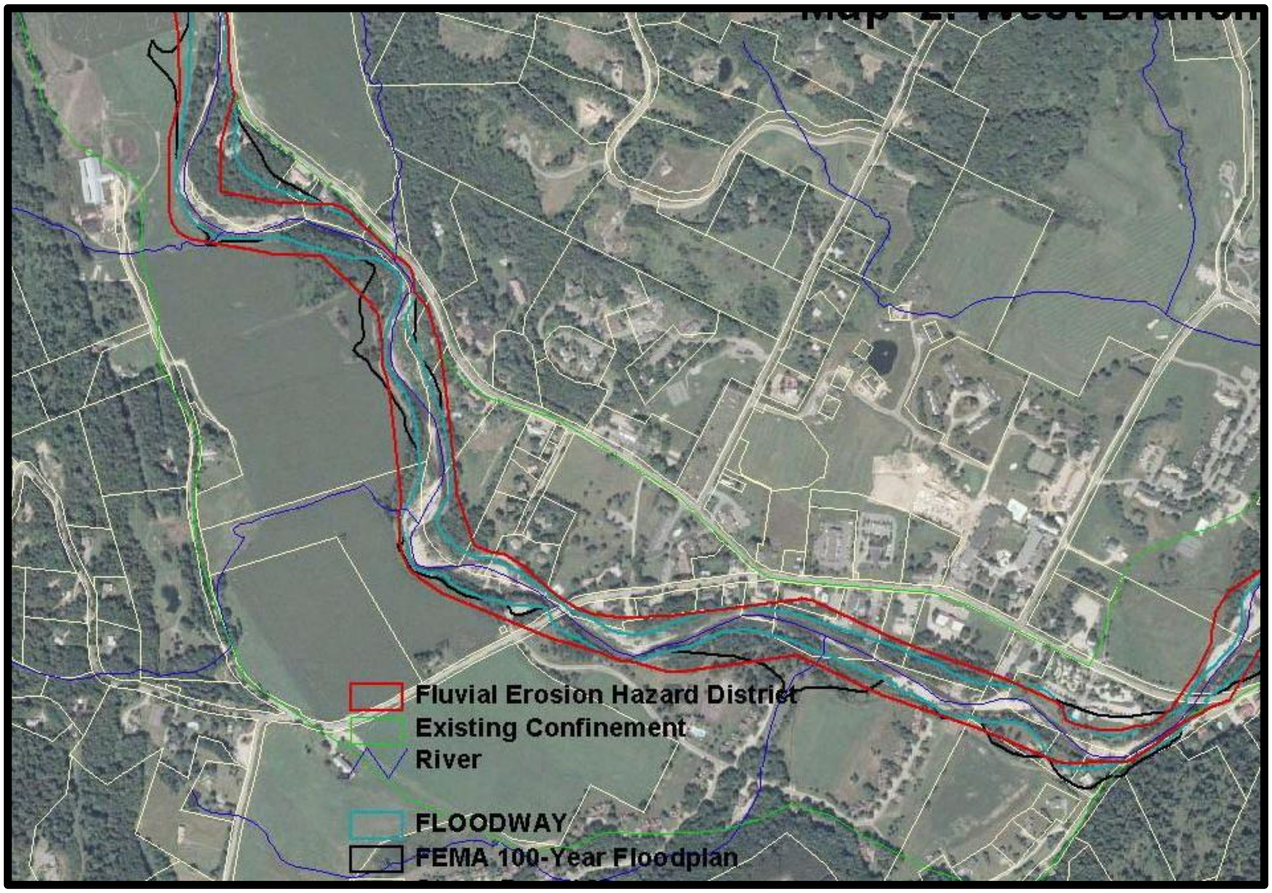
Vermont Agency of Natural Resources

River Corridor Protection Guide



Fluvial Geomorphic-Based Methodology

to Reduce Flood Hazards and Protect Water Quality

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Vermont River Corridor Protection Guide

Agency of Natural Resources
River Management Program

1.0 Overview

The Vermont Agency of Natural Resources (ANR) uses the river corridor as a primary tool in its avoidance strategy to restore and protect the natural values of rivers and minimize flood damage. River corridors consist of lands adjacent to and including the present channel of a river. River corridor delineations are based primarily on the lateral extent of stable meanders, the meander belt width (Figure 1), and a wooded riparian buffer to provide streambank stability. The meander belt width is governed by valley landforms, surficial geology, and the length and slope requirements of the river in its most probable stable form.

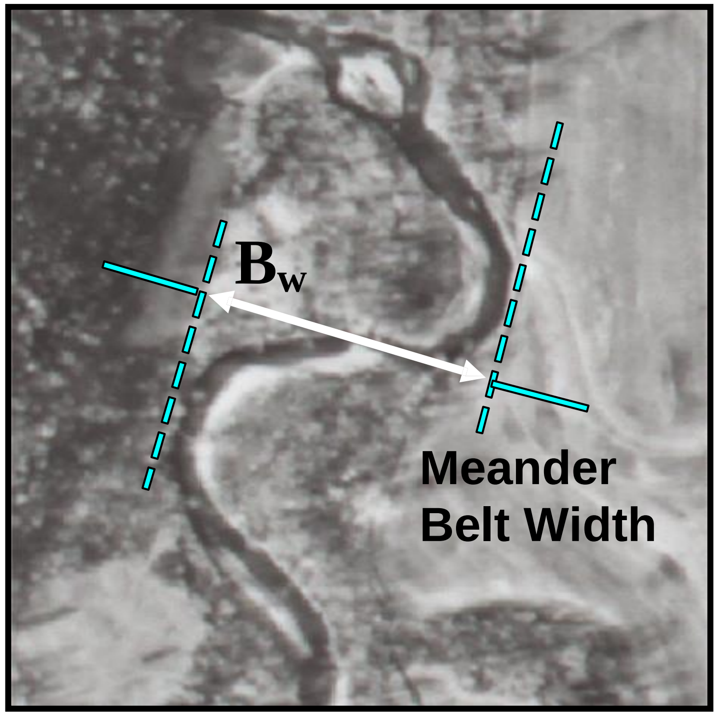


Figure 1. Meander Belt Width (**B_w**) defined by the lateral extent of meanders when the channel slope is in equilibrium with the sediment transport requirements of the river.

River corridors provide an important spatial context for restoring and maintaining the river processes and dynamic equilibrium associated high quality aquatic habitats. River corridors are also intended to provide landowners and town, state, and federal agencies with a science-based river and riparian land use planning and management tool to avoid fluvial erosion hazards (FEH). Reducing current and future near-stream investment and achieving natural stream stability promotes a sustainable relationship with rivers over time, minimizing the costs associated with floods and maximizing the benefits of clean water and healthy ecosystems. Vermont ANR programs to protect river corridors consist of technical assistance to a host of municipal, state, and federal river resource and floodplain management programs, Act 250 floodway protections, municipal fluvial erosion hazard zoning, and river corridor easements.

The Corridor Protection Guide is intended to provide the science behind river corridors and why Vermont is managing for meanders; it explains how and where corridor widths differ in valleys across Vermont; defines different types of administrative corridors; provides procedures and tools for corridor delineation, and outlines the existing state programs for protecting river corridors. A Technical Appendix of the Guide offers very detailed guidance on specific aspects of the corridor delineation process.

2.0 Managing for Meanders

Stable, equilibrium river channels erode and move in the landscape, but have the ability, over time and in an unchanging climate, to transport the flow, sediment, and debris of their watersheds in such a manner that they generally maintain their dimension (width and depth), pattern (meander length), and profile (slope) without aggrading (building up) or degrading (scouring down) (Rosgen, 1996; Leopold et. al, 1964). Stable, equilibrium rivers are considered a reasonable and sustainable management objective in consideration of the repeated and catastrophic flood damages experienced in Vermont. Many rivers of the State are in major vertical adjustment (i.e., aggrading or degrading) due to human imposed changes in the condition of their bed and banks, slope and meander pattern, and/or watershed inputs (see Lane's Balance in Figure 2).

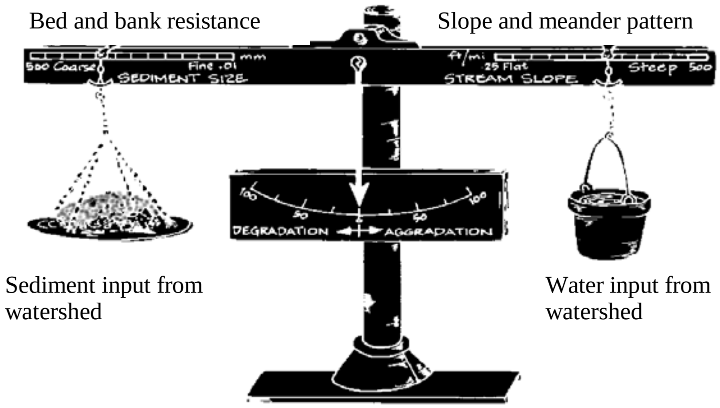


Figure 2. Stable Channel Equilibrium (Lane, 1955)

Some Vermont rivers are presently in balance. The power produced by flood flows and channel slope (a function of meander length) is not so great as to cause significant scour (degradation) of the river bed, or so diminished as to cause a loss of sediment transport capacity and a build up of sediment (aggradation) in the channel. In these cases, it is cost effective to simply keep investments out of the river corridor and avoid the eventual use of channelization practices to protect those investments, which would ultimately change the river's length and slope and lead to increased erosion as the river readjusts.

For most Vermont rivers and streams, however, a combination of watershed, floodplain, and channel modifications over the past 150 years, has led to the major vertical channel adjustments that are ongoing today. The initial stage of adjustment typically involved the bed scour and head-cutting associated with channel straightening and degradation. Steeper, straightened channels are now adjusting or "evolving" back into more gentle gradient, sinuous channels through an aggradation process (Figure 3). The narrower belt widths observed during Stages II and III of channel evolution, which held for decades and encouraged human encroachment, have now begun to widen during recent floods as new sediments deposit and longer meanders develop, putting human investments at risk.

The practice of dredging sediment to avoid flood hazards has typically worked until there is another flood. Berming and armoring may hold longer, but cause the unbalanced condition to extend upstream and downstream. Such practices are unsustainable and eventually fail requiring extensive maintenance operations. Corridors can be defined by applying fluvial geomorphic principles to calculate the belt widths and buffer which will accommodate the stable meanders, slope, and banks of the equilibrium river channel.

Establishing channel equilibrium as a river management objective, however, demands a recognition that the dynamic form of certain river channels, due to their location in the watershed, may be influenced by a net storage or net export of sediment. In such cases, the "inherent instability" is assessed and managed differently than the river that is aggrading or degrading, building up or eroding down through bed sediments, as a result of one or more human imposed changes. For instance, it may not be prudent to manage against the aggradation which occurs on an active alluvial fan, i.e. where streams transition between steep mountain and gentle valley locations.

