RHODE ISLAND
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
OFFICE OF WATER RESOURCES
235 Promenade Street, Providence, Rhode Island 02908-5767

Regulatory Provisions and Guidance Pertaining to Floodplain and Floodway Standards of the RIDEM Freshwater Wetland Program

This guidance package has been developed to provide design engineers with information on relevant regulations and definitions with respect to floodplains and floodways, as well as provide helpful tips and techniques regarding the determination of floodplain and floodway limits, calculation of displacement, and design of effective compensation for impacts.

In addition, this guidance document contains visual examples of several different methods commonly used to perform floodplain displacement and volumetric compensation analysis.

Please note: This guidance package is for general informational purposes only and is not meant to be used as a substitute for the RI Fresh Water Wetlands Act (R.I.G.L. §2-1-18 et. seq.) or the Rules and Regulations Governing the Administration and Enforcement of the Freshwater Wetlands Act (250-RICR-150-15-3; "FWW Rules"). In general, applications involving the identification of floodplain or floodway limits, or that involve alterations to these areas, must be prepared by a Rhode Island Registered Professional Engineer. Refer to FWW Rules Section 3.8.6 for specific requirements regarding the use of professionals.

Table of Contents

Freshwater Wetland Rule Excerpts Pertaining to Floodplain and Floodway

Pertinent Definitions

As per FWW Rules Section 3.4(A):

- **Area Subject to Flooding (ASF)** means areas that include, but are not limited to, low-lying areas that collect, hold or meter out storm and flood waters from any of the following: rivers, streams, intermittent streams or areas subject to storm flowage.

- **Area Subject to Storm Flowage (ASSF)** means areas that include drainage swales and channels that lead into, out of, pass through or connect other freshwater wetlands or coastal wetlands, and that carry flows resulting from storm events, but may remain relatively dry at other times.

- **Floodplain** means as defined by R.I. Gen. Laws § 2-1-2(7), that land area adjacent to a river or stream or other body of flowing water which is, on the average, likely to be covered with flood waters resulting from a one hundred (100) year frequency storm. A "one hundred (100) year frequency storm" is one that is expected to be equaled or exceeded once in one hundred years; or may be said to have a one percent (1%) probability of being exceeded in any given year.

- **Floodway** means the channel of a river or stream and any immediately adjacent areas that must be kept free of encroachment to allow one hundred year flood waters to be carried without increases in flood heights and without endangering life or property.

- **Flowing Body of Water** means any river, stream, or intermittent stream that flows long enough during the year to develop and maintain defined channels, and generally has flowing water at times other than those immediately following storm events. Such watercourses have defined banks, a bed, and maintain visible evidence of flow or continued reoccurrence of flowing water.

- **River** means, as defined in R.I Gen. Laws §2-1-20(13), a body of water that is designated as a perennial stream by the Unites States Department of Interior Geologic Survey on 7.5 minute series topographic maps, and that is not a pond as defined in [Section 3.4(A)(54)].

- **Stream (includes intermittent streams)** means any flowing body of water or watercourse other than a river that flows long enough each year to develop and maintain a channel and that may carry groundwater discharge or surface runoff. Such watercourses may not have flowing water during extended dry periods but may contain isolated pools or standing water.

Wetland Function and Value Protection

- As per FWW Rules Section 3.2(B)(3)(c): "Flood Protection: Freshwater Wetlands, buffers, setbacks, and floodplains protect life and property from flooding and flood flows by storing, retaining, metering out and by otherwise controlling flood waters from storm events. Freshwater wetlands, buffers, and floodplains also control the damaging impacts of flood flows by providing frictional resistance to flood flows, by dissipating erosive forces, and by helping to anchor the shoreline."

- As per FWW Rules Section 3.2(B)(5): "Consistent with the purposes of the Act, it is the public policy of the State to preserve the purity and integrity of all freshwater wetland, buffers, and floodplains in Rhode

Island. Random, unnecessary, or undesirable alteration of any freshwater wetland, buffer, or floodplain is contrary to the Act and not in the best public interest because of the adverse impacts of such alterations on their functions and values."

Regulatory Applicability

- As per FWW Rules Section 3.5.6(A): "Projects or activities within a jurisdictional area that may alter freshwater wetlands, buffers, floodplains, areas subject to flooding or areas subject to storm flowage are subject to regulation and are required to obtain approval from the Director in accordance with these Rules. Certain limited activities are exempt in accordance with §3.6 of this Part."

Site Plan Requirements Pertaining to Floodplain & Floodway

- As per FWW Rules Section 3.8.5(A)(4), all site plans must accurately depict "the edge and elevation of any floodplain and the limit of any floodway, except the Department may grant an exception to this requirement when:
    a. Pre-determined one hundred (100) year flood elevations are not available from published sources including previous flood studies; and
    b. When a Registered Professional Engineer provides clear and convincing evidence that the project site is above any probable one hundred (100) year flood elevation."

Identification of Floodplain Limits

- As per FWW Rules Section 3.21.3 "Floodplain

A. The edge of any floodplain shall be identified as the maximum horizontal extent of flood water which will result from the statistical one hundred (100) year frequency storm event.
B. The one hundred (100) year floodplain elevation shall be determined by the most recently available flood profile data prepared under the National Flood Insurance Program of the federal Emergency Management Agency (FEMA); or
C. In instances where FEMA has not established the elevation of the one hundred (100) year floodplain, the floodplain elevation and floodplain edge shall be determined through calculations prepared by a Registered Professional Engineer. These calculations shall be based on the following:
    1. Calculation of one hundred (100) year flood discharge based on a one hundred (100) year rainfall event identified in the Stormwater Design and Installation Rules, Subchapter 10 Part 8 of this Chapter, and a generally accepted hydrologic model including, but not limited to TR-20, TR-55 or commercially available software based on TR-20 or TR-55. In certain cases involving very large watersheds an acceptable regression methodology may be used, such as a U.S.G.S. regression equation for Rhode Island.
    2. Using flood discharge established as described in § 3.21.1(C)(1) of this Part along with detailed topography mapping, prepare a determination of peak one hundred (100) year flood elevation using a widely accepted hydraulic model such as the U. S. Army Corps of Engineers' Hydrologic Engineering Center River Analysis System (HEC-RAS). Once this elevation is established the edge of the one hundred (100) year floodplain must be plotted on a detail site topography map."

Identification of Floodway Limits

- As per FWW Rules Section 3.21.4(A)(1), "Where FEMA has designated a floodway for any river or stream on a FEMA Flood Insurance Rate Map (FIRM), the Department will recognize the same floodway."

- As per FWW Rules Section 3.21.4(A)(2):, "Where no FEMA Floodway has been established for a river or stream, the edge of the channel as identified in §3.21.2(A) of this Part shall also be considered the edge of the floodway."

Flood Protection Standard

- Per FWW Rules Section 3.7.1(E):
  - Section 3.7.1(E)(1): "Flood storage capacity: Projects and activities taking place in a floodplain shall not result in any net reduction in flood storage capacity and shall not reduce the rate at which floodwater is stored by the floodplain."
  - Section 3.7.1(E)(2): "Floodway obstruction: projects and activities taking place within or adjacent to rivers or streams shall not encroach into floodway limits with any fill, structure or other development."

