Franklin Regional Council of Governments

June 3, 2024

Documents submitted as attachments to FRCOG's Comment letter on the FirstLight 401 Water Quality Certificate Application, listed from most recent to oldest

*Note: The review by **Dr. Evan Dethier** is contained within Attachment 1. The peer review by **Princeton Hydro** is contained within Attachment 3. The review by the **University of Illinois at Urbana-Champaign** is contained within Attachment 10.*

Contents

Franklin Regional Council of Governments

CONNECTICUT RIVER STREAMBANK EROSION COMMITTEE

April 2, 2015

Mr. John Howard
Director FERC Compliance, Hydro
FirstLight Power Resources, Inc.
99 Millers Falls Road
Northfield, MA 01360

Re: Northfield Mountain Pumped Storage Project No. 2485-063
Turners Falls Project No. 1889-081
Comments on Addendum to Study 3.1.1, the 2013 Full River Reconnaissance

Dear Mr. Howard:

The Connecticut River Streambank Erosion Committee (CRSEC) has reviewed the Addendum to the 2013 Full River Reconnaissance (FRR), a study related to both license compliance and Study 3.1.1 in the Integrated Licensing Process. FERC required an addendum be filed within 90 days of their January 22, 2015 "Determination on Requests for Study Modifications and New Studies for Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project." The Addendum was provided to CRSEC members electronically on February 24, 205, and two of our members were available to attend the meeting held on March 4, 2015. Our comments are as follows.

Comparison of 2007 and 2014 photo logs

A comparison of the photo logs from 2007 and 2014 was to have been part of Task 4 as written in the approved Revised Study Plan (RSP), but it was missing in Study 3.1.1. CRSEC member Connecticut River Watershed Council is on record for having commented that collecting a set of 2014 photos during the middle of summer was not valuable. Despite changes in technology since 2007 and difficulty repeating the same photos, the comparison is more valuable and interesting than we had expected. Looking at the changes in gross vegetation over time has some value, and we think it is interesting to see how some sites have filled in. Going forward, these photo logs can serve as a baseline for future work to document leaf on conditions and monitor changes over time.

2013 Full River Reconnaissance – 2015 Addendum: Riverbank Segment Quality Assurance (QA) Comparison

The 2013 FRR Quality Assurance Project Plan (QAPP) stated: "An appendix to the FRR report will include a comparison of the specific riverbank features and characteristics from the data logging files, or field data sheets, collected during the field surveys to a photograph of that same segment of riverbank captured from the digital geo-referenced video. A discussion will be presented in the FRR report based on this comparison. The process of comparing the data logging files to video/still images of a selected percentage of segments, or any segment of particular interest, provides a high level of quality assurance and control on the field data collection. This approach also provides a method for reference checking any subsequent interpretation of the field survey data after the survey has been completed."

This appendix was missing in the 2013 FRR submitted as Study 3.1.1 with the Initial Study Report in September 2014. The 2015 draft riverbank segment QA comparison submitted by FirstLight lacks key information that would "provide a high level of quality assurance" and a "method for reference checking any subsequent interpretation of the field survey data." A complete data set for the QA comparison should be provided so that FERC staff and stakeholders can replicate the QA methods and have a high degree of confidence in the results of the 2013 FRR.

Methods:

FirstLight looked at every 10th segment, identified gaps, and added six supplemental segments, for a total of 65 QA segments.[1] While FirstLight indicated they found gaps that led to adding certain segments, they did not indicate whether or not there was an over-abundance of any riverbank characteristic. FirstLight had said in their QAPP that the QA comparison would be done using video, but they used still images instead. FirstLight states that the QA analysis led to several revisions mainly consisting of adding indicators of potential erosion to segments, but did not change overall conclusions.

Analysis:

CRSEC continues to believe that sections of the 2013 FRR need to be re-done pursuant to section 5.15(d) of the Commission's regulations because the study was not conducted as provided for in the approved study plan. Specifically, the bank characterization (stage and extent of erosion) should be redone. Both the 2013 FRR and the QA comparison indicate that FirstLight did not follow the definitions laid out in Table 3.1.1-3 of the approved RSP dated August 14, 2013, for Study 3.1.1. Table 3.1.1-3 is attached to this letter.

