DEPARTMENT OF ENVIRONMENTAL CONSERVATION

TECHNICAL GUIDANCE

FOR DETERMINING COMPENSATORY STORAGE REQUIREMENTS UNDER THE FLOOD HAZARD AREA AND RIVER CORRIDOR PROTECTION RULE

April 19, 2018

Table of Contents

1.0 Introduction

The purpose of this Technical Guidance is to explain methods to calculate compensatory storage needed to satisfy the No Adverse Impact Standard (NAI) of the Vermont Agency of Natural Resources (ANR) Flood Hazard Area & River Corridor (FHARC) Rule[1]. Site requirements and best management practices for compensatory storage areas is also discussed. Floodplains have several beneficial functions including storing and conveying flood waters, providing habitat for plant and animal communities, and maintaining and improving water quality. The placement of fill in floodplains impairs these functions. Incremental development and associated fill within a floodplain has a cumulative effect of increasing flood elevations, velocities, and river instability on adjacent properties and within a watershed. Compensatory storage requirements are intended to ensure that new floodplain development does not exacerbate current flooding issues in an area. The NAI standard requires that actions of one property owner shall not negatively affect public infrastructure nor the rights of adjacent property owners or residents. The best way to meet the NAI standard is to avoid developing within the Special Flood Hazard Area (SFHA). However, in cases where fill within the SFHA is unavoidable, potential increases in flood damage may be mitigated by providing an equal volume of flood storage by excavation or other compensatory measures at or adjacent to the development site.

2.0 No Adverse Impact Standard

The FHARC rule provides the following No Adverse Impact Standard (NAI) to be applied to compensatory storage for determining whether or not a proposed development meets the criteria for permit issuance:

"*...development shall not decrease flood fringe storage capacity. Development that displaces floodwater storage in the flood fringe must provide compensatory storage to offset the impacts of the proposal, when the development will cause an increase or will contribute incrementally to an increase in the horizontal extent and level of flood waters during peak flows up to and including the base flood discharge. NAI volumetric analyses and supporting data must be provided by the applicant and certified by a registered professional engineer.*

The Secretary may require a hydraulic analysis to verify that a proposed development will not increase flood elevations or velocities on floodwaters that would materially impact adjacent landowners. Hydraulic analyses and supporting data must be provided by the applicant and certified by a registered professional engineer "

A conceptual model of the NAI standard is shown in Figure 1. Proposed fill that results in a loss of floodplain storage at incremental depths up to the Base Flood Elevation (BFE) must be compensated for with new and equivalent storage. Proposed storage should be at incremental depths corresponding to the proposed fill, however, storage provided at lower elevations than the proposed fill may be considered. Fill within floodways must demonstrate adherence to applicable no-rise standards using hydrologic and hydraulic modeling.

