

Competing With Natural Channel Design Crediting Paradigms: Review of Dam Removal as an Innovative Stream Mitigation Approach

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Alternative Forms of Stream Mitigation

- Dam Removal and River Restoration
- Endangered Species and Aquatic Habitat Restoration
- Hydrologic Flow Regime Modifications
- Restoration of Larger Streams and Rivers
- Watershed and Stormwater Management



Credit for alternate forms of stream restoration is typically based on **objective and measured** improvement in identified functional attributes.



Credit for natural channel design on headwater streams is typically based on **subjective and inferred** improvement due to geophysical stability and vegetation survival.



Impediments to Alternate Forms

- Quantitative functional assessments are consistently rejected
- IRT and the industry are sometimes resistant
- Mitigation bank IRT approval and permitting timelines are much longer
- State laws and guidelines codifying NCD stream crediting cause collateral damage



Typical IRT Comment on Proposed Alternate Forms of Mitigation

- “We acknowledge that the proposed Bank has the potential to provide ecological improvements but may not provide appropriate compensatory mitigation for activities authorized by Section 404 of the Clean Water Act”.
- “Some portions of the proposal may exceed the legal authority of these programs which are not intended to be for environmental restoration. In addition, The proposed project does not meet State Laws for Wetland and Stream Mitigation.” (i.e. the paradigm)



North Carolina Dam Removal Task Force (NCDRTF)

Established in 2021

- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Services
- Environmental Protection Agency
- N.C. Division of Water Quality
- N.C. Wildlife Resources Commission

Objectives

- Dam Removal Ranking and Prioritization
- Quantitative Functional Assessment Method
- Mitigation Credit Determination

