VERMONT

AGENCY OF NATURAL RESOURCES

TECHNICAL GUIDANCE
FOR DETERMINING FLOODWAY LIMITS
PURSUANT TO ACT 250 CRITERION 1(D)

ISSUED OCTOBER 7, 2003
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AGENCY OF NATURAL RESOURCES

Technical Guidance for Determining Floodway Limits Pursuant to Act 250 Criterion 1(D)
October 9, 2009

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EXECUTIVE SUMMARY

The Agency of Natural Resources (the Agency) adopted the *Vermont ANR Procedure on Floodway Determinations in Act 250 Proceedings*, pursuant to Act 250 Criterion 1(D) (10 V.S.A. §6086) on February 6, 2003 and issued the *Technical Guidance for Determining Floodway Limits* on October 7, 2003. The purpose of this revision to the Technical Guidance is to enhance understanding of the ANR Floodway Procedure, provide greater clarity to ensure consistency in decision-making, describe opportunities for both public and expert involvement, provide an incentive for flood hazard avoidance, and render clear, consistent, and broadly accepted floodway determinations.

This revision of the Technical Guidance includes a new section which describes the process the Agency uses to delineate the inundation component of the Floodway and the Letter of Map Revision (LOMR) process for modifying the National Flood Insurance Program (NFIP) floodway, per the NFIP requirements.

Since 2003, the Technical Guidance has acknowledged the existence of structures in the Act 250 Floodway pertaining to erosion hazards. The updated Technical Guidance expands the fluvial erosion hazard (FEH) discussion to further describe the science behind using a belt width-based geomorphic approach to managing erosion hazards, while achieving and maintaining stable equilibrium conditions. Stream sensitivity is described as a factor in belt width determinations, while side slope stability, certain infrastructure, and existing channel/floodplain geometry are considered in defining the FEH floodway limits. This Technical Guidance also lays out additional assessment parameters to determine whether to modify the floodway, and/or the application of the floodway procedure.

The Technical Guidance identifies specific opportunities for project proponents and municipalities to participate in the Agency's floodway delineation process and implementation of the ANR Floodway Procedure. Opportunities involve conducting technical studies, design work, and municipal planning to achieve conformance with the Agency floodway determination or to determine and/or modify the initial floodway.

With respect to the inundation component of the Act 250 Floodway, such opportunities include:

- Conduct a hydrologic and hydraulic analyses to demonstrate that the proposed encroachment would not result in an increase in flood levels in the inundation floodway;
- Where there is no regulatory floodway but there are published base flood elevation data, demonstrate that the cumulative effect of the proposed development will not increase the water surface elevation of the base flood more than one foot at any point within the community;
- Develop "flood-proofing" designs for construction in the Floodway Fringe;
- Undertake the Flood Insurance Rate Map (FIRM) Letter of Map Revision process.

Opportunities for participation concerning the FEH component of the Act 250 Floodway include:

- Collect quality assured geomorphic assessment data to delineate initial FEH floodway limits;
- Analyze watershed hydrologic changes that support modifications to stream sensitivity;
- Conducting a Phase 3 geomorphic assessment to calculate an equilibrium channel slope and belt width;
- Analyze boundary conditions to recommend stream sensitivity modification related to natural resistance;
- Conduct a geo-technical/engineering analysis to determine a slope stability allowance to address bank and valley side-slope failure or river-associated landslide hazards.

The Technical Guidance also describes the opportunity to promote growth center planning, which is consistent with state and municipal fluvial erosion hazard mitigation goals. The public's interest in growth and hazard mitigation, as expressed in municipally adopted development and hazard mitigation plans, coincides with the objectives of the ANR Floodway Procedure – protecting healthy, safety, and welfare of the public, minimizing damage, property loss, and costs of recovery, and avoiding human suffering during floods. The

opportunity involves seeking a modified reference condition designation to modify the FEH component of the Act 250 Floodway and result in a floodway that is compatible with an existing municipal village and growth center planning effort.

In sum, this Technical Guidance lays out the Agency's process for determining the Act 250 floodway. That process is based on FEMA-mapped inundation information and geomorphic principles for achieving stable fluvial processes and applies to development that is within the jurisdiction of Act 250. It is the ANR's opinion that this revised Technical Guidance strikes an acceptable balance between having a consistent set of guidelines to reduce inundation and erosion hazards while allowing consideration of existing and future development. This Technical Guidance strives to keep FEH zones as small as reasonably possible while still remaining consistent with the science-based stream equilibrium objective. The prospect of under-predicting and over-predicting the extent of the FEH zone is minimized by using the sensitivity rating based on site-specific stream conditions ascertained from fluvial geomorphic assessments, identifying vulnerable areas adjacent to the stream as described in Section G of the Technical Guidance, and conducting boundary verification as the basis for the FEH area. Section H of the Technical Guidance also provides some options, if modifications to the FEH floodway are warranted.

I. INTRODUCTION

Pursuant to the *Vermont ANR Procedure on Floodway Determinations in Act 250 Proceedings* (the Procedure)[1] adopted February 6, 2003, this Technical Guidance provides for Act 250 permit applicants and other statutory parties a consistent and standardized procedure for determination of floodway limits under Criterion 1(D). The Vermont Agency of Natural Resources ("ANR" or the "Agency") encourages comments from users, as periodic updates to this Technical Guidance occur. Users should occasionally visit the web site noted below to check for updates.

Inundation, or overbank flooding, occurs when a stream channel or waterbody receives a significant amount of rain or snow melt from its watershed due to a large storm event, or when the stream channel is blocked by a debris or ice jam. The excess water spills out onto floodplain. Fluvial (river-related) erosion occurs when stream power, due to the increased velocities and height of floodwaters, act on the stream channel's bed and banks. The magnitude or rate of fluvial erosion is highly variable, ranging from a gradual and continual process to an episodic and catastrophic event.

