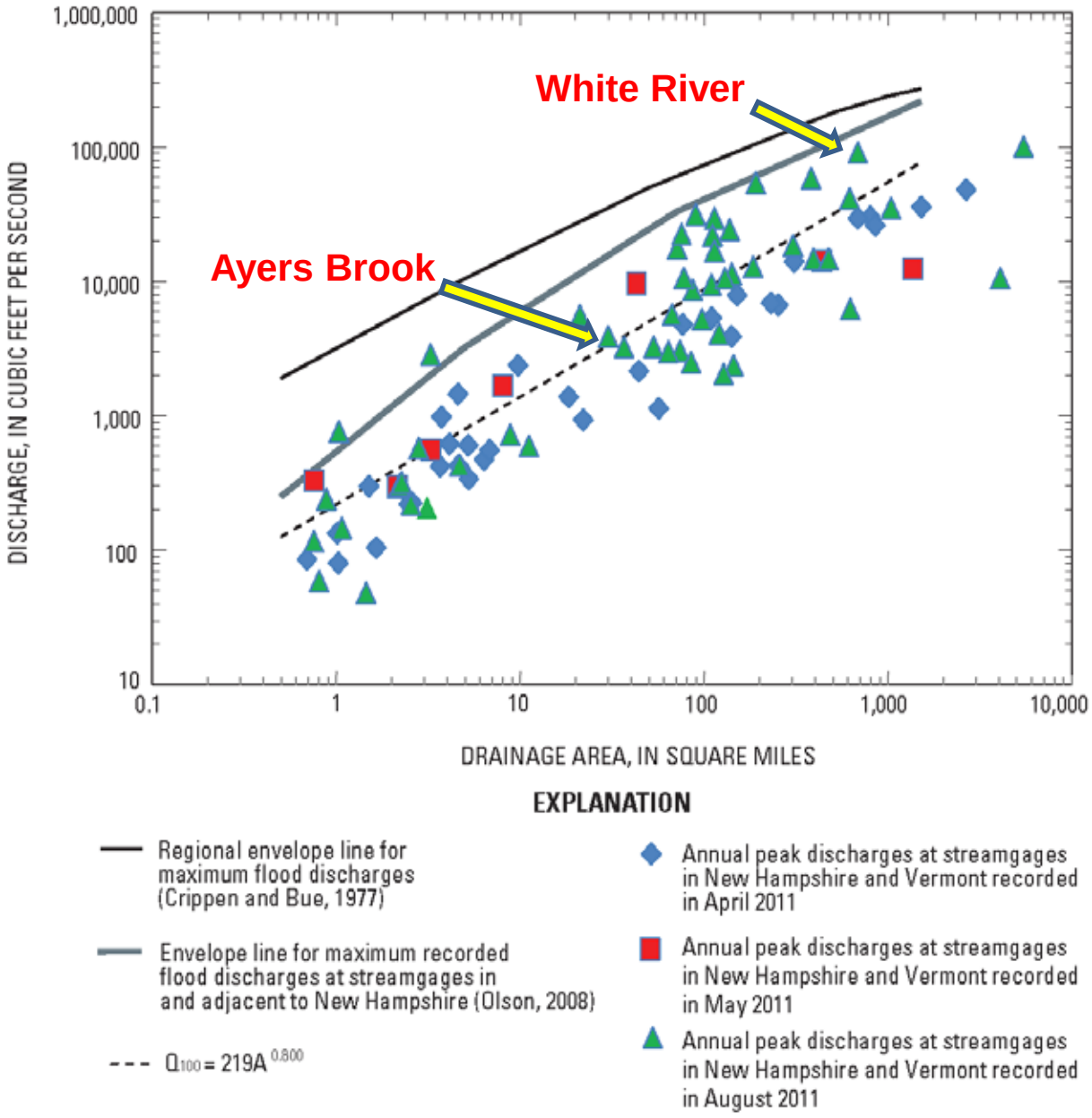
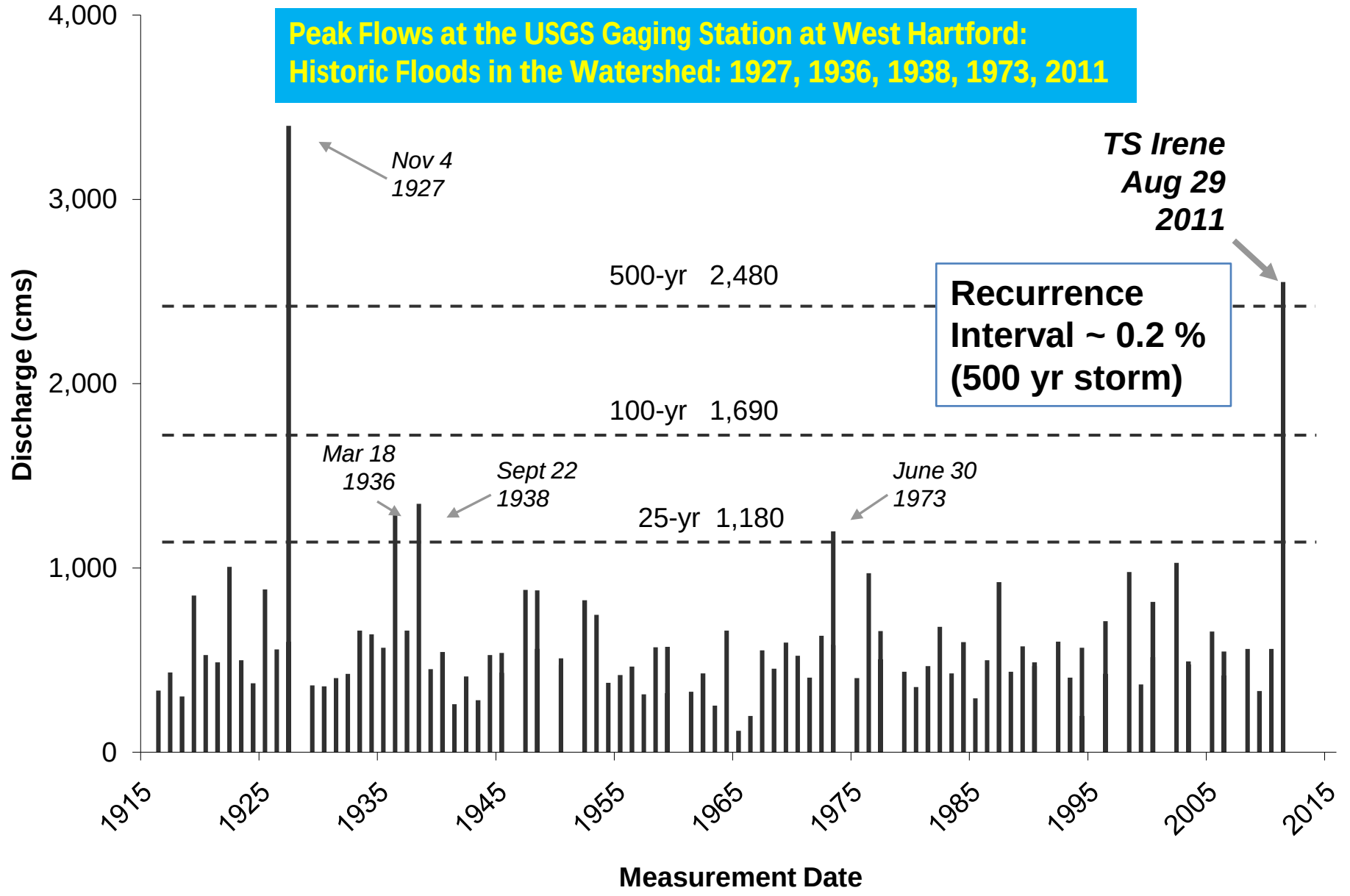
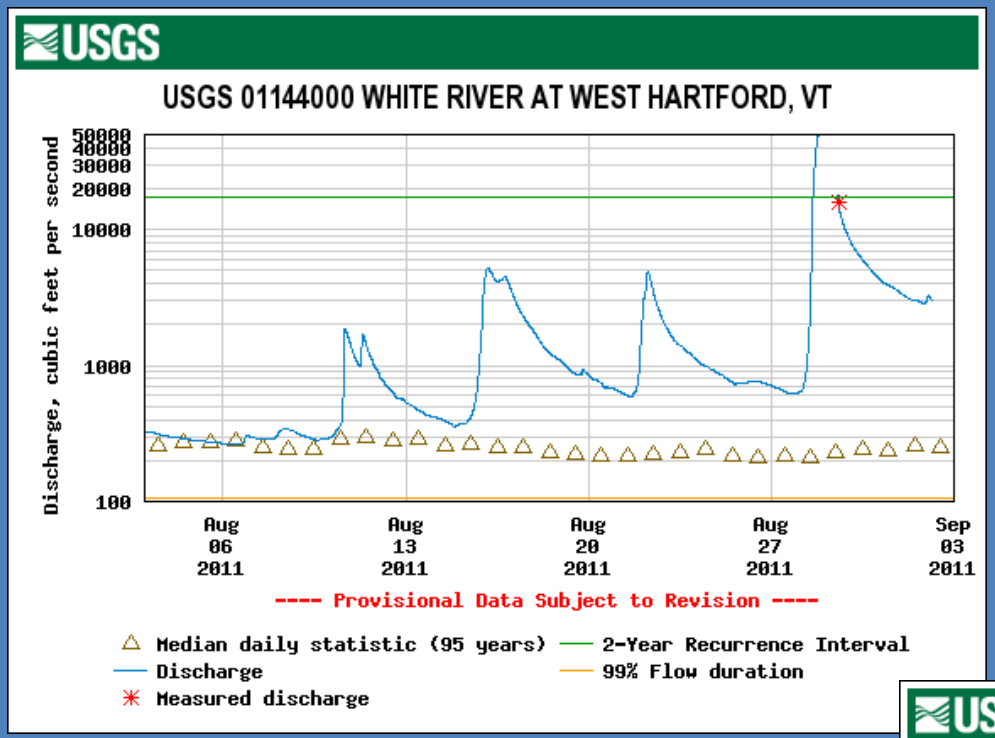
3/15/2013