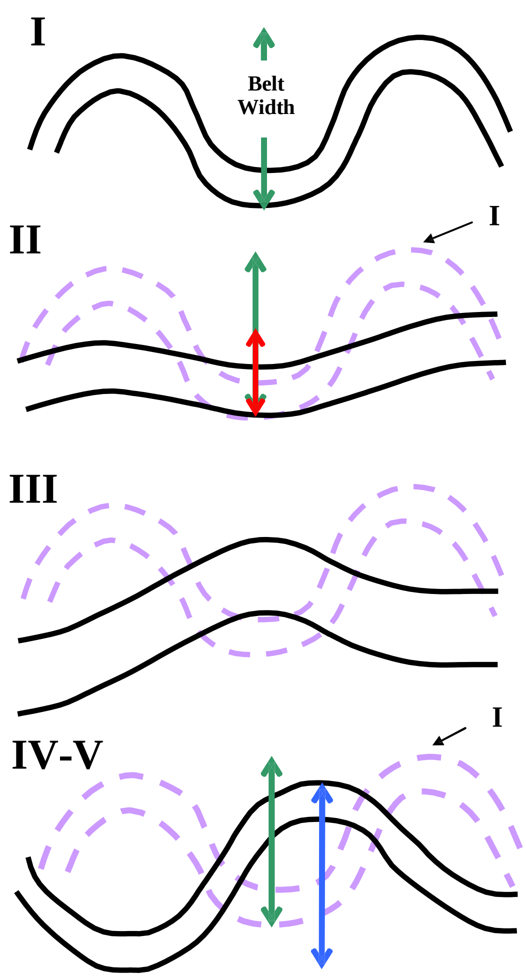


Figure 3. A planform view of the Schumm (1984) channel evolution model showing how adjustment processes lead to a narrowing and then widening of the meander **belt width** as the channel equilibrium re-establishes at a more gentle slope.

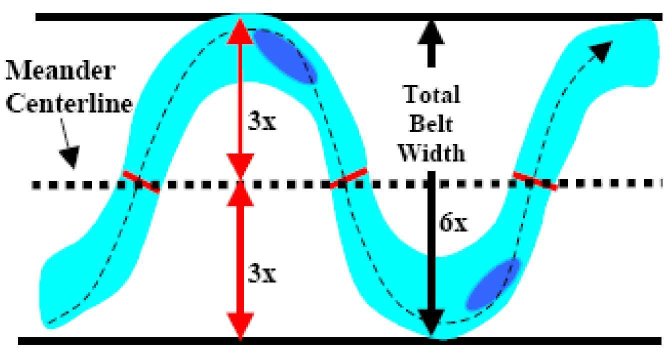
3.0 River Meander Belts

Vermont ANR has an expanded view of the river. It is much more than the low-flow channel that conveys summer runoff. It is the valley land forms that convey floods and transport and deposit quantities of sediment and debris. The natural stability and balance in the river system will depend on the river's opportunity to build and access a floodplain and create meanders that help evenly distribute the energy and sediment load along the cross-section and profile of the river.

When rivers are in dynamic equilibrium, a sustainable meander geometry provides for the dissipation of the energy of moving water and sediment. Thorne et al. (1997) note that unconfined, single thread streams tend to follow a sinuous or meandering course due to the vertical oscillations of the stream bed. Turbulence and secondary or lateral currents cause the selective entrainment, transport, and deposition of bed sediments which produce systematic sorting of sediment sizes between scour pools and riffle deposits. Riffles are the topographic high points in the undulating stream bed and pools are the intervening low points. The combination and sequence of bed features results in converging and diverging flows and leads to the development of a sinuous channel, with riffles becoming points of inflection, where the flow crosses over from one side of the channel to the other (Thorne et al., 1997).

Researchers have developed meander geometry formulas to relate channel dimensions with planform measurements. Williams (1986) using data collected from 153 alluvial rivers found that the relationship between channel width and the meander belt width is expressed by ($B = 3.7W^{1.12}$), where B is the belt width, and W is the channel width in feet. This formula results in a meander width ratio approximately equal to six, i.e., the belt width is equal to about six bankfull channel widths. Meander belts for gentle gradient rivers and streams (in Vermont, slopes generally 0.5 to 2%) in narrow to broad alluvial valleys are calculated and drawn to accommodate a meander belt width that is equal to (at least) six times the width of the river channel.

Where rivers are assessed as being at or near equilibrium, and the lateral extent of their meanders represent the meander belt, which is drawn as two roughly parallel lines following the river down-valley and capturing existing meanders. If the river has become straightened, the meander belt is drawn, for instance, using three channel widths either side of a meander centerline or six channel widths out from the toe of the valley, where the river is less than three channel widths from the toe (Figure 4).



Valley and river settings that may justify alternate meander belt widths, include:

- Steeper, confined to narrow valleys with less erodible boundaries, where beltways of "1 to 4 times channel width" are recommended based on stream type and specific valley characteristics; and
- High to Extremely sensitive stream types or landslide areas that may require corridors > 6 channel widths.

Figure 4. Schematic for drawing the outer meander belt lines of a low gradient, meandering channel capturing the extent of existing meanders or located in equal measure from a meander centerline drawn through meander inflection points. Exceptions to the "six times channel width" are indicated.

Rarely does one find the idealized sinuosity shown in Figure 4. Rivers and streams in Vermont are usually less sinuous, many having been straightened against the toe of a valley side slope. In these cases, the meander belt, drawn at six times channel width, extends laterally out from the valley toe. Detailed descriptions of how Vermont data are used to delineate mender belts are provided in the Technical Appendix.

4.0 River Corridors: The Integration Meander Belts and Buffers

In response to the extreme erosion of the early twentieth century, buffers became a "best management practice" in working landscapes. Buffers are defined as setbacks from the top of the stream bank, where land uses are separated from the water, and vegetation management or removal is restricted. Science further bolstered the use of buffer provisions in land use regulations as the ecological services of wooded riparian areas became further understood (i.e., intercepting sediment and pollutants, stabilizing streambanks and water temperatures, and providing critical habitat for both terrestrial and aquatic species).

On large, open parcels (i.e., farms and forests), buffer practices are reasonably applied in consort with stream dynamics. The incremental costs associated with adjusting buffers to the movement of a stream may be absorbed more readily, when compared with the losses that potentially occur when inhabited structures are placed in riparian areas. The greater the investment, the greater the desire to keep the stream and its buffers from moving in the landscape. The history of channelization to protect riparian land use investments, and the erosion and flood damage that follow, are among the most significant threats to water quality, aquatic habitat, and public safety in Vermont.

Establishing socially acceptable buffers, as development setback areas, without considering river corridor functions, may make it very difficult if not impossible to establish the corridor setbacks necessary to sustainably achieve the State's water quality and hazard avoidance objectives. Once people build within the corridor, corridor functions are compromised. Buffers as a setback zone, that do not provide for the functions of a corridor, will most likely be eroded away.

Vegetated buffers and meander belts, largely free of encroachment, are both important management tools, especially when combined as a single river corridor protection practice. A good river corridor zoning provision includes setbacks and restrictions on the management or removal of perennial vegetation within a riparian buffer. From a river stability standpoint, *a river corridor is designed with a meander belt to accommodate the geometry of the river in its least erosive, equilibrium condition, and extended laterally to include a buffer zone, equal in width to the bankfull channel, such that any down valley movement on the channel along the perimeter of the meander belt has sufficient, adjacent open area, available now and in the future, for the maintenance of perennial, woody vegetation and naturally stable stream banks* (Figure 5). The support of other buffer values (e.g., water quality and wildlife), may require wider buffer extensions.

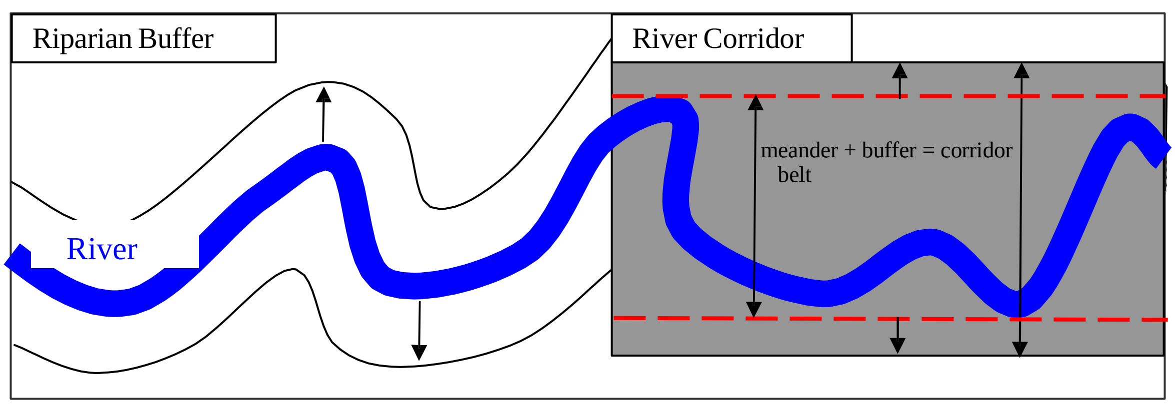


Figure 5. Comparing a buffer setback to a river corridor. Source: Adapted from Ohio DNR, Rainwater and Land Development Manual, 2006 Ed., Ch 2. Post Construction Stormwater Management Practices, p. 21

Although the basis for a corridor design is a meander belt integrated with buffer zones, the actual buffer vegetation is maintained along and parallel to the river (see cross hatched areas in Figure 5). The vegetated buffer area within the corridor may vary in width depending on the desired functions. River corridors are not designed with the expectation that rivers will always stay within them or that adjustments will occur and result in a perfect sine wave pattern which conforms to the calculated belt width. Rather, they provide an area within which channel adjustments may occur, equilibrium condition may become re-established, and there may be a reasonable expectation, as Leopold (1994) describes, for minimizing erosion and evenly distributing the energy of the stream.

If rivers in Vermont existed in a stable geometry and they did not move (i.e., flows were ever constant and sediments were stationary), the delineation of vegetated buffer zones on the existing river channel would also constitute a simple and sufficient development setback. But in fact, rivers are not static. Even stable streams, with access to meanders and floodplains, are dynamic, generally moving down valley during flood events through scour and deposition processes. Furthermore, survey and assessment of Vermont rivers have shown that they do not possess a stable geometry, many having been straightened, and most lacking access to floodplains during the more frequent annual floods. This altered geometry and subsequent evolution of river channels through intermediary forms, mean that the existing channels and meanders seen today do not necessarily indicate what amount of space or setback might be required in the future to achieve erosion hazard mitigation and stream equilibrium objectives (Figure 6).