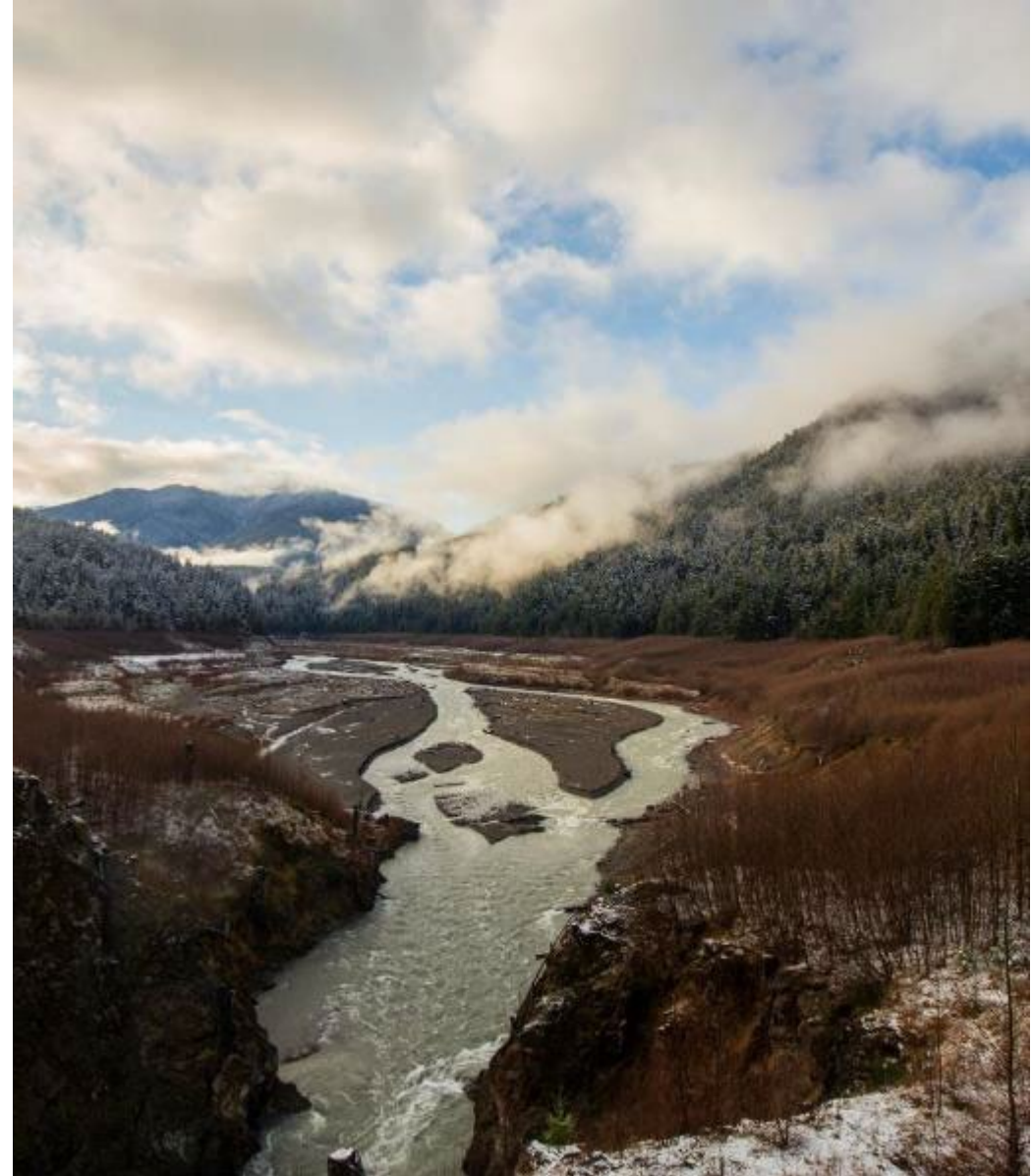


Table 1. Preliminary Dam Prioritization through Rankings of Environmental Advantages of Dam Removal. These ratings have been performed by agency representatives involved in the Dam Removal Task Force of North Carolina.

Dam	Threatened & Endangered Species Value				Water Quality Value				Anadromous Fish Value				Mean of Means	
	NCWRC	NHP	USFWS	Mean	DWQ-Pen	DWQ-D	EPA	Mean	NCMFS	NCWRC	NMFS	USFWS		Mean
Lowell	4.0	4.0	4.0	4.0	4.0		3.5	3.8	3.0	5.0	3.0	3.0	3.5	3.75
Lock & Dam #2	3.0	3.0	4.0	3.3	1.0		4.0	2.5	4.0	4.0	5.0	5.0	4.5	3.44
Lock & Dam #3	3.0	3.0	3.0	3.0	1.0		4.0	2.5	4.0	3.0	5.0	5.0	4.3	3.25
Carbonton Dam	5.0	5.0	5.0	5.0	4.0		4.0	4.0	0.0	0.0	1.0	1.0	0.5	3.17
Atkinson's Millpond	4.0	4.0	4.0	4.0	3.0		4.0	3.5	2.0	4.0	1.0	1.0	2.0	3.17
Fishing Creek Millpond	4.0	4.0	5.0	4.3	3.0		3.5	3.3	3.0	0.0	2.0	2.0	1.8	3.11
Buckhorn	3.0	3.0	4.0	3.3	2.0		3.5	2.8	2.0	2.0	4.0	4.0	3.0	3.03
Rocky Mount Millpond	3.0	3.0	1.0	2.3	4.0		4.5	4.3	2.0	1.0	2.0	2.0	1.8	2.78
Milburnie	1.0	1.0	2.0	1.3	0.0		4.6	2.3	2.0	5.0	5.0	5.0	4.3	2.63
Wiggins Millpond	1.0	1.0	1.0	1.0	3.0		4.5	3.8	2.0	3.0	2.0	2.0	2.3	2.33
Hoggards Mill	0.0	0.0	0.0	0.0	3.0		3.5	3.3	4.0	5.0	2.0	2.0	3.3	2.17

DRTF agencies include U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers (ACE), U.S. Fish and Wildlife Service (FWS), National Marine Fisheries Service (NMFS), N.C. Division of Water Quality (DWQ), N.C. Wildlife Resources Commission (WRC), N.C. Division of Marine Fisheries (DMF), N.C. Division of Coastal Management (DCM), and the N.C. Natural Heritage Program (NHP)



NCDRTF Quantitative Functional Assessment

- Reference (Steady-State) Functions Modeled
 - Water Quality
 - Appropriate Aquatic Community
 - Rare, Threatened, and Endangered Species
 - Migratory / Anadromous Fish Passage
- Credit Modifiers
 - Riparian Buffers Conserved Along Former Impoundment
 - Research and Recreation Opportunities Funded
- Success criteria quantified over seven years of objective and measured improvement in function relative to the reference standard



NCDRTF Quantitative Functional Assessment

1. *Water Quality*

- DO
- Nutrifcation (N+P) / Algae
- Temperature
- Sediment / Turbidity
- Pollutants (coal ash, distillates, PFAS, metals)
- Bacteria (fecal coliform, etc.)