The purpose of this Technical Guidance is to describe how the Agency will make floodway determinations that consider both inundation and fluvial erosion hazards (FEH) in the Act 250 regulatory process for the protection of the health, safety, and welfare of the public. Sufficient detail and references to technical documents are made throughout, such that project designers may conduct inundation and FEH analyses and factor floodway determinations into project planning, proposals, and design.

ANR reviews the National Flood Insurance Program (NFIP) maps in the evaluation of proposed projects for inundation-related hazards. The FEH determination relies on geomorphic (or physical) assessment protocols for erosion hazards associated with fluvial adjustment processes, which are contained within the Phase I and Phase II *Vermont Stream Geomorphic Assessment Handbooks* (Handbooks, VT DEC, 2003). The *Handbooks* are available from the VT DEC Water Quality Division.[2] The *Stream Geomorphic Assessment Program Introduction*[3] provides definitions of terms and informative background information to this technical analysis and is also available at the ANR website.

II. FLOOD HAZARDS

The Vermont State Hazard Mitigation Plan (2007) identifies flooding as the most common natural hazard event in Vermont, and the damages from flooding are due to inundation and/or fluvial erosion. Flooding, exacerbated by debris and ice jams or the plugging and failure of stream crossings such as culverts, can threaten public safety, test emergency services, cause widespread damage and property loss, bring about socio-economic disruption, and result in significant costs of recovery incurred by property owners, municipalities, the state, and federal government. Nationally, flooding accounts for more losses in lives and damages to property and crops than any other natural disaster. [4]

The goal of Act 250 Criterion 1(D) is to promote the health, safety, and welfare of the public.[5] The Act 250 floodway denotes the flood hazard area that may include both inundation and fluvial erosion hazards. The Act 250 floodway limit, as described in greater detail below, may be determined in consideration of inundation hazards as delineated by the NFIP inundation maps (Flood Insurance Rate Maps, or FIRMS) **and** of fluvial erosion hazards areas. Fluvial erosion hazard areas are distinct from the NFIP inundation-based Special

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[1] http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_floodwayprocedure.pdf.
[2] Contact ANR at 802-241-3777 or visit its website: http://www.anr.state.vt.us/dec/waterq/riversgeo.htm.
[3] http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_geomorphassess.pdf.
[4] http://www.dps.state.vt.us/vem/StateHazMitPlan_update10-07.pdf
[5] 10 V.S.A. §6086(1)(D).

Flood Hazard Areas (SFHA) mapped on the FIRMs, and may apply to lands that lie outside of the regulatory inundation floodplain. Upon comparison of the two determinations (NFIP and FEH area), the Act 250 floodway limit shall be whichever laterally extends further from the stream.

The Procedure should be referred to for additional background information pertaining to the purpose, statutory authority, and history of floodway evaluations in Act 250 proceedings. The floodway, as determined under the Procedure and this Technical Guidance, is intended to address only the provisions of Act 250 Criterion 1(D). These delineated floodway limits may or may not capture all other Act 250 regulatory considerations for stream buffers which depend on site-specific conditions.

III. INUNDATION HAZARDS

Riparian areas and floodplains serve the vital function (among other functions) of dissipating hydraulic energy and providing storage or attenuation of water, sediment, and debris during flooding, as described in the National Flood Insurance Act of 1968.[6] Land use changes adjacent to stream channels can result in unintended deleterious consequences, such as increases in the magnitude and volume of the effective discharge and channelization practices that heighten channel instability (Ward, 2002).

A. Inundation Floodway

For the purpose of determining the inundation floodway under 10 V.S.A. §6001(6), and the impacts of a project built in a floodway under Criterion 1(D), Agency technical staff will consider the regulatory floodway as defined by the Federal Emergency Management Agency (FEMA) and NFIP regulatory standards. The following describes two scenarios that require a floodway analysis: (1) projects being proposed in a regulatory floodway; and (2) projects where a regulatory floodway has yet to be established:

1. Projects Proposed in a Regulatory Floodway
If a project is proposed within the designated regulatory floodway, as shown on the effective Flood Insurance Rate Map (FIRM) for the community, the project will need to comply with 44 CFR §60.3(d)(3) which states:

> "Prohibit encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practices that the proposed encroachment would not result in **any** increase in flood levels within the community during the occurrence of the base flood discharge" [emphasis added].

Proposed floodway development must meet the 60.3(d)(3) criterion, which is commonly termed the "no-rise" standard. For streams with detailed studies, the 100-year floodplain has been divided into two zones, the floodway and the flood fringe (sometimes referred to as the “floodway fringe”). The floodway is that area that must be kept open to convey flood waters downstream as required by 44 CFR §60.3(d)(3). The flood fringe is that area that can be developed in accordance with FEMA building standards as adopted in the local flood hazard bylaw.[7]

Any proposed development within the floodway requires a hydraulic analysis to demonstrate "no-rise." "No-rise" is defined as a 0.00 foot (ft) difference in the computed base flood elevations (BFEs) at each modeled cross-section. The first step is to acquire and duplicate the effective FEMA hydraulic model which is the basis of the floodway and flood fringe delineations. The determination of "no-rise" is demonstrated by compar-

[6] 42 U.S.C. §4121.
[7] Refer to local flood hazard bylaws, which may be more protective than FEMA minimum standards.

ing the natural run BFEs, as listed in the output of the duplicate effective (pre-project) and post-project hydraulic models.[8]

If the analysis results in any increase to base flood elevations (greater than 0.00 ft), then a Conditional Letter of Map Revision (CLOMR) must be obtained from FEMA per 44 CFR §60.3(d)(4).[9]

2. Projects Proposed Where a Regulatory Floodway has yet to be Determined

If a project is proposed within 100-year floodplain, where **base flood elevations have been determined**, but not a regulatory floodway, as shown on the effective FIRM for the community, then the project will need to comply with 44 CFR §60.3(c)(10) which states:

> "Require until a regulatory floodway is designated, that no new construction, substantial improvements, or other development (including fill) shall be permitted within Zones A1-30 and AE on the community's FIRM, unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one foot at any point within the community."