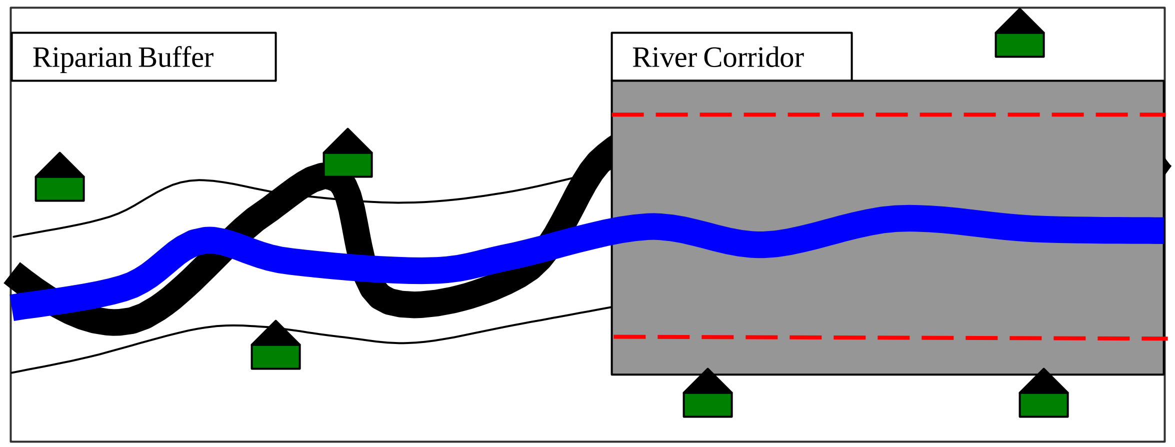


Figure 6. Typical straightened river shadowed by the equilibrium meander geometry to which it is likely to evolve (from Figure 5). The degree of conflict with encroachments (green/black houses) and future loss of buffer vegetation is illustrated, in consideration of the channel's evolution, in buffer setback and protected corridor scenarios.

The ANR River Management Program is using a Vermont Hydraulic Geometry Curve (Jaquith and Kline, 2006) and well documented empirical relations (Williams, 1986) to calculate the stable channel geometry and corridor widths for Vermont rivers that are in early stages of the channel evolution process.

Roughly one-third of Vermont stream and river miles are in low gradient valley settings, where the River Management Program is using the delineation process described above. These rivers seek a more gentle slope and are much more sensitive to the processes which lead to meandering. The higher gradient streams in the narrow and confined valleys of Vermont's mountainous terrain are not as sensitive. Even though many of these high gradient streams have also been channelized, they are more naturally straight, dissipating energy in the boulders and steps of their beds, and becoming stable in narrower meander beltways.

In the steeper valley settings, corridors that serve stable channel geometry functions, may be devised as top-of-bank-type setbacks. Using top-of-bank setbacks to accommodate meander belt and buffer functions and achieve ecological and erosion hazard objectives in the mountain streams is desirable from a programmatic standpoint. The top-of-bank setback is easy to determine and administer on the ground, i.e., by a municipal zoning administrator, and allows the ANR to focus limited assessment, design, and mapping capabilities on the more sensitive and altered streams within wider valley settings.

5.1 River Corridors and Floodplains

Floodplains are an essential component to a healthy river system. They are generally flat geologic features adjacent to rivers and streams, constructed of alluvial (river-deposited) material, separated from the channel by a stream bank, and subject to flooding. Floodplains function to provide:

- Natural flood storage, attenuating flood velocities and flood peaks, evenly distributing stream energy, maintaining stable equilibrium conditions, and thereby limiting property damage;
- Water quality benefits, by settling and storing sediments, nutrients, and other impurities;
- Groundwater recharge, maintaining stream base flows;
- Riparian (riverside) and aquatic habitat functions; and,
- Recreational opportunities.

Flood-prone land forms exist at different elevations relative to the river. Active floodplains are accessed by river flows during flood events that occur on an annual basis, such as those during spring run-off. Terrace features exist at higher elevations, being accessed by floods during only the largest storm events. Terraces are typically identified as abandoned floodplains, accessed by the river at a time when it flowed at a higher elevation in the landscape.

Floodplains and the meander belt-based river corridors, described above, overlap in the landscape. The non-channel portion of the river corridor is either active or abandoned floodplain. In wider valleys, flood-plains are typically wider than the meander belt width (see Figure 7). Both are worthy of protection for different though complementary objectives. The wider the floodplain, the greater the amount of flood storage function provided during storm events. Although the river corridor may provide flood storage when it consists of active floodplain, its fundamental intent is to provide the area a river needs to re-establish or maintain equilibrium conditions, specifically the meander (stream length) and slope requirements of a stable stream channel. The river corridor also represents land most vulnerable to erosion from flooding.

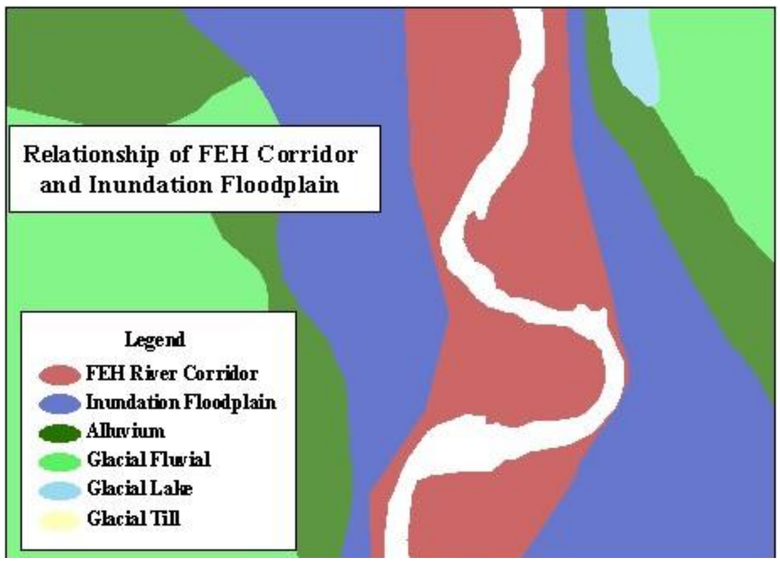


Figure 7. Showing the overlap of an FEH Corridor and the floodplain inundated by the 100 year flood.

5.1 Limitations of State and Federal Floodplain Protection Programs

State and federal law requires the mapping of floodplains. Federal incentives for local floodplain protection are provided through the National Flood Insurance Program (NFIP), which is a voluntary program intended to reduce federal expenditures pertaining to flood losses and disaster assistance. Communities participating in the program must adopt and enforce a floodplain management ordinance, enabling property owners in those communities the opportunity to purchase federally subsidized flood insurance protection (pursuant to 42 U.S.C. 4012(c), 4102(c)).

The Federal Emergency Management Agency (FEMA) publishes flood insurance maps used in the NFIP program to identify the location of floodplains. The maps are based on studies of historical river flows, rainfall, community knowledge, floodplain topographic surveys, and hydrologic and hydraulic data. An NFIP map identifies the "Special Flood Hazard Area" (SFHA), the area that has a one percent chance of being inundated by a flood in any given year (the one-percent annual flood; also commonly referred to as the base flood, or 100-year flood). These maps are used by communities to evaluate flood risk when reviewing development proposals in floodplains. They are also used by insurance companies to rate clients' flood insurance policies, and lending institutions use them to determine flood insurance requirements. More on floodplain management is at: www.watershedmanagement.vt.gov/rivers/htm/rv_floodhazard.htm.

Despite the increased and widespread participation in the NFIP program nationally and in Vermont, flood losses, damages, risk to public safety, and cost of recovery continue to escalate. Floods are responsible for more loss of life nationwide than all natural disasters combined. Vermont is no exception, suffering an average of $14 million in flood damages annually.

The escalating damages, risks, and costs are largely due to the limitations of the NFIP program and associated floodplain maps, which portray an incomplete picture of flood risk:

- The NFIP maps only focus on inundation (areas covered by rising waters);
- The NFIP maps do not focus on fluvial erosion, which in Vermont accounts for most of the damages associated with flooding;
- Many maps are outdated, and thus, do not reflect current flood inundation conditions. Although, map modernization efforts are critical, few floodplains are restudied due to limited federal funding. The detailed surveys and hydraulic calculations that go into mapping floodplains are very expensive and time consuming, often making it very difficult to keep pace with existing and future development pressure;
- The NFIP floodplain maps underestimate a community's true flood hazards and risks by assuming the river channel is static. The maps assume that the river channel has not adjusted vertically or laterally over time. Vermont ANR data indicate that 75% of river miles in the state are moderately to severely incised and disconnected from an active floodplain (Kline and Cahoon, 2008). NFIP maps that show little or no floodway or floodplain adjacent to alluvial channels (deemed safer to encroach upon), are highly suspect as being a snapshot of a deepened river that will eventually erode during floods to redevelop floodplains at a lower elevation (see Figure 8). The maps also do not take into consideration changes in hydrology, such as; increased stormwater runoff from urbanization which can result in channel enlargement; or channel adjustments from anticipated climatic changes over time;
- Not all streams in a participating community have been mapped. In fact, most of the flood-related damages in Vermont occur to property and infrastructure located in unmapped areas;

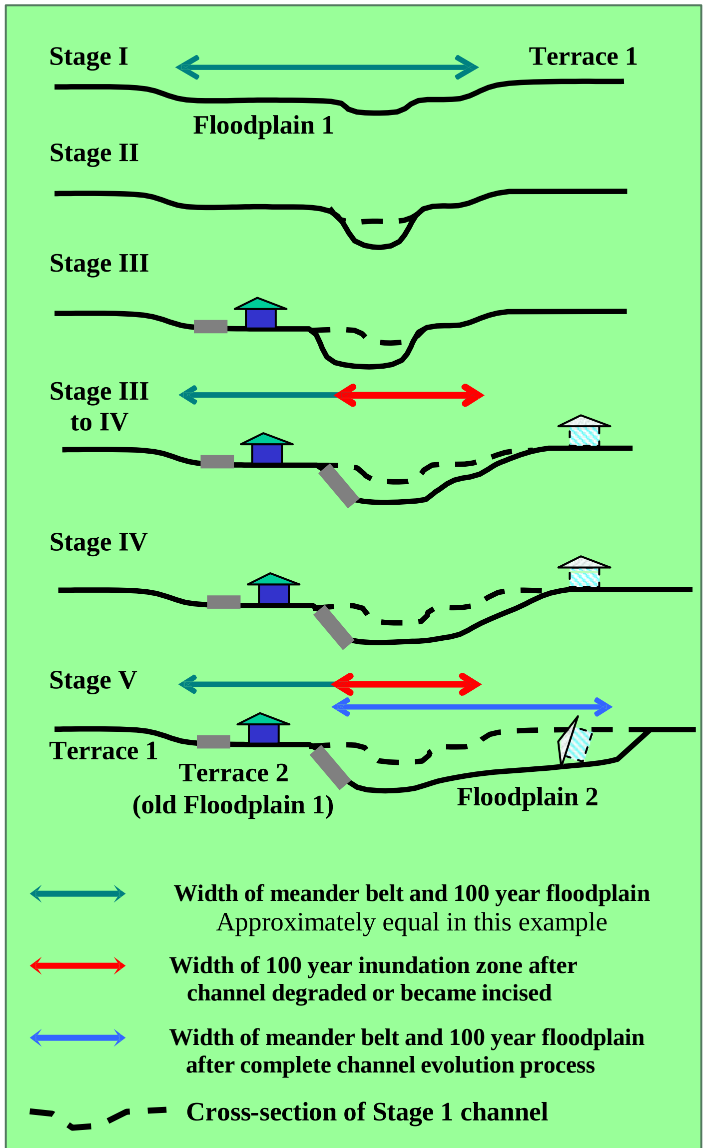


Figure 8. Showing the potential NFIP map deficiencies when the SFHA or inundation floodplain is developed for a deeply incised channel at the intermediary stages of the channel evolution process