2. *Appropriate Aquatic Community*

- Diagnostic Species Presence
- Substrate
- Velocity
- Riffles / Runs / Pools / Glides
- Knick Points / Velocity Shades
- overhanging banks / hyporheic zones
- floodplain access



NCDRTF Quantitative Functional Assessment

3. Rare, Threatened, and Endangered Species

- Re-establish Protected Species Population
- Re-establish Associated Species
- Restore Habitat

- 1) *restore habitat 11%*
- 2) *re-establish associate species (i.e. egg carriers) 11%*
- 3) *re-establish T&E species population 11% (total = 33% of impoundment length)*

Functional Attribute	Method of Measurement	Functional Score
Substrate (D84)	100mm to 313mm (Small Cobble to Small Boulder)	1.00
	64mm to 99mm (Small Cobble)	0.75
	32mm to 63mm (Very Coarse Gravel)	0.50
	16mm to 31mm (Coarse Gravel)	0.25
	<16mm (Sand to Medium Gravel)	0.10
Substrate Embeddedness	7% to 30%	1.00
	30% to 60%	0.50
	>60%	0.10
Pool Habitat	Present	1.00
	Developing	0.50
	Absent	0.10
Hyporheic Zone Voids (Index)	0.75-1.0	1.00
	0.25-0.75	0.50
	0.00-0.25	0.10
Stream Bank Aspect (at CHS Habitat Pool)	North Facing (typically right bank)	1.00
	Southeast Facing with Limited Pools (typically left bank)	0.50
	Southwest Facing or Pools Absent (left bank)	0.10
Associate Mussel Species	Present	1.00
	Absent	0.10
Stream Bank Stability	Stable	1.00
	Intermediate, episodically eroding	0.50
	Unstable, actively eroding	0.10
Knickpoint	Present within 1,000 feet upstream; backwater influence or grade control apparent	1.00
	Present within 1,000 feet upstream; backwater influence or grade control marginal	0.25
	Absent or substantially degraded	0.10

NCDRTF Quantitative Functional Assessment

4. Migratory / Anadromous Species

Diadromous (Chesapeake Bay / Ocean) dwelling species	Reconnected River Network (Figure 5)		Description
	Miles	Feet	
American Shad	38.3	202,334	5 th order rivers ¹
Hickory Shad, Alewife, Blueback Herring	108.7	574,019	5 th , 4 th , and 3 rd order streams and rivers ²
American Eel (major impediment), Sea Lamprey	440	2,324,730	Functional drainage network ³ including 1 st and 2 nd order streams.

Credit for anadromous fish passage totals 5:1 for reaches where the anadromous fish are sampled and collected as specified in the monitoring plan and success criteria.

NCDRTF Mitigation Credit Determination (Example)

Description	Quantity (linear feet)	Mitigation Ratio (mitigation:impact)	Mitigation Credit
Water Quality Issues and Appropriate Aquatic Community	12,250	1:1	12,250
Rare, Endangered, and Threatened Aquatic Species	12,250	3:1 (0.33) ¹	4,043
Anadromous Fish Passage (shad)	202,334	5:1	40,467
POTENTIAL TOTAL			56,759
Riparian buffers not conserved along the former impoundment		Deduct 25%	-14,190
Research and Recreational Functions added		Add 10%	+5,676
TOTAL			48,245

N.C. Dam Removal Task Force (NCDRTF)

