

REPEAT PHOTOGRAPHY: Methods and Applications in the Geological and Ecological Sciences

Chapter 8. Clearcutting, Reforestation, and the coming of the Interstate: Vermont's Photographic Record of Landscape Use and Response

Paul Bierman

Department of Geology and Rubenstein School of the Environment and Natural Resources

University of Vermont

Burlington, VT 05405

pbierman@uvm.edu; 802 656 4411

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1.0 Introduction

In the early to mid 1800s, the men and woman of New England cleared what was once continuous forest cover off the rocky, glacial landscapes of northeastern North America, and thus ran one of the largest, most significant landscape-scale experiments in human history. The experiment had no plan nor any coordinated leadership but in a matter of decades settlers nearly stripped the forests from the hills and valleys of the northeastern United States. Then, half a century or more later, with similarly little planning and coordination, many of the cleared fields were abandoned and an equally extensive and unplanned experiment in reforestation and landscape response ran its course.

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This regional-scale vegetation disturbance took place on a part of North America that had been continuously forested for more than 10,000 years since the climate warmed and the last of the continental glaciers had melted far back into interior Canada (Webb et al. 1987). In the uplands, forest clearance exposed thin soils developed on glacial till to the direct impact of heavy rainfall exacerbated by the hoofs of grazing animals, a pounding that compacted the soils and, as long as it continued, prevented re-growth of the forests. In the lowlands, sandy glacial outwash or river terraces left behind as streams readjusted after deglaciation, were stripped of trees. As stumps were pulled or roots rotted away, the strength imparted to the soil by those roots, termed effective cohesion, was lost (Bierman et al. 2005) and otherwise stable hillslopes failed in landslides and gullies (Figure 1).

The impact of land-use practices was not lost on those living in the mid-1800s. Artwork from the time clearly records landscape-scale responses to human actions including clear-cutting and road-building (Figure 2). With the popularization, during the 1850s, of photography as a medium for recording both human and landscape conditions, the deforested, pre-civil War, New England landscape was clearly and extensively documented (Figure 3). Such documentation was both intentional, e.g., in images where landscapes were the subject, and unintentional in images where the landscape was an incidental background to portraits, images of homes, and depictions of rural life (Figure 4). By 1882, George Perkins Marsh had documented the effects of unsustainable land management practices and decried in print the lack of concern over and the impact of human-induced erosion (Marsh 1882).

In this chapter, we use both original and reshoot images of Vermont to document how the landscape has responded to human actions including deforestation, reforestation, and road

building. We use three examples to demonstrate how repeat photography of the same site at different times can be used to document, both qualitatively and quantitatively, landscape response to human actions with the thought that by examining past landscape responses, we can better inform future land use decisions. The images and research reviewed in this chapter are part of the *Landscape Change Program*, a digital image archive described below.

2.0 The Landscape Change Program

Since 1999, the University of Vermont has hosted a web-based archive of landscape imagery known as the *Landscape Change Program*. Funded primarily by the National Science Foundation, the *Landscape Change Program* contains (as of fall 2007) almost 14,000 images of Vermont landscapes documenting over 200 years of landscape change and human/landscape interaction. Almost 20% of the archive is re-photography, useful for depicting change over time.

The archive is unusual in that contains imagery useful for documenting changes in the natural and built environment of a rural area in contrast to image repositories or rephotography efforts documenting urban or well-known park landscapes such as Yellowstone or the Grand Canyon, e.g., Webb (1996). The archive is student- and community-centered having been built over time by a series of student interns and projects. There is strong community outreach and involvement in both image collection and image description; nearly 2000 images now have public comments. All images in the archive are described with at least a narrative paragraph and a set of Library of Congress, *Table of Authorities* keywords. The archive is publicly accessible and fully searchable at uvm.edu/landscape. Users can download 800 pixel wide images and use a

zoom tool to investigate details in the images. High resolution scans are available by permission of the source archives.

3.0 Examples from Vermont

The images of the Landscape Change Program provide a rich visual archive of changing landscape conditions over time. Below, three examples show the power of different types of imagery taken over time for different purposes.

3.1 Deforestation and Reforestation

Within several thousand years after the last glacial ice melted away from Vermont, pollen records, preserved in ponds and bogs, clearly indicate that many different tree species cloaked Vermont's hillslopes. Although the species distribution was well known, their prevalence on the landscape was not. Recent historical research (Cogbill et al. 2002) has determined the pre-settlement forest composition for New England. Prior to the settlement of many New England towns, the land was divided by surveyors who used distinctive trees as boundary points. These "witness" trees represent a sample of the pre-settlement forest. Cogbill's regional scale compilation suggests that the pre-settlement forest in Vermont was dominated by beech with significant amounts of maple, hemlock and spruce. There were gradients that reflected latitude and elevation with spruce and fir more prevalent in the mountains and oak and pine more prevalent to the south.