- Many of the mapped floodplains in Vermont are determined by "approximate" methods, generally showing the location of special flood hazard areas. These floodplains lack elevation data, making it difficult for communities to evaluate the risks to existing development, and whether a proposed development will increase flood hazards;

- The NFIP minimum standards allow some fill and development in floodplains, and FEMA will even revise the map to show those structures as removed from the mapped floodplain, as long as the structures are placed on fill and elevated at or above base flood elevation (BFE; the water surface elevation associated with the one-percent annual flood.); and

- The NFIP minimum standards will even allow some fill and development in floodways – the part of the floodplain adjacent to the stream that must remain open to allow conveyance of the base flood – as long as an adequate hydraulic analysis is provided or the community meets the floodway revision requirements to demonstrate that the floodway can maintain conveyance of the base flood.

The channel evolution scenario depicted in figures 3 and 8 may be common in Vermont. The accuracy of flood inundation hazard mapping is dependent on when cross-section data is collected. Field studies to complete NFIP maps were largely conducted during the 1970s and 80s, during a period of what was probably the greatest channel degradation in Vermont. The channels, bank-to-bank, were more deeply entrenched in their valleys and disconnected from their recent floodplains. Therefore, the channels contained larger floods, and as a result, the NFIP maps depict narrower Special Flood Hazard Areas. Towns in Vermont working with these maps may unwittingly allow development adjacent to and outside these areas when, as shown in Figure 8, the evolution of the channel and new floodplain would seriously threaten these nearby structures.

Placing fill in floodplains causes significant long-term impacts, namely diminishing the property protection and ecosystem service functions described above. Communities concerned about how to best protect themselves from flood-related impacts need to adopt strategies that go beyond the NFIP minimum standards and protect floodplains as important community assets. Ideally, the flood hazard zones of the future will combine floodplain and river corridor delineations that identify both inundation and erosion-related hazards. Vermont ANR is working diligently toward that future by building the mapping tools, model ordinances, education materials, and technical assistance capabilities to support communities as part of an incentives-based program that will encourage local adoption of an avoidance approach.

5.2 Protecting the Ecological Processes of Floodplains and River Corridors

The Vermont ANR has also partnered with conservation organizations working to identify floodplains as important conservation targets. "Floodplains in particular have great biological productivity that is directly linked to the dynamic connectivity between river and floodplain (Smith et. al., 2008). Groups such as The Nature Conservancy (TNC) are identifying "Active River Areas," comprised of floodplains, wetlands, and river corridors, to protect important and unique habitat features and promote the ecological processes at work at the watershed scale (See TNC link: http://conserveonline.org/workspaces/freshwater/web/documents). "These active river areas serve as useful frameworks for developing comprehensive strategies for protecting, restoring, and managing rivers and riparian ecosystems."

6.1 Designing River Corridors

The Vermont River Management Program uses the following technical process for delineating meander belts and river corridors. This science-based methodology was designed with the usability of the final product in mind. River corridors should be science-based and, at the same time, reasonable for landowners, towns, and other partner organizations to administer. They should:

1. Capture the meander belt and the anticipated down-valley meander migrations and avulsions of an equilibrium channel; and,
2. Be readily surveyed for land titles and setback determinations.

In general appearance: *River corridors consist of two primarily straight lines which parallel a mid-valley line, and deviate from this course only to capture the cross valley turns and extended bendways of the current river channel.* After meeting the two criteria above, establishing a meander belt of the necessary width is more critical than the exact lateral location of the meander belt within the valley. River corridors drawn to follow every small inflection of the river will appear sinuous, and create unnecessary hardship for those managing the corridor. On the other hand, corridors that do not follow major cross-valley turns of the river may end up being much wider than necessary to accommodate the equilibrium channel and lose support as a land use zoning practice.

This Section first walks through the process for designing and mapping meander belts and buffers, and then provides the methods ANR uses to combine these areas as river corridors in different valley settings. Designing and mapping meander belts is based on stream geomorphic data collected using the Vermont Phase 1 and Phase 2 Stream Geomorphic Assessment Protocols (Kline et. al. 2007).

6.1 Phase 1 Corridors

The initial phase of geomorphic assessment involves collecting data from maps, aerial photographs, existing studies, and limited field investigations, in order to establish geomorphic reaches and expected or “reference” stream types based on geographic, geologic, and hydrologic factors. In addition, Phase 1 assessments predict expected stream conditions based on watershed and river corridor land use as well as channel and floodplain modifications. Phase 1 investigations identify areas with a high potential for fluvial adjustment and conflict, and help guide decisions about where to conduct Phase 2 assessments.

The first steps of a Phase 1 corridor delineation involve the establishment of a watershed project within a GIS extension developed by the Vermont ANR called the Stream Geomorphic Assessment Tool (SGAT). The reach end points are identified, and data layers used for river corridor development are created. Primary among these data layers are the watershed boundaries, the toe of each valley wall, and a meander centerline. Methods for the later two delineations are broadly described here, but more detail quality assurance protocols and illustrations are provided in the Technical Appendix. Verifying valley walls and meander centerlines also involves Phase 2 field assessments.

6.1.1 Defining the Toes of the Valley

For the purposes of Vermont’s river corridor protection initiatives, valley walls or side slopes represent the lateral extent to which the river will meander and are therefore used to delimit river meander belts. Polygon shape files showing the location of the toes of valley walls are one of the user-created inputs to SGAT and are also used by the extension to determine valley length and average valley width (used to calculate sinuosity and confinement).

The purpose of this guidance is to clarify both the intent and application of the valley wall shape file, and to provide guidelines that will help assessors develop the best possible valley wall shape files. In many of Vermont’s narrower valleys, valley walls often define one or even *both* sides of the meander belt.

Soils maps and data are used in conjunction with topographic maps to determine the location of the toe of the right and left valley walls. Generally, the toe of a valley wall can be identified by looking for the break in slope as the steeper valley wall turns into the gentle sloped valley floor. Soils data help with identifying changes in slope and include other soil characteristics that may indicate the need to adjust a valley wall line one way or the other (see Figure 9). Lines are drawn starting at the mouth of the main stem and tributaries, and continue along the right and left valley wall toes to an upstream point where distinguishing between the valley toes and the stream line becomes too difficult (in confined valleys). Additional valley wall delineation tips and rules of thumb are offered in the Appendix.

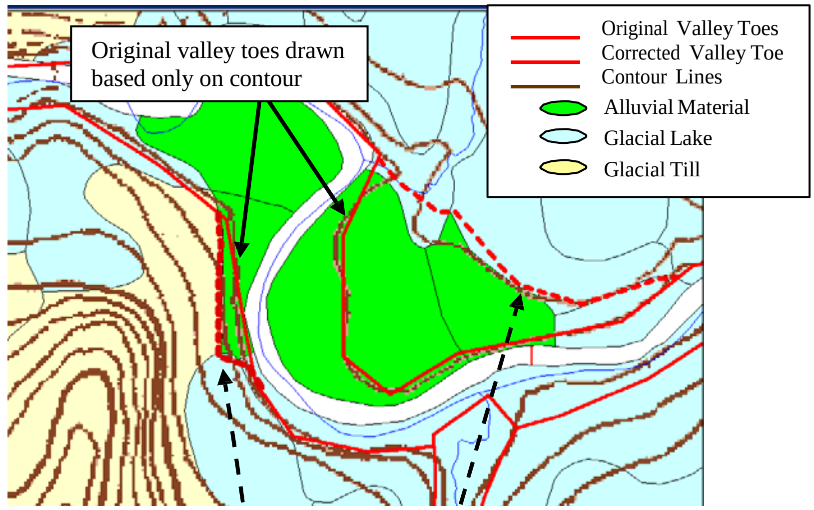


Figure 9. Corrected valley toe based on soils map, showing alluvial material beyond change in slope contours.

Phase 1 assessments include a windshield survey using an orthophoto-based map with the initial valley wall shape file, during which the location of the valley wall should be verified where ever possible. If the valley wall location differs from the original delineation, the true location is noted on the field map and later changed in the SGAT project files. If available, an accurate GPS unit is used to capture locations of the valley wall toes.

6.1.2 Defining the Meander Centerline

The Meander Centerline (MCL) is a line connecting meander crossovers between meander bends. The MCL is created on reaches where the stream has an opportunity to meander, i.e., primarily where there is alluvium, and mostly, but not always, along unconfined reaches. The mathematical analog of a meander crossover is a "point of inflection," or the point where a curve changes from concave to convex (Figure 10). Imagine driving a car down a curving stream, the meander crossovers are the points where the steering wheel is momentarily straight, being turned from left to right or vice versa.

The MCL is used in Phase 1, primarily to calculate sinuosity, estimate meander wavelengths for a given reach, and determine the extent to which a channel has been straightened. The MCL is also used in developing meander belts and river corridors. Similar to valley toes, the MCL is initially drawn in Phase 1 and modified during the Phase 2 assessments or for different applications (e.g., fluvial erosion hazard corridors). The Technical Appendix contains very detailed guidance for creating and modifying meander centerlines.

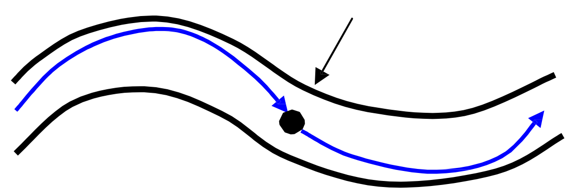


Figure 10. Meander cross-over point.