- 2004: NC Dam Removal Task Force (NCDRTF) publishes quantitative credit determination to compete with NCD crediting protocol.
- NCDRTF Dam Removal Priority Ranking
- Several Priority Dams removed
- 2006: NCDRTF Credit Determination rescinded by USACE
- 2008: NCDRTF Credit Determination re-issued by USACE
- 2010: NCDRTF Credit Determination rescinded by USACE
- 2010-2017: Regulatory issues delay dam removals
- **2018: RGL 18-01 and NWP #53 issued to remove roadblocks to alternative form of 404 mitigation**
- Priority Dam removed after 14+ years



Regulatory Guidance Letter (RGL) 18-01 (September 2018) and Nationwide Permit #53 (Removal of Low-Head Dams)

- Determination of Compensatory Mitigation Credits for the Removal of Obsolete Dams.
- “If an appropriate quantitative functional assessment is available, this assessment method should be used.”
- “For larger river systems, surface area of river bed may better quantify relative mitigation credits on an area basis by using acres or square feet of river ecosystem restored.”
- “The river bed upstream and downstream of the impoundment should both be considered for credit production.”
- “Losses of impoundment induced wetlands due to dam removal should not require compensatory mitigation.”

2020 Dam Removal and River Restoration Proposed Quantitative Crediting Tool (VA Project)

Primary Functions

- 1.0 Water Quality
- 2.0 Aquatic Community
- 3.0 Aquatic Habitat for Rare, Threatened, and Endangered Species
- 4.0 Diadromous / Migratory Species Passage
- 5.0 Downstream Water Quality and Aquatic Habitat (based on RGL 18-01)
- 6.0 River Corridor Connectivity (Chesapeake Bay)
- 7.0 Research and Recreation Functions