Preliminary Considerations – Floodplain

Once it is determined that a project involves work near a flowing body of water, including rivers and streams, a determination must be made as to the limit of floodplain adjacent to the river or stream. Determining that limit will involve one of the following three scenarios:

1. The 100-year flood hazard area that is depicted on the FEMA Flood Insurance Rate Map (FIRM) provides elevations of the 100-year flood plain. Unless this elevation is shown to be erroneous (such as where the FEMA study is superseded) this elevation needs to be used as the basis for the delineation of the 100-year floodplain limits on the site plan.
2. The FEMA FIRM depicts a flood hazard area but does not provide the elevation(s) or the profile(s) of the 100-year flood plain level. In this case, the designer would need to perform a study (as per Section 3.21.3(C) of the FWW Rules) to determine a floodplain elevation.
3. The FEMA FIRM does not depict a flood hazard area, but the project is adjacent to a river or stream, all of which have floodplain as defined in the Rules. Similar to the scenario presented in item 2 above, a designer would need to provide a study to determine a floodplain elevation.

With respect to identifying and depicting a floodplain elevation, reference is made to FWW Rules Section 3.21.3(D), which states, "*the flood plain edge must coincide with the flood plain elevation and topographic contour elevations as depicted on submitted plans. Transposing flood boundaries from FEMA maps by using horizontal scaling is not acceptable for plans submitted to the Department. Identification of the one hundred year flood elevation must be expressed as North American Vertical Datum 1988 (NAVD88).*"

In all cases, the designer will need to identify the presence and edge of the floodplain on the site plans and will need to determine whether the proposed project will involve alterations within floodplain. In the alternative, as per Section 3.8.5(A)(4) of the FWW Rules, when the elevation of the floodplain is not available from published sources a designer may, where appropriate, provide "clear and convincing documented evidence that the project site is above any probable one hundred (100) year flood elevation".

Other floodplain considerations

- Ponds: If a pond is situated along a river or stream, such as segments of a river or stream that represent ponded areas behind a dam, these areas are considered to be part of the river or stream system and will have associated 100-year floodplains. Natural ponds that do not have inflowing rivers or streams and that are not impounded by a dam would not be considered to have RIDEM-regulated floodplains, even if FEMA indicates presence of Zone A floodplain on FIRM maps.
- Coastal floodplain: The FEMA Flood Insurance Rate Maps include the elevations of 100-year floodplains adjacent to coastal areas of the state. It is important to ascertain whether the elevations represented on the FEMA FIRM are based upon flooding from adjacent / nearby rivers / flowing bodies of water or from adjacent/ nearby coastal waters. Generally coastal floodplains have a horizontal flood profile that extends inland from coastal waters, as opposed to a sloping flood profile that generally follows a river system down to coastal waters. These flood profiles can typically be seen on the pertinent FEMA Flood Insurance Study for the subject community. It is important to note that if an indicated FEMA FIRM floodplain elevation is based upon coastal flooding, volumetric floodplain compensation to the mapped floodplain elevation is not required, given the fact that the elevation of flood waters from a coastal flooding event are from storm surge from the ocean (typically from a major hurricane) and will not be adversely impacted by the presence of fill being placed on a site. It may be possible that rivers or streams within this coastal floodplain area may also have a separate riverine component of 100-year floodplain. On a case-by-case basis, it may be necessary to determine this elevation by a separate floodplain study. This elevation will be at an elevation that is typically less than the coastal flooding elevation mapped by FEMA.

Guidance on Analysis Methods to Determine Floodplain Elevation

In cases where a floodplain elevation has not been established by FEMA or another known published study, the determination of a riverine floodplain elevation or elevation profile at a site involves a two stage analysis process. The first step is the determination of a 100-year return period flood discharge rate for the site. The final step is the hydraulic modeling of this flood discharge through the pertinent sections of the watercourse to produce a floodplain elevation at a given point or floodplain elevation profile along a segment of the watercourse. This elevation or flood profile is then used with the site's topography map to depict the limits of the 100-year floodplain.

First Part of Analysis: Determination of the 100-year flood discharge rate

The first is a hydrologic analysis to determine the peak 100-year flood discharge rate for the site. In smaller watersheds this is typically a hydrologic analysis based on the 100-year return period (1% probability in any given year) rainfall event for the watershed. (Use the 100-year return period rainfall data contained in the RIDEM Stormwater Rules RICR-150-10-8.6(E)). In larger watersheds other factors such as snowmelt may become involved and regression equations may be more appropriate.

In some larger watersheds, especially in the rural areas of the state, it may be necessary to use regression equations to determine flood flows. The USGS StreamStats web-based tool may be used in these instances.

In relatively small watersheds that lack any significant hydraulic controls or significant natural or manmade ponding areas a relatively simple hydrologic model can be used, such as TR-55. In somewhat larger and more complex watersheds, a TR-20 analysis or similar commercially available hydrologic and hydraulic software package would be appropriate. Such a method would be able to model the effects of ponds, swamp areas, and ponding upstream of culverted roadway crossings, bridges, and dams.

The following are some key considerations in the submittal of the hydrologic analysis portion of a floodplain analysis:

- Include a watershed map drawn to an engineering scale that depicts topography, hydrologic soil groups, ground cover types, and time of concentration flow path. On this map also depict natural and manmade detention storage areas.
- Provide an analysis of the weighted curve number for each separate subarea of the watershed and the time of concentration of each separate subarea.
- Provide pertinent input and output information for the analysis of all storage routing through areas of natural and manmade detention (such as ponds, swamps, culverted roadway crossings, bridges, and dams).
- Provide all pertinent information that is used to perform the analysis. This information needs to be presented in a clear and concise manner, conducive to verification (spot checking). The submittal needs to provide an adequate level of watershed mapping detail and hydraulic structure & detention storage detail. Associated detailed input and output information is also necessary.
- The analysis should also be accompanied by an adequate narrative to explain all methodologies used, as well as any parts of the analysis that may need further clarification.

Second Part of Analysis: Determination of the Extent of Inundation Resulting from the 100-year flood discharge rate

- Using the 100-year flood discharge rate that is obtained for the site in question, the designer needs to provide a hydraulic analysis to determine the corresponding flood elevation / flood profile that this discharge will cause at this location. Typically, all of these methods rely on some form of the Manning's equation. Specifically, the key inputs to any of these analyses will involve:
  - the development of areas of cross-sections based on topography of the river or stream channel and adjacent river bank / streambank areas and adjacent overbank areas,
  - the slope of the channel,
  - the roughness coefficients (the Manning's n-values) for both the river /stream channel and the overbank areas, and
  - the analysis will require calculation of the wetted perimeter of the flow, or the analysis method will automatically calculate this.
- The primary output is the resulting depth of flow for the 100-year flood discharge.
- Once this is obtained the limits of the 100-year floodplain can be plotted on the proposed condition site topography.

There are many models available that will perform this type of analysis. These models have varying levels of precision. At the lower end of this spectrum is the use of a programmable calculator analysis using the Manning's equation at two or three relatively consistent stream cross-sections. An intermediate level analysis might involve a hydrologic and hydraulic software package that includes both capabilities to calculate flood discharge and to provide a basis level of channel discharge analysis. At the upper level of the analysis spectrum would be the various levels of the HEC-RAS analysis method. The HEC-RAS software uses the standard step-backwater models to develop the 100-year floodplain. The most basic level would be a steady state HEC-RAS model. This will utilize the routing of the peak flood discharge through the site assuming that this rate does not vary with time. This method has the drawback of not being well-suited for evaluating how a floodplain will react to the loss of floodplain storage over the varying discharge rates of the flood event. The unsteady flow version of HEC-RAS allows the input of an actual flood hydrograph rather than simply a peak flood discharge rate. This allows the model to better predict the effect of loss of flood storage on the calculated floodplain elevation.