For example, CRSEC has determined that 24 of the segments used in the QA analysis do not meet the definitions laid out in Table 3.1.1-3. These segments were classified as *stable* but had one or multiple *indicators of erosion* and often a *type of erosion* (e.g., undercut). In Table 3.1.1-3, stable is defined as "riverbank segment does not exhibit types or indicators of erosion." The 24 segments characterized as both "stable" and with an Erosion Type and/or Indicator of Erosion are: 20, 30, 40, 50, 110, 130, 160, 180, 240, 290, 320, 390, 400, 410, 430, 440, 450, 460, 510, 520, 530, 550, 279, and 89. The following table summarizes our analysis of the segments labeled as stable.

[1] CRSEC believes that stratified random sampling would have been a more effective sampling method to cover the entire Turners Falls impoundment and range of stream bank categories present, but we think that the methods that FirstLight used are adequate.

FERC Project No. 2485-063

	# of Riverbank Segments (excluding islands)	# of Segments categorized as *Stable*	# "Stable" segments with an Erosion Type and/or Indicator of Erosion
2013 Full River Reconnaissance Report	596	459	226
2015 Addendum QA	65	47	24

Segment 230 (Addendum page A-76 and slides 21 and 22 of PowerPoint presentation for 3/4/15 meeting) exhibited three indicators of potential erosion. The stage of erosion is listed as "Potential Future Erosion" and the Extent of Current Erosion is listed as "Some," which is defined as 10-40% of the bank has active erosion. The bank indeed has erosion based on the photos. It appears that a fall has occurred where a tree that had been growing on the upper bank is now sitting on the lower bank. We are surprised that, on further analysis, it was not determined that this segment merited a state of erosion as "active erosion or eroded." When asked about this at the March 4, 2015 meeting, Bob Simons said that it was a good question, but he thought this segment had good indicators of erosion. To CRSEC, this is an indication that the FRR does not follow its approved RSP and is very subjective.

A review of the pictures and summary table information provided in the QA comparison indicates the stage and extent of erosion were not properly identified using the definitions in Table 3.1.1-3. We've discussed our concerns about characterizing banks as stable (stage of erosion). We also have concerns about the same segments being characterized as having none/little erosion (extent of erosion), which is defined as "generally stable bank where the total surface area of the bank segment has approximately less than 10% active erosion present". The stage and extent of erosion for the segments cannot be verified because FirstLight provided only partial information for each of the QA segments. We believe the data set for each QA segment should include:

1. The length of each segment clearly identified with start and end points. Part of the QA process should be verifying the characteristics that differentiate one segment from another. We noted in our November 14, 2014 comment letter that Extent of Erosion is highly dependent on the breakdown of river segments and how these segments were mischaracterized in the FRR segments.
2. The field data sheets and data logging files for each segment. This is the only record, other than photographs, of the river bank characteristics, including the stage and extent of erosion for each segment. (See our November 14, 2014 letter for a list of deliverables in the approved RSP that were not provided to stakeholders.)
3. All pictures for each segment, presented sequentially (downstream to upstream) and clearly labeled with the downstream and upstream limits of the segment and the riverbank features and erosion classifications pursuant to Table 3.1.1-3. We found that most segments are missing pictures or have pictures that show the same area. For example, the pictures for segment 10 are the same. We further note that the location of segment 10 on the map does not align with the location of the pictures included in the QA addendum.

The QA documentation for Segment 20 does not include a photo of the upstream portion of this segment and segments 450 and 520 do not have a complete photo log.

4. A discussion of how the stage and extent of erosion was determined. When viewed in their entirety, the pictures for each segment should clearly reflect the information in the QA summary table for each segment. Most of the QA segments indicate that the bank is "stable" with "none/little" erosion. These classifications do not meet the definitions in Table 3.1.1-3 and are not supported by the QA data presented by FirstLight. (See our November 14, 2014 comment letter that included a table of segments that had been mischaracterized by FirstLight.)

Using the definition from the approved RSP that "stable" is having no types or indicators of erosion, then only 233 segments of the 459 segments categorized as "stable" meet the definition of stable (459-226 from table above). These 233 segments add up to approximately 97,500 feet of river bank length, which is about 43% of the total river bank length (not including islands). This is in stark contrast to Table 6-1 in the FRR which stated that 83.5% of the length of river bank was categorized as "stable."