Under this Scenario 2, an inundation-based floodway will have to be determined. This is normally done by acquiring and duplicating the effective FEMA hydraulic model, and subsequently performing a floodway encroachment model run, inclusive of the proposed development. If the analysis results in an increase to base flood elevations (greater than 1.00 ft as per 44 CFR §60.3(c)(10)), then a Conditional Letter of Map Revision (CLOMR) must be obtained from FEMA per 44 CFR §60.3(c)(13).

B. Flood Fringe

Agency technical staff will recommend that all development in the flood fringe – the portion of the floodplain outside of the inundation floodway – be made reasonably safe from flooding by adhering to the following criteria: [10]

- Elevated such that the lowest floor (including basement or crawlspace) is one foot above the base flood elevation;
- Designed and adequately anchored to prevent flotation, collapse or lateral movement of the structure during the occurrence of the base flood;
- Constructed with materials resistant to flood damage;[11]
- Constructed by methods and practices that minimize flood damage; and,
- Constructed with electrical, heating, ventilation, plumbing and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the design components during conditions of flooding.

C. Modifications to the Floodway Associated with Inundation Hazards

NFIP floodway delineations may only be modified by obtaining a Letter of Map Revision (LOMR) from FEMA in accordance with the NFIP regulations.[12] A LOMR is FEMA's modification to an effective Flood Insurance Rate Map (FIRM). LOMRs are generally based on the implementation of physical measures that

[8] A discussion of the modeling procedure may be found on the following web pages:
http://www.vtwaterquality.org/rivers/docs/nfip/rv_FEMA_NoRiseCert.pdf
http://www.dec.ny.gov/lands/24281.html

[9] Additional information on CLOMRs may be found on this website:
http://www.fema.gov/plan/prevent/floodplain/nfipkeywords/clomr.shtm

[10] 44 CFR §60.3.

[11] Refer to FEMA Technical Bulletin 2-93: Flood-Resistant Materials Requirements.

[12] 44 CFR §65.7.

affect the hydrologic or hydraulic characteristics of a flooding source and thus result in the modification of the existing regulatory floodway, the effective Base Flood Elevations (BFEs), or the Special Flood Hazard Area (SFHA). The LOMR officially revises the FIRM and the Flood Insurance Study (FIS) report, and when appropriate, includes a description of the modifications. The LOMR is generally accompanied by an annotated copy of the affected portions of the FIRM, and FIS report. Since communities adopt and enforce the regulatory floodway, they must concur on floodway revision requests. Therefore, all requests for changes to effective maps, other than those initiated by FEMA, must be made in writing by the Chief Executive Officer (CEO) of the community or an official designated by the CEO. In Vermont, the CEO is typically either the mayor or the chairperson of the select board. NFIP requirements include submitting a copy of a public notice distributed by the community stating the community's intent to revise the floodway or a statement by the community that it has notified all affected property owners and affected adjacent jurisdictions.[13]

IV. FLUVIAL EROSION HAZARDS

FEMA's minimum standards under the NFIP allow development to take place in portions of the regulatory floodplain, as long as the structures are elevated equal to or above the base flood elevation – the water surface elevation associated with the one-percent annual flood – and that the floodplain can maintain the conveyance of the base flood. However, these structures remain at risk of being damaged due to their proximity to the stream, particularly if the stream is unstable, and the high velocity stream flows and channel movements that may occur during flooding. An evaluation of the NFIP (Galloway, 2006, page 118) acknowledges this limitation:

> "FEMA should consider establishing a classification system for riverine floodplains to guide a decision-making process to assess the adequacy of the 1 percent standard for protecting the natural and beneficial functions of floodplains. A geomorphic classification approach to floodplain management would also help better identify and manage flood-related erosion hazards."

Concerns about channel stability and erosion hazards require a geomorphic (or physical) evaluation to characterize a stream's type, size, existing condition, and sensitivity to erosion hazards. A geomorphic evaluation recognizes the dynamic nature of streams. Streams are constantly adjusting their form and configuration due to the influence of and variation in geology, climate, drainage area; the direction and gradient of flow in relation to a given valley slope; turbulence associated with curved flow; roughness of the bed and banks; erosion, transport, and deposition of sediment; the influx of debris; and the degree of floodplain access (Leopold, 1994, Thorne et al., 1997).

A river is considered stable or in a state of "dynamic equilibrium," if it can adjust its channel geometry (width, depth, and slope) requirements to efficiently discharge, transport, and store water, sediment, and debris without significant aggradation or degradation of its bed (i.e., vertical channel adjustments) (Leopold, 1994, Rosgen, 1996). A river requires a sufficient corridor to accommodate equilibrium conditions and the channel adjustments that occur when channel geometry is changing vertically and laterally to achieve equilibrium (Brierley and Fryirs, 2005). Failure to provide a sufficient corridor will constrain the river from achieving the equilibrium condition. Thus, managing the floodway to accommodate equilibrium and associated channel adjustment processes will serve to reduce damages to existing structures and property, avoid new damages, protect public safety, achieve the general health of the river system, and avoid the high cost to install and maintain channelization practices (Piegay, 2005). Precluding the use of channelization practices, in turn, will avoid the unintended consequences of transferring bank erosion and other damaging effects from concentrated flow and vertical channel adjustments to other locations along the river (Brookes, 1988; Huggett, 2003, Brierley and Fryirs, 2005).

