

Adjusted Flood Prone Acres

The flood prone area is defined as the area adjacent to the stream that is inundated or saturated when the elevation of the water is at twice the maximum depth at bankfull stage (Rosgen, 2002). This area typically floods at a frequency of approximately once every 50 – 100 years depending upon the characteristics of the stream valley, gradient of the channel, and the hydrology of the area. The flood prone area adjacent to the stream provides extremely important ecological and water quality related services that not only determines the integrity of specific stream reaches, but which also influence downstream water quality and stream channel condition.

Entrenchment of stream channels through filling of the adjacent flood prone area or channel incision caused by gradient changes, channel straightening, or other alterations inevitably results in degradation of the quality of the habitat for aquatic life, increased bank erosion, and water quality degradation. The disconnection of the stream from the adjacent flood prone area caused by entrenchment of the stream also significantly increases the water velocities in the stream channel during high flow events and reduces flood water storage along the stream corridor. These changes can then result in detrimental impacts on downstream segments with respect to flood frequency and amplitude, bank erosion, sedimentation in and along the stream channel, and pollutant transport. For these reasons, the degree of loss or creation of functional flood prone area along the stream corridor is used as a metric for debit and credit calculations for the determining stream impacts or mitigation credit in the 401 water quality certification program.

For purposes of this protocol, the frequently flooded area adjacent to the stream of interest for mitigation debit-credit modeling is based upon the concept of the streamway (Ward and Trimble, 2004; ODNR, 2006; Ward, et. al, 2008). The streamway is an area adjacent to the stream that encompasses sufficient width to accommodate the stream meander pattern and buffer vegetation. The technical definition is as follows:

“The streamway is the zone within an active floodplain that is large enough to sustain dynamic equilibrium and provides enough space for the main channel to adjust its pattern”. (Ward, et. al, 2008)

For low gradient streams in Ohio (slopes less than 2%), the streamway target width used in this protocol is drawn from Appendix 7 of Third Edition of the *“Rainwater and Land Development”* manual (ODNR, 2006). Development of the relationship between drainage area and the streamway target is fully described in this resource and will not be replicated here. General targets for design of replacement stream channels and minimum design standards for mitigation credit eligibility are discussed in Sections x.y.z and a.b.c. It should be noted that the streamway target is only calculated on a site-specific basis only when there are geological constraints or other overwhelming considerations (such as historical preservation concerns, the presence of permanent structures, etc.) which limit the extent of potential flood prone area creation to an area less than the calculated target. Use of alternative streamway targets is allowed at the discretion of the Ohio EPA.

Comment [P1]: The purpose of providing this section of the draft to the work group is to allow evaluation of the adjusted flood prone area metric.

Comment [P2]: In draft, specific references will be provided in the final protocol.

Adjusted Flood Prone Width Calculation

Overview

The Adjusted Flood prone Area (A_{fp} , in acres) is used as a measurement for stream debits and credits. This debit-credit calculation is applicable for all stream mitigation categories. The flood prone area is defined as the area adjacent to the stream channel that is inundated or saturated at flows less than or equal to two times the maximum depth at the bankfull stage. For stream segments with gradients less than two percent, the flood prone acreage is normalized through calculation formulae to provide an adjusted acreage based upon a site survey (for existing condition assessment) or project plans (for post-construction conditions). Adjustments are based upon the ratio of the flood prone area to the streamway target area and upon the total acreage lying within three elevation categories corresponding to the maximum bankfull stage elevation and the flood prone elevation (see Figure 1). Elevation categories used to adjust the flood prone acreage calculation are as follows:

1. The area that is inundated or saturated when the water elevation is at the bankfull stage (including the bankfull channel).
2. The area that lies within the elevation range between the bankfull stage and 1.5 times the maximum stream depth at the bankfull stage
3. The area that lies within the elevation range between 1.5 times the maximum stream depth at the bankfull stage to 2.0 times the maximum stream depth at the bankfull stage (Figure x).