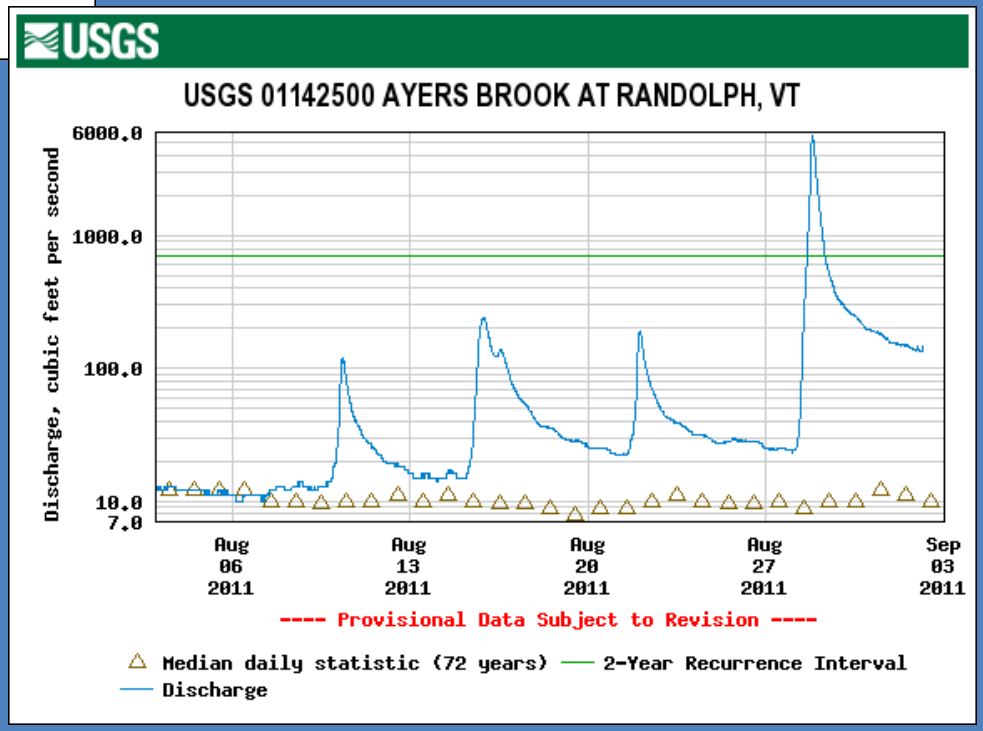
Water Year 2011 Peak discharges at stream gages in Vermont and New Hampshire in relation to drainage area.


Peak Flows at the USGS Gaging Station at West Hartford:
Historic Floods in the Watershed: 1927, 1936, 1938, 1973, 2011
Nov 4
1927
TS Irene
Aug 29
2011
500-yr 2,480
100-yr 1,690
25-yr 1,180
Recurrence
Interval ~ 0.2 %
(500 yr storm)
Mar 18
1936
Sept 22
1938
June 30
1973
Discharge (cms)
4,000
3,000
2,000
1,000
0
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
2015
Measurement Date



Peak Discharge On White River at West Hartford = 2,552 cubic meters per second (90,100 cfs)

Peak Discharge on Ayers Brook at Randolph = 111 cubic meters per second (3,920 cfs)

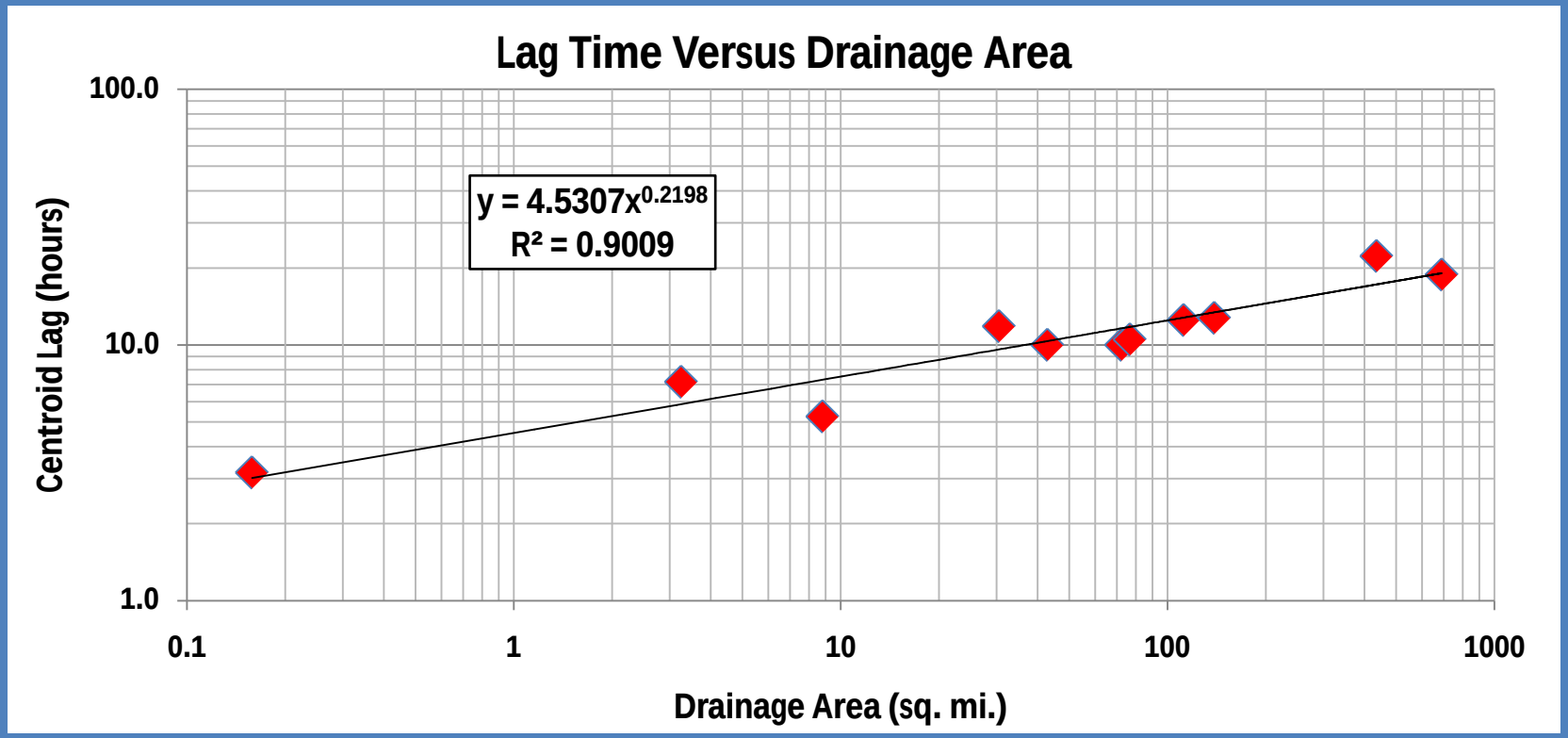


Preliminary Analysis of Runoff Versus Rainfall for Tropical Storm Irene, Eastern Vermont

USGS Gage	Stream	Drainage Area (sq. mi.)	Rainfall (inches)	Runoff (inches)	Runoff/ Rainfall
01135100	Pope Brook Trib W-9	0.16	5.4	1.07	0.20
01135150	Pope Brook	3.25	5.31	1.31	0.25
01139800	East Orange Branch	8.8	6.92	1.30	0.19
01142500	Ayers Brook	30.5	6.22	2.42	0.39
01135300	Sleepers River	42.9	5.06	2.03	0.40
01154000	Saxtons River	72.2	5.40	3.72	0.69
04287000	Dog River	76.7	6.27	3.84	0.61
01153550	Williams River	112.0	6.13	3.13	0.51
04288000	Mad River	139.0	6.18	3.00	0.49
01135500	Passumpsic River	436.0	4.56	1.26	0.28
01144000	White River	690.0	6.07	3.28	0.54
Mean					0.41