[1] http://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/state-permits

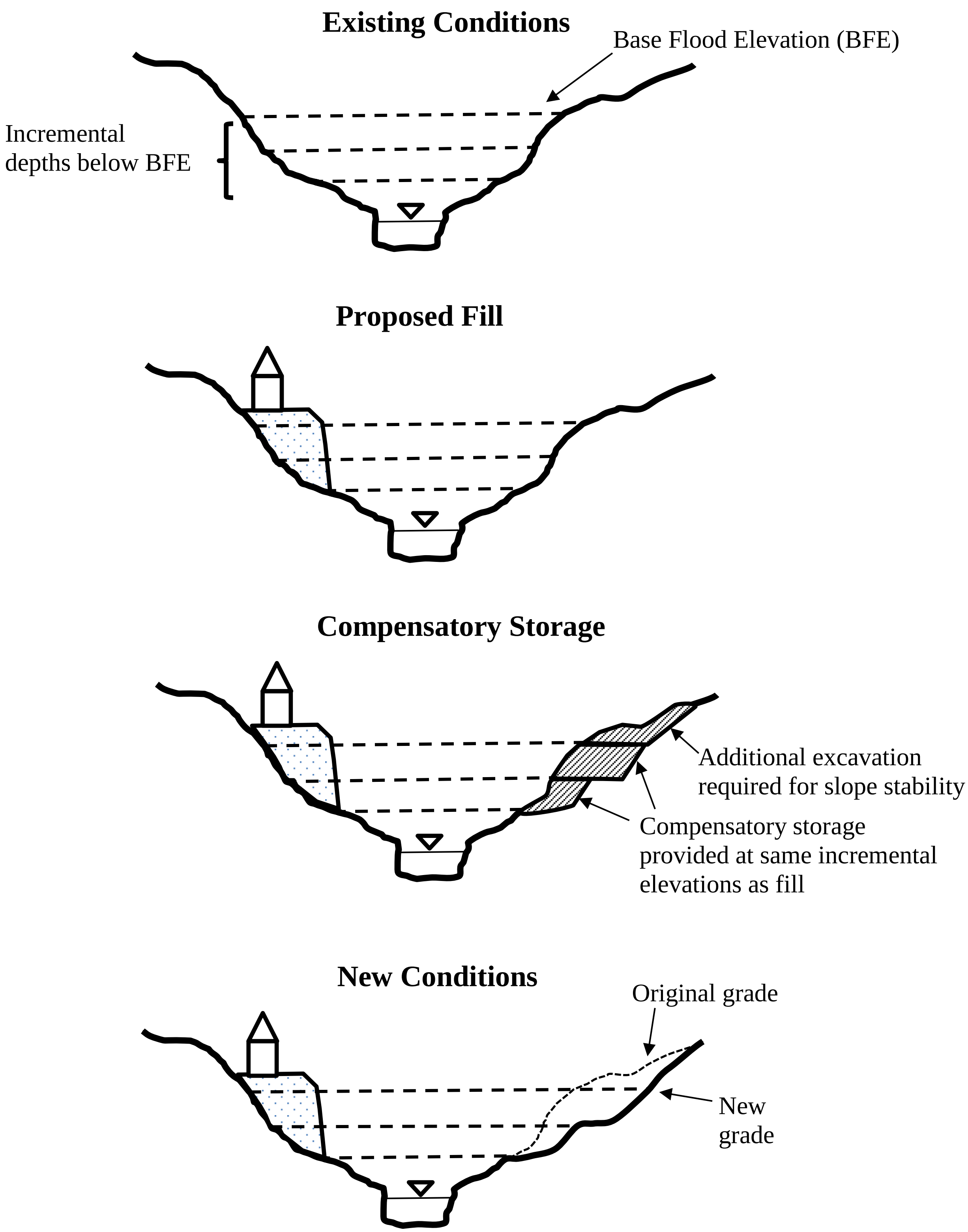


Figure 1. Conceptual model of compensatory storage requirements along a river to meet No Adverse Impact standard.

2.1 Exceptions to NAI Standards

The FHARC rule describes the circumstances in which the NAI standards for compensatory storage may be waived. The complete rule should be referred to for determining exceptions, however, compensatory storage standards may generally be waived only when:

1. A project will have no more than a minimal effect on floodwater storage and will not divert floodwaters onto adjacent property.

2. Replacement structures do not increase in footprint and comply with the elevation and floodproofing standards in the rule, as appropriate (see requirements in § 29-401).

3. Replacement structures are relocated to a less hazardous location within the flood fringe provided that there is no increase in the structure's footprint.

Projects planning to qualify as an exception to the NAI compensatory storage requirement will still need to submit detailed site plans to DEC for review. Applicants are encouraged to discuss possible exceptions to these standards with the appropriate Regional Floodplain Manager.[2]

3.0 Act 250, Section 248 and Local Bylaws

In addition to the projects subject to the Rule, this technical guidance may also be applied to projects requiring review under Floodways Criterion in Act 250 or Section 248 proceedings and/or inform ANR comments on local permits. However, in instances where a local permit is required, and community bylaws place greater restrictions on the floodplain fill, those bylaws may take precedence over NAI standards.

4.0 Siting Compensatory Storage Areas

Compensatory storage should be located onsite and adjacent to or opposite the areas of new floodplain fill. If such placement is not feasible, analysis must show that the proposed location is a hydraulically equivalent site and will not result in an adverse impact to adjacent properties or development. Compensatory storage located on a hydraulically equivalent site provides additional floodable area so that flood elevations or velocities of floodwater are not increased at the site of fill nor on adjacent properties. All excavations should be constructed to drain freely to the adjacent watercourse and not pond water in the area as flood levels recede. No area below the waterline of a pond or other body of water can be credited as a compensating

[2] http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/floodplain_mngr_regions.pdf

excavation. An alternatives analysis may be required to identify a location for compensatory storage that minimizes the impact to other resources (i.e. riparian buffers, wetlands and fisheries). Additionally, test pits should be excavated to demonstrate that the proposed compensatory storage will not intercept the seasonal high groundwater table.