More recently, HEC-RAS models have been developed to utilize digitized topographic data and digitized roughness coefficients to create floodplain mapping.

The following are some key considerations regarding the submittal of the hydraulic analysis portion of a floodplain study:

- Provide the name and version of all software packages used to prepare the analysis.
- Provide cross-section drawings, to an indicated scale (preferably using a scale on a typical engineer's scale) that depicts the cross-section data that is input to the analysis. The submittal needs to facilitate the cross-checking of cross-section input date with topographic site plan data. For distance vs. elevation cross-section data, clearly indicate the base line / starting point of each cross-section.
- Clearly depict and label all of the cross-sections used in the analysis. Cross-sections that are part of a previous study (such as a FEMA Study) need to be differentiated from cross-sections that may be added to create a more refined or more site-specific hydraulic model.
- Roughness coefficients (Manning's n-values) used in the analysis for the channel and for the overbank areas need to be clearly indicated. The source and basis of these n-values needs to be clearly presented for both existing and proposed conditions. Appropriate narrative will be needed to support the selection of the various n-values used in the analysis. It is advised that n-values be developed using a reliable hydraulics reference, such as Chow, <u>Open Channel Hydraulics</u>. Also, to be conservative, the summer-condition assumption of floodplain vegetation in leaf-out condition should be used for vegetated areas of riverbank and overbank.
- The submittal must clearly identify and label which parts of the analysis represent inputs, and which represent outputs.
- The analysis needs to address how any tailwater conditions are taken into account in the model. Also provide and describe in accompanying narrative any other key hydraulic inputs used in the site specific hydraulic analysis.
- Typically, inputs and outputs will include existing and proposed condition cross-section data, existing and proposed condition hydraulic roughness data, and existing and proposed condition flood profiles.
- The pages of the analysis should be numbered to facilitate reference by the reviewer in the event that questions need to be directed to the modeler.

<u>Guidance Specific to Submittal of HEC-RAS Analysis</u>

Below is a list of items concerning floodplain impacts analysis that may be helpful in submitting a HEC-RAS analysis.

- Provide an analysis of any proposed structures which will fill and/or displace any volume of 100-year floodplain. This analysis should utilize a HEC-RAS hydraulic model in order to provide a better analysis of how any loss in floodplain storage volume will affect river flows and river flood elevations, especially the peak flood elevations downstream of the site.
- Please provide the name and version of the software package used to prepare the hydraulic analysis.
- Please indicate whether the HEC-RAS is a steady flow model or an unsteady flow (varied flow) model. Please note that an unsteady flow model will be able to better predict the extent of impacts from floodplain displacement, especially in a river that has relatively short-duration peak flows.
- Provide both pre-project and post-project flood profiles for the pertinent reaches of the river. Plot the 10 and the 100-year profiles for the pre-project and the post-project conditions.
- Include all pertinent hydrologic and hydraulic analyses which have been used to determine the pre- and post-development peak flood discharges in the 10 and 100-year flood events.
- Provide cross-section drawings, to an indicated scale, that depict the river sections that are included in the submitted analysis. For all river stations used in both the pre-project and the post-project analysis, provide a section view drawn to a scale found on a typical engineer's scale.
- Depict the locations of all existing and proposed condition hydraulic cross-sections on a site plan that depicts existing and proposed condition topography. Each cross-section location must be in the form of a line segment with a starting and ending location clearly indicated.
- Manning's n-values need to be provided for the main channel section of each river cross-section, as well as for each overbank area of that cross-section. Please provide appropriate documentation and substantiation to support the n-values employed in each submitted analysis. It is advised that the n-values be developed using Chow, <u>Open Channel Hydraulics</u> as a reference. Also, in order to be conservative, the summer condition assumption (vegetation in leaf-out condition) should be utilized for all vegetated floodplain overbank areas.
- Where possible, correlate the pre-project analysis with the pertinent FEMA hydraulic analysis which supports the FEMA Flood Insurance Study flood profile. Also, please clearly indicate which cross-sections pertain to a previously developed FEMA study and which cross-sections have been added to provide additional detail to the analysis.
- Provide all input data, including all data used to define the cross-sections input into the hydraulic analyses. The reviewer needs to be able to easily find the specific location of this information in the hydraulic analysis submittal. The locations of all input data needs to be clearly presented.
- For each river station used in both the pre-project and the post-project analysis, provide the data input used to define each river cross section. These are the points found in distance vs. elevation table. Please clearly indicate the location of these points with the corresponding river station in the submitted input data.
- Please clearly address how all pertinent tailwater conditions were addressed in the analysis.
- Please clearly indicate and label all input data and all output data, and clearly differentiate between input and output data. Also, clearly indicate and label these data as to whether they represent existing or proposed conditions.
- Please clearly label each analysis run, specifically labeling which flood event is being analyzed and

whether a pre-project or post-project condition is being analyzed.

- With respect to digital modeling of HEC-RAS the submittal will need to provide a sufficient level of input and output data and detailed description of the method of analysis to enable cross-checking by the reviewing agency and to provide an adequate public record. Such key data inputs as Manning's n-values and elevation (whether in cross-section format or in topographical format) need to be clearly presented for review.
- Please number the pages of the submitted hydraulic analysis. This will facilitate reference to any part of the analysis by the reviewer, should questions arise of any portion of the analysis.

Flood Protection Standard with respect to Floodplain

As already noted above, per Section 3.7.1(E)(1) of the FWW Rules, "*Projects and activities taking place in a floodplain shall not result in any net reduction in flood storage capacity and shall not reduce the rate at which floodwater is stored by the floodplain.*" Projects outside floodplain limits, or that do not result in displacement of floodplain capacity from fill or structures, are presumed to meet this standard. If fill or structures are proposed that result in displacement of flood storage capacity, the standard can only be met if compensatory storage is appropriately provided, with supporting documentation, as part of the project design. Otherwise, an applicant would need to seek a Variance from this standard as set forth in Section 3.7.3 of the FWW Rules.

Volumetric Floodplain Compensation: Pertinent Rules and Considerations:

The following items provide guidance on the design and submittal of the plans and analysis for such mitigation.