Initially, the settlers cleared these northern hardwood and softwood forests for agriculture, including both crops and grazing; later, higher elevation sites and those with poor soil were cleared for timber resources and for fuel (Cogbill et al. 2002). In some cases, stumps were pulled to clear fields (Figure 5); in other cases, the stumps, where

timber was the object, not land clearance, the stumps were left in place (Figure 6).

Because photography came to Vermont after the old growth forests had been cleared, many of the images of active clearance from the late 1800s (such as Figure 6) show the cutting of second growth trees.

3.2 River Channel Response

Rivers are dynamic landscape elements that respond over varying timescales to hydrologic and sedimentologic changes in their source basins. The widespread and rapid deforestation of New England slopes changed both the timing and magnitude of run-off events and made copious quantities of sediment available for transport. Sequences of photographs, taken over time, can be used to examine the physical riverine response to landscape change. We start by analyzing a single massive disturbance, the 1927 flood.

3.2.1 Characterizing Flood Hydraulics and Effects

In 1927, a November flood, with peak flows more than two times higher than any other recorded event, struck Vermont. The flood destroyed >1000 bridges and caused significant channel change and channel bank erosion. October 1927 had been very wet, leaving soils saturated. The storm dropped up to 22 cm of rain in central Vermont with at least 12.5 cm falling over most of the state (National Weather Service 2002). Within days of the devastating flood, the US Army flew over Vermont photographing the damage. Of the 90 images taken, 67 are extant. During the summer of 2004, these 67 were rephotographed to show the changes in riparian corridors, development, and channel characteristics. We also examined hundreds of ground-level images taken both during and after the flood (Stanley Mann et al. 2004).

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Modern rephotography of flood and post-flood images in the archive allows us to quantify changes that have occurred since 1927 (Figure 7). Examining the 67 pairs of aerial images, shows that between 1927 and 2004 forest cover increased in 70% of the images, new roads were built in almost 60%, development altered the landscape in almost 50%, and vegetation cover in riparian zones increased in over 60% of the images. These changes have differing effects on surface water hydrology with reforestation tending to reduce peak flows and storm flow volumes, whereas development and road building both tend to increase runoff and storm peaks (Dunne 1978).

More generalizable is the identification of flood heights from historic photographs, river stage being critical data for flood hazard evaluation. In bedrock channels, flood heights recorded by photographs can allow calculation of channel roughness coefficients (n), important for modeling flood flows with the Manning equation (Dunne 1978). Roughness coefficients of bedrock channels during exceptionally high flows are not well known (Wohl 1998, Reusser et al. 2004). In order to calculate n , we use USGS data to constrain peak flood discharge, survey data to determine channel geometry, and historical photographs to define a water level at the presumed flood peak (Figure 8). Combining the latter two data sources, we estimate the wetted perimeter at the time of flooding. We solve for n using values for all other variables in Manning's equation.

Assuming that the flood image (Figure 8) was taken at peak flow (118,000 cfs), Manning's n for this bedrock channel during the peak of 1927 flood was 0.020. This value is similar to a contemporary estimate (0.017) made at lower flow (18,000 cfs). Uncertainties in this approach include random errors in channel cross-section surveys and discharge estimates as well as potential underestimation of the wetted perimeter and

consequent over estimation of n if the image used to determine flow depth (and thus wetter perimeter) were not taken at peak flow. It is important to note that the example we give is of a bedrock reach, where we can reasonably assume that the channel geometry has not changed since the 1927 flood. Such an approach would fail in an alluvial system where channel scour during the flood and subsequent changes from later events would alter channel geometry as shown in the section that follows.

3.2.2 Characterizing Channel Change over Time

Rephotography of the oblique aerial imagery from the 1927 flood indicated that some parts of the river systems were more susceptible to change than others. For example, the Winooski River forms the boundary between the cities of Winooski and Burlington. Here, the river has just become alluvial, passing over the last set of bedrock falls. For the next ~20 river kilometers, this major river flows across a broad alluvial lowland, termed the Intervale, before emptying into Lake Champlain.