Digitizing the MCL in SGAT is completed using the stream layer from the 1: 5000 Vermont Hydrography Dataset (VHD), as may be verified on the most recent ortho photographs. The stream lines on topographic maps are not used as they are much less accurate. A polyline shape file is created with vertices (or nodes) placed at each meander crossover. Straight or straighten reaches of the river present the greatest challenge in drawing meander centerlines. A stable alluvial channel in equilibrium should exhibit a cross-over point at a distance along the channel length of approximately 7-10 channel widths. Where there are no discernible equilibrium-scaled meanders, and the channel was historically straightened back and forth across the valley, placing nodes only at the un-natural inflections would result in a computer generated meander belt that is laterally over-extended, capturing both mid-valley and valley toe locations (Figure 11a). In these cases, cross over points should be placed along the stream line at an interval of 7-10 channel widths.

Similarly, where a previously straightened channel has begun to meander, but none of the bendways have developed to a scale consistent with an equilibrium length and radius, the MCL should not be built with vertices at every "micro" inflection, thereby resulting in a highly sinuous meander belt. In these cases, some nodes are eliminated to help achieve a straighter river corridor that will not only accommodate the equilibrium channel but represent a land use zone that is much easier to administrate (Figure 11b).

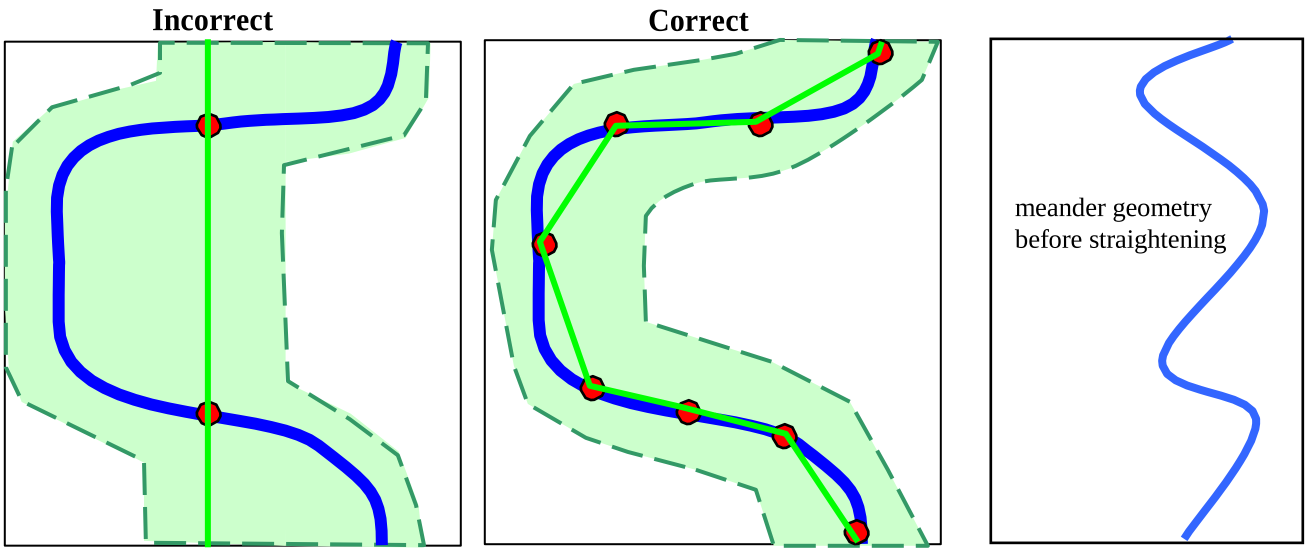


Figure 11a. Channel straightened back and forth across the valley, comparing the placement of nodes at un-natural inflections (left) versus along the channel every 7-10 channel widths (right). At the Phase 1 stage of development, the corridor following the river across the valley (right) is preferable to the laterally over-extended corridor (left). The corridor on the left is extra wide because SGAT combines a polygon centered on the MCL with one centered on the channel.

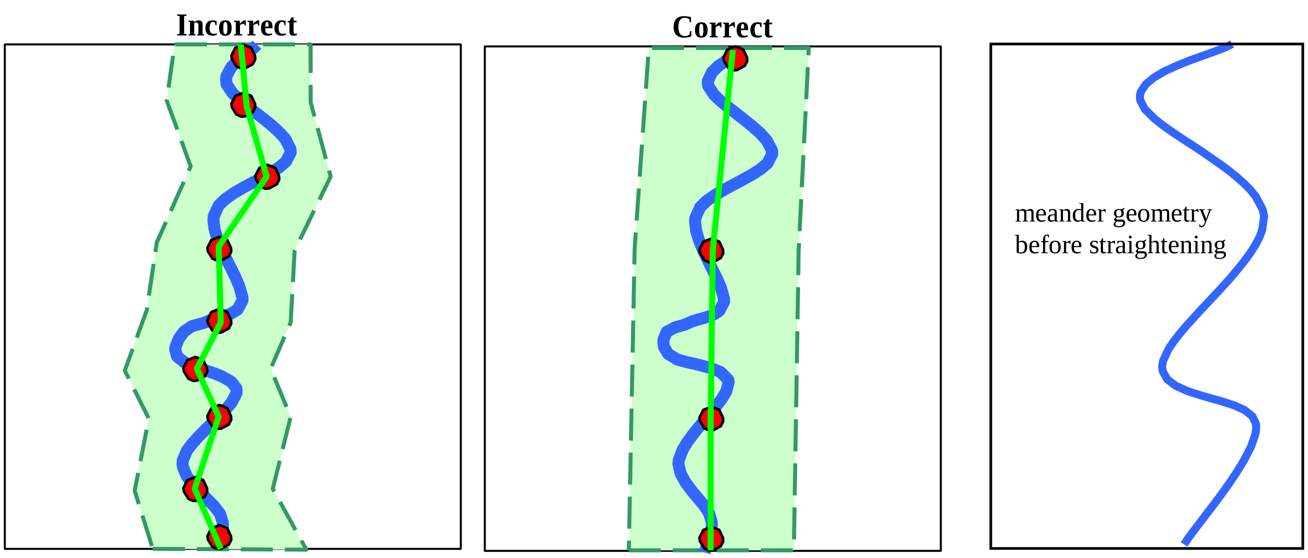


Figure 11b. Historically straightened channel that has begun to re-meander, comparing the placement of nodes at every micro inflection (left) versus being placed at periodic inflections along the channel (right) so that SGAT draws a straighter corridor.

Finally, in confined valleys, where streams are more naturally straight and meanders are not readily interpreted from maps, there is no need to draw a meander centerline. During the Phase 1 delineation process, meander belts and corridors in confined valley settings are created using default setbacks from the stream line.

6.1.3**Phase 1 River Corridors**

River corridors are first drawn in the SGAT program once geomorphic reaches and their watershed boundaries have been defined, and the valley toe polygons and meander centerlines are finished. Phase 1 is a remote sensing exercise, therefore corridors are delineated to include space for meander belt and buffer functions and defined by lines either side of and parallel to the:

- Meander centerline (where drawn) in unconfined settings at a distance equal to 4 channel widths, for total corridor width equal to 8 channel widths; and the
- Stream line (where MCLs are not drawn) in confined settings at a distance of 100 feet or 2.5 channel widths (which ever is greater), for a total corridor width equal to 200+ feet.

In both settings, the vegetated buffer allowance in the corridor is minimally set, for the purposes of bank and temperature stabilization, at a distance equal to one channel width on either side of the corridor.

The corridors for confined streams in mountainous-settings are conservative in the sense that they will, in most cases, occupy the entire valley floor and extend a certain distance up the valley walls. Many of these corridors will become more narrow in the Phase 2 process, but in Phase 1 they suffice to define an area for assessing physical stressors and accommodating the geometry and vegetated buffer needs of a stable equilibrium channel. Phase 1 corridors may be used in some applications where the conservatism is desired by all parties, but in land use regulatory applications, the River Management Program typically uses the field-verified corridors devised in Phase 2.

In unconfined settings, valley toes have been drafted and are used to further define and/or limit the river corridor. When rivers flow along, or were straightened against, the toe of the valley, a portion of the initial corridor centered on the MCL will extend outside the valley floor. Since it would make little sense to conserve an area on the valley side-slope for the river to meander, a process is used to shift and provide for the full corridor on the valley floor, away from the toe of the valley. This is accomplished by delineating an area 8X channel width offset from the valley toe toward the center of the valley. The just drawn valley toe-based polygon is concatenated with the initial MCL-based corridor and the combined area is clipped at the valley toes (Figure 12). In this way, the entire corridor, meander belt and buffer, lies between the toes of the valley floor. River corridors are less than 8X channel width only when the valley floor itself is narrower than 8X channel width.

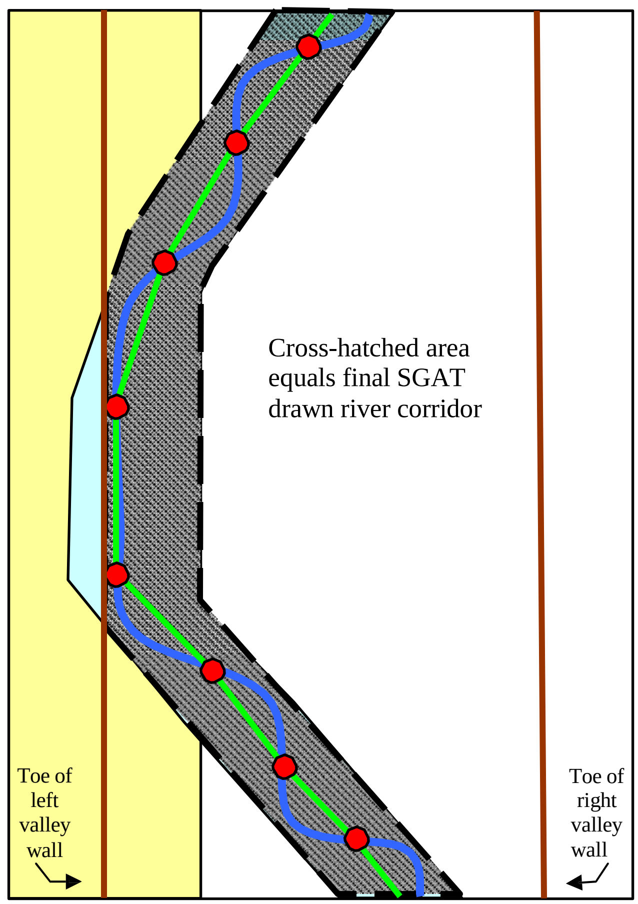


Figure 12. The SGAT drawn corridor (shown as a cross-hatched area) created by combining an area produced by buffering the MCL (blue polygon) with an area produced by buffering the valley wall line (yellow polygon), and clipped at the left valley wall (brown line). The resulting corridor provides 8 channel widths of meandering space on the valley floor.