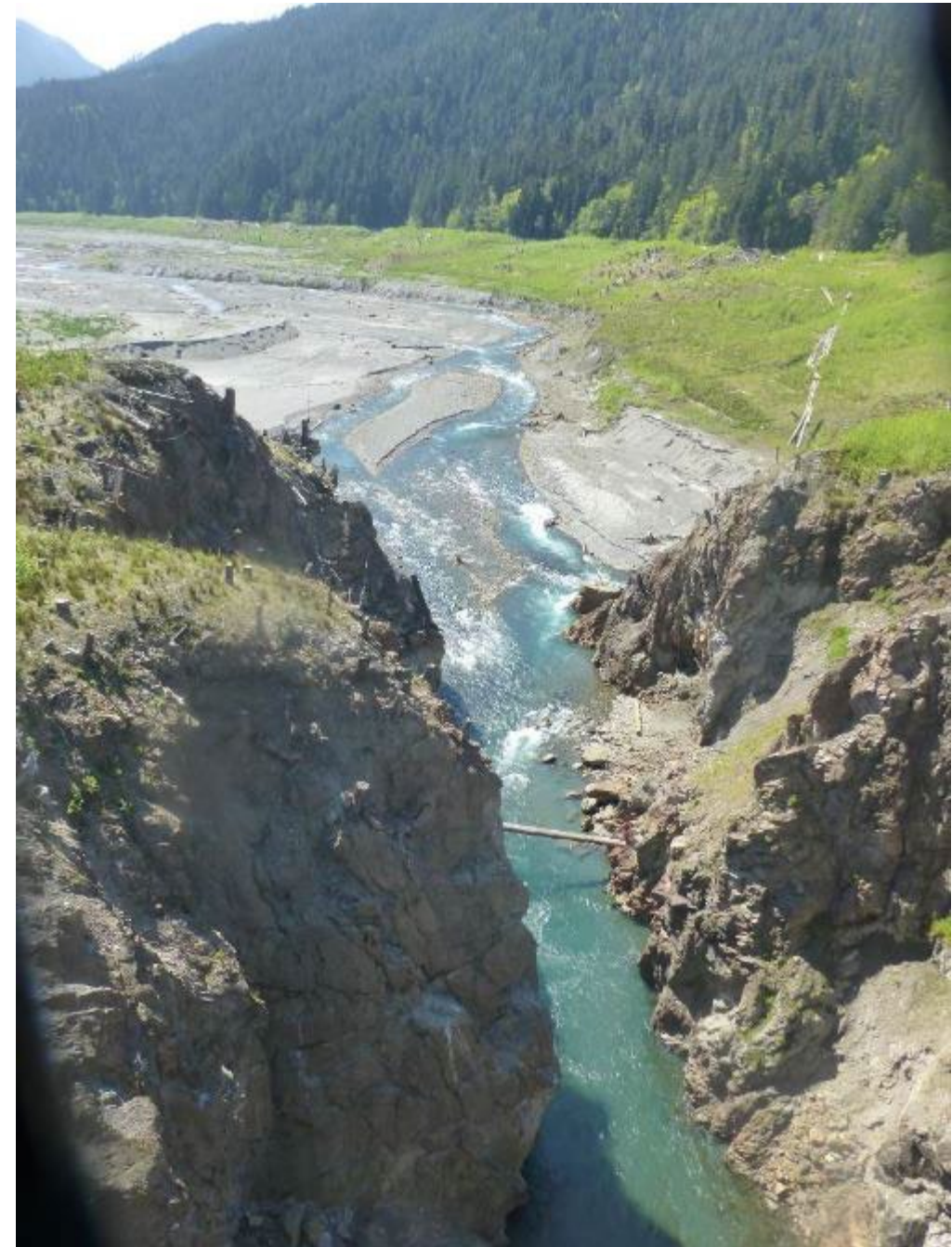
No.	Function	Variables
1.0	<p><u>Water Quality</u></p> <p>Rapid Bio-Assessment Protocol (RBP) Index = $(V_{dol} + V_{tem} + V_{svl} + V_{bmi} + V_{frb})/5$</p> <p>Detailed Bio-Assessment Protocol (DPB) Index: V_{acc}, V_{acn}, V_{acp} represent research variables that may be applicable to aquatic barrier removals during research activities and / or within DBP functional scores due to import of migratory biomass into the upper watershed.</p> <p>DBP: Add V_{fec} (Fecal Coliform)</p> <p>Definition: The capacity of a river to support the water quality functions characteristic of the reference standard.</p>	<p>V_{acc}: Carbon Import and Sequestration</p> <p>V_{acn}: Nitrogen Import and Sequestration</p> <p>V_{acp}: Phosphorous Import and Sequestration</p> <p>V_{fec}: Fecal coliform</p> <p>V_{dol}: Dissolved oxygen</p> <p>V_{tem}: Temperature</p> <p>V_{svl}: Flow Velocity</p> <p>V_{bmi}: Benthic macroinvertebrate rating</p> <p>V_{frb}: Forested riparian buffers</p>
2.0	<p><u>Aquatic Community</u></p> <p>$(V_{fks} + V_{bmi} + V_{sah} + V_{sap} + V_{sar})/5$</p> <p>Definition: The capacity of a river to support the resident aquatic community characteristic of the reference standard.</p> <p>DBP: Add V_{sub}, surface area of coarse substrate, (gravel with no fines, or coarser (Nislow and Keiner 2009, sea lamprey)</p>	<p>V_{fks}: Presence of diagnostic / keystone species</p> <p>V_{bmi}: Benthic macroinvertebrate rating</p> <p>V_{sah}: Surface area of riverine aquatic habitat</p> <p>V_{sap}: Surface area of riverine pool habitat</p> <p>V_{sar}: Surface area of riverine riffle habitat</p> <p>V_{sub}: Surface area of coarse substrate (Nislow and Keiner 2009)</p>