Although several image pairs showed significant changes in river channel morphology in the 77 years between the original 1927 images and the rephotography done in 2004, one image pair (Figure 9) was located in an area where there mapping and other historic imagery provided more than a 100 year record of channel change over time (Figure 10). Analysis of all the records (Figure 10), catalyzed by the observations made on the image pair (Figure 9) demonstrated that the flood of 1927 removed a mid-channel island (which has since reappeared) but that the channel narrowing documented in the paired imagery (Figure 9) had been on-going since at least 1910 (Figure 11).

One can speculate on the why the Winooski River (as pictured in Figure 9) responded the

way it did to changes in watershed conditions as Vermont was settled and cleared by westerners. Field reconnaissance suggests that the channel narrowing observed near the bridge (Figure 11) is the result of incision over time. This incision has left terraces composed of historic sediment several meters above the channel and beyond what is today bankful stage. Trenching studies elsewhere in the Winooski Intervale indicate that one to as much as several meters of historic alluvium were deposited during the 1800s after the Winooski watershed was deforested (Thomas). Presumably, this widespread alluvial deposition reflects increased sediment supply from the cleared and eroding uplands (Bierman et al. 1997). Map analysis indicated that the Winooski River delta prograded into Lake Champlain in the mid to late 1800s before sediment yields dropped (due to reforestation) and longshore drift moved much of the sediment away from the river mouth (Severson 1991). This dynamic landscape history and fluvial response can be represented graphically (Figure 12).

3.3 Coming of the Interstate

Vermont remains a place where residents take pride in the statistic that more miles of the State's roads are dirt than paved. With few exceptions, the paved roads are narrow, two-lane affairs that twist their way up and down steep hills and through narrow valleys.

Until the 1930s, many of Vermont's roads were unimproved, and in spring, when the snow melted and the ground thawed, the roads turned to swamps of mud, stranding cars and bringing commerce and transportation to a near standstill.

The late 1920s and early 1930s saw the first of two major changes in road networks and thus the landscape of Vermont. Photographers from the Vermont Highway Department traveled the state, documenting the changes as roads were straightened and improved,

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guardrails were added, bridges rebuilt, and drainages rerouted (Figure 13). Presumably these images were used to show the public the effectiveness of their tax dollars. This was rephotography on a short timescale but an approach that documented significant and rapid changes that affected both the built and natural environment. The resulting pairs of images show a landscape in transition in response to the growing importance of the automobile.

The revolution in transportation brought about by the internal combustion engine and the creation of a modern road network, as well as other technological changes, spawned some imaginative views of what might happen in small rural towns. During the 1920s or 1930s, a series of post cards were created that depict small, rural Vermont towns sometime in the future (Figure 14). These images do not feature the automobile; rather, all of the extant cards are dominated by imagery of mass transit: trains, subways, busses, and dirigibles. With three quarters of a century perspective, one can look back and see how this vision evolved. One finds a transportation landscape not at all like what the artist imagined but rather a landscape dominated by single occupancy vehicles and the interstate highways that carry them.

The interstate highway came to Vermont in the 1960s. Two interstates (I-89 and I-91) were built and extended a little more than 300 miles within the state. Construction began in the 1950s and the last section was completed in 1978. The process of planning, constructing, completing and opening the highways was extensively documented, primarily by one photographer, Donald Wiedenmayer. His work, nearly 40,000 negatives over several decades documents in detail the landscape change brought about by massive earthmoving, paving, and blasting activities. Channels were redirected,

slopes were reshaped and bedrock was blasted to carve exits through outcrops and carry 4 lanes of traffic over raging rivers.

Within Wiedenmayer's work are sets of images that were reshoot over several years from exactly the same locations. Some of these image sets (e.g., Figure 15) contain up to four images. These image sets clearly show the scale and impact of Interstate highway construction on the landscape. Entire slopes are moved, rivers are dammed, banks are rip-rapped and the hydrology is radically changed. Our experience is that presentation of these images sets in sequence is most effective at awakening audiences to the immensity of earth movement and landscape change occasioned by highway construction. People who lived through the decades it took to build the highways tend to view the change as gradual. Those whose knowledge of the landscape post-dates highway construction are typically shocked at the scale of change. It appears that such sequential rephotography of massive earth moving projects has the potential to inform and perhaps sway public opinion.

4. Conclusions

The photographic record is a rich archive that reveals how the landscape responds, over time, to both human and natural influences. Repeat photography of the same location allows both qualitative and quantitative evaluation of landscape change. The image record and rephotography over time provide a unique means by which to study landscape response to widespread but uncoordinated, human-induced disturbances such as land clearance. One example presented in this chapter demonstrates that river channel width responded gradually to changing sediment and water loads; the same channel also changed shape abruptly in response to a discrete event, in this case, the rare, high-

magnitude, 1927 flood.