4.1 Stormwater Practices

Compensatory storage is a separate volume than that required for peak attenuation under the Vermont Stormwater Management Manual Rule and Design Guidance (Vermont Agency of Natural Resources, 2017). While Vermont stormwater treatment practice (STP) standards mandate peak discharge control designed for a 100-year storm, floodplain regulations including the NAI standard typically regulate up to the 100-year flood. A 100-year storm and a 100-year flood are not the same; several factors can influence the relationship between rainfall and streamflow making it unlikely that a 100-year storm will cause a 100-year flood. Therefore, STPs generally may not be counted towards compensatory flood storage. During flood events, available storage volume within a STP will likely be occupied by local stormwater and consequently unavailable for the storage and conveyance of floodwaters (Figure 2). Compensatory storage must be available at each elevation increment lost to the proposed fill and able to accept flood flows at any time. Stormwater practices that have voids associated with fill, such as permeable pavement with a stone base layer, may not be considered compensatory storage. Additionally, any use of the floodplain for stormwater management which involves the loss of flood storage, such as placement of a berm for a detention basin, would not meet the NAI standard and therefore require compensatory storage.

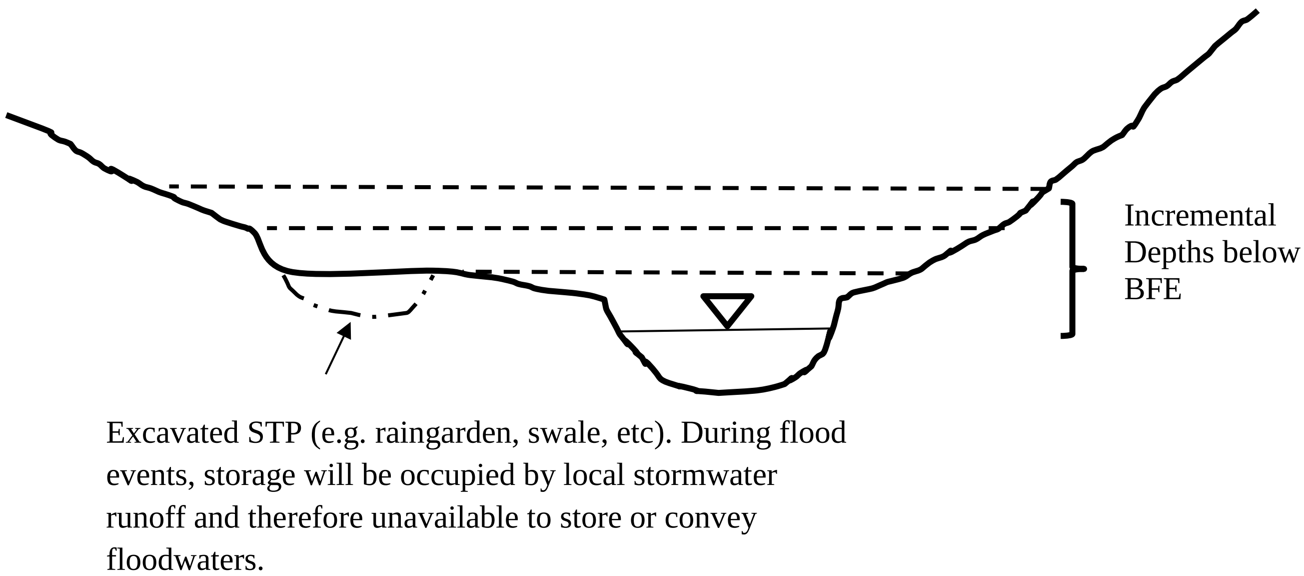
4.2 Lakes

Generally, most proposed fill within the floodplain of a lake will be of insufficient volume to result in a demonstrated increase in BFE. However, new development may result in wave action and energy deflected onto adjacent properties. Therefore, compensatory storage may be provided through the implementation of BMPs including planting and maintaining vegetated areas, including as a form of bank stabilization, establishing no-mow zones, and conservation easements. Such BMPs may be required in an area equal to the area of proposed fill and in a location expected to be impacted by the proposed development.