[13] For additional information on LOMRs, refer to: http://www.fema.gov/plan/prevent/fhm/dl_mt-2.shtm

Establishing the floodway pertaining to belt width-based fluvial erosion hazards relies on determining the channel (bankfull) width, locating the meander centerline (also commonly referred to as a line of axis) and toe of the valley walls that laterally confine the channel, determining the existing channel type, and evaluating whether channel adjustment processes are underway. Phase 2 geomorphic data may provide an additional basis for determining the degree to which the stream channel is sensitive to erosion hazards. The Phase 2-based sensitivity ratings reflect the variability among stream types in their sensitivity to natural and human disturbance. Highly sensitive streams are prone to active adjustment of channel width and depth dimensions, longitudinal slope and plan form when exposed to significant disturbance and as the river system responds by attempting to re-establish equilibrium conditions.[14]

The rationale supporting a geomorphic-based floodway determination is the strong association between stable, sustainable fluvial processes and minimal conflicts with human investments with an unconstrained river corridor which provides a belt width dimension (Thorne et al., 1997, Thorne, 1998). For streams in unconfined alluvial settings, the average belt width is approximately 6 channel widths wide (Williams, 1986).[15] The belt width extends laterally across the river valley from outside meander bend to outside meander bend, thereby encompassing the natural plan form variability of the stream channel, which maintains the equilibrium slope and minimizes vertical channel instability over time along the extent of the stream reach (Riley, 1998).

Minimizing vertical channel instability is crucial to maintaining or restoring equilibrium stream conditions and minimizing erosion during floods. Vertical channel instability may be initiated by an increase in scour of the stream bed and banks and subsequent sediment transport due to: (a) increasing runoff volume; (b) confining and/or shortening the stream channel thereby increasing its slope; or, (c) restricting the stream's access to its floodplain. Therefore, *ANR Floodway Procedures* seek to provide an adequate floodplain area to accommodate channel adjustment processes necessary to achieve and maintain vertical stability in the longitudinal profile over time. The belt width represents, on average, the minimum amount of floodplain necessary to accomplish vertical stability (Ward et al., 2002, Ward, 2007).

Note that many of Vermont's streams have been straightened, channelized, or have become incised (deepened), losing access to their historic floodplains. Their existing belt width would be narrower than its reference belt width, and the streams may very well be undergoing channel adjustment consisting of erosion and deposition to re-establish long-term stability, or equilibrium conditions. Any floodway determination which considers erosion hazards should accommodate both existing and reference belt widths in order to support these fluvial processes (Ward, 2007).

Investments placed within the belt width inevitably result in human-imposed structural constraints placed on the channel adjustment process to protect those investments and address associated threats to public safety. Typically, constraining adjustment processes in one location will result in a transfer of stream sediment load and erosive energy that can trigger a sequence of channel adjustments and erosion in adjacent and downstream locations, especially in sensitive stream types. Recognizing and avoiding development within the belt width because of its incompatibility with channel adjustment processes will mitigate these impacts.

Basically, an FEH floodway delineation for unconfined, alluvial streams seeks to provide for an unconstrained belt width with a total lateral dimension (measured perpendicular to the meander centerline) equal to 6 times the channel width (Williams, 1986). Ideally, the belt width can be achieved by 3 channel widths

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[14] Refer to Sensitivity Ratings, Table 1, on page 14 of the River Corridor Protection Guide: http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_RiverCorridorProtectionGuide.pdf.
[15] ANR River Corridor Protection Guide, page 4.

either side of the meander centerline (Figure 1). Often, however, the valley topography or other constraints prohibit channel plan form adjustment, such that the full 6 channel widths can only be achieved by providing more width on one side of the stream than the other.[16]

The meander centerline consists of a line drawn connecting the cross-over points between the meander bendways, or in a straight channel, points along the center of the channel spaced longitudinally every 7 to 10 channel widths. Where feasible, the channel width should be associated with the **reference channel** for the reach in question. The reference channel condition may differ from the **existing channel** condition.[17] If a significant departure from the reference condition is known, use the reference channel width. Otherwise, use the existing channel width. Channel width is equal to the bankfull width as referred to in the *Handbooks*.

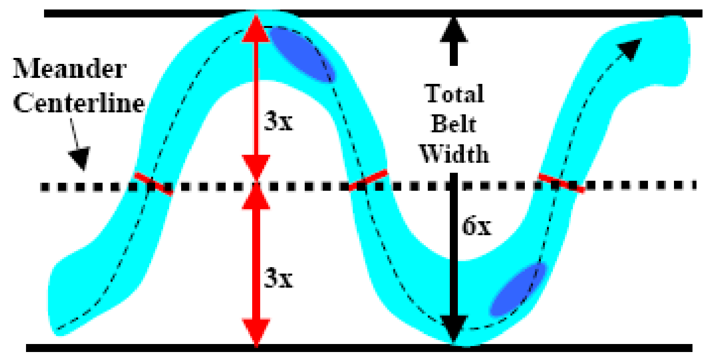

Figure 1. Depiction of Meander Centerline and Belt Width

A complete description of the Phase 1 and Phase 2 stream geomorphic data and the delineation process required to create a belt width for a stream are provided in the River Corridor Protection Guide and its technical appendix (Kline and Dolan, 2008). The following steps describe how to use the belt width and other valley characteristics to ascertain the floodway limits pertaining to fluvial erosion hazards. Such floodway limits are a function of a variety of factors, including the inherent stability of the stream channel, its sensitivity to erosion hazards, the presence of natural or significant human-created confining features, the evidence or likelihood of slope failure, and the presence of hydrologically-connected features.[18]