Repeat photography is also a powerful educational and political tool. In environmental decision-making, the emotional or affective power of imagery compliments other means of information delivery. When the scale of landscape change is significant, such as the road-building example presented in this chapter, the visual data provided by repeat photography become a particularly germane part of the decision-making process allowing stakeholders to see by analogy the likely landscape-scale impacts of their landuse choices.

5. Acknowledgements

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Figure 1. Deforestation catalyzed erosion by removing not only the trees but their roots which for millennia had bound weak soils on steep slopes (Bierman et al. 2005). In Tunbridge, Vermont, valley clearance exposed the steep slopes between sandy river terraces and led to gully erosion and small-scale landsliding. The sediment eroded from the steep slopes accumulated below on cone-shaped alluvial fans; the horse now stands on one of these fans. Trenching revealed the layers of sand and soil buried in such fans clearly shows a peak in sedimentation (and thus hillslope erosion) during settlement and post-settlement times (Bierman et al. 1997, Jennings et al. 2003). Image used by permission of the Vermont Historical Society. LS07574.



Figure 2. Local artists recorded the denuded landscape. Charles Heyde painted this view of Mount Mansfield and the Browns River in northwestern Vermont, c. 1857. He faithfully recorded stumps in the stream-side field and deep gullying that resulted from undercutting the toe of the adjacent hillslope. Image used by permission of the University of Vermont, Robert Hull Fleming Museum. LS09924.

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Figure 3. Early stereo photograph of the cleared Vermont landscape near the town of Duxbury, Vermont (c. 1875). Such images show the degree to which New England slopes were cleared of trees during much of the 1800s. Image used by permission of the University of Vermont, Bailey-Howe Library, Special Collections. LS03480.

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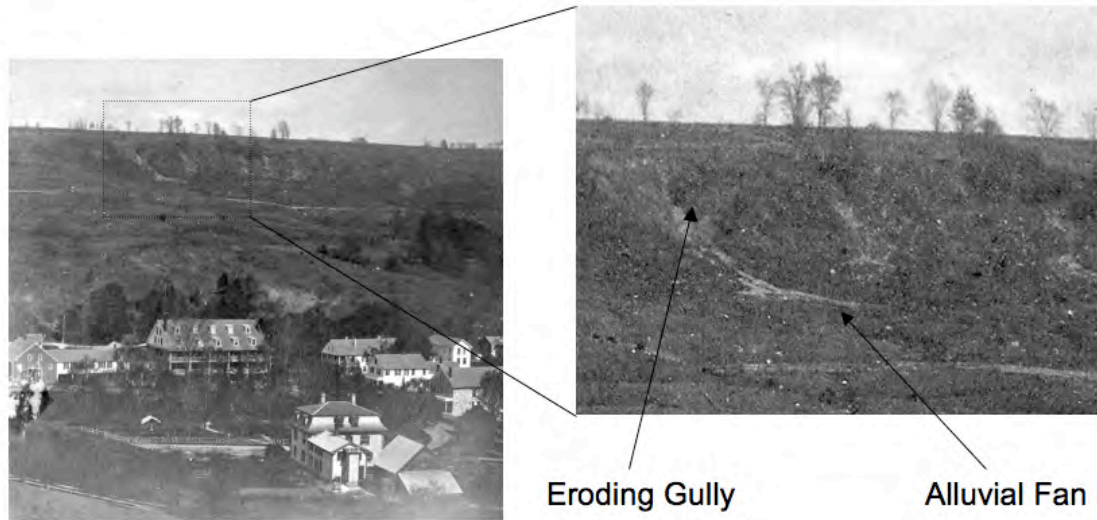


Figure 4. Image of hotel at Clarendon Springs, Vermont, c. 1880. Looking closely at the main image, one can see the barren slopes and clear evidence of gullying and deposition of sediment on an alluvial fan (see inset). In this image, erosion and sediment transport are not the subject but rather incidentally captured as part of the distant background.

Image used by permission of the University of Vermont, Bailey-Howe Library, Special Collections. LS03684.



Figure 5. Stump fences were a means by which to re-use what otherwise would have been wasted resources (the stumps). Highgate Falls (c. 1880) is pictured along the Missisquoi River in northwestern Vermont. The stump fence defines an enclosure in the lower right of the image. Unstable, deforested slopes shown in the distance. Stereoview used by permission of the University of Vermont, Bailey-Howe Library, Special Collections. LS04684.