5.0 Methods for Calculating Compensatory Storage Requirements

Proposed development in the SFHA with structures, fill, or other items in the flood fringe must be compensated with excavation of *at least* 1.0 times the volume of the displaced storage volume. For the purposes of accuracy, any compensatory storage site plans, calculations or modeling shall be based upon at least 1’ contours that have been field surveyed. All proposed fill and compensatory storage must be clearly identified on the site plans. A comparison of storage volumes impacted at all elevations up to the base flood elevation (100-year flood event) must be summarized to quantify the impacts from the development. This information may be

STP in SFHA meets NAI standard but cannot be considered compensatory storage



STP in SFHA does not meet NAI standard

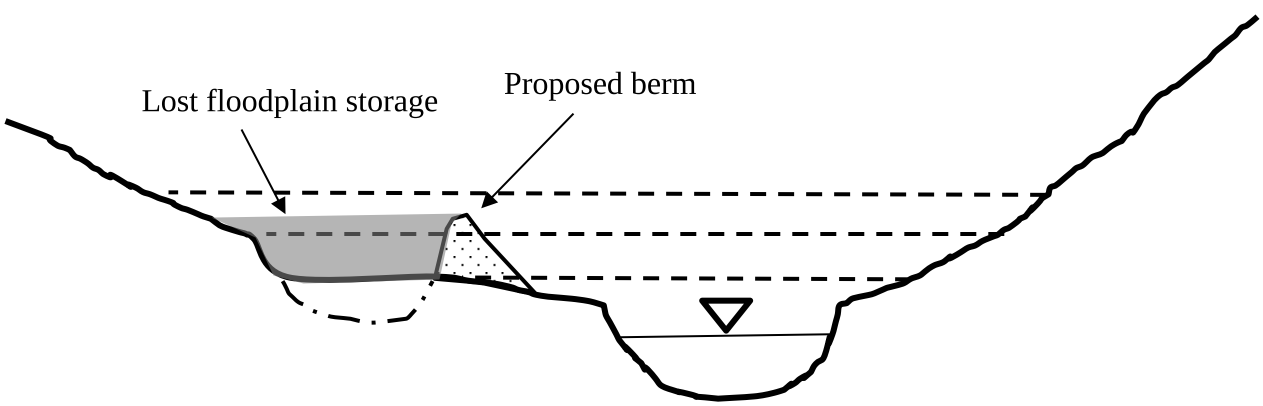


Figure 2. No Adverse Impact (NAI) standard applied to two stormwater treatment practices (STP) in the Special Flood Hazard Area (SFHA)

presented as a separate report or as a summary table on the site plans in a format like that provided in Appendix A.

Methods to complete a compensatory storage analysis are presented below. Other methods may be utilized by the designer after discussion with the Regional Floodplain Manager. Please discuss the use of alternative methods with the regional floodplain manager prior to undertaking any modeling or design efforts to ensure all relevant information is being provided for a review, and that the alternative methods would be acceptable for meeting the NAI standard.

5.1 Calculating Volumes Using Mapping Software

Topographic data derived from field survey including digital elevations 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 SFHA with elevation contours, then split the polygon feature into elevation intervals by tracing the contours. The area of these new polygons can then be multiplied by the depth to BFE to calculate flood storage volume. 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.

5.2 Volumetric Hand Calculations

The average end area method is a common approach to estimating earthwork volumes (Figure 3). In this method, the areas at each end of a cross section are averaged over the length between them. The results are volumetric estimations of proposed fill or compensatory storage in each cross section.

The volume between two cross sections is computed by the formula:

$$V = (A1 + A2) \times L / 2$$

where, A1 represents the fill (or compensatory storage) area of the first cross section, A2 represents the fill (or compensatory storage) area of the second cross section, L represents the length between the two cross sections, and V is the fill (or compensatory storage) volume between the two sections.