A. Low Sensitivity Streams

The belt width shall be equal to the existing channel width, where the stream is a bedrock or boulder substrate reference stream type (very low to low sensitivity). The floodway limit shall be the top of the stream bank of the existing channel, the top of the immediately adjacent side-slope[19], or a minimum of 1/2 channel width on either side of the meander centerline, whichever provides the greater lateral extension on either side of the floodway; or,

B. Moderate to Highly Sensitive Streams

The belt width shall be equal to 4 channel widths, where the stream is a steep to moderate gradient (> 2 % gradient) reference stream type (moderate to high sensitivity), and the existing stream type does not represent a stream type departure. The floodway limit shall be the existing belt width – i.e., a minimum of 2 channel widths either side of the meander centerline – or the top of the immediately adjacent side-slope (that is less than one channel width from the top of the stream bank), whichever provides the greater lateral extension on either side of the floodway; or,

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[16] For more discussion of the delineation of the meander centerline and the belt width, refer to Appendix E of the *Handbooks*, or the River Corridor Protection Guide.

[17] Refer to the *Program Introduction*, pg. 7 for a more detailed discussion of reference and existing stream types; see Footnote #3 above for a link to the ANR website.

[18] Refer to the State River Management Program's website to examine fluvial geomorphic data stored on the Data Management System or via Map Viewer: http://www.anr.state.vt.us/dec/waterq/rivers.htm; for further discussion of stream sensitivity, refer to River Corridor Protection Guide, page 14 and *Handbooks* Phase 3, Step 6.

[19] In this context, and adjacent side slope is a non-bedrock terrace or hillside slope, as described in Phase 2, Step 1.4.

C. Moderate to Highly Sensitive Streams as Stream Type Departures

The belt width shall be equal to 6 channel widths, where the stream is a steep to moderate gradient reference stream type (moderate to high sensitivity), and the existing stream type represents a stream type departure.[20] The floodway limit shall be the existing belt width – i.e., a minimum of 3 channel widths either side of the meander centerline – or the top of the immediately adjacent side-slope (that is less than one channel width from the top of the stream bank), whichever provides the greater lateral extension on either side of the floodway (diagramed in Figure 2); or,

D. Highly and Extremely Sensitive Streams

The belt width shall be equal to a minimum of 6 channel widths, where the stream is a gentle gradient or braided reference stream type (high to extreme sensitivity). The floodway limit shall be the existing belt width – i.e., a minimum of 3 channel widths either side of the meander centerline – or the top of the immediately adjacent side-slope (that is less than one channel width from the top of the stream bank), whichever provides the greater lateral extension on either side of the floodway; and,

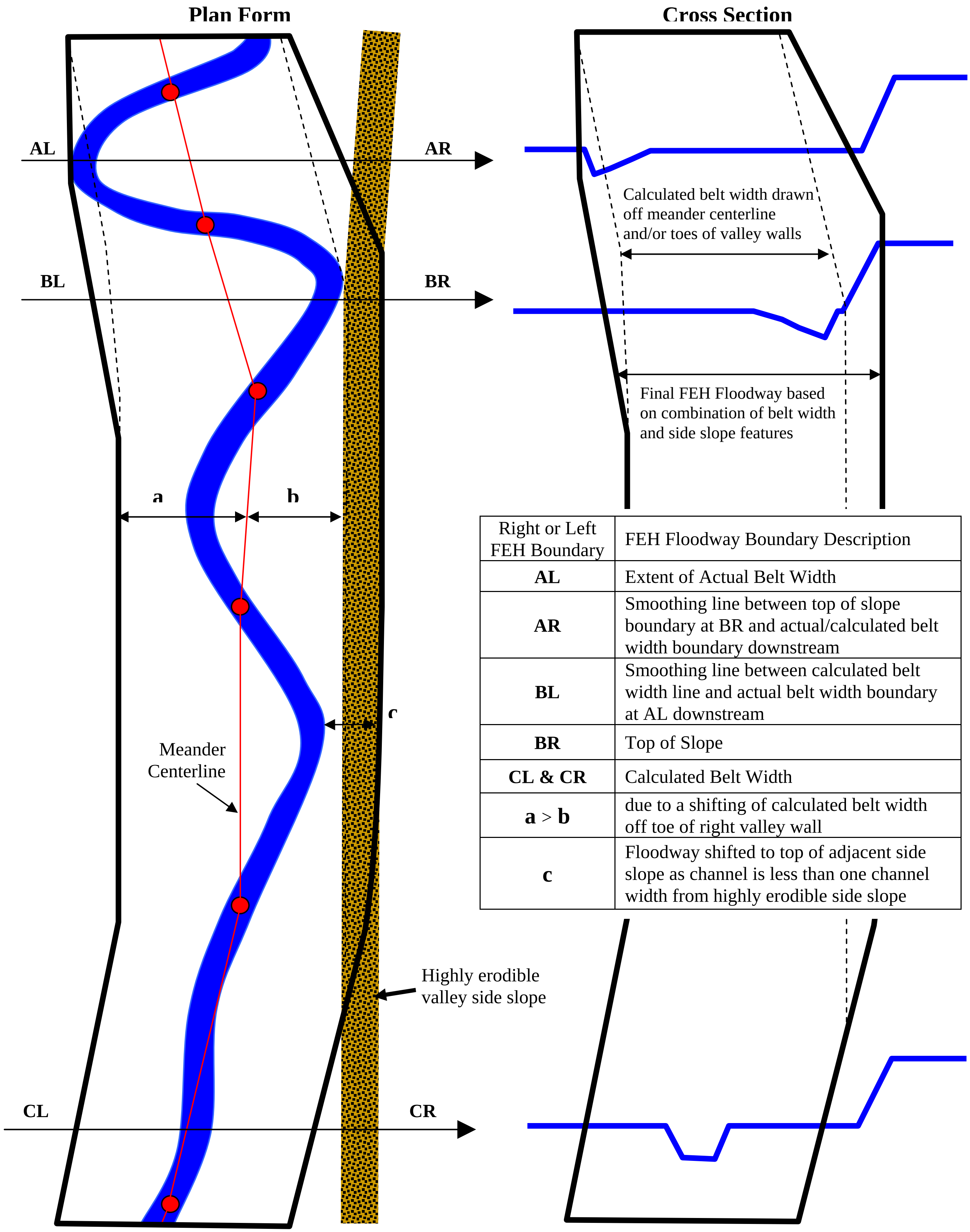
E. Natural or Human-Imposed Confining Features