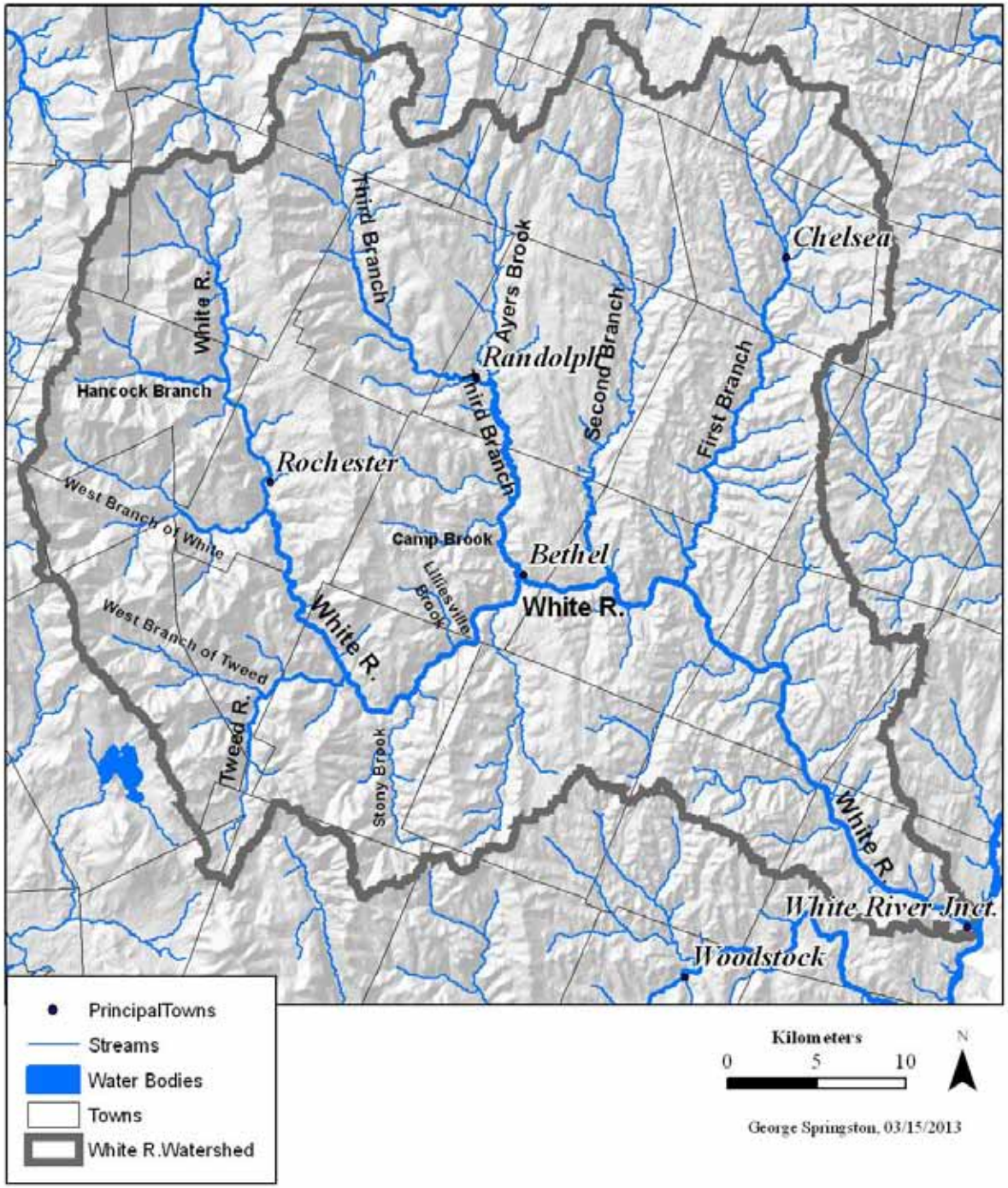
Runoff is expressed in inches of runoff from the gage watershed.
The general form of this calculation is the total amount of storm flow in cubic feet divided by the area of the watershed in square feet. Depth of runoff in feet is then converted to inches.
Hydrograph separation after method of Linsley, Kohler, and Paulhus (1975, Section 7-3).

George Springston, 4/1/2013

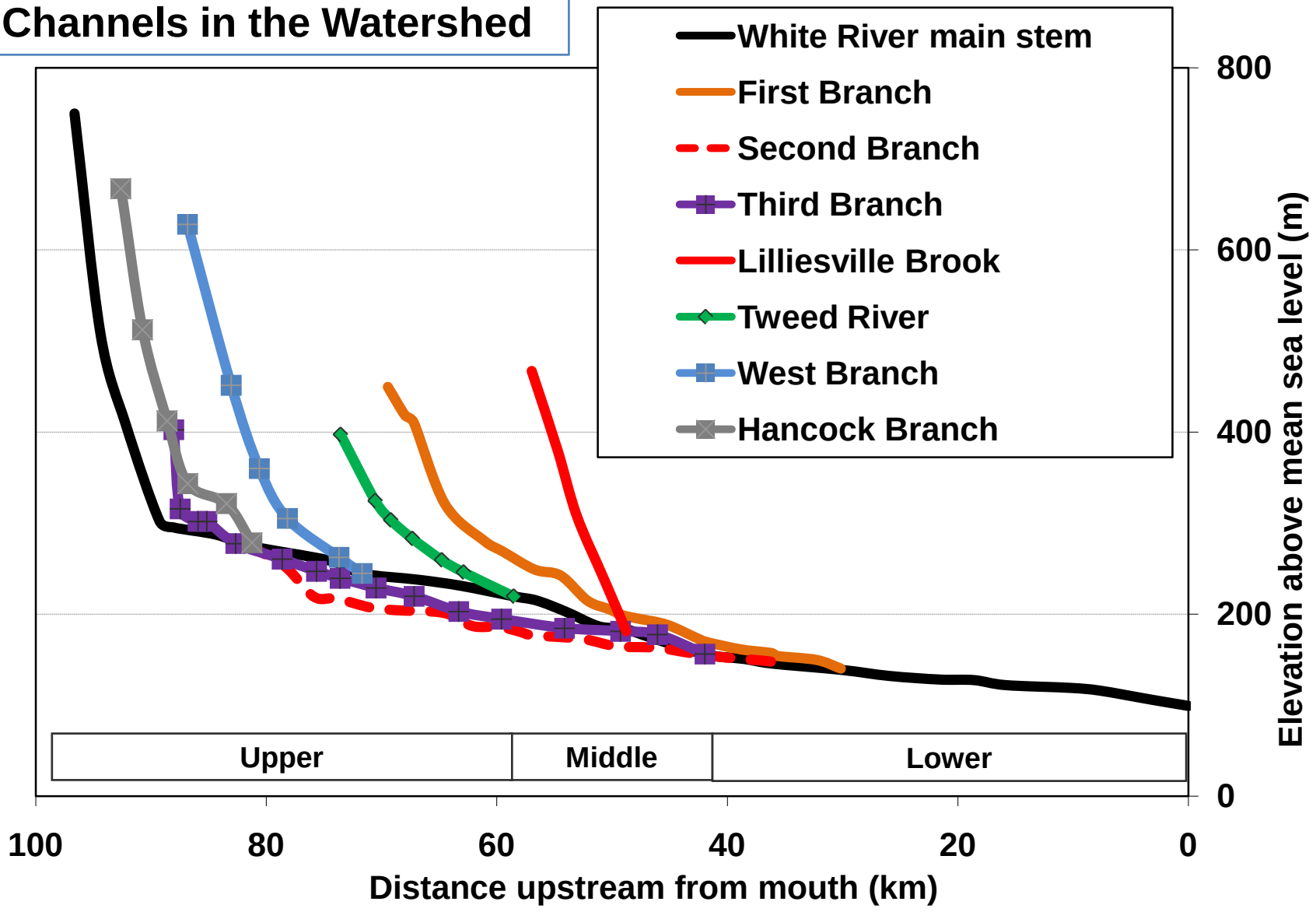


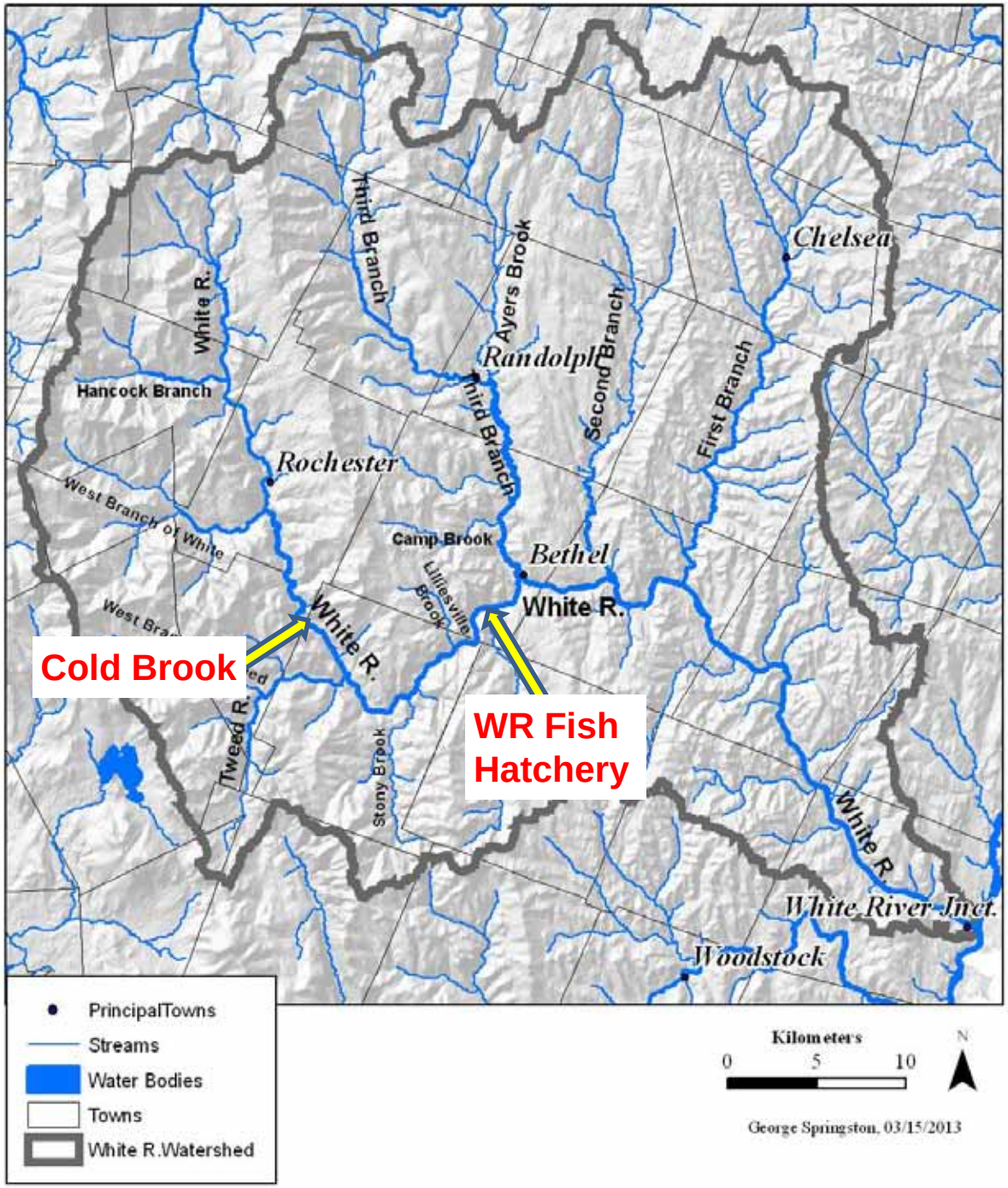
USGS Gage	Stream	Drainage Area (sq. mi.)	Rainfall Centroid (hrs after midnight EDT on the 28th)	Runoff Centroid (hrs after midnight EDT on the 28th)	Lag Centroids (hours)
01135100	Pope Brook Trib W-9	0.16	13.3	16.5	3.2
01135150	Pope Brook	3.25	13.3	20.5	7.2
01139800	East Orange Branch	8.8	12.5	17.8	5.3
01142500	Ayers Brook	30.5	12.7	24.5	11.8
01135300	Sleepers River	42.9	13.5	23.5	10.0
01154000	Saxtons River	72.2	10.0	20.0	10.0
04287000	Dog River	76.7	13.0	23.5	10.5
01153550	Williams River	112.0	10.0	22.5	12.5
04288000	Mad River	139.0	13.0	25.8	12.8
01135500	Passumpsic River	436.0	13.5	35.8	22.3
01144000	White River	690.0	12.7	31.5	18.8