Figure 6. Historic stereoview of valley bottom clear-cut c. 1870, Champlain Spring, Highgate, Vermont. In the background are shallow planar landslides, hosted in fine-grain glacial deposits, on a cleared slope. These slides were likely catalyzed by loss of effective root strength after the slope was cleared (Bierman et al. 2005). In the middle ground, are many stumps and much slash, the remains of cutting second-growth timber. Spring house at the center of the image. Note the size of the stump that the man is sitting on; it remains from the old growth, pre-settlement forest that once covered Vermont lowlands like this. Stereoview used by permission of the University of Vermont, Bailey-Howe Library, Special Collections. LS03668.

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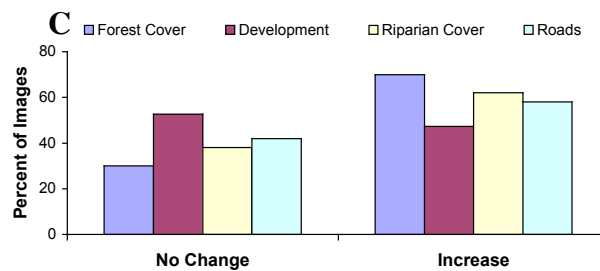
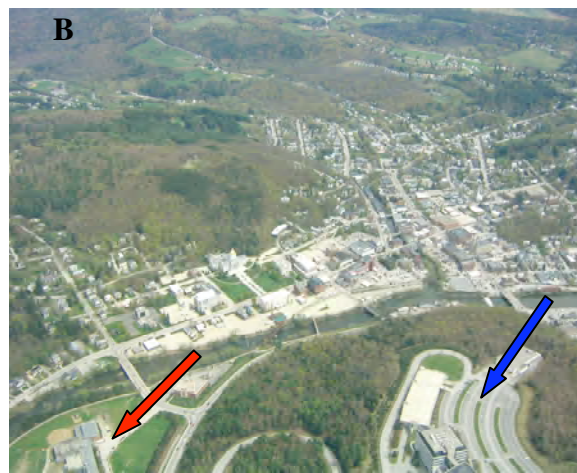
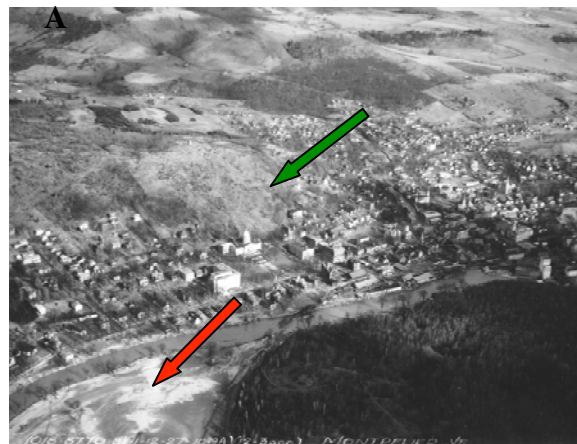


Figure 7. Rephotography of oblique imagery taken just after the 1927 flood shows specific examples (A and B) and the broader pattern of landscape change between 1927 and 2004. A. 1927 image of Montpelier, Vermont. B. 2004 image of Montpelier, Vermont. Green arrow shows area that has reforested. Red arrows show over bank deposits now covered by a high school. Blue arrow shows commercial development of once-wooded site. Note the lack of bridges (they have been washed out) in the older image. C. Characterization of images (n=67 pairs) showing percentage in which characteristics studied (forest cover, development, riparian cover, and roads) either remained similar (no change) or increased. Historic image (LS01429) used by permission of the University of Vermont, Bailey-Howe Library, Special Collections.

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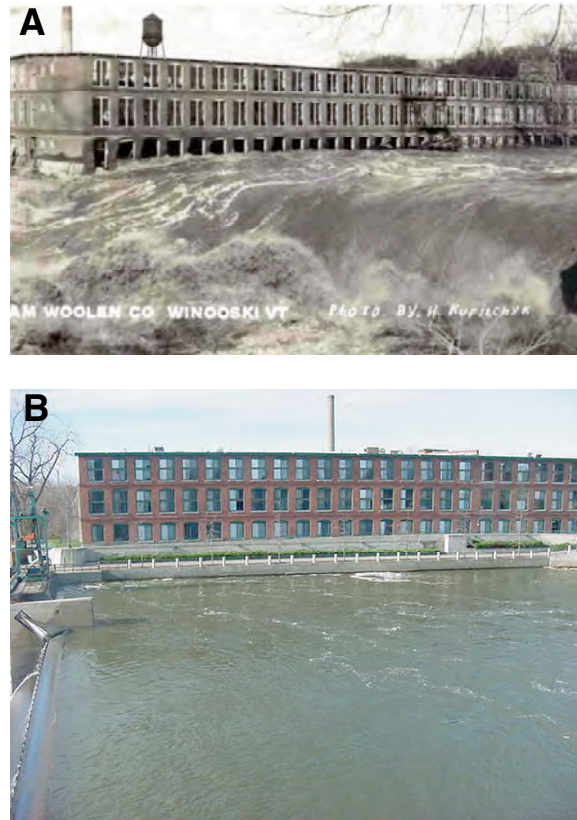