Where any belt width delineation extends beyond the toe of the valley wall, the belt width shall be laterally extended on the opposite side, to provide a belt width as described in A-D above, measured from the toe of the valley wall (Figure 2). This extension may, in some cases, be limited by the valley wall on the opposite side of the stream as well; in which case, the belt width may be less than the multiple of channel widths prescribed above. Where any floodway delineation extends beyond a federal or state-constructed feature, such as an engineered levee, railroad, or major federal or state road (with or without an embankment), the floodway limit shall be measured from the toe of that feature and extend laterally on the opposite side to provide for a floodway as described in A-D above. This approach acknowledges that entities such as federal and state agencies will maintain the infrastructure's existing alignment, even if it becomes damaged due to flooding. Maintaining structural alignments may require reestablishing stream channel dimensions in those locations. In such cases, the stream would be limited from establishing an equilibrium plan form on lands beyond the significant human-constructed structure. Recognizing such broad societal-accepted human constraints may require an appropriate sizing and lateral shift of the belt width in order to allow for the stream adjustment processes and to optimize attainment of equilibrium conditions within the stream reach; and,

F. Streams Subject to Bank or Slope Failure

The objectives of establishing belt widths determined in A-E above are to provide for the vertical stability of the channel and the maintenance or re-establishment of equilibrium conditions by minimizing an uneven distribution of stream power, erosion, and sediment deposition along the longitudinal profile of the river. Erosion hazards outside the belt width may also exist. If field evidence indicates bank erosion and/or large, mass wasting failures along the valley wall exist or would exist concurrent with the edge of the calculated floodway, either an additional setback, or slope stability allowance determined by a geo-technical analysis, may be added to the floodway limit to accommodate stable bank slopes (see Floodway Modification #4 below); and,

[20] A stream type departure may be represented by a shift of stream type, C3 to D3 for instance or a **major** vertical stream adjustment (degradation and/or aggradation); see Steps 2.14 (pp. 34-37) in the *Handbooks*, Phase 2: http://www.anr.state.vt.us/dec/waterq/rivers/docs/assessmenthandbooks/rv_phase2cvpagethrustep4.pdf.



Right or Left FEH Boundary	FEH Floodway Boundary Description
AL	Extent of Actual Belt Width
AR	Smoothing line between top of slope boundary at BR and actual/calculated belt width boundary downstream
BL	Smoothing line between calculated belt width line and actual belt width boundary at AL downstream
BR	Top of Slope
CL & CR	Calculated Belt Width
a > **b**	due to a shifting of calculated belt width off toe of right valley wall
c	Floodway shifted to top of adjacent side slope as channel is less than one channel width from highly erodible side slope

Figure 2. Planform and cross-sectional views of FEH floodway construction based on a highly sensitive river type, existing and calculated belt widths and the location of an erodible valley side slope.

G. Natural or Manmade Depressions Adjacent to Streams

If field evidence indicates hydrologicaly-connected features such as natural or human-created depressions, and old channels adjacent to the stream, the floodway limit may extend laterally to encompass those features, in recognition of their potential to be captured by the river or contribute to a channel avulsion (relocation) during a flood; and,

H. Modifications to the Floodway Associated with Erosion Hazards

Lane's Balance[21] in Figure 2 is often used to illustrate the relationship of four fundamental variables – stream flow, channel slope, sediment load, and resistance of channel boundary conditions (e.g., median sediment size of the streambed) – in determining a stable (or equilibrium) channel morphology described above. Water discharge and sediment load are on opposite sides of the balance. Water discharge and slope define the stream power necessary to move the sediment load. A change in any one of these variables may set in motion a self-adjustment process that changes one or more of the other variables to restore equilibrium conditions (Lane, 1955).