6.2 Phase 2 Corridors

Phase 2 stream geomorphic assessments involve the collection of detailed field data pertaining to channel and floodplain characteristics, equilibrium departures, ongoing channel adjustments, as well as riparian land use and habitat. The Phase 2 assessment allows heterogeneous reaches to be further subdivided into segments, which exhibit different conditions or types of departure from the reference condition. Phase 2 data is entered into ANR's web-based Data Management System (DMS), and undergoes a thorough quality assurance/quality control process. Phase 2 corridors are primarily a refinement of the Phase 1 river corridor. The Phase 2 corridor delineation process includes a much more considered evaluation of river sensitivity to scale meander belt widths; verifying valley walls and meander centerlines; and extending meander belt and vegetated buffer prescriptions to achieve other water quality, flood hazard, and habitat objectives.

6.2.1 **Stream Sensitivity Refinements**

Phase 2 assigns a stream sensitivity rating to each reach or segment of a stream. Table 1 shows how stream sensitivity ratings are assigned based on existing stream type and geomorphic condition.

Table 1. Vermont ANR Stream Sensitivity Ratings based on geomorphic stream type and condition.

Stream Type Group	Existing Geomorphic Stream Type[1]	Sensitivity		
		Reference or Good Condition	Fair-Poor Condition in Major Adjustment	Poor Condition, Represents a Stream Type Departure
1	A1, A2, B1, B2	Very Low	Very Low	Low
2	C1, C2	Very Low	Low	Moderate
3	G1, G2	Low	Moderate	High
4	F1, F2	Low	Moderate	High
5	B3, B4, B5	Moderate	High	High
6	B3c, C3, E3	Moderate	High	High
7	C4, C5, B4c, B5c	High	Very High	Very High
8	A3, A4, A5, G3, F3	High	Very High	Extreme
9	G4, G5, F4, F5	Very High	Very High	Extreme
10	D3, D4, D5	Extreme	Extreme	Extreme
11	C6, E4, E5, E6	High	Extreme	Extreme

The Vermont ANR stream sensitivity ratings are based on the findings of numerous researchers (Lane, 1955; Schumm, 1977; Leopold and Maddock, 1953; Rosgen, 1996; Montgomery and Buffington, 1997; Thorne et al., 1997; Knighton, 1998; Center for Watershed Protection *et. al.* 1999; MacBroom, 1998; Lane, 1995; Simon and Thorne, 1996) and include consideration of the:

Inherent sensitivity of the geomorphic stream type as dictated by the:

- Channel and floodplain geometry in relation to flow and sediment regimes;
- Bed and bank material erodibility, bank stratigraphy, and presence of alluvial fans;
- Occurrence and influence of colluvial and mass failure processes;
- Riparian vegetation; and,

The likelihood of major vertical and lateral channel adjustments in response to:

- Changes in flow (flood history, direct human manipulation of flow, and/or alteration of watershed hydrology);
- Changes in sediment supply;
- Channel modification (e.g., channel straightening, armoring, and/or berming); and,
- Valley constrictions and floodplain modifications.

[1] Geomorphic stream types from the Rosgen (1994) Classification System.

Stream types are generally ordered by sensitivity in Table 1 (from Very Low to Extreme) and by stream type groups (1-11), which maintains information about valley setting. Stream sensitivity ratings reflect both the inherent stability of the existing geomorphic stream type and the likelihood of major channel adjustment in response to various stressors (changes in flow, sediment supply, or channel modification). Sensitivity ratings are being used to create the more graduated set of meander belt width prescriptions laid out in Table 2. Streams with Very Low and Low sensitivity are generally steep, confined streams, with very erosion-resistant bed and banks (bedrock or boulders). These streams are exceptionally stable (unlikely to migrate laterally), so they will have very narrow meander belt widths. In contrast, streams with Very High or Extreme sensitivity are very dynamic and prone to rapid lateral migration, either because they are inherently unstable, or are undergoing major adjustment processes that lead to instability. These streams will have a wider meander belt (6 channel widths or more), allowing sufficient space for a stream to adjust toward or maintain dynamic equilibrium. In some cases the morphology and fluvial processes of the stream have been so altered from the reference equilibrium (represented as a stream type departure), that an even greater sensitivity is prescribed.

As stated above, Williams (1986) found a statistically significant relationship between meander belt width and channel width, translating to a meander belt width approximately equal to six (6) times the width of the stream channel ($W_{mb} = 6 \times W_{bkf}$). The width of the bankfull channel (W_{bkf}), in many cases, must be calculated in Vermont due to the highly altered physical condition of the stream. Hydraulic Geometry Curves (Jaquith and Kline, 2006), statistically relating channel dimensions to watershed size, are used to calculate channel widths and subsequently meander belt widths. Ward et al. (2002) found that belt widths of at least eight (8) channel widths are adequate to allow streams the room to re-establish and maintain equilibrium conditions in the generally low gradient, fine sediment, high stream sensitivity environments measured in the state of Ohio. Vermont ANR is using these studies, collecting field data and validating belt width ranges to continually align this guidance and its meander belt prescriptions with evidence of site specific and regional geologic and climatic conditions. Stream sensitivity may also be re-evaluated where long-term stressors, such as urban land use change and hydrologic modification, tend to shift equilibrium channel geometry out of the predicted range that would otherwise apply to the observed stream and valley conditions.

Table 2. Meander Belt Widths based on Stream Sensitivity

Sensitivity	Meander Belt Widths based on reference channel widths
Very Low (VL)	**Equal to reference channel width**
Low (LW)	**Two (2) channel width**
Moderate (MD)	**Four (4) channel widths**
High (HI)	**+ Six (6) channel widths + Eight (8) channel widths – E streams**
Very High (VH)	**Six (6) channel widths Eight (8)+ channel widths – E streams**
Extreme (EX)	**Six (6) channel widths Eight (8)+ channel widths - D & E streams**

6.2.2 <u>**Mapping Refinements**</u>

The ANR River Management Program, in consultation with field assessors, reviews the river corridor to determine if adjustments to the draft map are necessary. Refinements of the corridor include two different methods:

1. SGAT redrawing of the corridor based on revisions to meander centerline and valley wall shape files. Orthophoto analysis and field visits are necessary to verify the toe of valley wall location. The revised shape files are then used to redraw the river corridor using SGAT
2. Manual redrawing of the corridor when field, map, or remote sensing data indicates that a wider or narrower corridor is warranted. Documentation and technical justification is a part of any manual redrawing.

6.2.2.1 Valley Walls

As mentioned above, the Phase 1 valley walls may be coarse determinations of the river corridor boundaries, which are typically based on contour lines from USGS maps. Therefore, valley walls must be verified as a prerequisite for finalizing maps used in conservation projects and land use regulation.

Verifying valley walls typically means walking along both sides of the stream, and is ideally completed during the Phase 2 assessment of targeted segments and reaches. Field visits are also an opportunity to talk with landowners and local officials about the flood history of a river. Local knowledge is often very helpful in determining a stream's sensitivity to erosion during flood.

Natural Features

While identifying valley walls is generally a simple task, it may be complicated by the presence of features, both manmade and natural, which act as confining features. For instance, as a result of Vermont's glaciated past, valleys contain abundant terraces of both glacial and fluvial origin. Making a decision as to whether a terrace is a confining feature for a stream, is one of the more difficult technical decisions in the corridor delineation process. One must decide whether a terrace is presently, or will be in the future, a land form that governs or impedes the lateral migration of the stream channel.

In general, most high (greater than 20 ft. high) glacial terraces, comprised of dense tills, and cohesive, glacio-lacustrine deposits are quite resistant to fluvial erosion. These terraces act as semi-confining features, and, for the purpose of corridor delineation, should be mapped as valley walls. On the other end of the spectrum, large terraces made up of un-cohesive glacio-fluvial materials are often very erodible and do not act as confining features. Thus, time scale is an important factor in deciding whether a landform is going to confine a stream. In geologic time scales, few features would be truly "confining" to a river. However, current river corridor management applications are concerned with human time scales (several decades to a hundred years), and this should be the time scale of concern when mapping valley walls.

The Vermont Geological Survey maps terrace features of glacial-origin that are susceptible to landslide. They have determined that a common mode of slope failure in high terraces is the fluvial erosion occurring at the toe of these high features. So, while it makes sense to map landslide hazard areas in tandem with a fluvial erosion hazard corridor, this procedure does not address the technical aspects related to slope failures and should not be used to determine the extent of landslide hazard areas. Often, when a mass failure occurs, the area inundated with slide material becomes unavailable to the stream as a place to meander, adjust its slope, and achieve equilibrium conditions. For some period following a landslide, the river is often pushed in the opposite direction by the accumulated slide material.

Smaller alluvial terraces that are actually abandoned floodplains are mapped as part of the valley floor. While these features can be fairly large in deeply incised streams (i.e.,, where the old floodplain is now nearly 20' above the present day channel bed), such features can easily be eroded, and do not confine the lateral migration of a river.

Manmade Features

Significant human-constructed features, such as engineered levees and major road and railroad embankments placed on fill, are treated as confining features to lateral stream migration and are mapped as valley walls. Such structures are particularly confining along smaller streams. Even if a highway or railroad does not sit on a levee, all major public infrastructure are considered valley walls. This approach recognizes that the administrative entity overseeing the maintenance of the major infrastructure will have the need and capacity to do so for the foreseeable future.

Smaller roads and other manmade and non-engineered structures, such as berms and floodwalls, are not typically mapped as valley walls. Past experience shows that such structures are prone to failure due to fluvial erosion during large floods, often with catastrophic results. They are rarely confining features, and communities are faced with the decision as to whether to move or replace such features when they become damaged. The Agency will work with communities to evaluate the status of local roads and infrastructure during the corridor delineation process (see Municipal Guide, Dolan and Kline, 2008).

6.2.2.2 Meander Centerlines

The shape file representing the meander centerline in a Phase 1 assessment may also need to be modified on the basis of field observations to better ensure the corridor completely captures the stream channel. The river corridor must contain the stream line and be as straight as possible. The MCL will not be accurate if the mapped stream line is incorrect. While in the field, an assessor is verifying the location of the stream channel relative to other landforms. Actively adjusting streams may have moved tens of feet, cut off meanders, or avulsed to entirely new locations since the Vermont Hydrography Dataset or aerial photographs were developed.

The observed condition of the stream is also factored into verifying Phase 1 decisions on how and where the stream was straightened, and whether the meander geometry of the channel is at or near equilibrium. Cross over points and vertices of the MCL may be moved, added, or subtracted accordingly. Adjusting the MCL, if appropriate, may help later to reduce the number of modifications to the river corridor

A key Phase 2 exercise is adding meander centerlines and valley walls along segments and reaches in alluvial settings thought to be confined by their valleys during the previous map work. Small to medium-sized mountain streams usually look confined on a topographic map. It is common to encounter areas where these streams are not so confined and actually meander in a significant pocket of alluvium. Especially critical are the transition reaches, those where the stream leaves a narrow to enter a broader valley setting. It is here where the Phase 1 assessor had to make a decision as to where they would end the valley wall and MCL delineation process. The field assessor has the opportunity to more accurately demark these features.