Elevation and Lateral Width Categories Used to Calculate Adjusted Floodprone Acres Debits and Credits

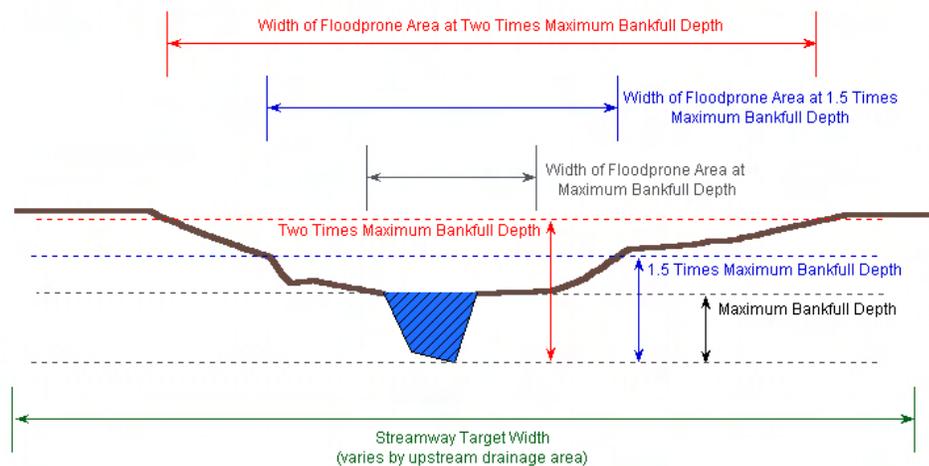


Figure 1. Elevation and lateral distance categories used to adjust flood prone acreage debits and credits.

Calculation for Low Gradient Streams (<2% Gradient):

Streamway Target Area Calculation¹:

$$W_{SW} = 12.6 * DA^{0.38} \quad (eq. 1)$$

Where: W_{SW} = width (ft) of the target streamway (streams with gradients < 2%)

DA = upstream drainage area (in acres).

$$A_{SW} = (W_{SW} * L_v) / 43,560 \quad (eq. 2)$$

Where: A_{SW} = area (in acres) of the target streamway (from eq. 1)

L_v = length of the high flow valley (feet)

Flood Prone Area Elevation Categories (determined by site survey)^{2,3}:

A_{BkF} = Area inundated or saturated at maximum bankfull flow elevation (acres).

A_{int} = Area inundated or saturated at 1.5 times the maximum bankfull flow elevation (acres)⁴.

A_{high} = Area inundated or saturated at 2.0 times the maximum bankfull flow elevation (acres)⁵.

Incremental Flood Prone Areas:

$$I_{low} = A_{BkF} \quad (eq. 3)$$

$$I_{int} = A_{int} - A_{BkF} \quad (eq. 4)$$

$$I_{high} = A_{high} - A_{int} \quad (eq. 5)$$

Comment [P3]: Automated calculations can be made using the mitigation spreadsheet. The calculation equations listed in this text are those used in the spreadsheet and will be included in the protocol to allow manual calculation of the adjusted flood prone acres.

¹ Note: for constrained valleys, alternative streamway targets may be allowed on a case-by-case basis.

² Note: all flood prone areas include the area of the stream channel.

³ Data from field verified GIS resources may be utilized where appropriate.

⁴ Note: cumulative area that includes A_{BkF} .

⁵ Note: cumulative area that includes all areas below 2.0 times the maximum bankfull elevation.

Flood Prone Area Elevation Weighting Factors:

$$F_{low} = \text{Weighting factor for } I_{BkF} = 1.0$$

$$F_{int} = \text{Weighting factor for } I_{int} = 0.8$$

$$F_{high} = \text{Weighting factor for } I_{high} = 0.4$$

Entrenchment Ratios for Flood Prone Areas based on Elevation:

$$E_{low} = I_{BkF} / A_{sw} \quad (eq. 6)$$

$$E_{int} = I_{int} / A_{sw} \quad (eq. 7)$$

$$E_{high} = I_{high} / A_{sw} \quad (eq. 8)$$

Flood Prone Area Lateral Distance Weighting Factors:

$$D_{low} = 0.6 / 2^{E_{low}} + 0.7 \quad (eq. 9)$$

$$D_{int} = 0.6 / 2^{E_{int}} + 0.7 \quad (eq. 10)$$

$$D_{high} = 0.6 / 2^{E_{high}} + 0.7 \quad (eq. 11)$$

Adjusted Flood Prone Acres:

$$A_{fp} = (I_{BkF} * F_{low} * D_{low}) + (I_{int} * F_{int} * D_{int}) + (I_{high} * F_{high} * D_{high}) \quad (eq. 12)$$

Where: A_{fp} = Adjusted flood prone area (acres) for debit – credit allocation.