Based on the information provided in the FRR Addendum, the QA/QC effort did not correct the error of interpreting stage and extent of erosion categorization differently from the definitions laid out in the approved RSP. CRSEC continues to assert that the 2013 FRR was not conducted as written in the approved RSP and instead was conducted based on subjectivity skewed to interpreting the banks as stable. The stages of erosion and extent of erosion for the 2013 FRR should be re-calculated according to FirstLight's own definition of the stages and extent (Table 3.1.1-3).

In summary, the QA addendum and the interpretation of the data collected for the 2013 FRR do not support the conclusion of overall bank stability reached by FirstLight.

Thank you for the opportunity to comment.

Sincerely,

Tom Miner
Chair
Connecticut River Streambank Erosion Committee

Linda L. Dunlavy
Executive Director
Franklin Regional Council of Governments

Cc: Congressman James McGovern
Franklin County Legislative Delegation
Kimberly Bose, FERC

FERC Project No. 2485-063

Brandon Cherry, FERC
Chris Chaney, FERC
NOAA – National Marine Fisheries
U.S. Fish and Wildlife Service
Connecticut River Atlantic Salmon Commission
U.S. Army Corps of Engineers
Massachusetts Department of Environmental Protection
Massachusetts Division of Fisheries and Wildlife
Connecticut River Watershed Council
Franklin Conservation District
Windham Regional Commission
Landowners and Concerned Citizens for License Compliance
Town of Gill, MA Conservation Commission
Town of Northfield, MA Selectboard and Conservation Commission

ATTACHMENT: Table 3.1.1-3

Table 3.1.1-3: Riverbank Classification Definitions

RIVERBANK CHARACTERISTICS *(Upper and Lower)*[9]	
Riverbank Slope	**Overhanging** – any slope greater than 90º
	Vertical – slopes that are approximately 90º
	Steep – exhibiting a slope ratio greater than 2 to 1
	Moderate – ranging between a slope ratio of 4 to 1 and 2 to 1
	Flat – exhibiting a slope ratio less than 4 to 1[10]
Riverbank Height	**Low –** height less than 8 ft above normal river level[11]
	Medium – height between 8 and 12 ft above normal river level
	High – height greater than 12 ft above normal river level
Riverbank Sediment	**Clay –** any sediment with a diameter between .001 mm and 2 mm
	Silt / Sand – any sediment with a diameter between .062 mm and 2 mm
	Gravel – any sediment with a diameter between 2 mm and 64 mm
	Cobbles – any sediment with a diameter between 64 mm and 256 mm
	Boulders – any sediment with a diameter between 256 mm and 2048 mm
	Bedrock – unbroken, solid rock
Riverbank Vegetation	**None to Very Sparse –** less than 10% of the total riverbank segment is composed of vegetative cover
	Sparse – 10-25% of the total riverbank segment is composed of vegetative cover
	Moderate – 25-50% of the total riverbank segment is composed of vegetative cover
	Heavy – 50 % or greater of the total riverbank segment is composed of vegetative cover
Sensitive Receptors	Descriptions of important wildlife habitat use on or near the riverbank such as bank swallow colonies, kingfisher nests, eagle nests, prime odonate and mussel habitat, etc.
EROSION CLASSIFICATIONS	
Type(s) of Erosion[12]	**Falls –** Material mass detached from a steep slope and descends through the air to the base of the slope. Includes erosion resulting from transport of individual particles by water.
	Topples – Large blocks of the slope undergo a forward rotation about a pivot point due to the force of gravity. Large trees undermined at the base enhance formation.
	Slides – Sediments move downslope under the force of gravity along one or several discrete surfaces. Can include planar slips or rotational slumps.
	Flows – Sediment/water mixtures that are continuously deforming without distinct slip surfaces.
Indicators of Potential Erosion	**Tension Cracks –** a crack formed at the top edge of a bank potentially leading to topples or slides (FGS, 2007)
	Exposed Roots – trees located on riverbanks with root structures exposed, overhanging.
	Creep – defined as an extremely slow flow process (inches per year or less) indicated by the presence of tree trunks curved downslope near their base (FGS, 2007)
	Overhanging Bank – any slope greater than 90º
	Notching – similar to an undercut, defined as an area which leaves a vertical stepped face presumably after small undercut areas have failed.
	Other – Indicators of potential erosion that do not fit into one of the four categories listed above will be noted by the field crew.
Stage(s) of Erosion	**Potential Future Erosion –** riverbank segment exhibits multiple or extensive indicators of