- Pertinent calculations must be prepared by a Rhode Island registered professional engineer. All plans and analysis must include a signed and dated RI professional engineer's stamp.
- The plans will need to clearly indicate the datum used and its relationship to the NAVD88 datum.
- The site plans need to clearly depict and clearly label the perimeter areas of both the floodplain displacement and the areas of proposed floodplain compensation.
- The floodplain compensation areas need to include provisions that will preclude the future placement of fill or obstructions within these areas.
- To allow adequate review of the floodplain compensation plans and analysis provide existing and proposed condition topography using a one-foot contour interval. As per FWW Rules Section 3.12.2(A)(4)(d)(3)(DD)(i), *"the volume of compensatory flood storage must be equal to or greater than the volume of floodwaters displaced by the project on a foot-by-foot elevation basis unless otherwise specified by the Department."* In order to clearly demonstrate this, the submitted pre-project vs. post project analysis needs to provide the floodplain volumes displaced vs. compensatory storage volume on a foot-by-foot elevation range basis. The amount of storage created must exceed the volume displaced for *each* one-foot elevation range of the floodplain.
- As per FWW Rules Section 3.12.2(A)(4)(d)(3)(DD)(ii), *"the compensation area must have an unrestricted hydraulic connection to the affected floodplain and provide the same rate of flood storage capture and discharge over the course of the flood event as in pre-project conditions."* To this end clearly depict adequate site grading details to demonstrate this hydraulic connection to floodplain of the river or stream. If the proposed hydraulic connection is a relatively small opening, provide an analysis to show that the length of time to fill the floodplain compensation volume will be relatively short, so as to allow the compensatory storage to be effective during the peak portion of the flood event. Small openings need to be avoided due to potential for clogging. The design needs to demonstrate that the floodplain compensation volume will fully

empty after the storm event so as to allow it to be available for a subsequent flood event. The design cannot result in ponded water remaining after flood waters recede.

- As per FWW Rules Section 3.12.2(A)(4)(d)(3)(DD)(iii), *"the compensatory storage must be located within the same reach of the river or flowing body of water (i.e., between the nearest features controlling the flood water elevations upstream and downstream from the proposed displacement area) as the project involving flood water displacement, and must be located as close to the proposed displacement area as possible."* Typical physical boundaries of reaches are dams, bridges, culverted roadway crossings, major changes in river bottom slope, and other changes that will significantly change river hydraulics. The site plans or floodplain study plan views need to indicate the boundaries of each separate reach involved. The floodplain displacement vs. compensation analysis requirements described above need to be met for each separate reach of the impacted floodplain. For each separate river or stream reach involved provide a separate incremental floodplain displacement vs. floodplain compensation analysis on a foot-by-foot elevation range basis.
- As per FWW Rules Section 3.12.2(A)(4)(d)(3)(DD)(iv), *"creation of compensatory storage must precede or occur simultaneously with the construction of any portion of the project which displaces flood waters."* To this end provide pertinent notes on the plans to require construction of the floodplain compensation volume prior to or concurrently with the proposed floodplain displacement.
- As per FWW Rules Section 3.12.2(A)(4)(d)(3)(DD)(v), *"where the applicant proposes a compensatory storage area on property owned by others, the applicant must submit a written agreement between such landowner and the applicant allowing compensatory storage, and to permanently maintain such area for flood storage purposes in the event that the Department approves the applicant's project."*. The agreement must be provided along with other standard required enclosures.
- As per FWW Rules Section 3.12.2(A)(4)(d)(3)(DD)(vi), *"the design must include all features and best management practices to ensure that impacts to the functions and values of other freshwater wetlands and buffers have been mitigated."* Therefore, provide all pertinent soil erosion and sediment control details and all pertinent revegetation details on the site plans.
- For floodplain analyses that use floodplain cross-sections, all cross-sections need to be depicted on a site plan. Also, each cross-section needs to be drawn to an indicated scale and needs to depict a common reference / base line which also needs to be depicted on a site plan.
- Be sure not to consider any areas within or beneath buildings, including pile or column-supported buildings, as floodplain compensation volumes. All areas represented on site plans as buildings need to be considered as solid fill or displacement. Please note that FWW Rules Section 3.12(A)(4)(d)(3)(DD) does allow for *"permanently eliminating structures which currently displace flood waters"* to be considered as floodplain compensation.
- All areas within proposed stormwater basins must be considered as floodplain displacement, even though these areas may consist of voids or stormwater. Please note that typically the stormwater that will fill a stormwater basin will arrive at a basin well in advance of the waters that arrive in a flood event. Detention storage for peak flow and/or water quality management are not to be considered as volumetric floodplain compensation.

Associated Guidance on Variance Requests for Floodplain Displacement

As noted earlier, projects that cannot meet the Flood Protection Standard either through avoidance of work in floodplain or through compensatory storage for floodplain displacement will need to seek approval for a Variance of the standard as described in Section 3.7.3 of the FWW Rules. To this end, the following guidance should be followed:

- The Submittal should provide an engineering estimate of the amount of resulting increase in floodplain elevation involved, along with information on the approximate areal extent of this increase.
    - One approximate method of providing an estimate of impact is the “bathtub” approach of calculating the available area at the uppermost limit of the floodplain and then apportioning the increased volume onto this area to obtain an approximate level of increase.
    - Another method would be to model the storage function behind a structure at the down-gradient end of a particular reach (such as a culverted roadway crossing or a dam) and running the model under both the existing and the proposed elevation-storage -discharge relationships.
    - A more precise model would be to use a steady state HEC-RAS model, which uses a constant flood discharge rate.
    - The most precise method would be the modeling of the reach with an unsteady state HEC-RAS model under existing and proposed conditions.
- The submittal needs to clearly address whether the increases will be confined solely to the applicant’s property or whether offsite impacts are expected.
- Offsite impacts may require written authorization from the affected off-site owners as part of the application package, per FWW Rules Section 3.8.3(C).
- The submittal should address whether any structures or other infrastructure (such as on-site wastewater treatment systems (OWTSs) will be impacted by any increased floodplain elevation.

Common Floodplain Displacement and Compensation Analysis Methods:

1. Average End Area Method Using Stationed Cross-Sections:

Description:

This method utilizes a number of cross-sections taken in a vertical plane, typically at set intervals or stations along the length of the area of the floodplain containing the proposed floodplain displacement and the proposed compensation storage. At each stationed cross-section the existing vs. proposed grade is plotted. Subsequently an area of fill and /or cut is determined based on the area between the two grade lines within each one-foot elevation range of the floodplain. This is done at each station.

To obtain the volume of floodplain displacement or compensation between a successive pair of cross-sections the areas within each pair of cross-sections is averaged. This average value is then multiplied by the distance between the successive stations.

This analysis needs to be done for every reach of the floodplain. Also, note that no calculation of volume may be tallied for levels above the 100-year floodplain, nor for levels below the normal river or stream water level.

Please note that the goal of this analysis is to demonstrate a net gain in floodplain for each one-foot elevation range of the floodplain.

Typical calculation:

Volume of Displacement or Fill (-) or Compensatory Gain in Flood Storage (+) =

((XS area 1 (+ if gain, - if fill) XS area 2 (+ if gain, - if fill)) /2 x distance between cross-sections

This process is repeated along the entire length of the study area and for each separate elevation range interval. In instances where a long reach might involve a gradually changing floodplain elevation, the depth of the floodplain may be used in place of the elevation range at every cross-section.

The goal is to demonstrate no net loss in floodplain storage for each separate elevation range.

Typical Uses:

This method is commonly used for linear projects such as roadways, bike paths, and utility projects. It can also be used for other types of projects that involves a length of floodplain that can be adequately modeled using appropriately spaced cross-sections. This method is conducive to the analysis of compensation vs. displacement on an incremental basis over the entire range of the floodplain.