Fill and compensatory storage should be accounted separately for each pair of cross sections. The volumes between cross-sections are then tabulated and summed to obtain total estimated fill and compensatory storage volumes. This method is suitable for either level or sloped BFEs across a site. Figure 3 shows example cross sectional areas for proposed fill. The length between the cross sections is 100 feet (Table 1). Once the incremental volumetric fill has been calculated, a separate analysis should demonstrate that at least an equal amount of compensatory storage will be provided.

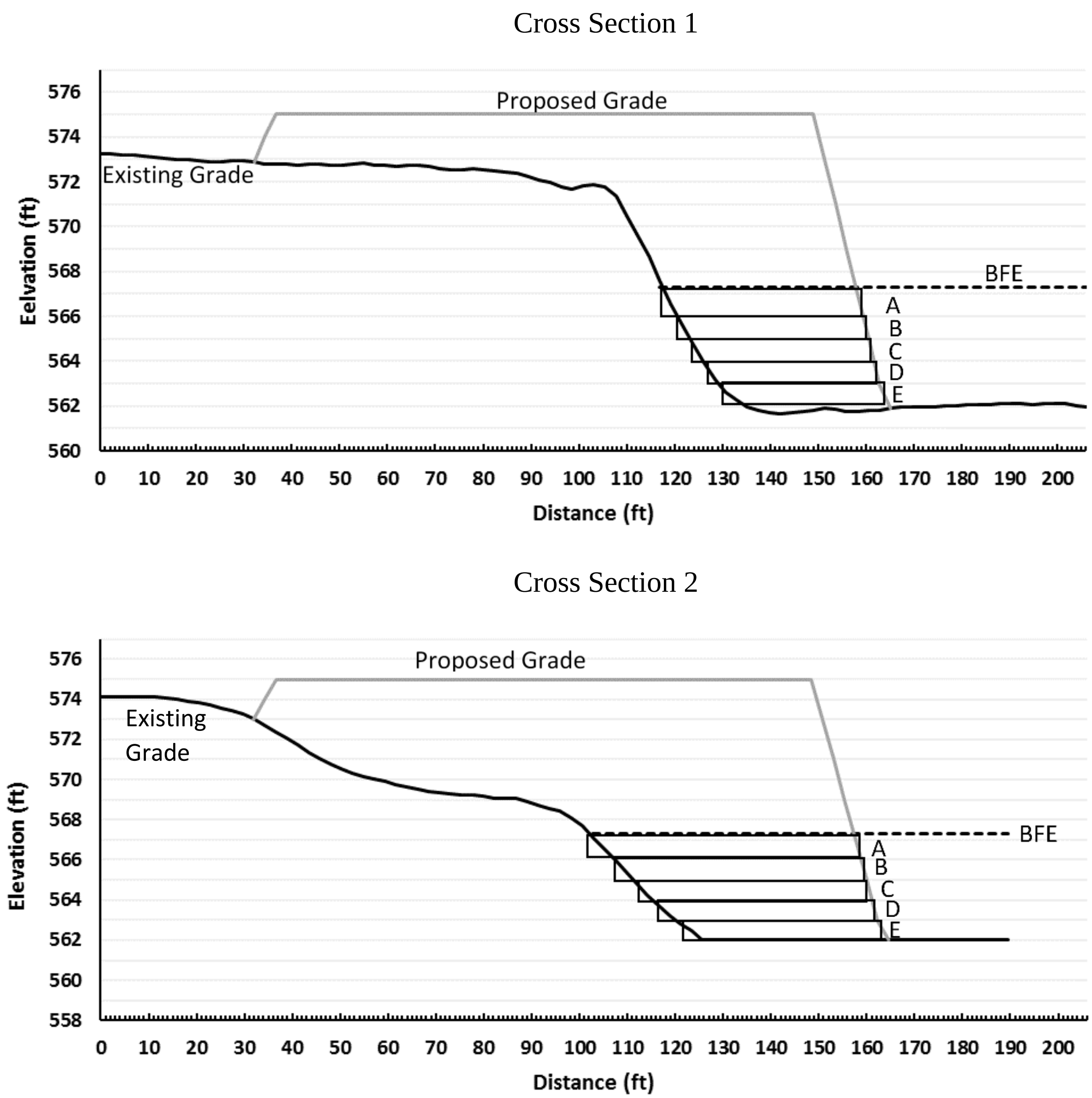


Figure 3. Example average end area method for a cross section of proposed fill

Table 1. Example volumetric calculations for the proposed fill shown in Figure 2 using average end area method