Figure 8. Imagery used to calculate Manning's n for a bedrock reach of the Winooski River. A. Image of woolen mill in Winooski, Vermont during high water of 1927 flood (118,000 cfs). Image used by permission the University of Vermont, Bailey-Howe Library, Special Collections. LS01132. B. Same mill from slightly different angle in summer 2003. The woolen mill is now an apartment complex. Note the considerably lower level of water (18,000 cfs). Level of windows used to match the imagery and determine river stage. Dam is present in both images but washed over in A.

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Figure 9. The earliest wide spread aerial photography of Vermont was taken by the Army Air Corps within days of the devastating 1927 flood. A 1927 image (A), taken 8 days after the flood, is juxtaposed with a 2004 image of the same view (B). There are many differences between the two images but the most striking is the magnitude of channel change, specifically the narrowing of the channel near the bridge (same abutments marked by arrows in both images) and the reappearance of the island, farther north (circled). Extensive, light colored sandy splay deposits are visible in the 1927 image. Image used by permission of the University of Vermont, Bailey-Howe Library, Special Collections. LS01418.

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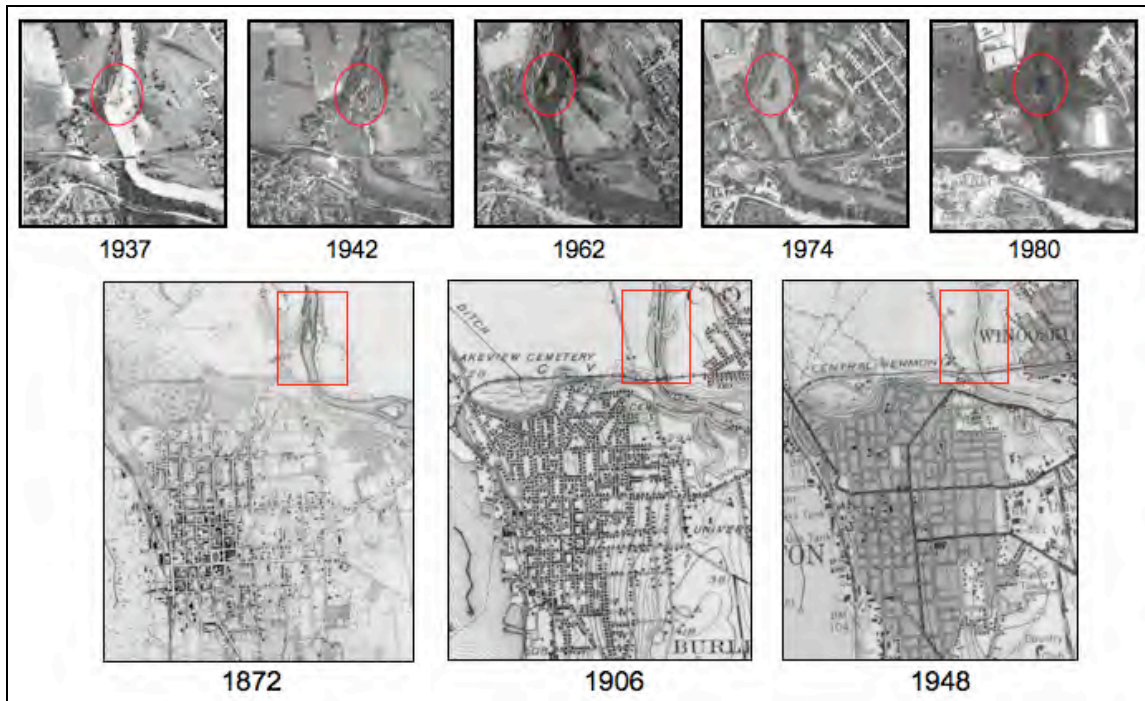


Figure 10. The channel change documented in Figure 9 can be quantified over time using maps and aerial photographs. There is a rich cartographic and aerial photographic record of landscape change in parts of New England. In parts of Burlington, Vermont surveyed maps date back over 135 years. Upper images are aerial photographs with the island circled (see Figure 9). Lower maps have the approximate area of the aerial photographs boxed. Maps and aerial photographs used by permission of the University of Vermont, Bailey-Howe Library.