2. Average End Area Method Using Sections Taken in a Horizontal Plan:

Description:

This method utilizes cross-sections taken in a horizontal plan at each one-foot interval of the floodplain area being evaluated. First a polygon is depicted which encompasses the area of floodplain displacement and /or compensation being evaluated. Each polygon or study area needs to be in a separate reach of the floodplain being evaluated. Next a base elevation is selected that is at or below the lowest elevation of the proposed floodplain displacement. Then for each elevation contour, calculate the area of floodplain inundation, both for the existing condition and the proposed condition. The volume between adjacent pair of elevation contours is then calculated for both the existing and the proposed condition for both the existing and the proposed conditions. Again, the goal of this analysis is to demonstrate no net loss of flood storage volume in the proposed condition for each one foot elevation range of the floodplain. The analysis needs to be performed for every reach of the floodplain.
Also, do not consider any volumes below the normal water level of the river nor any above the 100-year floodplain.

Typical calculation:

Available floodplain storage for interval between one-foot elevation contours = (Area of inundation 1 + Area of inundation 2) / 2.

This value is obtained for both existing and proposed conditions.

The goal is to ensure that for each one-foot elevation range there is no net loss in floodplain storage.

Typical Uses:

This method is suitable for most situations. It is most commonly used in situations where the floodplain displacement and compensation areas can be readily included within a polygon so as to facilitate calculation of areas. This is the preferred method of analysis for most projects, except for those of a linear nature.

3. Grid Method

Description:

This method involves the creation of a grid of corner points, typically in a square pattern, over the study area. The existing and proposed condition volumes between a base elevation and the site grade is then mathematically determined. The difference between the existing condition volume and the proposed condition volume represents the volume of floodplain storage lost or gained.

This method needs to be employed separately for each separate reach of the floodplain. Also, do not consider any volumes below the normal water level of the river nor any above the 100-year floodplain.

Typical calculation:

Volume of displacement between a base elevation set at higher than the normal river level and the site grade = ((H1 + H2 + H3 +H4) X SIDE^2 , where H1 + depth of earth at corner #1 of each grid, etc., and where SIDE is the side dimension of the grid square.

Calculation steps:

1. Enclose the study area in a polygon.
2. Set up a grid of squares.
3. Indicate the elevation of the 100-year floodplain.
4. Calculate the height of earth (ex., H1) above a base level that is arbitrarily set but can be set at the normal river level.
5. Calculate the height of the existing earth by subtracting the base elevation from each corner point elevation.
6. Calculate the volume of earth in each grid "box" as described above.
7. For areas on the edges of the project that do not involve complete coverage by a grid square, make appropriate adjustments for partial grid coverage. Sum up all of the volumes to obtain the total of earth within the study area polygon.
8. This value is obtained for both existing and proposed conditions. A decrease in this volume of earth in the proposed condition represents a gain in floodplain storage and an increase represents a loss.

Typical Uses:

This method is useful for situations that have relatively intricate or irregular topography, typically with many areas of shallow cuts and fills. An example would be the proposed regrading of an athletic field, park, or golf course. This method does not lend itself well to the analysis of displacement vs. compensation on an incremental basis over the entire range of the floodplain. Therefore it is best employed in situations that have relatively minimal range (such as approximately 1' to 2') in existing vs. proposed grades.

4. **Digital Applications:** While RIDEM does not recommend or endorse any particular digital application of floodplain calculation, it recognizes that many digitally assisted technologies may be useful in the required calculations of floodplain displacement and compensation. The following is from Vermont DEC Compensatory Storage Technical Guidance, April 19, 2018 and provides useful guidance for digital technologies.

   "Topographic data derived from field survey including digital elevation models (DEM), triangulated irregular networks, (TIN), digital terrain models (DTM), and contours may be used to compare existing and proposed ground surface elevations. This data can be used in computer programs including Geographical Information Systems (GIS) and computer aided design (CAD) to calculate volumes. One method in a GIS would be to overlay a polygon of the Special Flood Hazard Area (SFHA) with elevation contours, then split the polygon feature into elevation intervals by tracing the contours. The area of these new polygons can be multiplied by the depth to the Base Flood Elevation (BFE) minus the average elevation between the two contours. The depth to BFE should be calculated as the BFE minus the average elevation between two contours. This approach is appropriate for use on most sites, including those with more complex terrain or hydraulic dynamics."

   When submitting a digital model of the floodplain compensation analysis the submittal needs to contain an adequate level of existing and proposed condition input data and a detailed explanation of the methodology to allow both the reviewer and the public at large to be able to verify the validity of the model's input and outputs.

Floodway Considerations

Once it is determined that a project involves work near a flowing body of water, including rivers and streams, a determination must be made as to the limit of floodway adjacent to the river or stream. This is a simple and straightforward determination and is described in Section 3.21.4 of the FWW Rules. In brief, DEM will recognize any floodway limit identified on FEMA FIRM maps. If a floodway has not been designated for any particular river or stream, the floodway limit will correspond to the edge of the river or stream as described in Section 3.21.2(A) of the FWW Rules.

Flood Protection Standard with respect to Floodway

As already noted above, per Section 3.7.1(E)(2) of the FWW Rules: "*Floodway obstruction: projects and activities taking place within or adjacent to rivers or streams shall not encroach into floodway limits with any fill, structure or other development.*" Projects that do not include fill, placement of a structure, or any other development within the limits of a floodway are presumed to meet this standard. An applicant would need to seek a Variance from this standard as set forth in Section 3.7.3 of the FWW Rules for any project that does not meet this standard.

Floodway Impacts: Pertinent Rules and Considerations

Floodway Guidance:

- All river and stream crossings by roadways, driveways or other access ways will need to utilize either a bridge or box-culvert at least as wide as the floodway so as to avoid any obstruction of the defined floodway.
- Endure that all proposed obstructions, including fences, solar panels, etc. are located outside of the limits of floodways.
- When the exact boundary of a FEMA-designated floodway comes into question the designer will need to contact FEMA for detailed location information regarding the exact position of the FEMA Floodway. Please refer to the additional resources section at the end of this guidance document.
- If the project cannot avoid encroachment within the floodway limits with fill, structures or other development in order to meet the standard, supporting documentation prepared by a RI registered Professional Engineer must be provided to satisfy all of the Variance Criteria of Section 3.7.3 of the FWW Rules, including that the relevant Review Criterion (noted below) has been met.

Review criteria for work involving floodways

Per Section 3.7.2(B)(19) of the FWW Rules: "Before issuing a permit, the Department must determine that a proposed project or alteration will not result in: Placement of any structure or obstruction within a floodway so as to cause harm to life, property, or other functions and values provided by freshwater wetlands or their associated buffers".