Calculation for High Gradient Streams ($\geq 2\%$ Gradient):

Streamway Target Area Calculation:

$$W_{fp} = 3.8 * DA^{0.38} \quad (\text{feet}) \quad (\text{eq. 13})$$

Where: W_{fp} = width (ft) of the target flood prone area
(streams with gradients $\geq 2\%$)

DA = upstream drainage area (in acres).

$$A_{target} = (W_{fp} * L_v) / 43,560 \quad (\text{acres}) \quad (\text{eq. 14})$$

Where: A_{target} = the area (in acres) of the target flood prone area.

W_{fp} = width (in feet) of the target flood prone area (from eq. 13)

L_v = length of the high flow valley (feet)

Flood Prone Area Elevation Categories (determined by site survey)⁶:

A_{high} = The existing or design site-specific area (in acres) adjacent to the stream that is inundated or saturated at 2.0 times the maximum bankfull flow elevation (acres).

Incremental Flood Prone Areas:

For high gradient channels, the site-specific existing or design flood prone area (total area inundated or saturated at 2.0 times the maximum bankfull flow elevation) is subdivided into two zones dependent upon the relationship of the site specific value to the target value.

I_{high} = Area inundated or saturated at 2.0 times the maximum bankfull flow elevation (acres) within the target flood prone area.

$I_{residual}$ = Area inundated or saturated at 2.0 times the maximum bankfull flow elevation (acres) beyond the target flood prone area⁶.

Comment [P4]: Automated calculations can be made using the mitigation spreadsheet. The calculation equations listed in this text are those used in the spreadsheet and will be included in the protocol to allow manual calculation of the adjusted flood prone acres.

⁶ Note: all flood prone areas include the area of the stream channel.

Notes for high gradient channel adjusted flood prone area calculations:

1. For site-specific flood prone areas where $A_{\text{high}} \leq A_{\text{target}}$:

a. $I_{\text{high}} = A_{\text{high}}$ (eq. 15)

b. $I_{\text{residual}} = 0$ (eq. 16)

2. For purposes of debit calculations where $A_{\text{high}} > A_{\text{target}}$:

a. $I_{\text{high}} = A_{\text{target}}$ (eq. 17)

b. $I_{\text{residual}} = A_{\text{high}} - A_{\text{target}}$ (eq. 18)

3. For purposes of calculating mitigation credits:

a. I_{high} cannot be greater than the target flood prone area (A_{target})

b. I_{residual} is not used, no credit is given for area beyond A_{target}

Flood Prone Area Elevation Weighting Factors:

F_{high}	=	Weighting factor for I_{high}	=	1.1
F_{residual}	=	Weighting factor for I_{residual}	=	0.5 (impact debits)
			=	0.0 (mitigation credits ⁷)

Entrenchment Ratios for Flood Prone Areas based on Elevation:

Entrenchment ratios are not used for debit-credit calculations in high gradient channel stream reaches.

Flood Prone Area Lateral Distance Weighting Factors:

Lateral distance adjustment is not used for debit-credit calculations in high gradient channel stream reaches.

Adjusted Flood Prone Acres:

$$A_{\text{fp}} = (I_{\text{high}} * F_{\text{high}}) + (I_{\text{residual}} * F_{\text{residual}}) \quad (\text{eq. 19})$$

Where: A_{fp} = Adjusted flood prone area (acres) for debit – credit allocation.

⁷ No stream mitigation credit is given for flood prone area greater than the design target for high gradient channels. This does not exclude awarding vegetated acre credits for the riparian zone where applicable.

Literature Cited

ODNR (2006). Rainwater and Land Development: Ohio's Standards for Stormwater Management Land Development and Urban Stream Protection. Third Edition. Ohio Department of Natural Resources, Division of Soil and Water Conservation. Columbus, Ohio.

Rosgen, D. L. (2002). Applied River Morphology. Second Edition. Wildland Hydrology. Pagosa Springs, Colorado.

Ward, A. D., and S. W. Trimble (2004). Environmental Hydrology, Second Edition. Lewis Publishers, Boca Raton, FL. 462 pp.

Ward, A. D., J. L. D'Ambrosio, J. D. Witter, A. D. Jayakaran, and D. Mecklenburg (2008). Floodplains and setbacks. Agricultural and Natural Resources Fact Sheet AEX-445-02. The Ohio State University Extension, Columbus, OH. 7 pp.

<http://ohioline.osu.edu/aex-fact/pdf/AEX44502FloodplainsandStreamwaySetbacks.pdf>