[9] All quantitative classification criteria (e.g. slope, height, vegetation, extent, etc.) will be based on approximate estimates made during field observations of riverbanks. The FRR is a reconnaissance level survey that will not include quantitative analysis.
[10] Beaches are defined as a lower riverbank segment with a flat slope
[11] For the purpose of this study, Normal Water Level will be defined as water levels within typical pool fluctuation levels, but below Ordinary High Water (186').
[12] FGS, 2007

	potential erosion
	Active Erosion – riverbank segment exhibits one or more types of erosion as well as evidence of recent erosion activity
	Eroded – riverbank segment exhibits indicators that erosion has occurred (e.g. lack of vegetation, etc.), however, recent erosion activity is not observed. A segment classified as Eroded would typically be between Active Erosion and Stable on the temporal scale of erosion.
	Stable – riverbank segment does not exhibit types or indicators of erosion
Extent of Current Erosion	**None/Little**[13] **–** generally stable bank where the total surface area of the bank segment has approximately less than 10% active erosion present.
	Some – riverbank segment where the total surface area of the bank segment has approximately 10-40% active erosion present
	Some to Extensive – riverbank segment where the total surface area of the bank segment has approximately 40-70% active erosion present
	Extensive – riverbank segment where the total surface area of the bank segment has approximately more than 70% active erosion present

[13] Riverbanks consist of an irregular surface and include a range of natural materials (silt/sand, gravel, cobbles, boulders, rock, and clay), above ground vegetation (from grasses to trees), and below ground roots of different densities and sizes. Due to these characteristics, there are small areas of disturbance which often occur at interfaces between materials, particularly in the vicinity of the water surface. These small disturbed areas can be considered as erosion, or sometimes can result from deposition or even eroded deposition. No natural riverbank exists which does not have at least some relatively small degree of disturbance or erosion associated with the natural combination of sediment types/sizes and vegetation. As such, the extent of erosion for generally stable riverbanks that include these relatively small disturbed areas is characterized as little/none.

Attachment 1. FRCOG Comments and Recommended Terms of the License

May 22, 2024

Contains review by Dr. Evan Dethier

Franklin Regional Council of Governments

May 22, 2024

Honorable Debbie-Anne A. Reese, Acting Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project No. 2485-071
Turners Falls Project No. 1889-085
Comments and Recommended Terms of the License Submitted for Consideration by the Franklin Regional Council of Governments

Dear Acting Secretary Reese,

The Franklin Regional Council of Governments (FRCOG) hereby submits comments and recommended license terms for the Turners Falls Hydroelectric Project (P-1889) and Northfield Mountain Pumped Storage Project (P-2485). FRCOG is a statutorily created regional service organization comprised of and serving the 26 municipalities of Franklin County, Massachusetts. FRCOG replaced the former county government. The Connecticut River bisects Franklin County and is a major economic, recreational, and environmental resource for the residents of our member towns. We advocate on behalf of our communities and the county at the federal, state, and regional levels. FRCOG also serves as the Regional Planning Agency for the 26 municipalities in Franklin County.

On April 29, 2016, FirstLight Hydro Generating Company filed a Final License Application for the Turners Falls Project and Northfield Mountain Pumped Storage Project while several relicensing studies were still underway. On December 4, 2020, FirstLight MA Hydro LLC, owner of the Turners Falls Hydroelectric Project and Northfield Mountain LLC, owner of the Northfield Mountain Pumped Storage Project, collectively "FirstLight," filed an Amended Final License Application ("AFLA"). FERC issued a letter of deficiency and additional information request on January 14, 2021 and an additional information request on April 19, 2021.

FirstLight then re-engaged interested parties in separate settlement negotiations starting in late 2021. On March 31, 2023, FirstLight filed a Flows and Fish Passage Settlement Agreement, which also included whitewater releases for recreation. On June 12, 2023, FirstLight filed a Recreation Settlement Agreement.