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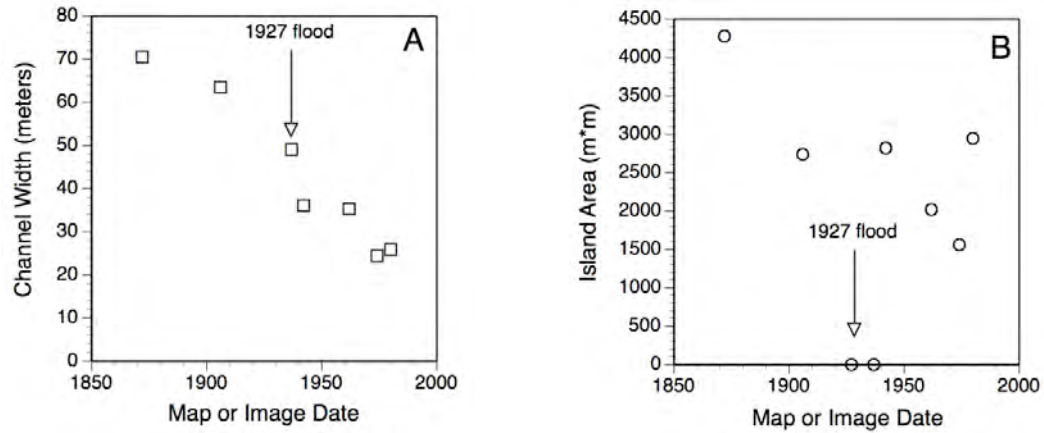


Figure 11. Using both aerial photographic imagery and a variety of map products demonstrate that the channel of the Winooski River at the location shown in Figure 9 has narrowed over time (A). The adjacent island, which existed prior to its removal by the flood of 1927, had reappeared by 1948 (B).

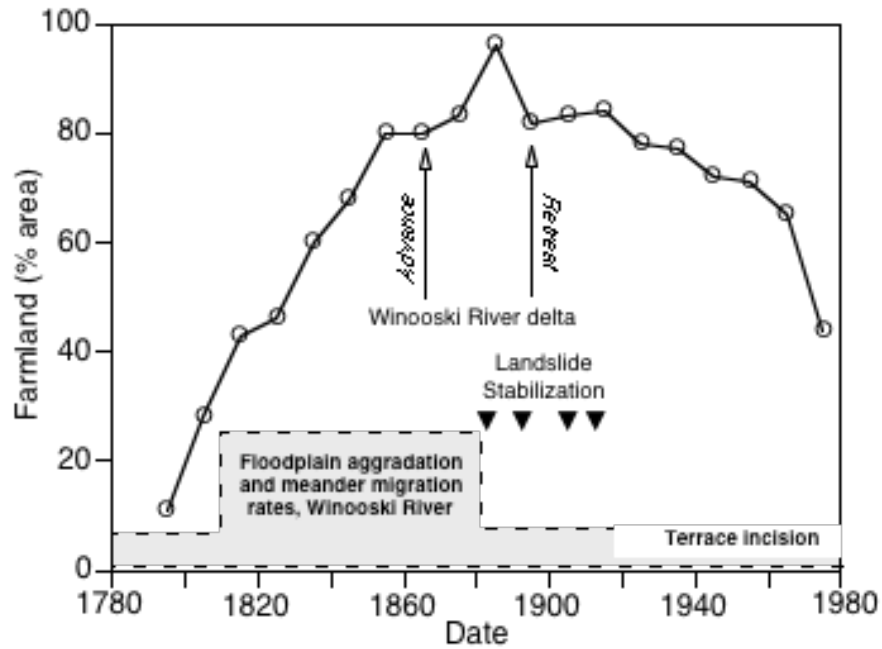


Figure 12. Graph summarizing Vermont landscape history and fluvial response. Percent farmland for Chittenden County, Vermont over time, is shown by open circles connected by a solid line. Advance and retreat of the Winooski River delta into Lake Champlain (Severson 1991). Timing of landslide stabilization in tributary of the Winooski River determined by coring trees occupying landslide scars (Baldwin et al. 1995). Timing of floodplain aggradation (Thomas). Modified from figure first presented in Bierman et al. (1997).