George Springston
4/1/2013


Third Branch
White R.
Ayers Brook
Chelsea
Randolph
Second Branch
First Branch
Hancock Branch
Third Branch
Rochester
West Branch of White
Camp Brook
Bethel
Lilliesville Brook
White R.
West Branch of Tweed
White R.
Tweed R.
Stony Brook
White R.
White River Jnct.
Woodstock
PrincipalTowns
Streams
Water Bodies
Towns
White R.Watershed
Kilometers
0
5
10
N
George Springston, 03/15/2013

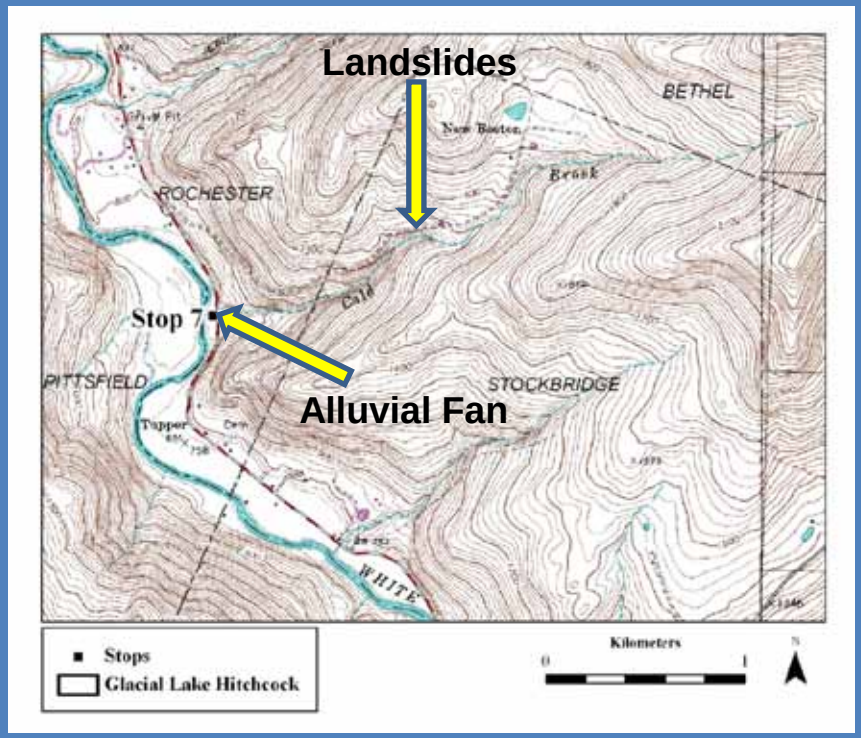
Longitudinal Profiles of Channels in the Watershed




Cold Brook
WR Fish Hatchery
White R.
Third Branch
Ayers Brook
Second Branch
First Branch
Chelsea
Randolph
Hancock Branch
Rochester
West Branch of White
Camp Brook
Bethel
Lillieville Brook
Tweed R.
Stony Brook
White River Jnct.
Woodstock
PrincipalTowns
Streams
Water Bodies
Towns
White R.Watershed
Kilometers
0
5
10
N
George Springston, 03/15/2013

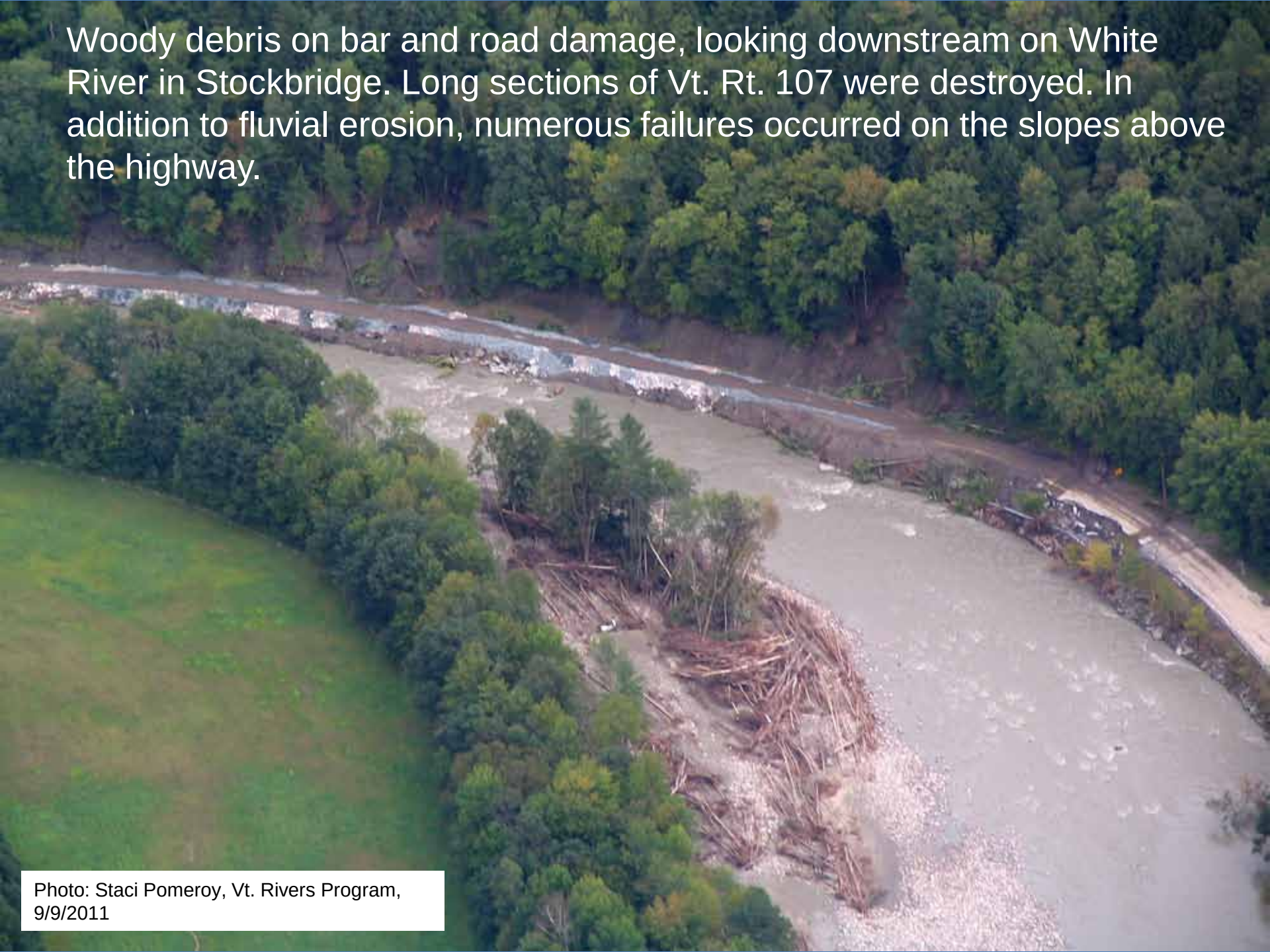

Active landslides in dense till along Cold Brook. Shovel for scale.


Surface of alluvial fan. White River in background.

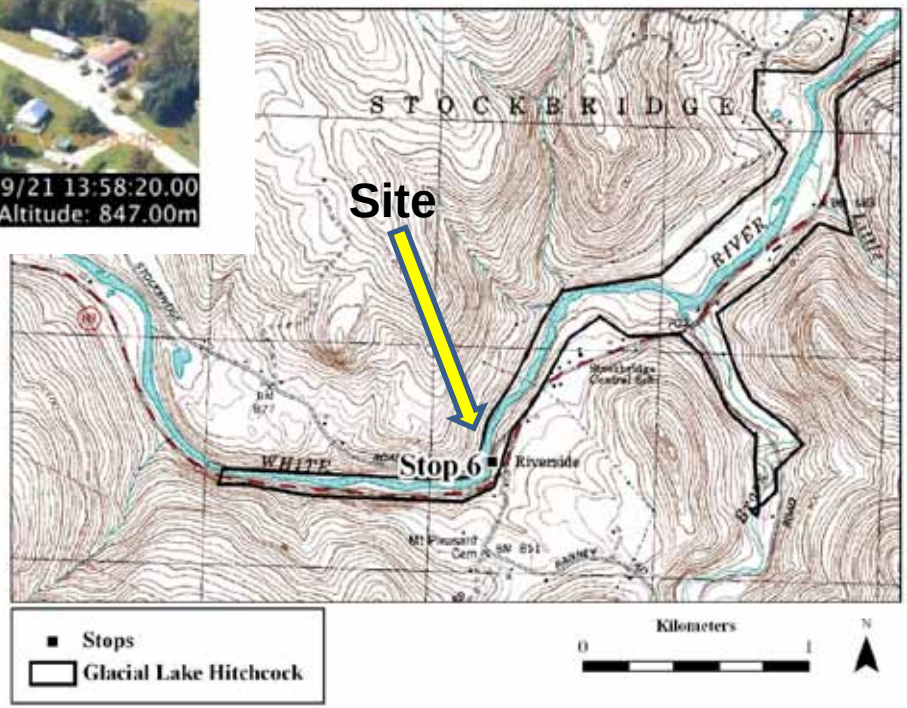

Landslides
BETHEL
ROCHESTER
Stop 7
Alluvial Fan
PITTSFIELD
STOCKBRIDGE
WHITE
Stops
Glacial Lake Hitchcock
Kilometers


Alluvial fan gravel exposed in brook. Orange field book for scale.