On February 22, 2024, the Commission issued a Notice of Application Accepted for Filing, Soliciting Motions to Intervene and Protests, Ready for Environmental Analysis, and Soliciting Comments, Recommendations, Preliminary Terms and Conditions, and Fishway Prescriptions, requiring motions to intervene to be filed on or before April 22, 2024. FERC extended this deadline to May 22, 2024 in a Notice dated April 10, 2024.

FRCOG has standing and is a party to the Recreation Settlement Agreement

On April 16, 2024, FRCOG submitted a Motion to Intervene in response to FERC's Notice of Ready for Environmental Analysis issued on February 22, 2024. FRCOG has been an active participant in issues related to Northfield Mountain project operation for the last 30-40 years, and FRCOG has actively participated in relicensing proceedings since 2013. When the relicensing process began in 2013, FRCOG and its Connecticut River Streambank Erosion Committee (CRSEC) had decades of experience with the effect of Northfield Mountain's operations on erosion along the Connecticut River upstream of the Turners Falls Dam. As explained later in this letter, the CRSEC has actively worked with the project owner to implement the 1999 Erosion Control Plan and was recognized by FERC as an ad hoc committee with which FirstLight and the project's previous owners were required to consult.

FRCOG is a party to the Recreation Settlement Agreement filed with FERC on June 12, 2023. FRCOG fully supports the recreation provisions in the settlement agreement and requests FERC to accept the Recreation Management Plan (RMP). The RMP and Recreation Settlement Agreement satisfy the FRCOG's recreational interests with regard to both projects, and if kept intact in the final license, its provisions will be a great asset to the region. In accordance with Section 2.2 of the Recreation Settlement Agreement, although we were not a party to the Flows and Fish Passage (FFP) Settlement Agreement, the FRCOG has agreed not to oppose any of the terms of the FFP Settlement Agreement.

Erosion Comments

The Connecticut River has undergone a large experiment over the last 52 years serving as the lower impoundment for a large pumped storage project, wedged in between two other hydroelectric dams. The entire Massachusetts part of the river upstream of the Turners Falls Dam is listed as impaired in the 2022 Massachusetts Integrated List of Waters due to the Turners Dam impoundment and pumped storage project operations. Appendix 15 to the 2018-2020 Massachusetts Integrated List states that these segments are "not supporting" the Fish, other Aquatic Life and Wildlife Use because of the impairments described below.[1] These impairments, except for E. coli and PCBs, are related to the existence of the impoundment and project operations.

- Segment 34-01 is the 3.5-mile segment between the Vermont/New Hampshire/Massachusetts state line and the Route 10 bridge. This segment is listed as impaired for <u>alteration in streamside or littoral vegetative covers, flow regime modification</u>, and PCBs in fish tissue.

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[1] https://www.mass.gov/doc/20182020-integrated-list-of-waters-appendix-15-connecticut-river-watershed-assessment-and-listing-decision-summary/download

- Segment 34-02 is the 11.4-mile segment between the Route 10 bridge and the Turners Falls Dam, excluding Barton Cove. This segment is listed as impaired for alteration in stream-side or littoral vegetative covers, flow regime modification, water chestnut, and PCBs in fish tissue.
- Barton Cove is MA34-122, a 160-acre cove of the Connecticut River upstream of the Turners Falls Dam, is listed as impaired for curly-leaf pondweed, Eurasian water milfoil (*Myriophyllum spicatum*), fanwort, water chestnut, Escherichia coli (E. coli), and PCBs in fish tissue.[2]

Additonally, in MassDEP's letter to FERC on the Updated Proposed Study Plan dated July 12, 2013, MassDEP stated that in 2001, the U.S. EPA approved New York and Connecticut's Long Island Sound dissolved oxygen Total Maximum Daily Load, and explained that nutrient loading has been established as a cause for low dissolved oxygen levels observed in Long Island Sound. While MassDEP did not recommend nutrient sampling as part of the relicensing studies, they explained "actions taken to minimize nutrient loading are justified now."