3.0	<p><u>Aquatic Habitat for Rare, Threatened, and Endangered Species</u></p> <p>$(V_{teh} + V_{fts} + V_{fas})/3$</p> <p>Definition: The capacity of a river to support communities of or habitat for rare, threatened, and endangered species.</p>	<p>V_{teh}: Presence of Rare, Threatened, and Endangered Species Habitat</p> <p>V_{fts}: Presence of Rare, Threatened, and Endangered Species</p> <p>V_{fas}: Presence of T&E associated diagnostic species (i.e. egg carriers)</p>
4.0	<p><u>Diadromous / Migratory Species Passage</u></p> <p>$(V_{dia} + V_{fds} + V_{fmm})/3$</p> <p>Definition: The capacity of a river to provide diadromous / migratory species passage.</p>	<p>V_{dia}: Length of reconnected diadromous/migratory species habitat</p> <p>V_{fds}: Presence of diadromous/migratory species</p> <p>V_{fmm}: Upstream Functional Network Miles</p>
5.0	<p><u>Downstream Water Quality and Aquatic Habitat</u></p> <p>RBP Index = $(V_{wod} + V_{tem} + V_{bmi} + V_{bhr} + V_{fks} + V_{fts} + V_{fas})/7$</p> <p>Definition: The capacity of an altered river reach immediately below an impoundment to support the water quality functions and aquatic communities characteristic of the reference standard.</p> <p>DBP: Add V_{fec} (Fecal Coliform)</p>	<p>V_{wod}: Frequency and sizes of woody debris</p> <p>V_{tem}: Temperature</p> <p>V_{bmi}: Benthic macroinvertebrate rating</p> <p>V_{bhr}: Evidence of Bank Erosion (bank-height ratio, presence of downstream incision)</p> <p>V_{fks}: Presence of diagnostic / keystone species</p> <p>V_{fts}: Presence of rare, threatened, and endangered species</p> <p>V_{fas}: Presence of T&E associate species (i.e. egg carriers)</p> <p>V_{fec} (Fecal Coliform)</p>



<p>6.0</p>	<p><u>River Corridor Connectivity</u></p> <p>RBP Index = $(V_{frb} + V_{frg} + V_{dia} + V_{dsh} + V_{fmm})/5$</p> <p>DBP Index: Add V_{rci} (River connectivity index (Grill et. al. 2015))</p> <p>Definition: The capacity of a river to remain connected to floodplains (lateral), to groundwater hyporheic zones (vertical), and to remain connected to upriver and downriver reaches (longitudinal).</p>	<p>V_{frb}: Forested riparian buffers</p> <p>V_{frg}: Length of reconnected stream</p> <p>V_{dia}: Length of reconnected diadromous species habitat</p> <p>V_{dsh}: Length of reconnected downstream aquatic habitat</p> <p>V_{fmm}: Upstream Functional Network Miles</p> <p>V_{rci}: River connectivity index</p>
<p>7.0</p>	<p><u>Research and Recreational Functions</u></p> <p>$(V_{res} + V_{rec})/2$</p> <p>Definition: The capacity of a river to provide human values such as research, education, economic development, and recreation that increase conservation uses and protection, thereby increasing functional lift over time.</p>	<p>V_{res}: Presence of Research Opportunities</p> <p>V_{rec}: Presence of Recreational Opportunities</p>



DBP V_{acc}: Carbon Import and Sequestration DBP V_{acn}: Nitrogen Import and Sequestration DBP V_{acp}: Phosphorous Import and Sequestration		
Method of Measurement	Measure Relative to Reference Standard	Index
Numerous studies have shown that anadromous species transport and sequester biomass and nutrients from estuaries into upper reaches of the river watershed (Ben-David et al. 1998, Naiman et al 2002, Schindler et al 2003, Hocking and Reynolds 2011, Donaldson 1967, Schindler et al. 2003). Up-river nutrient transport can increase primary and secondary production not only in freshwater ecosystems, but also in surrounding floodplain and terrestrial ecosystems. American shad and other anadromous species have the potential to convey large quantities of carbon, nitrogen, and phosphorous from Chesapeake Bay into upper reaches of the River after dam removal. Nutrient flux models revealed that American shad can convey over 15,000 kg of nitrogen (N) and 3,000 kg of phosphorus (P) annually, with juveniles exporting just 31% (N) and 46% (P) of the nutrients imported by adults (Haskell 2017).	Nutrient models predict carbon, nitrogen, and/or phosphorous import and sequestration rates within 75% to 100% of the Reference Standard. Because reference nutrient migration models have not been found for Chesapeake Bay, these variables have been excluded from the RBPs. However, These monitoring variables may be included in the DBPs as a research component during the detailed pre-project and post-project monitoring stages, if practicable.	1.0
	50% to 75% of the Reference Standard	0.75
	25% to 50% of the Reference Standard	0.50
	0% to 25% of the Reference Standard	0.25