Heavy road damage on Lilliesville Brook, Stockbridge. Left: Flooding over road and bridge at height of storm. Below, road washout at same location after the storm. Photos courtesy of Erika Keller Rogoff.


Woody debris on bar and road damage, looking downstream on White River in Stockbridge. Long sections of Vt. Rt. 107 were destroyed. In addition to fluvial erosion, numerous failures occurred on the slopes above the highway.
Photo: Staci Pomeroy, Vt. Rivers Program, 9/9/2011

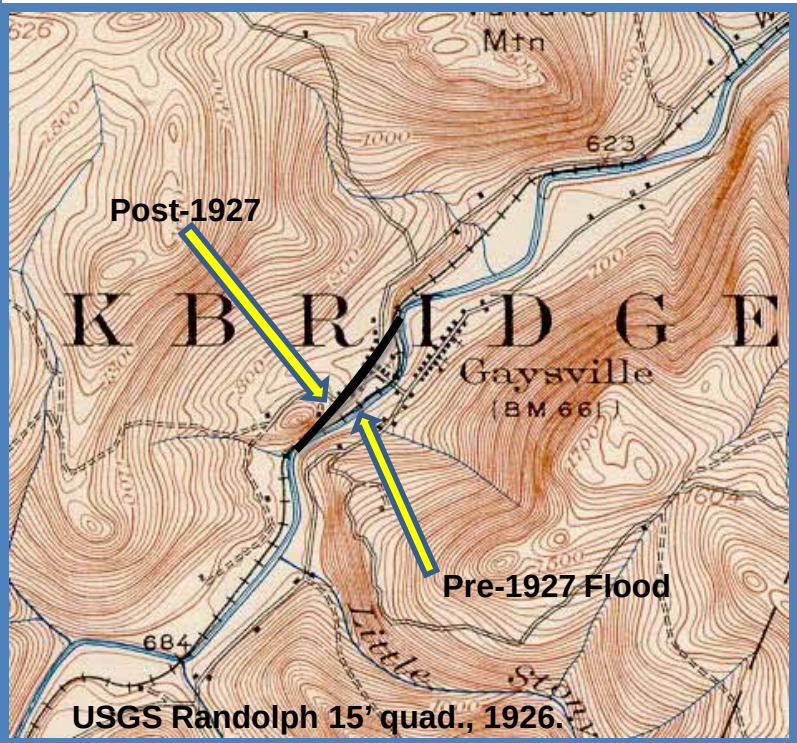
Landslide downstream of Blackmer Road Bridge, Stockbridge. At left is aerial view looking north (courtesy of Staci Pomeroy, Vermont River Management Program).



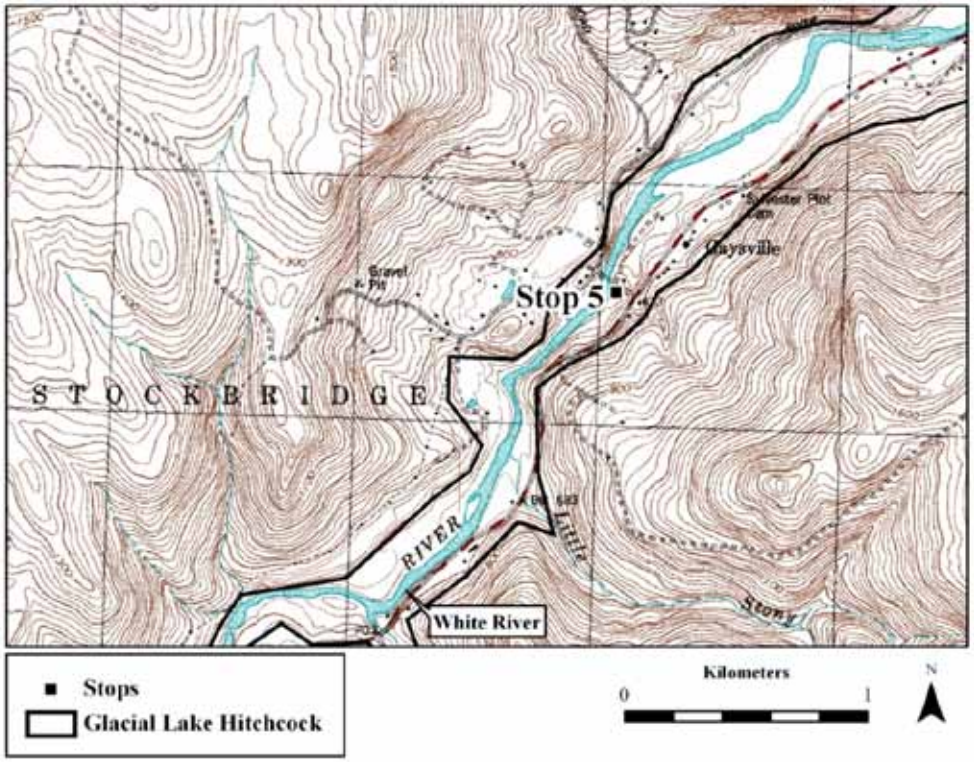
Landslide downstream of Blackmer Road Bridge. Clockwise from top left: Landslide on left (north) bank looking downstream from bridge, view looking downstream from boulder bar with landslide on left bank , exposure of bedded gravels in landslide (orange field book for scale). Photos by G. Springston, 8/2013).

Photo: Staci Pomeroy, Vt. Rivers Program, 9/21/2011

Village of Gaysville. Post-Irene aerial view in upper left. Despite heavy damage at a campground, the damage from Irene here is far less than from the major channel avulsion that occurred during the 1927 flood. Map at bottom left shows channel before and after 1927 flood.

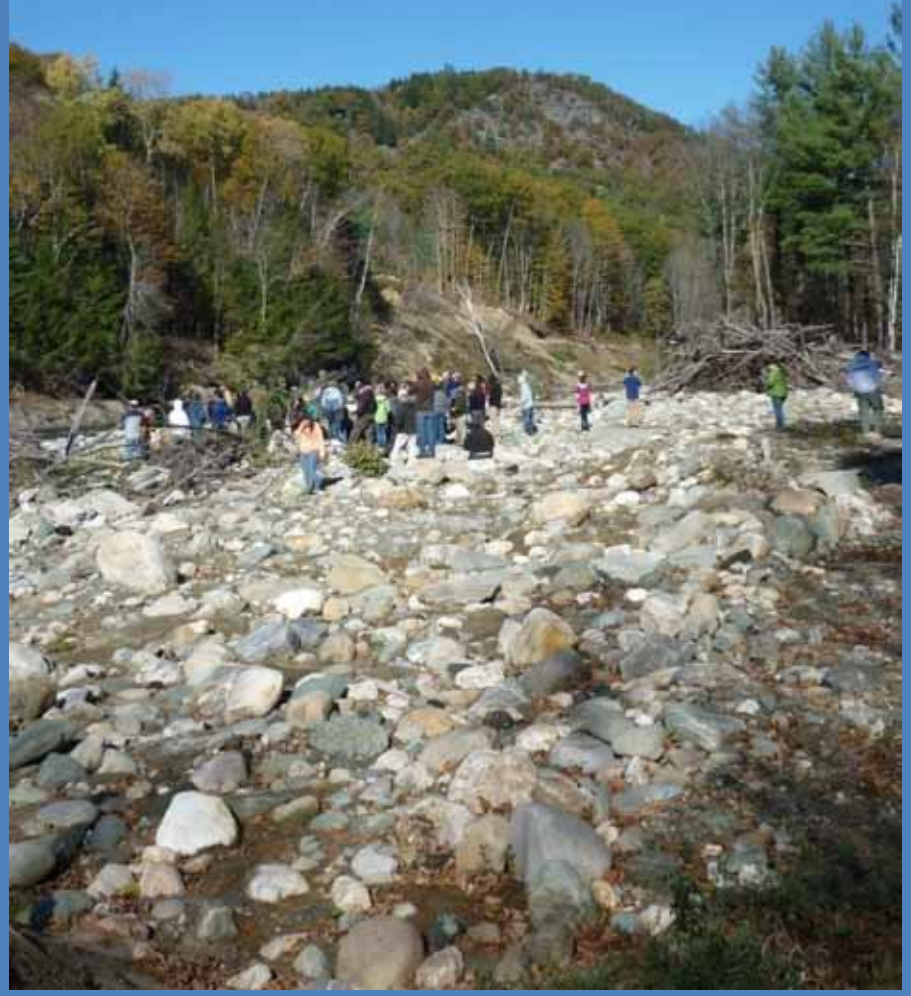


USGS Randolph 15' quad., 1926.