6.2.2.3 Active River Features

When a river is at flood stage, it will either stay within a single channel, as with incised or entrenched streams, or it will spill into a floodplain. When a river comes over its banks, the flood water will generally flow down-valley within the meander belt area. There may be areas outside the meander belt that become inundated with flood water, but the more erosive flowage will be between the bendways. It is the exceptions to this general rule, that the field assessor is looking for.

The Phase 1 drawn corridor placed with digital contour lines on a 1:5000 orthophoto is used with other map products, e.g., the wetland inventory maps, to help identify features such as flood chutes, oxbow wetlands, and abandoned or braided channels that could become available to the stream at flood stage. Also of concern are existing man-made ponds or gravel pits in floodplains that could become captured by the stream during a future flood event. These features are mapped in the field and later evaluated for inclusion in the river corridor.

6.2.3**Phase 2 River Corridors**

Once a Phase 2 Stream Geomorphic Assessment is completed (i.e., the data are entered in the web-based data management system and quality assured), draft meander belts and river corridors can be produced using the Stream Geomorphic Assessment Tool (SGAT). SGAT is a GIS extension which automates the drawing of corridors. Field verified revisions to the valley walls and meander centerlines are made, and these reference shapefiles are used, as in the Phase 1 process, to create meander belts; this time based on Phase 2 sensitivity ratings (Table 2). Modifications to the meander belt to capture active river features are also made within the SGAT project. The details of this process and its documentation requirements are described in the Technical Appendix.

6.2.3.1 *Buffer Allowances*

Rivers with existing meander amplitudes far less than the calculated meander belt width (i.e., they were straightened) are perceived as one day evolving to the full extent of the meander belt (Figure 3). If the corridor were no wider than the meander belt, and encroachment went to the corridor's edge, there would be no space for the critical functions of the vegetated buffer (Figure 6). The SGAT extension, can be used to design a river corridor with an allowance for a buffer when the river reaches equilibrium. The buffer can be scaled to the river by adding an additional channel width to each side of the meander belt, as in the Phase 1 mapping process; or tailored by adding some other specified setback to the meander belt in the SGAT program. A channel width-based buffer may be adequate to support the woody vegetation necessary to achieve bank stability, stream shading, and some aquatic and riparian habitat functions; but may be inadequate to achieve the full set of water quality and habitat objectives described in the Agency Buffer Procedure (2006).

6.2.3.2 *Corridors for Small Streams*

This chapter of the guide and the technical appendix lay out a very detailed process for developing belt width-based river corridors. Agency programs and their respective policies for applying the science are discussed in later chapters. This Section, on designing corridors for small streams, bridges the Agency's use of science and its policies for running efficient and effective programs.

The Vermont Hydrography Dataset (VHD) shows 23,006 miles of streams in Vermont. The detailed Phase 2 assessment and verification process described above, would take the ANR River Management Program decades to complete on all streams in the State. Therefore, the Agency had to look for areas to increase efficiency and established priorities for developing meander belt-based corridors, while, at the same time provide a simpler corridor delineation process that largely accomplishes it's resource objectives.

A solution was found in the development of corridors for small streams. An analysis of the VHD showed that approximately two-thirds of Vermont stream miles are in narrow to confined valleys with slopes in access of two percent (2%), with nearly two-thirds of these streams having watersheds at or less than two square miles. While these numbers vary in different parts of the State, the majority of stream miles are in steep mountainous areas. Within the narrow to confined valley setting, the stream line and meander centerline converge, and the meander belts are more naturally straight. Therefore, great efficiency can be gained by using the stream line and establishing setbacks to accomplish the corridor needs of small streams.

Table 3 gives the default values for small stream setbacks. They are conservative, in that for most instances when applied, a corridor is created where the space for an equilibrium channel geometry of a moderately sensitive stream will be set aside (see Tables 1 and 2) . They also assume that the stream has been straightened against the toe of they valley and that the needed space for the evolution of meanders and a buffer must be attained on one side or the other (Figure 13).

Table 3: Guidance for Developing Corridors Based on Watershed Size

Watershed	Valley Slope	Minimum Setback Width	Setback Measured From:
≤ 2 sq. miles	Any	50'	top of bank
> 2 sq. miles	≥ 2 %	100'	top of bank
> 2 sq. miles	< 2 %	one half meander belt width plus buffer width	meander centerline

Table 3 also shows a default setback for small streams (watershed ≤ 2 square miles) in gentle gradient settings (< 2 %). This is not ideal, as these streams will meander, but given the small stream size, the 50 foot setback from the top of the bank will, in most cases, cover the horizontal distance of the meander belt and buffer requirements of a highly sensitive stream type. The small to moderate risk of the corridor not capturing all down-valley meander migrations is weighed against the great gain that is accomplished in being able, programmatically, to offer town-wide map coverage for river corridors that include the many small low-land streams for which Phase 2 assessments have yet to be completed.

These default setbacks are scientifically valid in providing for the corridor functions and meander belts of small streams. They suggest top of bank setbacks for the sake of efficiency, and with acknowledgement that towns and the State may have and desire the use of data to create Phase 2-defined corridors for any stream or set of streams. A development proposal for a site-specific encroachment (e.g., in an Act 250 review) may warrant a Phase 2 analysis and corridor delineation under the auspices of the ANR Floodway Procedure. Another example may be town plans and zoning that utilize default small stream setbacks with the objective of finding the resources over time to complete more detailed corridor planning and delineation for these reaches.

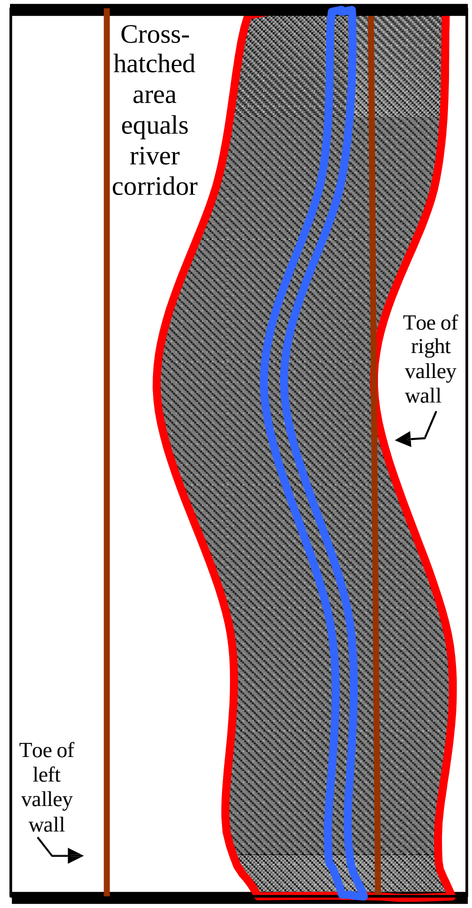


Figure 13. Small stream setback serving river corridor functions in narrow valley.

7.0 River Corridors in Watershed Planning and Management Applications

This Section of the River Corridor Protection Guide briefly describes some of the Vermont programs actively protecting and restoring river corridors. Look for specific mention of how and why the corridor concepts and delineations laid out in previous sections are being tailored to individual applications.

7.1 River Corridor Planning

Defining river corridors is essential to the development and implementation of Vermont ANR-sponsored river corridor plans. Such plans include an analysis of fluvial geomorphic conditions; the physical stressors and constraints affecting the attainment of stream equilibrium; a process for selecting and implementing river corridor management alternatives; and a basis for corridor protection through various land use planning and incentives programs. Vermont ANR has drafted a River Corridor Planning Guide (Kline et al., 2007) which offers step-wise procedures for analyzing geomorphic and physical habitat data, and identifying practices such as:

- protecting river corridors;
- planting stream buffers;
- stabilizing stream banks;
- arresting head cuts and nick points;
- removing berms and other constraints to flood and sediment load attenuation;
- removing/replacing/retrofitting structures (e.g. undersized culverts, constrictions, low dams);
- restoring incised reaches; and
- restoring aggraded reaches.

The State of Vermont utilizes the river corridor planning process to identify "key attenuation assets." Attenuation areas are based on the river corridor delineation laid out in this Guide and include riparian floodplains, wetlands, and vegetation, connected to geomorphically sensitive streams, that store flood flows and sediments and reduce the transport of organic material and nutrients from the watershed. Focusing the limited conservation dollar on the protection of key attenuation assets, and the ecological processes they provide, is a critical component of our watershed and corridor plans to reduce flood and fluvial erosion hazards and provide for water quality and habitat improvement.

Vermont ANR incorporates river corridor plans into the watershed (or basin) plans developed by regional, state, and federal agencies. River corridor plans define flood hazard zones or overlay districts thereby supporting implementation of town pre-disaster mitigation plans. Plans "adopted" as part of a public process become a practical, science-based planning tool for directing the use of public funds to reduce fluvial erosion hazards.

River corridor plans, while setting objectives for managing toward a geomorphically-stable river and reducing fluvial erosion hazards, also recognize that nearly all landowners have made some investment in their lands along a river. Technical and social feasibility of river projects are explored in the plans by examining a range of restoration and protection alternatives and a process for resolving conflicts.

Implementing river corridor plans will require a long-term commitment to reducing fluvial erosion hazards and restoring the natural and recreational values of rivers, while respecting traditional settlement patterns and the importance of a prosperous agriculture in Vermont. From one decade to the next, opportunities arise to work with landowners in a cooperative fashion, increasingly if not gradually giving the river more space to achieve equilibrium. Without a corridor plan, encroachments will continue, compounding the cost of flood recovery, and necessitating river management that is both economically and ecologically unsustainable.

7.2 *Fluvial Erosion Hazard (FEH) Program*

Vermont ANR provides communities with technical assistance as they consider adopting a Fluvial Erosion Hazard Area District as an enhanced flood hazard bylaw or as an overlay into their zoning ordinances. Adopting such an avoidance strategy is one of the primary ways a community may overcome the shortcomings of the NFIP program, prevent the squandering of remaining floodplains, and realize the full suite of economic, social, and ecological functions and values of river corridors and floodplains. Such steps will serve to adequately protect public safety and minimize flood damages and property losses by avoiding new development in inundation and erosion hazard areas. Vermont ANR's Model Flood Hazard Regulations, can be found at the ANR website: http://www.watershedmanagement.vt.gov/rivers.htm.

To address erosion hazards, Vermont ANR has established this guidance and a Municipal Guide to Fluvial Erosion Hazard Mitigation (Dolan and Kline, 2008) based on the delineation of the fluvial geomorphic-based meander belts and river corridors described above. The State uses both FEH areas and FEMA National Flood Insurance Program (NFIP) flood hazard area maps in defining floodways in State Act 250 development reviews where state land use jurisdiction is triggered.