1.0 V_{bmi}: Benthic Macroinvertebrate (BMI) Classification Rating (Aquatic Insects)		
Method of Measurement	Measure Relative to Reference Standard	Index
Benthic Macroinvertebrate (BMI) surveys utilizing accepted Standard Operating Procedures are used to calculate biotic indices according to criteria appropriate for the physiographic region. Virginia has developed a regional protocol for BMI / biological assessments that will be applied to this project. Biological assessments typically resemble guidelines in the USEPA document "Rapid Bioassessment Protocols for Use in Streams and Rivers"(Barbour et al. 1999).	Habitat Assessment Score or other suitable measurement 75% to 100% of the Reference Standard	1.0
	50% to 75% of the Reference Standard	0.75
	25% to 50% of the Reference Standard	0.50
	0% to 25% of the Reference Standard	0.25

19.0 V_{teh}: Presence of Rare, Threatened, and Endangered Species Habitat		
Method of Measurement	Measure Relative to Reference Standard	Index
Aquatic surveys utilizing accepted Standard Operating Procedures are used to identify and document the presence of habitat for these species.	Rare, threatened, or endangered species habitat present and similar to reference in extent and character.	1.0
	Rare, threatened, or endangered species habitat present and somewhat similar to reference in extent and character.	0.75
	Rare, threatened, or endangered species habitat present and somewhat dis-similar to reference in extent and character.	0.50
	Rare, threatened, or endangered species habitat present but very altered in character relative to reference.	0.25
	None / Not Applicable	Pre-0.0 Post-0.1

Comparison of Dam Removal and River Restoration to Conventional Headwater Stream Restoration (CHSRA) Assessment Type #1 (Dominant)

#	Function	Comparative Functional Score (Dam Removal/ CHSRA 1)	Comparative Mitigation Ratio (Dam Removal/ CHSRA 1)
1.0	Improve Water Quality	0.64/0.29	2.2:1
2.0	Improve Aquatic Community	0.79/0.14	5.6:1
3.0	Restore Aquatic Habitat for Rare, Threatened, and Endangered Species ¹	0.62 ¹ /0.10	6.2:1
4.0	Provide Diadromous / Migratory Species Passage	0.97/0.10	9.7:1
5.0	Enhance Downstream Water Quality and Aquatic Habitat	0.55/0.13	4.3:1
6.0	Increase River Corridor Connectivity	0.75/0.33	2.3:1
7.0	Provide Research and Recreational Opportunities	1.00/0.1	10.0:1
	Average Functional Capacity Ratio (Dam Removal / NCD Stream)		5.7:1
	Average Functional Capacity Ratio for Dominant Impoundment Related Functions (Functions 1 through 3)		4.7:1
	Average Functional Capacity Ratio for Dominant Regional (Chesapeake Bay²) Related Functions (Functions 4 through 7)		6.6:1³

1: The model run assumes that removal of the Dam will restore suitable habitat and Associate species (egg carriers) for threatened and endangered mussels but that mussel species will not be identified within the former impoundment by the end of the 5-year monitoring period. If threatened and endangered mussels are successfully re-established within the restored river reach, the functional score would increase from 0.62 to 1.0 relative to the reference standard.

2: The regional functions, including diadromous species passage, downstream water quality / aquatic community, river corridor connectivity, and research / recreational opportunities provide ecological benefits and functions to the Chesapeake Bay region which justifies a larger Primary Geographic Services (PGSA) than the PGSA assigned to conventional NCD stream mitigation on headwater streams. This enlargement of the PGSA will also assist in promoting dam removal towards an equal economic footing relative to NSD stream mitigation.

3: The average comparative ratio between dam removal and NCD ranges from 4.7:1 to 6.6:1 relative to the dominant form of NCD stream mitigation on headwater streams.