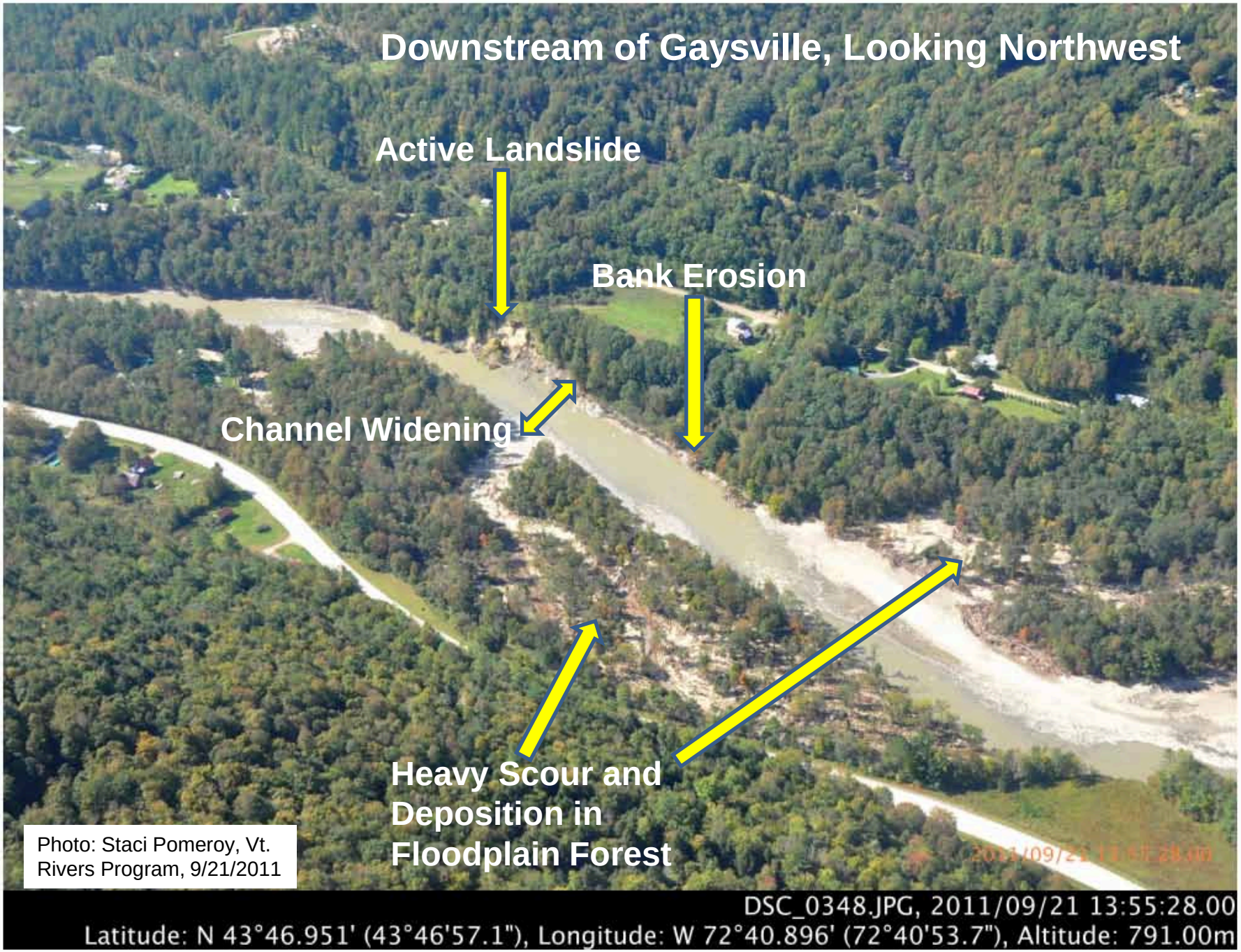


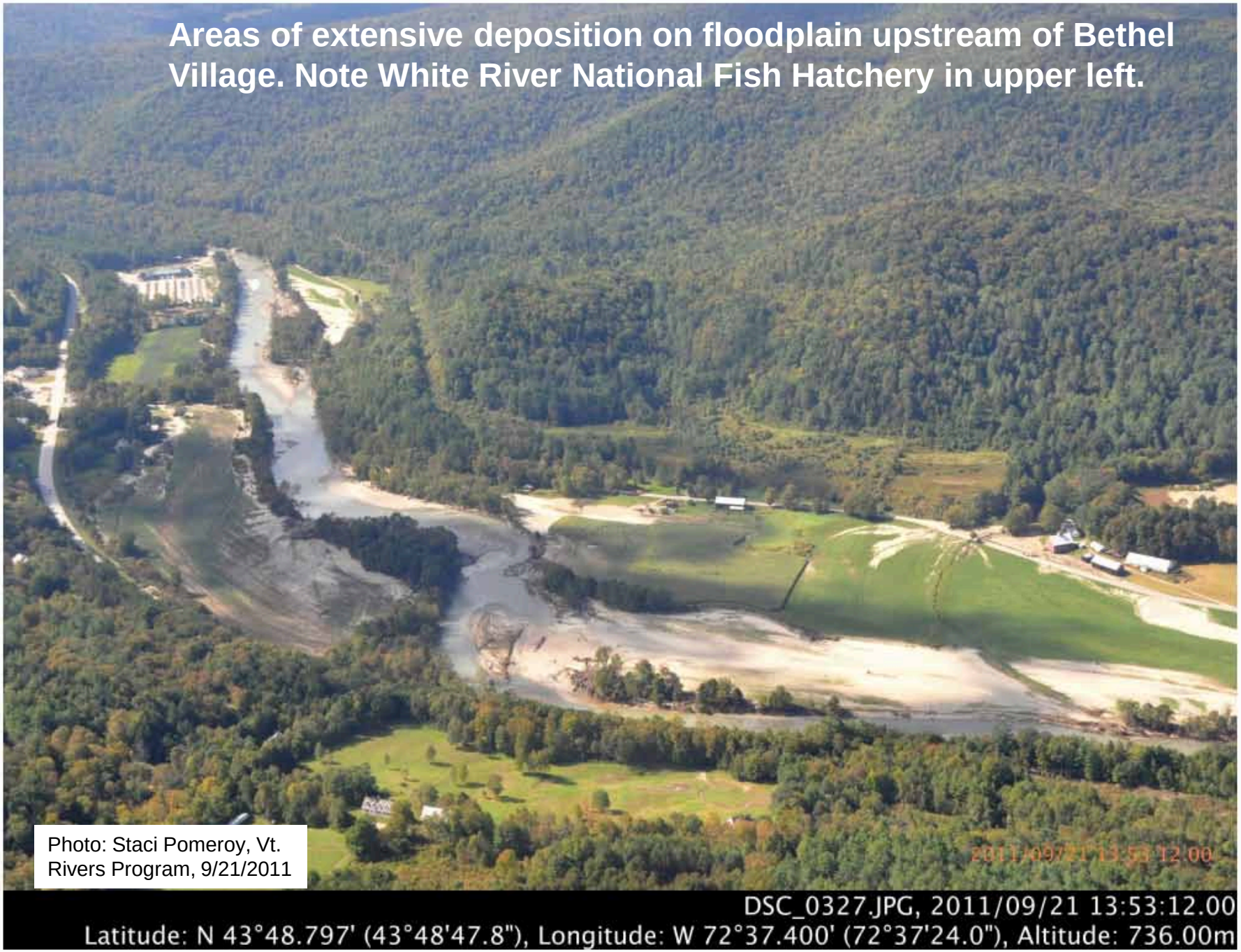
Left: Bing image of boulder bar in flood-scoured channel of White River downstream of the bridge at Gaysville. Vt. Rt. 107 in lower right of image.

Below: photo of same bar from ground level, looking downstream. Note landslide on far bank. Photo by Kristen Underwood, 10/13/2012.

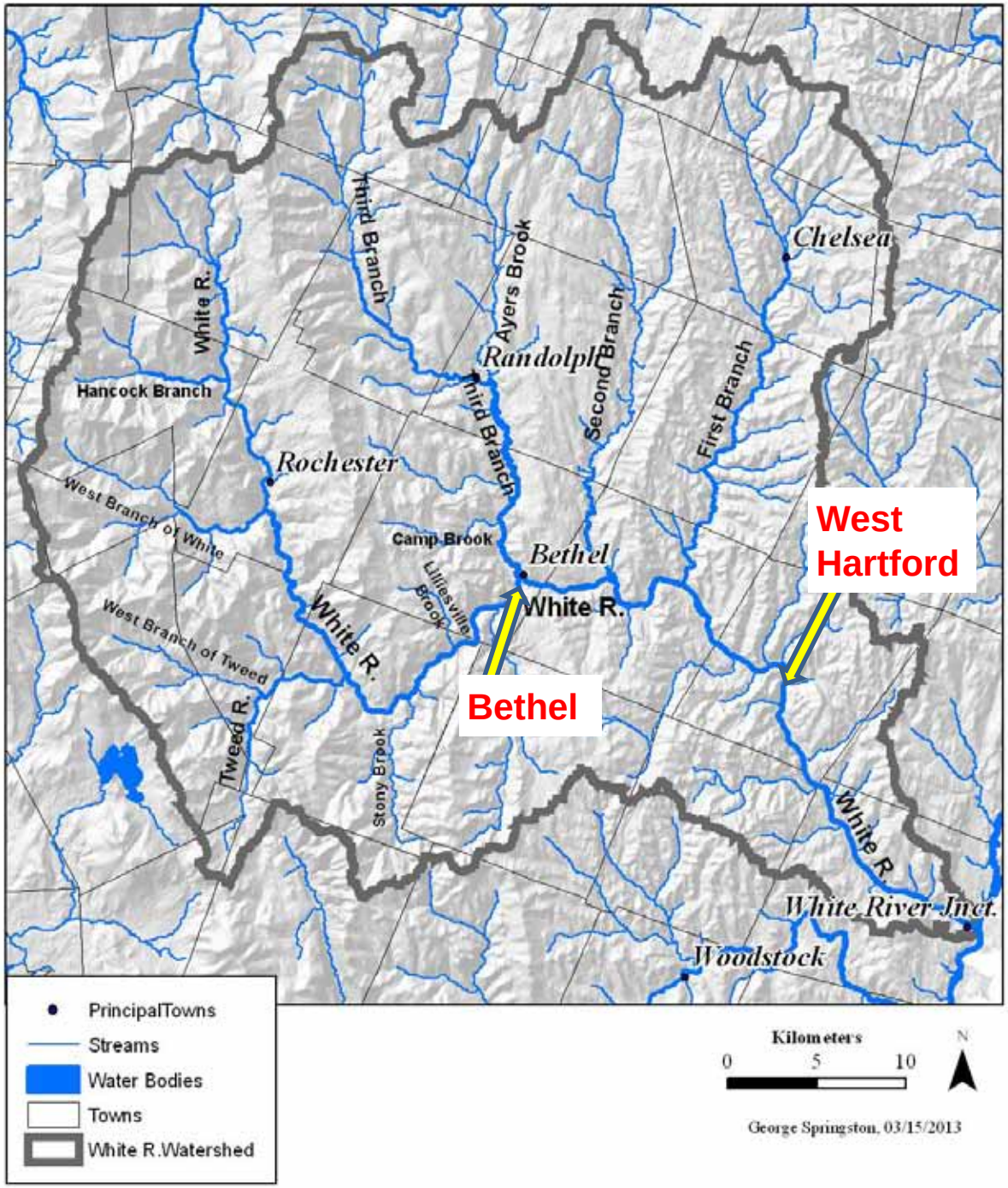


White River channel from bridge at Gaysville. Looking downstream. Note large woody debris piles on right.