Additional Resources:

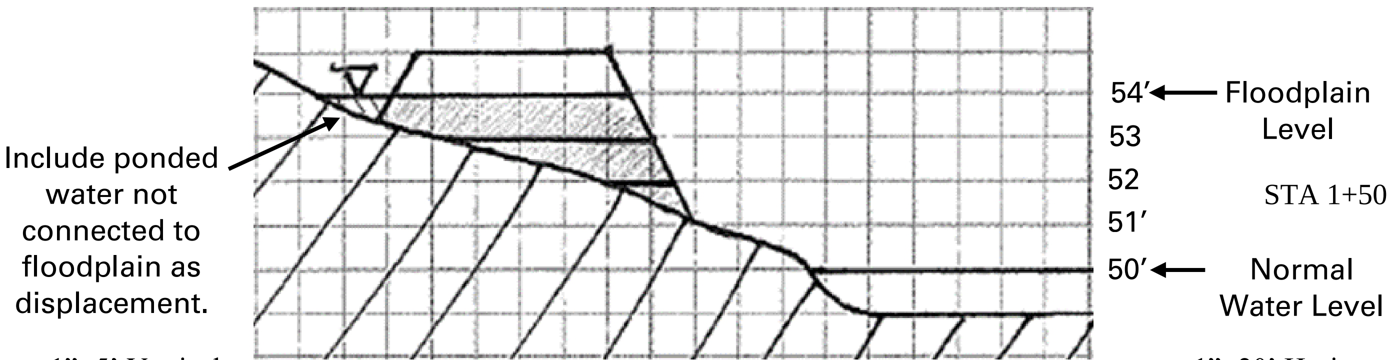
Per FEMA guidance, please note that effective FIRMs, FHBMs, FIS Reports, FIRM and National Flood Hazard Layer geodatabases (NFHL), and Letters of Map Change (LOMC) with determination dates after July 1997 are available from the FEMA Map Service Center: http://msc.fema.gov (phone: 877-FEMA-MAP).

Please see FEMA website for "Numerical Models Meeting the Minimum Requirements of the National Flood Insurance Program at http://www.fema.gov/national-flood-insurance-program-flood-hazard-mapping/numerical-models-meeting-minimum-requirements.

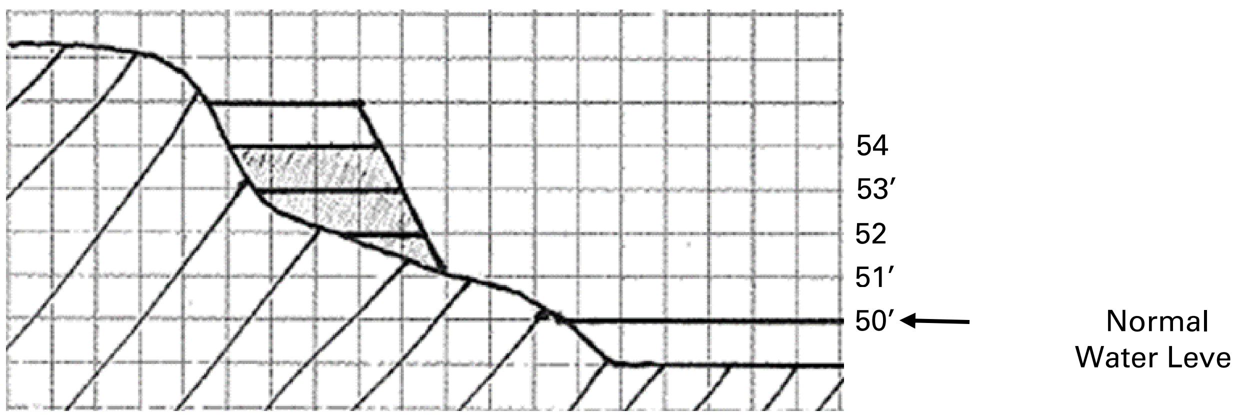
USGS Stream Stats link: The USGS StreamStats Application provides access to spacial analytical tools that may be useful for obtaining data related to calculating drainage areas and obtaining estimates of flows related to calculation of floodplain limits. The application can be accessed at:
https://www.usgs.gov/tools/streamstats-application

Computational Examples and Figures

Average End Area Method – Stationed Cross Sections:



1”=5’ Vertical, 1”=20’ Horizontal



STA 2+00
1”=5’ Vertical, 1”=20’ Horizontal

Calculate displacement in each stationed range of floodplain in each one-foot elevation range.

51’ to 52’: $\frac{5\ ft^2+10\ ft^2}{2} * 50' = 375\ ft^3$

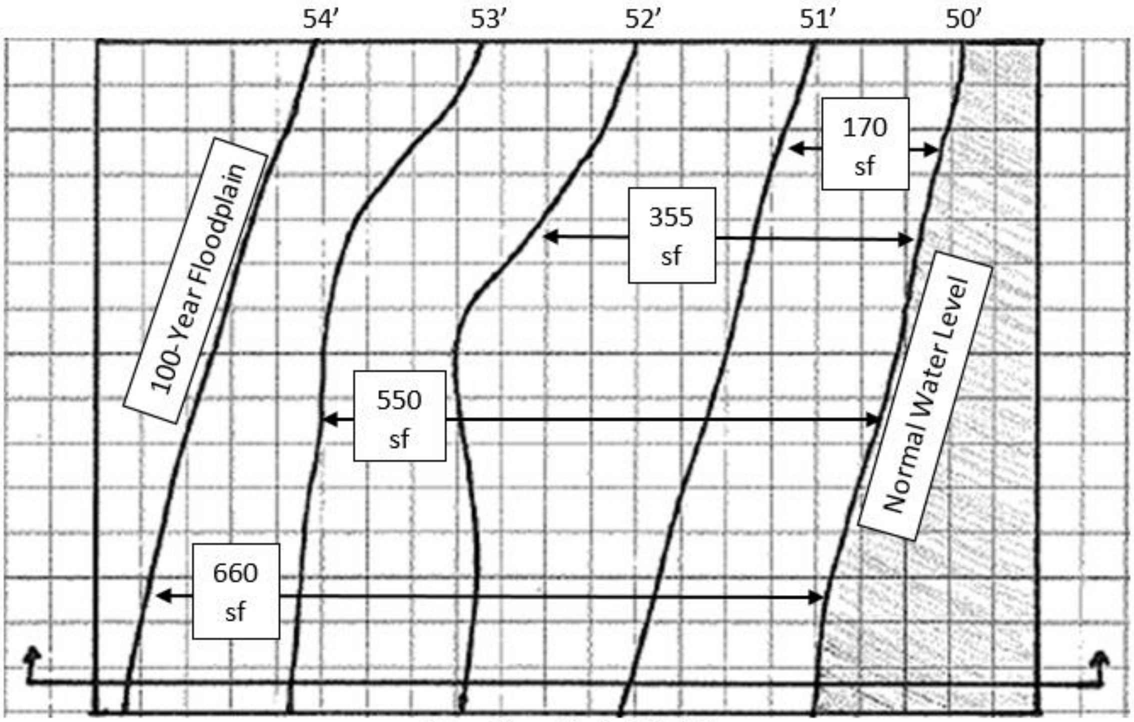
52’ to 53’: $\frac{12\ ft^2+14 ft^2}{2} * 50' = 650\ ft^3$

Note: 50′ is the station

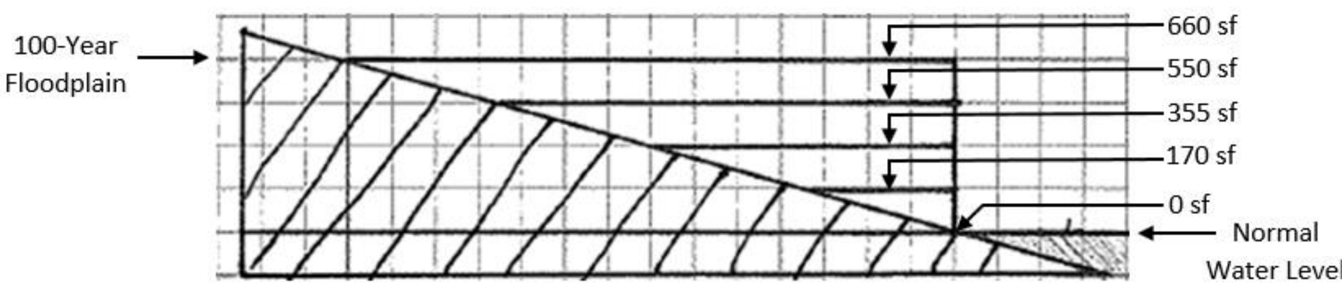
53’ to 54’: $\frac{30\ ft^2+20\ ft^2}{2} * 50' = 1{,}250\ ft^3$

- Floodplain compensation volumes would be calculated in the same manner.