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Figure 13. Photographers hired by the State of Vermont documented road reconstruction projects that changed the face of the state and enabled rapid movement by automobile. These views are from Alburg, Vermont and were taken in 1937. A. Muddy rutted road before reconstruction and paving. Same road after reconstruction. Note that earthmoving activities here are quite limited; paving is the greatest change. LS08600. Used by permission of the Vermont State Archives.

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Figure 14. What might the future of transportation have looked like to someone living in Vermont in the 1920s or 1930s? Here is one of a series of photographic postcards with hand-drawn imagery overlain. These futuristic views feature various forms of mass transit, none of which every came to the hamlet of Ascutneyville, Vermont, pictured here. Image used by permission of the University of Vermont, Bailey-Howe Library, Special Collections. LS01320.

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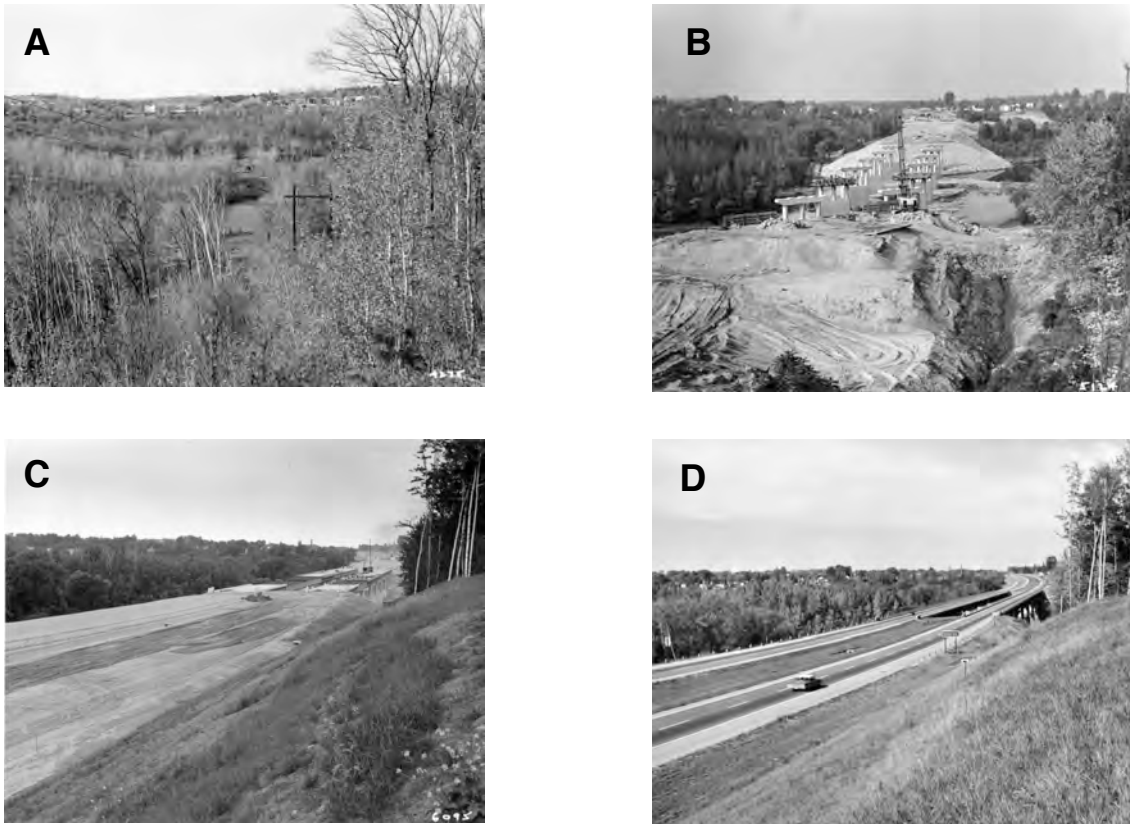


Figure 15. The coming of the interstate highway system fundamentally changed the Vermont landscape. This series of four images taken at the same site over a period for 3 years by Vermont Agency of Transportation photographer, Donald Wiedenmayer, shows the preconstruction view of the site (A), the construction of a bridge over the Winooski River about 10 km upstream from Lake Champlain (B), the grading of the roadbed (C) and the completed roadway (D). Both the channel-bordering slope and the riparian zone have been completely remolded by construction. The channel is now obstructed by bridge supports and the grass and wooded riparian zone has been replaced by stone rip-rap. Images used by permission of the Vermont State Archives. LS00376.

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