Downstream of Gaysville, Looking Northwest
Active Landslide
Bank Erosion
Channel Widening
Heavy Scour and Deposition in Floodplain Forest
Photo: Staci Pomeroy, Vt. Rivers Program, 9/21/2011
DSC_0348.JPG, 2011/09/21 13:55:28.00
Latitude: N 43°46.951' (43°46'57.1"), Longitude: W 72°40.896' (72°40'53.7"), Altitude: 791.00m


Areas of extensive deposition on floodplain upstream of Bethel Village. Note White River National Fish Hatchery in upper left.
Photo: Staci Pomeroy, Vt. Rivers Program, 9/21/2011
DSC_0327.JPG, 2011/09/21 13:53:12.00
Latitude: N 43°48.797' (43°48'47.8"), Longitude: W 72°37.400' (72°37'24.0"), Altitude: 736.00m


Hatchery
Large woody debris
Floodplain deposits
Photo: Staci Pomeroy, Vt. Rivers Program, 9/21/2011
DSC_0331.JPG, 2011/09/21 13:53:47.00
Latitude: N 43°48.444' (43°48'26.6"), Longitude: W 72°38.533' (72°38'32.0"), Altitude: 761.00m


Third Branch
Ayers Brook
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Hancock Branch
Third Branch
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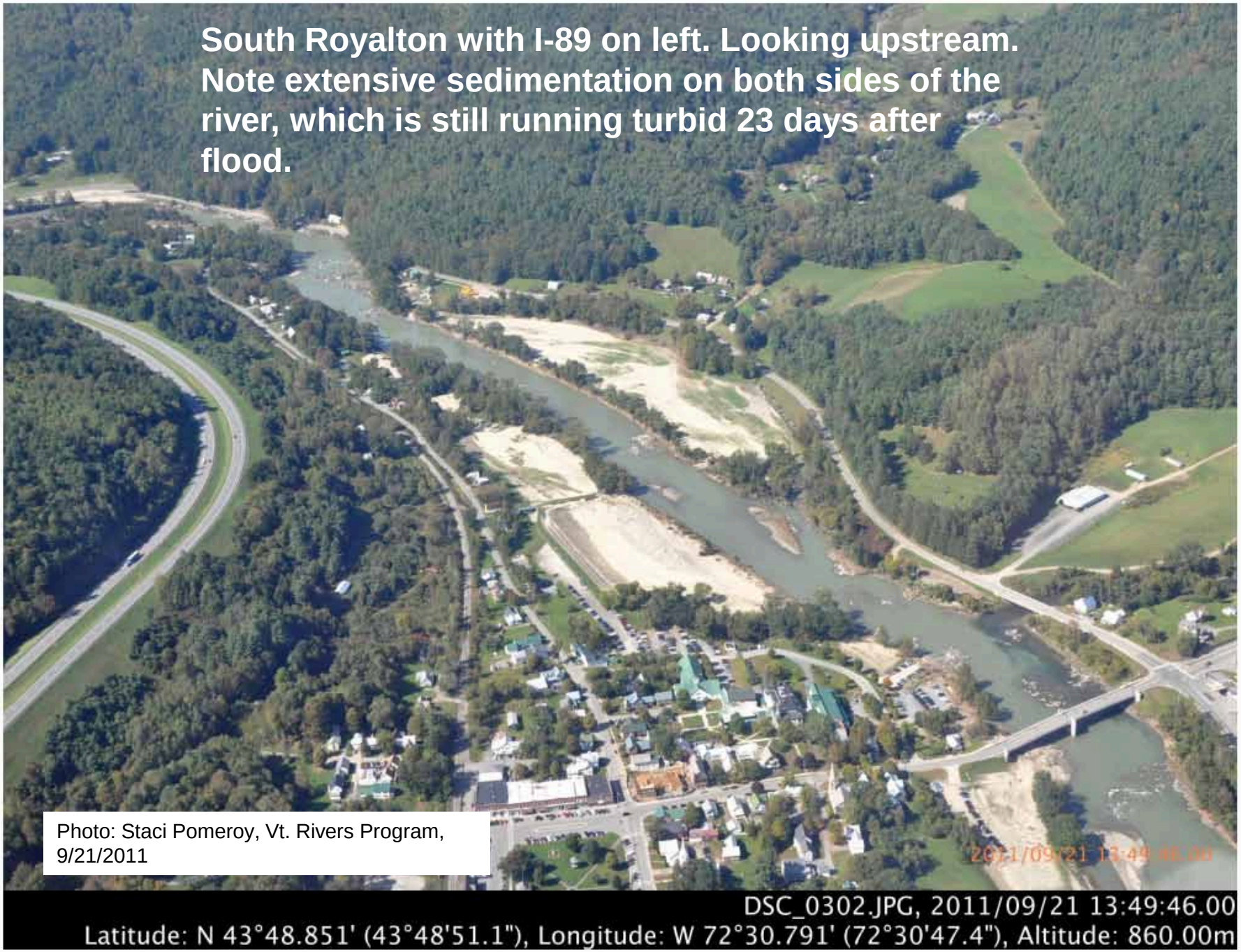
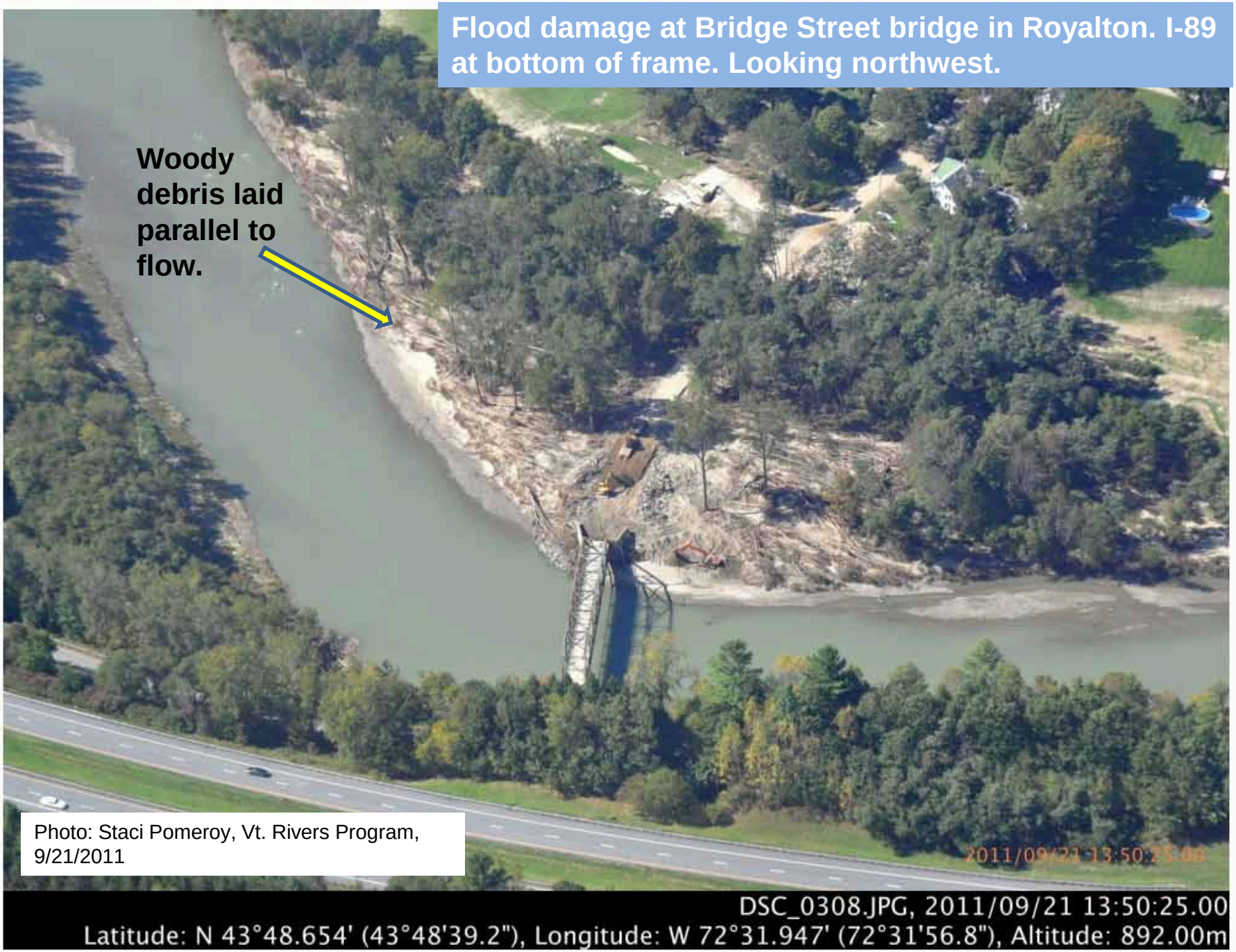
West Branch of Tweed
White R.
Tweed R.
Stony Brook
White R.
White River Jnct.
Woodstock
West Hartford
Bethel
PrincipalTowns
Streams
Water Bodies
Towns
White R.Watershed
Kilometers
0
5
10
N
George Springston, 03/15/2013