				Cross Section 1		Cross Section 2		
Parameter	Elevation	Width	Length	Distance	Area	Distance	Area	Volume
Calculation	-	-	-	-	(W*D1)	-	(W*D2)	A1+A2*(L/2)
Symbol	E	W	L	D1	A1	D2	A2	V
Unit	ft	ft	ft	ft	ft^2	ft	ft^2	ft^3
Increment								
A	566-567.3	1.3	100	42	54.6	57	74.1	6,435
B	565-566	1	100	39	39	52	52	4,450
C	564-565	1	100	37	37	47	47	4,200
D	563-564	1	100	35	35	45	35	3,500
E	562-563	1	100	34	34	41	41	3,750
							Total Fill (ft^3):	22,435
							Total Fill (yd^3):	831

6.0 Hydrologic and Hydraulic Modeling

In addition to volumetric analysis, upon evaluation by the DEC Rivers Program, hydrologic and hydraulic analyses may be required to verify a proposed development will not increase flood elevations or velocities on floodwaters, given the proximity of fill to adjacent development. The Hydrologic Engineering Center (HEC) computer models are the software preferred by the Rivers Program. These are the standard step-backwater models used to develop the 100-year floodplain (SFHA) and floodway shown on the Flood Insurance Rate Map (FIRM) or Flood Boundary and Floodway Map (FBFM). However, other software listed by FEMA as meeting NFIP standards may be used. These modeling programs can be used to quantify impacts to floodwater height, storage and conveyance resulting from proposed development within a SFHA. Modeling must verify there is no impact to either flood water surface elevations and/or velocities at all flood events evaluated in the Flood Insurance Study (i.e. 10 percent, 2 percent, and 1 percent annual chance floods). Additional cross-sections may be necessary to accurately assess the impact of the proposed development. Analyses, including narrative description of modeling approach and assumptions, model inputs and outputs, and supporting maps/site plans must be accompanied by a certification signed and sealed by a professional engineer. Please consult with the Regional Floodplain Manager to discuss the proposed approach prior to the start of any modeling.

Please see FEMA website for 'Numerical Models Meeting the Minimum Requirements of the National Flood Insurance Program' at: https://www.fema.gov/national-flood-insurance-program-flood-hazard-mapping/numerical-models-meeting-minimum-requirements
Questions regarding the use of specific models should be directed to the FEMA Map Information eXchange (FMIX) at the following website: www.floodmaps.fema.gov/fhm/fmx_main.html

7.0 Best Management Practices

Best management practices should be followed to mitigate erosion and promote floodplain functions in compensatory storage areas. Best management practices for compensatory storage areas include:

- The compensatory storage area will be monitored annually for invasive species and for seedling mortality for a minimum of 3 years.
- Native shrubs and trees will be planted if practicable. Tree seedlings will be planted on 10-foot centers
- Existing native trees and shrubs will be removed with their root systems intact for eventual replanting following grading.
- When no invasive plants are present, the top 12 inches of soil will be removed, stockpiled, and re-applied following excavation. Where invasive plants are present, the top 12 inches of soil shall be replaced with clean top soil.
- The area will be seeded with a native seed mix.
- Exposed soils will be mulched with straw.
- Invasive species will be removed by hand as necessary on an annual basis.
- Seedlings will be replaced as necessary on an annual basis.

8.0 Project Completion and Encroachment Prevention

An as-built survey showing compensatory storage should be provided to verify final storage volumes and to facilitate the prevention of future encroachment. Site conditions should meet the approved design volumes.

Future development within compensatory storage areas shall be prohibited in almost all cases. This may be achieved through permit conditions and/or deed restrictions.

9.0 Definitions

"Agency"* or *"ANR" means the Vermont Agency of Natural Resources.

"Base Flood Elevation" (BFE) means the elevation of the water surface elevation resulting from a flood that has a one percent chance of equaling or exceeding that level in any given year. On the Flood Insurance Rate Map the elevation is usually in feet, in relation to the National Geodetic Vertical Datum of 1929, the North American Vertical Datum of 1988, or other datum referenced in the Flood Insurance Study report, or the average depth of the base flood, usually in feet, above the ground surface.