Vermont ANR recommends that municipalities consider the full river corridor, in adopting Fluvial Erosion Hazard (FEH) Areas. However, an FEH Area based on the meander belt will be fully supported and eligible for any municipal hazard mitigation incentives.

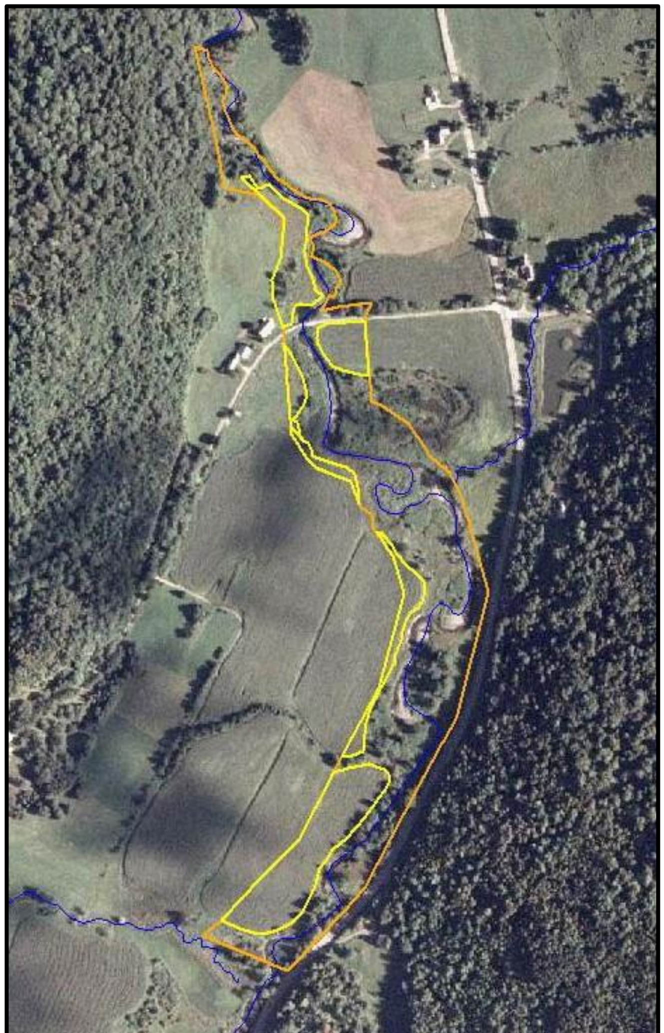
Maps with FEH areas and small stream setback recommendations are provided to Vermont municipalities as part of the FEMA sponsored pre-disaster mitigation planning program. Vermont ANR has established a Fluvial Erosion Hazard Coordinator to assist Vermont communities in mapping fluvial erosion hazards as part of municipal flood hazard zoning districts. Project reviews and map revisions are conducted in a manner similar to that provided through FEMA's Community Assistance Program.

7.3 *River Corridor Conservation Program*

A River Corridor Easement Program has been established in Vermont to conserve river reaches identified as high priority attenuation areas in Vermont's river corridor planning process. The opportunity to purchase and sell river corridor easements was created to augment the state and municipal fluvial erosion hazard zoning which, if adopted, avoids future encroachment and flood damage, but does not restrict channelization practices. A landowner may not be able to build near the river where an FEH overlay district is in place, but would still be free, with permits in hand, to dredge and armor the channel. The societally-ingrained notion to stop all erosion, even where few investments are at risk, may limit the channel evolution process and slow the attainment of equilibrium conditions. The key provision of a river corridor easement is the purchase of channel management rights (Kline, 2008).

The purpose of the river corridor easement is to allow the river to re-establish a natural slope, meander pattern, and access to floodplains in order to provide flood inundation and fluvial erosion hazard mitigation benefits; improve water quality through hydrologic, sediment and nutrient attenuation; and protect riparian habitats and the natural processes which form them. The easements gives the holder, or grantee, the right and opportunity within the corridor to establish a naturally vegetated, floating buffer measured from the river banks as they may move. The landowner may continue to conduct activities such as agriculture and timber harvesting within the river corridor, but is restricted from placing, repairing, modifying structural elements such as bank revetments, levees, or earthen fills. Within the corridor, the easement ensures that watercourses and wetlands are not manipulated so as to alter the natural water level or flow, or intervene in the natural physical adjustment of the water bodies.

The River Management Program has established a corridor appraisal calculator, based on soils, land use, and river sensitivity, that creates an incentive for the landowner, especially the farmer who may be experiencing the inevitable loss of otherwise productive land. The Program works closely with state and federal farm service agencies to combine corridor easements with farm enrollment in programs, such as the Conservation Reserve Enhancement Program (CREP), used to contractually take buffer lands out of production. In Vermont, CREP contracts may be made to reestablish grass and woody buffers for the entire meander belt area of highly unstable and sensitive streams (see Figure 14). This represent a unique opportunity to further assist the farmer with production losses on lands frequently flooded or eroded, and avoids the traditional practice of armoring the unstable river in order to establish and protect the public's investment in a much narrower buffer.



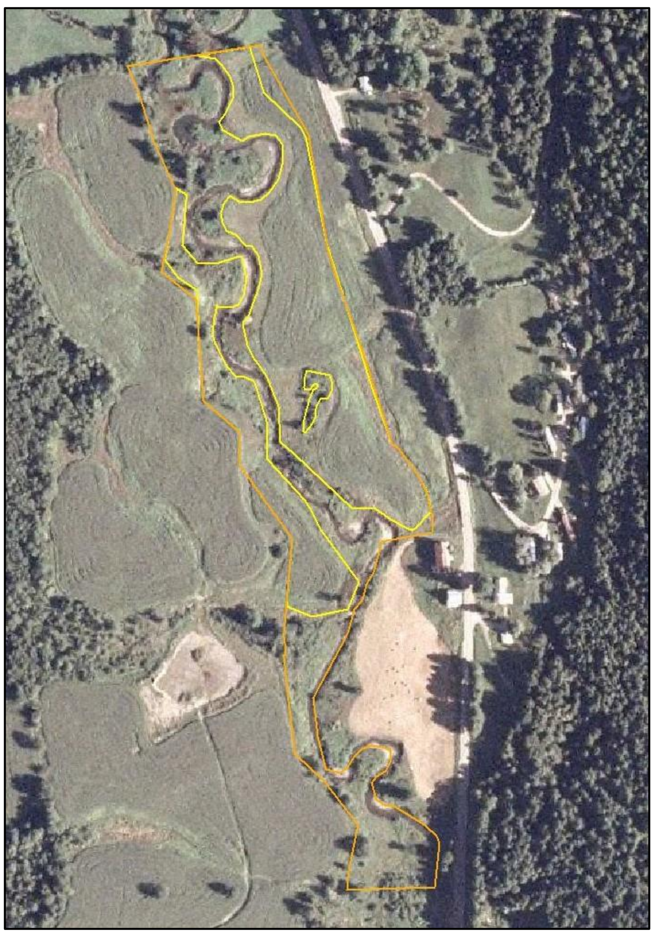


Figure 14. River Corridor Easements on the Ayers Brook in Randolph, VT (above and left). Protected meander belt (orange outlines) within which acres were enrolled in CREP (yellow outlines). Photo of Ayers Brook corridor below.

8.0 References

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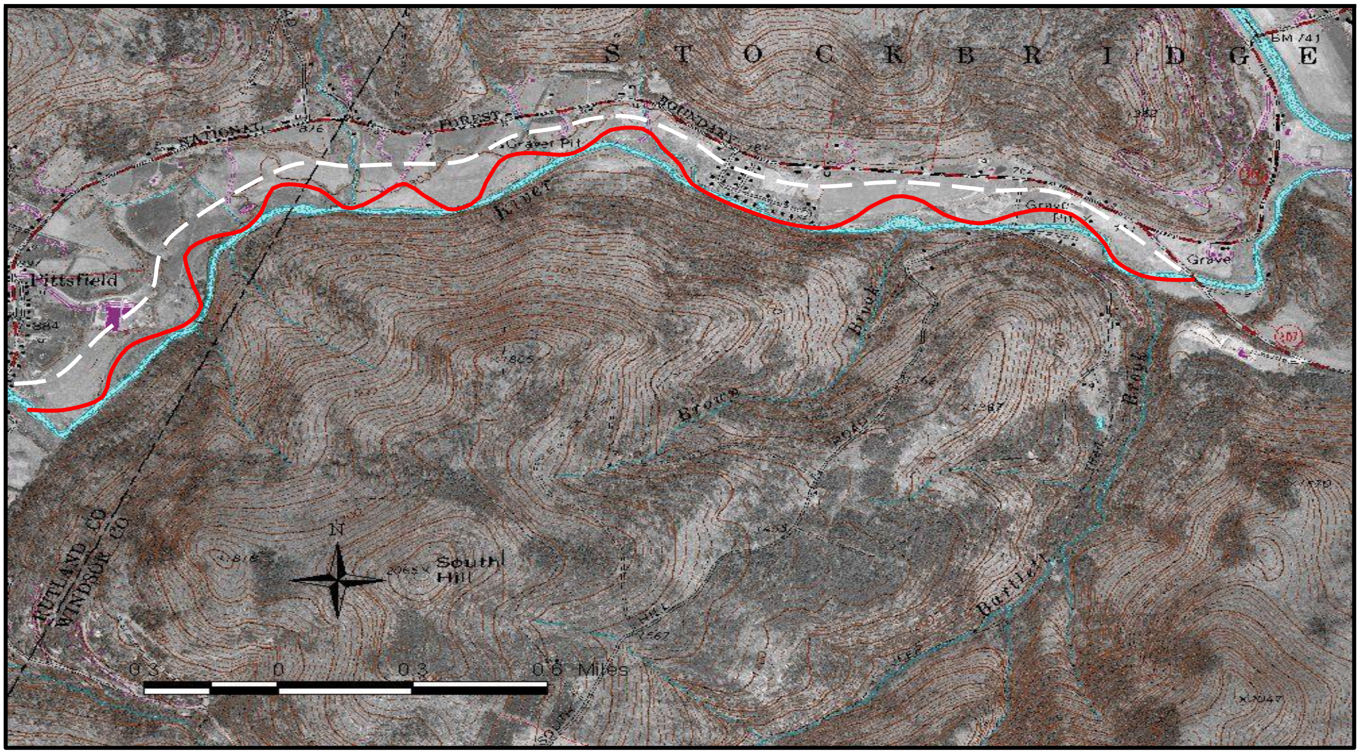
*Publications of the Vermont Agency of Natural Resource, River Management Program staff are published at: http://www.watershedmanagement.vt.gov/rivers.htm

Vermont Guide to River Corridor Protection

Technical Appendix

(Available as a Separate Document)



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