Comparison of Dam Removal and River Restoration to Conventional Headwater Stream Restoration (CHSRA) Assessment Type #1 (Dominant)

#	Function	Comparative Functional Score (Dam Removal/ CHSRA 1)		
1.0	Improve Water Quality	0.64/0.29		
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5.0	Enhance Downstream Water Quality and Aquatic Habitat	0.55/0.13		
6.0	Increase River Corridor Connectivity	0.75/0.33		
7.0	Provide Research and Recreational Opportunities	1.00/0.1		
	Average Functional Capacity Ratio (Dam Removal / NCD Stream)		5.7:1	
	Average Functional Capacity Ratio for Dominant Impoundment Related Functions (Functions 1 through 3)		4.7:1	
	Average Functional Capacity Ratio for Dominant Regional (Chesapeake Bay²) Related Functions (Functions 4 through 7)		6.6:1³	
#	Description	Quantity (linear feet)	Comparative Functional Capacity Rating	Equivalent Stream Restoration Credit
1.0	Improve Water Quality		2.2:1	
2.0	Improve Aquatic Community		5.6:1	
3.0	Restore Aquatic Habitat for Rare, Threatened, and Endangered Species		6.2:1	
4.0	Provide Diadromous / Migratory Species Passage		9.7:1	
5.0	Enhance Downstream Water Quality and Aquatic Habitat		4.3:1	
6.0	Increase River Corridor Connectivity		2.3:1	
7.0	Provide Research and Recreational Opportunities		10.0:1	
	Effective Impoundment Length		12,250	
	Average Functional Capacity Rating for Dominant Impoundment Related Functions (Functions 1 through 3, Water Quality, resident T&E Species, and Aquatic Community)		4.7:1	57,575
	Average Functional Capacity Rating for Dominant Chesapeake Bay Related Functions (Functions 4 through 7)		6.6:1	Influences Ecological Service Area

2021 Virginia Unified Stream Methodology (USM 2007)

The “effective” impoundment length will be credited at 1.0 credit per foot to reflect the restoration of riverine aquatic habitat and improvements to water quality resulting due to conversion from lentic to lotic ecosystems within the restored river

Dam Removal Adjustment Factors (AF)

- AF1: Rare, Threatened, and Endangered Species or Communities
- AF2: Diadromous Species
- AF3: Dam Removal Listed on the State Priority List
- AF4: River Order
- AF5: Down River Functional Benefits
- AF6: Long-Term Monitoring, Management, and Research

VA USM Draft Mitigation Credit Summary

Effective Impoundment Length		12,250 Linear Feet	
No.	Description	Credit Ratio	Mitigation Credit
Base-line	Baseline Impoundment Length (IL): Riverine Aquatic Habitat and Water Quality	1.0	12,250
AF1	Rare, Threatened, and Endangered Species or Communities ¹	0.3	3,675
AF2	Diadromous Species Fish Passage (American shad) ²	0.1	1,225
AF2	Diadromous Species Fish Passage (Blueback Herring)	0.1	1,225
AF2	Diadromous Species Fish Passage (Hickory Shad)	0.1	1,225
AF2	Diadromous Species Fish Passage (Alewife)	0.1	1,225
AF2	Diadromous Species Fish Passage (American Eel)	0.1	1,225
AF3	Dam Removal on State Priority List	0.3	3,675
AF4	River Order (5 th Order)	1.2	14,700
AF5	Down River Functional Benefits ³	0.1	1,225
AF6	Long Term Monitoring and Research	0.2	2,450
POTENTIAL TOTAL		3.6	44,100

Comparison of Mitigation Credit Determinations by Model

Effective Impoundment Length		12,250 LF
Method	Effective Mitigation Ratio (river length / credit)	Maximum Potential Stream Mitigation Credit ¹
N.C. Dam Removal Task Force	1 / 3.94	48,245
VA Dam Removal Quantification Tool ²	1 / 4.7	57,575
VA Unified Stream Method (USM)	1 / 3.6	44,100
Average	1 / 4.0 ³	49,973

1. Actual mitigation credit depends upon achieving success criteria over the seven-year monitoring period, as quantified by the monitoring plan and re-execution of the reference model.
2. Comparison to conventional Natural Channel Design (NCD) on headwater streams.
3. Dam removal on 5th order river supporting anadromous and endangered species migrations.

Greatest Advocates for a Recent Dam Removal Prospectus and Crediting Method Supporting Dam Removal as an Alternate Form of Section 404 Mitigation

- U.S. Army Corps of Engineers
- Virginia Department of Environmental Quality
- Virginia Marine Resources Commission

Thank you

Wes Newell

Senior Manager

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