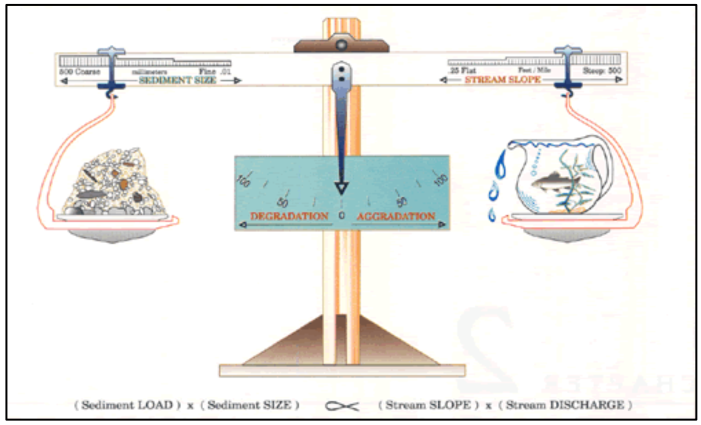


Figure 3. Lane's Diagram (1955) from Rosgen (1996)

Below are additional assessment parameters, most of which are associated with these four fundamental physical variables described in Lane's Balance, that may warrant modifications to the floodway pertaining to fluvial erosion hazards. For additional information on these parameters, refer to *Handbooks* Phase 3, Step 6. Permit applicants and other statutory parties may propose modifications to FEH floodway delineations for review by the ANR.

1. Watershed Hydrologic Modifications

Large watershed storage elements, hydroelectric facilities, water withdrawals, and other flow modifications which result in a significant decrease in peak discharges and significant watershed scale hydrologic attenuation, may, in effect, **reduce** the level of fluvial erosion hazard and stream sensitivity. The downstream channel adjustments associated with such alterations to the hydrologic and sediment regime may have occurred, in both a spatial and temporal sense, and dynamic equilibrium substantially re-established. Watershed level hydrologic modification associated with, for example, land use conversion which raises peak discharges may also be considered, as these activities serve to **increase** stream power, the level of erosion hazard, and stream sensitivity.

2. Slope Modifications Related to Sediment Transport and Sediment Regime Changes

The equilibrium channel slope critical for sediment entrainment and transport is governed by flow depths, channel dimensions, natural boundary materials, and bed load characteristics (see *Handbooks* Appendix O). Meander amplitude and therefore the belt width of a stream are a function of the equilibrium channel slope. Belt widths used by the Agency are based on a conventional, scientific-based procedure described above and

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[21] Refer to: (a) Vermont River Corridor Protection Guide, (b) River Dynamics 101 Fact Sheet, and (c) Phase 3 Geomorphic Assessment Protocols:
(a) http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_RiverCorridorProtectionGuide.pdf;
(b) http://www.anr.state.vt.us/dec//waterq/rivers/docs/Educational%20Resources/rv_RiverDynamics101FactSheet.pdf;
(c) http://www.anr.state.vt.us/dec/waterq/rivers/docs/assessmenthandbooks/rv_weblinkpgphase3.pdf

in more detail within the River Corridor Protection Guide.[22] This procedure captures a range of watershed factors and natural channel conditions and enables the State to cost-effectively implement a floodway policy statewide. Alternatively, project proponents and their consultants may propose a stream-specific equilibrium slope assessment for a geomorphically-defined stream reach, which, if approved, could be conducted and provide data to calculate a stream reach-specific belt width.

In the review of reach-specific equilibrium channel geometry, the Agency may consider imbalances in sediment regime. Sediment transport capacity imbalances may be triggered by upstream disturbances, at the reach or watershed scale, that may increase or decrease sediment supply. Reach level imbalances of channel geometry (width, depth, longitudinal slope and plan form) in relation to sediment supply, stream power, and bank and bed shear stress can have significant influence on the sediment regime, the adjustment processes, and sensitivity.

Stream reaches that exhibit a significantly higher capacity to transport sediment in relation to the available sediment supply (quantity and/or size) are characterized as exhibiting a very high level of erosion hazard and corresponding sensitivity. Similarly, stream reaches that adjust readily and frequently in response to sediment influxes and function primarily as sediment storage reaches are also characterized by having a very high level of erosion hazard and sensitivity. This latter example can be observed in transition zones from source (or transport) reaches to response (or storage) reaches in high bed load and extensively channelized fluvial systems.

Trained consultants may conduct additional assessments of the site, such as those outlined in the Agency's Phase 3 geomorphic assessment protocols, in order to ascertain the equilibrium channel slope associated with the distribution of energy grade, sediment continuity, and overall channel stability. The data from an assessment, based on a prior-approved methodology, will be used to make a final determination of the FEH floodway for the purposes of re-establishing and/or maintaining sediment transport continuity and equilibrium conditions. It will be the responsibility of the project proponent to conduct the additional assessment.

3. Boundary Conditions

The resistance of the channel boundary materials to the erosive power of the stream, as influenced by localized conditions such as material type, size and gradation, cohesiveness, vegetation (or lack thereof), may significantly influence the anticipated range of adjustment of channel geometry and may therefore increase or decrease the level of erosion hazard, channel sensitivity, and floodway extent. Bedrock, for example, will limit extent of lateral adjustment regardless of stream type departure or adjustment process. Unconsolidated sand and gravel bank stratigraphy with no mature bank vegetation is typically associated with very high sensitivity. The role of human constructed channel stabilization treatments (such as rock rip rap) with respect to constraining channel adjustments will not be considered. Bank revetments are commonly associated with flood plain and belt width encroachments that are incompatible with stable fluvial processes and/or channel geometry (equilibrium). The typical reach-level long-term response to human-placed bank revetments, which encroach within the belt width corridor, is a higher rate of channel adjustment and an increased erosion hazard.