Photo: Staci Pomeroy, Vt. Rivers Program, 9/9/2011


Extensive floodplain sedimentation, Royalton. Vt. Rt. 14 and CVRR in foreground, Exit 4 in background
Photo: Staci Pomeroy, Vt. Rivers Program, 9/21/2011
DSC_0312.JPG, 2011/09/21 13:51:10.00
Latitude: N 43°48.562' (43°48'33.7"), Longitude: W 72°33.324' (72°33'19.5"), Altitude: 853.00m


South Royalton with I-89 on left. Looking upstream. Note extensive sedimentation on both sides of the river, which is still running turbid 23 days after flood.
Photo: Staci Pomeroy, Vt. Rivers Program, 9/21/2011
DSC_0302.JPG, 2011/09/21 13:49:46.00
Latitude: N 43°48.851' (43°48'51.1"), Longitude: W 72°30.791' (72°30'47.4"), Altitude: 860.00m


Flood damage at Bridge Street bridge in Royalton. I-89 at bottom of frame. Looking northwest.
Woody debris laid parallel to flow.
Photo: Staci Pomeroy, Vt. Rivers Program, 9/21/2011
DSC_0308.JPG, 2011/09/21 13:50:25.00
Latitude: N 43°48.654' (43°48'39.2"), Longitude: W 72°31.947' (72°31'56.8"), Altitude: 892.00m

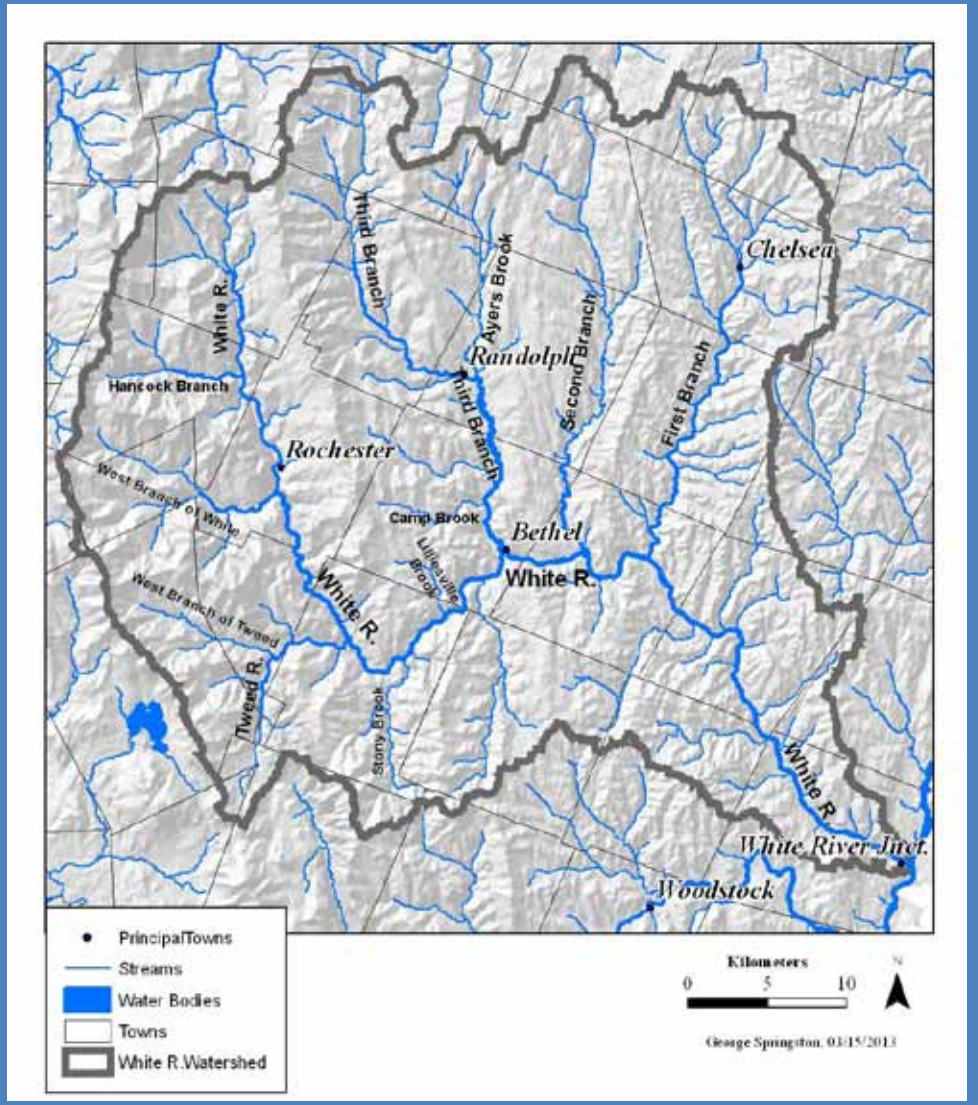
Active landslide in glacial Lake Hitchcock deposits on inside of bend at “The Pinnacle” on the White River, just downstream of Sharon. Looking southwest. Note bedrock rib in front of the landslide. G. Springston, 6/2012

Flood damage at West Hartford: Clockwise from top left: Bridge with flood debris in guardrails, USGS gaging station with flood level, and flood damage at store on north side of Vt. Rt.14

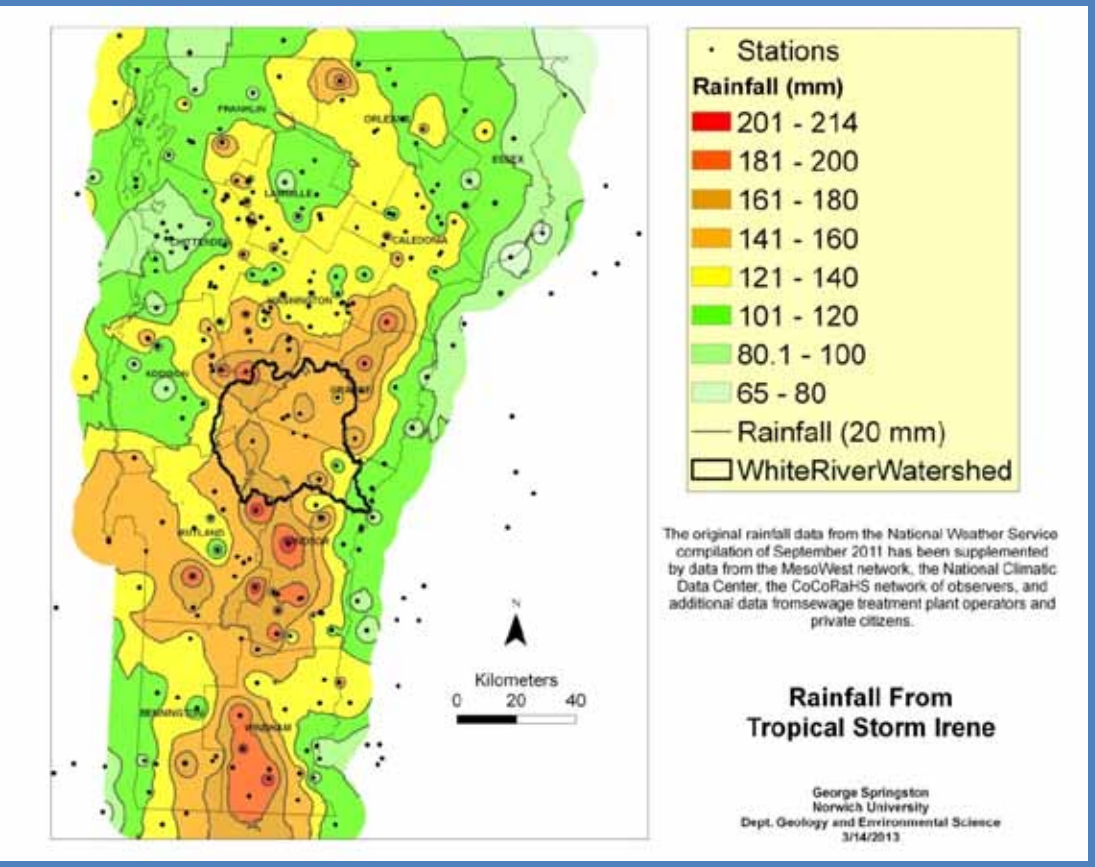
Photos courtesy of USGS, August 2012

Summary of Geomorphic Impacts

- Tremendous volume of sediments stripped from steep, eroding tributaries.
- Along mainstem scour was generally greatest where valley most constricted.
- In less-constricted reaches floodplains and low terraces overtopped, leaving behind extensive gravel and sand deposits and masses of woody debris.
- Impacts intensified at bridges, culverts.
- Adjustment processes triggered by Irene will take many years to play out.



Thanks to:



- Jonathan Croft, Vermont Agency of Transportation, for GIS data on impacts to State roads
- Pam Brangan, Chittenden County Regional Planning Commission, for GIS data on impacts to local roads
- Richard Kiah, Vermont-New Hampshire office of U.S. Geological Survey, for updated streamflow records
- Staci Pomeroy, Vt DEC River Management Program, for numerous aerial photos
- Evan Fitzgerald, Mary Nealon, Rudy Rudell, Dan McKinley, Jim Ryan, and Mary Russ for sharing their knowledge of the watershed
- Larry Becker, Vermont Geological Survey, for continued support of surficial geology and natural hazards studies in the state.