"***BFE***" see Base Flood Elevation.

"***Compensatory storage***" means a volume not previously used for flood storage and which shall be incrementally equal to the theoretical volume of flood water at each elevation, up to and including the base flood elevation, which would be displaced by the proposed project. Storage provided at lower elevations than the proposed displacement may be considered. Such compensatory volume shall have an unrestricted hydraulic connection to the same waterway or water body. Further, with respect to waterways such compensatory volume shall be provided within the same reach of the river, stream, or creek.

"Development" means any human-made change to improved or unimproved real estate including buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations, or storage of equipment or materials.

"Fill" means any placed material that changes the natural grade, increases the elevation, or diminishes the flood storage capacity at a site. Temporary storage of material is not considered fill.

"Flood" means (1) a general and temporary condition of partial or complete inundation of normally dry land areas from: (A) the overflow of inland or tidal waters; (B) the unusual and rapid accumulation or runoff of surface waters from any source; or (C) mudslides which are proximately caused by flooding and are akin to a river of liquid and flowing mud on the surfaces of normally dry land areas, as when earth is carried by a current of water and deposited along the path of the current; or (2) the collapse or subsidence of land along the shore of a lake or other body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels or suddenly caused by an unusually high water level in a natural body of water, accompanied by a severe storm, or by an unanticipated force of nature, such as flash flood or abnormal tidal surge, or by some similarly unusual and unforeseeable event which results in flooding.

"Floodplain" means any land area susceptible to being inundated by water from any source (see definition of *"Flood"*).

10.0 References

Vermont Agency of Natural Resources, 2015. Vermont Flood Hazard Area and River Corridor Rule. Department of Environmental Protection, Watershed Management Division, River Corridor and Floodplain Protection Program. Montpellier, Vermont. Available here: http://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/state-permits

Vermont Agency of Natural Resources, 2017. 2017 Vermont Stormwater Management Manual Rule and Design Guidance. Department of Environmental Protection, Watershed Management Division, Stormwater Management Section. Montpellier, Vermont. http://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/Permitinformation/2017%20VSMM_Rule_and_Design_Guidance_04172017.pdf

10.0 Other Supporting Literature

Bank stabilization BMPs
http://dec.vermont.gov/sites/dec/files/wsm/lakes/Lakewise/docs/LP_BMPReslopingRockToeRiprap.pdf

Establishing no-mow zones
http://dec.vermont.gov/sites/dec/files/wsm/lakes/Lakewise/docs/LP_BMPSHOREestablishing%20NoMowZones.pdf

Planting & maintaining vegetation areas
http://dec.vermont.gov/sites/dec/files/wsm/lakes/Lakewise/docs/LP_BMPPlantingandMaintainingVegetatedAreas.pdf

Appendix A – ANR Compensatory Storage Summary Sheet

ANR SUMMARY SHEET FOR COMPENSATORY STORAGE REQUIREMENTS

Example Sheet

Project Name: ______________________________ **Town**: _________________________

Receiving Water: _____________________________ **Site BFE**: _______________________

TABLE 1: Example of Summary Table for Compensatory Storage Analysis with a BFE at 293'

Elevation Range	Volume of Fill (material added)	Volume of Cut (material removed)	Change in Net Storage (+ / -)	Compensatory Storage req'd?
290 to 291	1,200	1,150	- 50	Yes
291 to 292	1,075	900	- 175	Yes
292 to 293	400	425	+ 25	No
Total Volume (cf):	**2,675**	**2,475**	**- 200**	

ANR SUMMARY SHEET FOR COMPENSATORY STORAGE REQUIREMENTS

This form needs to be provided to ANR for review of compensatory storage requirements for projects located in the Special Flood Hazard Area (SFHA).

Project Name: ______________________________ **Town**: _________________________

Receiving Water: _____________________________ **Site BFE**: _______________________

Summary Table for Proposed Project *(use 1 foot contour increments)*

Elevation Range	Volume of Fill (material added)	Volume of Cut (material removed)	Change in Net Storage (+ / -)	Compensatory Storage req'd?
Total Volume (cf):				

____ ___________________

Signature of Professional Engineer Date