4. Bank and Valley Side-Slope Failure/River-Associated Landslide Hazard

A valley wall or embankment slope failure is characterized by a sudden movement of a large mass of soil typically along a failure plane. Such failures pose significant risk to public safety, can damage property, public infrastructure, homes, and other structures, and overwhelm stream channels. Bank and slope failure can be triggered by one or a combination of factors, including fluvial erosion, soil saturation, natural geologic weathering processes such as the freezing and thawing of soils, human modification of the bank, increases in loading on top of the slope, surface or near surface drainage patterns, and loss of vegetation. Flu-

[22] Enabling the State to implement a scientifically valid floodway policy, cost effectively on a statewide basis.

vial erosion, causing bed and bank erosion or associated with water flowing along the toe of the slope, removes bank material to over-steepen and potentially under-cut the slope. Fluvial erosion is considered the most important contributing factor to valley wall or embankment slope failures.[23]

A subset of bank erosion hazards are captured by the Agency within the belt width-based floodway determination. There are, however, stream bank, landslide, and other erosion hazards that may exist at or beyond the boundaries of the belt width area. Step F above provides flexibility to extend the floodway beyond the top of the banks, slopes, or belt width, if there is evidence of active toe erosion or historic mass wasting failures. Often there is a shared interest to mitigate a present or future anticipated bank or slope failure hazard associated with fluvial erosion at the boundary of the belt width or the toe of an existing bank or slope. To determine how far back one should extend the hazard limit is challenging, due to the variety of geologic materials that make up Vermont's stream embankments and valley walls, how cohesive these materials are, the degree to which these materials are subject to weathering or erosive forces, the range of terrace heights, and variation in side angles of the slope or bank. Determining an acceptable setback allowance to mitigate a slope or landslide hazard by evaluating the erosion rate of an exposed and actively eroding terrace or high bank does not capture the degree to which erosion could occur (Rapp, 2003).

A Slope Stability Allowance (SSA) is an additional setback distance from the top-of-bank or top-of-adjacent side slope which would be added to the floodway determined in A-E above to mitigate damages and public safety concerns with respect to potential slope failure or landslide hazard (Table 1). The SSA is principally a function of the local soil type and geologic materials present along the slope adjacent to the stream where the proposed development is to occur, as well as any aggravating factors that could contribute to slope failure, such as the incised or entrenched condition of the stream, existing and proposed hydrologic conditions from groundwater or stormwater runoff (Simon, 2003).

Table 1. Slope Stability Allowance (SSA)

Condition	Local Conditions of Side Slope	Options
1	Bedrock present in the floodprone area of the sideslope (to an elevation 2 times maximum channel depth).	Toe of the side slope represents the boundary of the Act 250 floodway pertaining to FEH
2	Normal surficial materials present[24]	Calculate SSA as 2:1 slope measured from the toe of the slope[25] or conduct a geotechnical analysis
3	Champlain lowland clayey surficial materials present[26]	Calculate SSA as 3:1 slope measured from the toe of the slope or conduct a geotechnical analysis

Note that any slope stability analysis must demonstrate that the proposed development will not require channelization practices, such as rock armoring, to maintain a stable slope.

5. <u>Existence of Other Facilities Within the FEH Floodway</u>
In consideration of and in relation to existing structures within the FEH floodway, the proposed development may not create or increase the level of fluvial erosion hazard. For example, other structures or a public highway may be located between the proposed development within the floodway limits and the river channel. In such a case, the floodway delineation should conform to the NFIP floodway delineation. Another example is if the proposed development is to be located 50 feet or less from the existing structure (measured parallel or longitudinal to the channel). The proposed development or redevelopment must not be any less distance from the stream channel than the existing structure's setback, as measured horizontally from the

[23] Springston, G., 2007. Vermont Stream Bank Stability Manual, Draft, Norwich University, May 2, 2007.
[24] "Normal surficial materials" include alluvium, ice-contact deposits, and glacio-lacustrine materials. See Appendix F in *Handbooks* for more information and sources of geologic information in Vermont.
[25] Measure the setback, horizontally from the toe of the slope, at a distance two times the vertical height of the slope .
[26] Champlain lowland clayey materials include locations where glacio-marine deposits exist.

nearest point of the existing structure to the top of bank. For project proposals located more than 50 feet from existing structures (measured parallel or longitudinal to the channel), conforming to the floodway limits of the fluvial erosion hazard area would apply.

6. Modified Reference Condition

There are cases where it may be appropriate to substitute a modified reference condition for the reference equilibrium condition in the determination of channel width, channel type departure, or adjustment process; as applied above. A modified reference stream type must be assigned by the Agency and acknowledges channel, valley, and/or flood plain modifications that may prohibit the adjustment of a reach back to its reference condition. A modified reference condition, therefore, limits physically or administratively the lateral extent of the fluvial erosion hazard area. Typically, the consideration of a modified reference stream type will be limited to situations where modifications of watershed hydrology and/or the physical constraints associated with river corridor development are so pervasive as to effectively preclude any expectation of re-establishing reference equilibrium conditions.[27] One such example, is that the Agency may identify Modified Reference Condition as an outcome of FEH planning with municipalities in the treatment of historic villages and growth centers. ANR will consider such a determination along the reaches of river where a municipality's historic village or growth center is located, erosion hazards (vertical channel adjustments) upstream and downstream of the village or growth center are being mitigated, and/or the existing sensitivity of the river reach is **not** designated as very high or extreme.[28]

For assistance in the application of this Floodway Determination Technical Guidance, contact the Water Quality Division River Management Program at 802-241-3770 or by e-mail at Rebecca.pfeiffer@state.vt.us or Kari.dolan@state.vt.us.

VI. REFERENCES

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[27] See the *Program Introduction*, page 7 for additional discussion of modified reference condition, http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_fluvialgeomorph-intro.pdf.

[28] Refer to the Municipal Guide to Fluvial Erosion Hazard Mitigation for more information and model ordinance language: http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_municipalguide.pdf.

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*Publications of the Vermont Agency of Natural Resource, River Management Program staff are published at: www.vtwaterquality.org/rivers/htm.