Average End Area Method – Sections in Horizontal Plane:



Plan View, Scale 1"=10'



Section View

Calculate floodplain volume for each 1' interval in limit of study.

50' to 51': $\frac{0\ ft^2 + 170\ ft^2}{2} * 1' = 85\ ft^3$

51' to 52': $\frac{170\ ft^2 + 355\ ft^2}{2} * 1' = 262.5\ ft^3$

52' to 53': $\frac{355\ ft^2 + 550\ ft^2}{2} * 1' = 452.5\ ft^3$

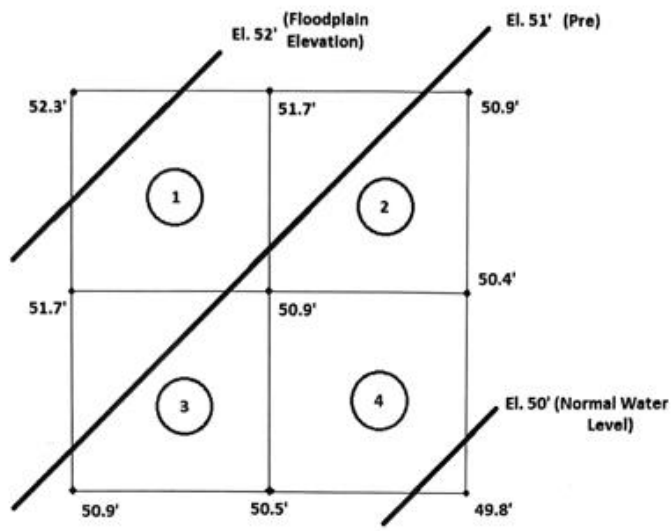
53' to 54': $\frac{550\ ft^2 + 660\ ft^2}{2} * 1' = 605\ ft^3$

Floodplain storage performed similarly for pre and post conditions.

Grid method:

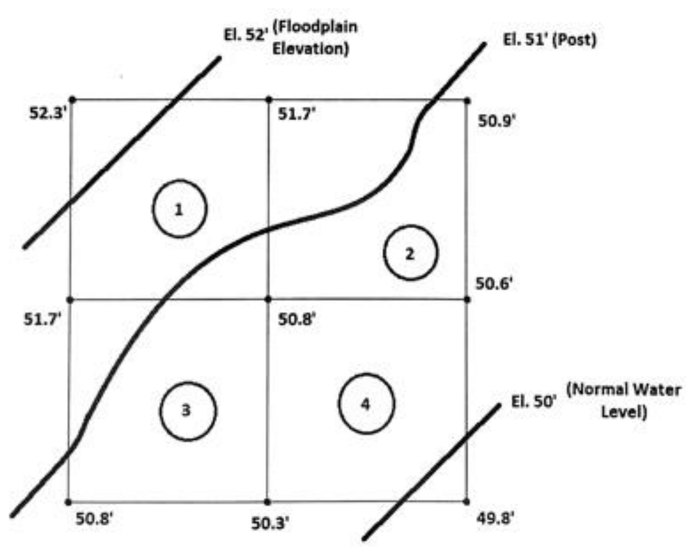
For calculation of available floodplain storage within a gridded area, pre- and post- project.

PRE-CONDITIONS



1" = 8'

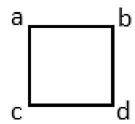
POST-CONDITIONS



1" = 8'

- Do not consider depths above 100-year floodplain elevation, use zero depth.
- Do not consider elevations below normal water level, substitute the normal water level.

Example:



Floodplain elevation ↓ Elevation at point ↓ Area of grid ↓

$$\frac{(x-a)+(x-b)+(x-c)+(x-d)*A}{4} = volume$$

- Calculate pre volume of floodplain storage.

(All units in feet unless otherwise noted)

Grid Box 1: $$\frac{[(52-52.3)+(52-51.7)+(52-51.7)+(52-50.9)]*8^2}{4} = \frac{[0+0.3+0.3+1.1]*8^2}{4} = 27.2\ ft^3$$

Grid Box 2: $$\frac{[(52-51.7)+(52-50.9)+(52-50.9)+(52-50.4)]*8^2}{4} = \frac{[0.3+1.1+1.1+1.6]*8^2}{4} = 65.6\ ft^3$$

Grid Box 3: $$\frac{[(52-51.7)+(52-50.9)+(52-50.9)+(52-50.5)]*8^2}{4} = \frac{[0.3+1.1+1.1+1.5]8^2}{4} = 64\ ft^3$$

Grid Box 4: $$\frac{[(52-50.9)+(52-50.4)+(52-50.5)+(52-50)]*8^2}{4} = \frac{[1.1+1.6+1.5+2.0]*8^2}{4} = 99.2\ ft^3$$

← Use 50 instead of 49.8 because 50 is normal water level.

$\sum$ pre storage = 256.0 ft^3

- Calculate post volume of floodplain storage.

Grid Box 1: $$\frac{[(52-52.3)+(52-51.7)+(52-51.7)+(52-50.8)]*8^2}{4} = \frac{[0+0.3+0.3+1.2]*8^2}{4} = 28.8\ ft^3$$

Grid Box 2: $\frac{[(52-51.7)+(52-50.9)+(52-50.8)+(52-50.6)*8^2}{4} =$

$$\frac{[0.3+1.1+1.2+1.4]*8^2}{4} = 64\ ft^3$$

Grid Box 3: $\frac{[(52-51.7)+(52-50.8)+(52-50.8)+(52-50.3)*8^2}{4} =$

$$\frac{[0.3+1.2+1.2+1.7]*8^2}{4} = 70.4\ ft^3$$

Grid Box 4: $\frac{[(52-50.8)+(52-50.6)+(52-50.3)+(52-50)]*8^2}{4} =$

$$\frac{[1.2+1.4+1.7+2]*8^2}{4} = 100.8\ ft^3$$

$\sum$ post storage = 264 ft^3

∴ no net loss of floodplain storage

Example of Reach -Typical FEMA Flood Insurance Study:

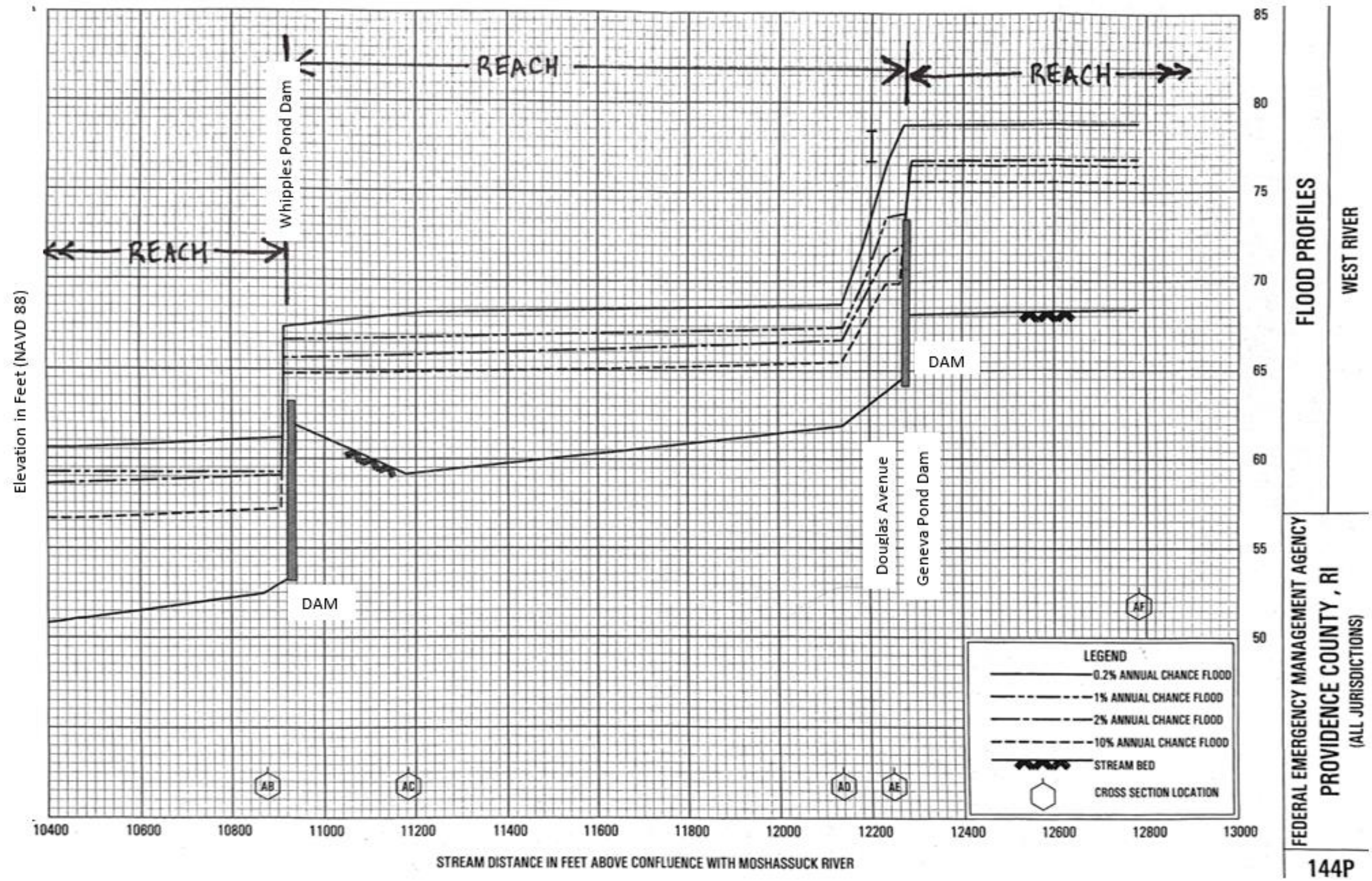


Figure Illustration from Vermont Compensatory Storage Guidance:

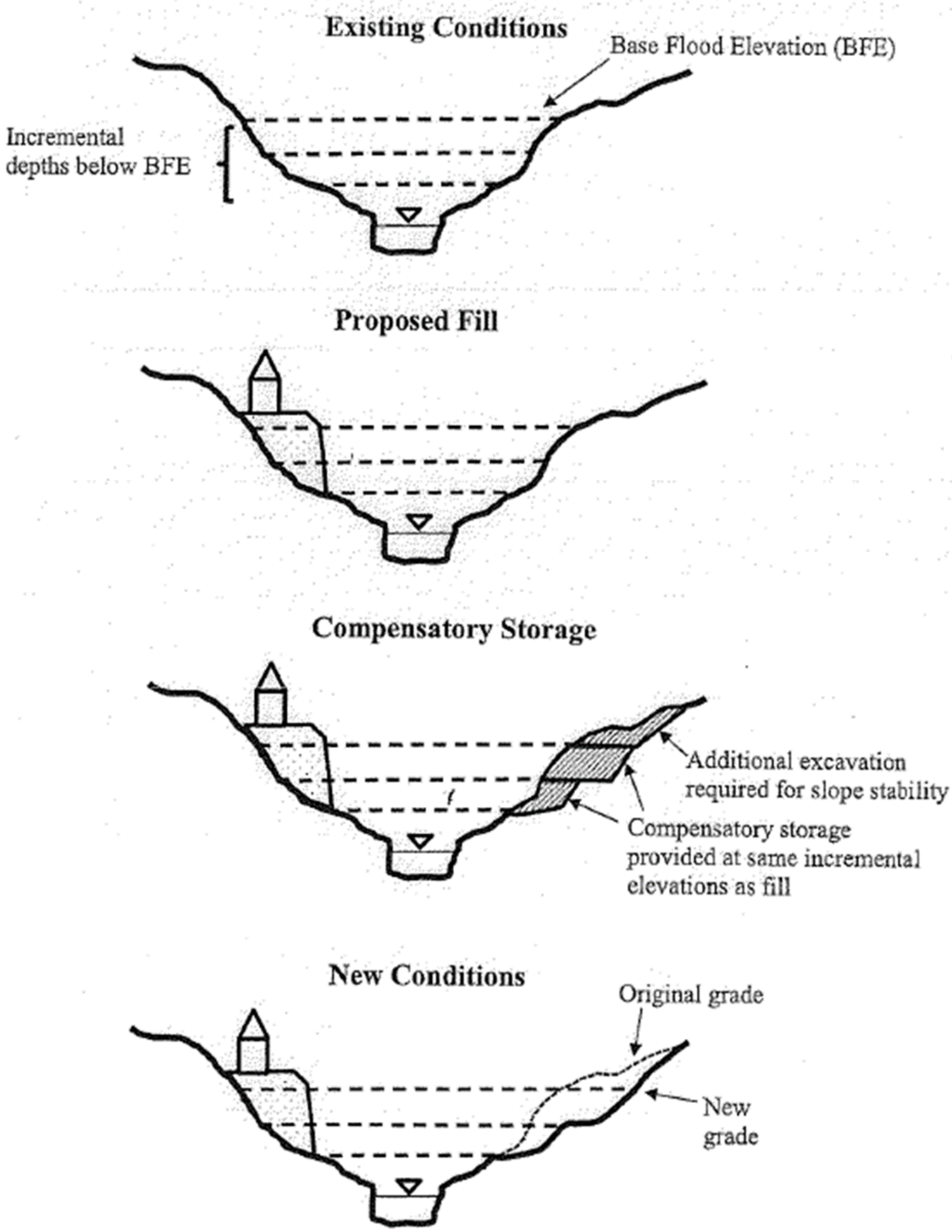


Figure 1. Conceptual model of compensatory storage requirements along a river to meet No Adverse Impact standard.

Vermont DEC Compensatory Storage Technical Guidance
April 19, 2018 4