This section of the Connecticut River has been a sacrifice zone for a long time already. The Northfield Mountain Pumped Storage project was issued its original (current) FERC license in 1968; the project was constructed and the Turners Falls Dam raised prior to the passage of the federal Clean Water Act. These projects have operated for over 50 years without a mechanism to address compliance with the Clean Water Act and Massachusetts' Water Quality Standards. The new license is a once-in-a-lifetime opportunity to craft license articles that will improve and protect the water quality status of the Connecticut River, a treasured regional and national Public Trust resource, and to indigenous groups, a living being deserving of respect and protection.[3] FirstLight's proposed operations will not resolve these problems, and may cause further impairment. FirstLight has not proposed adequate Protection, Mitigation and Enhancement measures to address the impairments and improve water quality. Below, FRCOG offers our comments and concerns on erosion, and we suggest recommendations for terms of the new license.

FERC has an obligation to mitigate

A new license will involve a balance between power generation and environmental quality. FERC is required to consider this balance and give equal consideration to environmental concerns.

> In deciding whether to issue any license under this subchapter for any project, the Commission, in addition to the power and development purposes for which licenses are issued, shall give equal consideration to the purposes of energy conservation, the protection, mitigation of damage to, and enhancement of, fish and wildlife (including related spawning grounds and

[2] Final Massachusetts Integrated List of Waters for the Clean Water Act 2022 Reporting Cycle. CN 568.1. Prepared by the Massachusetts Department of Environmental Protection Watershed Planning Program. May 2023.

[3] Public trust doctrine is a legal principle establishing that certain natural and cultural resources are preserved for public use. Natural resources held in trust can include navigable waters, wildlife, or land. The public is considered the owner of the resources, and the government protects and maintains these resources for the public's use. https://www.law.cornell.edu/wex/public_trust_doctrine

habitat), the protection of recreational opportunities, and the preservation of other aspects of environmental quality. 16 U.S. Code §797(e)

Northfield Mountain Project has a long history concerning erosion

Since the Northfield Mountain Project operation began in 1972, landowners along the Connecticut River in the Turners Falls impoundment (TFI) have watched their prime farmland soils and mature riparian trees slump and topple into the Connecticut River. Because of the complaints early in the life of the Northfield Mountain Project, the project owner engaged in helicopter logging along the banks in 1976 and 1977 to remove trees and "reduce" erosion. Because of continued landowner concerns, Congressional representatives requested that the Army Corps of Engineers assess the causes of streambank erosion. The resulting report, published in 1979, identified shear stress (velocity), <u>pool fluctuations</u>, boat waves, gravitational forces, seepage forces, natural stage variations, wind waves, ice, flood variations, and freeze-thaw as causative factors to erosion, in that order from most important to least important.[4]

The 1979 Army Corps report prompted demonstration bank protection projects installed by the Army Corps in 1981. In 1991, the Army Corps published an investigation study of the Connecticut River in the TFI, and reported that approximately one-third of the 148,000 linear feet of shoreline was undergoing some form of active erosion, concluding that since 1979, riverbank erosion had increased almost threefold.[5]

In 1991, Northeast Utilities Service Co., Inc. hired consultants Northrop, Devine, and Tarbell, Inc. to prepare a Connecticut River Riverbank Management Master Plan.[6] This study also documented that 30% of the riverbanks were eroding. The Master Plan recommended stabilization projects to be implemented by 1996. On July 28, 1994, FERC issued a letter to owner Northeast Utilities Company stating that no real attempt to control erosion on the riverbank had been made since 1991. The FERC letter described that the rising and falling pool level creates a wetting and drying cycle, which in turn fluctuates the pore pressure of the bank materials, and has the effect of dislodging riverbank material. FERC's letter said, "*Logically, one can attribute the pumped-storage operation as directly affecting the bank stability of the Turners Falls reservoir. The rapid daily drawdown of 3 feet or more is a major contributor to the rapid river bank erosion now taking place between Turners Falls and Vernon Dams as shown by the bank stability study*."

In September of 1994, Northeast Utilities submitted a riverbank action plan, and in August 1995, Western Massachusetts Electric Company (WMECO) submitted a Long-term Riverbank Plan for the Connecticut River. In September 1998, Northeast Utilities submitted an Erosion Control Plan that also

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[4] Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire, and Vermont. Prepared by D. B. Simons et al. for the U.S. Army Corps of Engineers, 1979. Contract No. DACW 33-78-C-0297.
[5] General Investigation Study Connecticut River Streambank Erosion: Connecticut River, Turners Falls Dam to State Line, MA. July 1991. U.S. Army Corps of Engineers
[6] Northeast Utilities Service Co., Inc. 1991. Connecticut River Riverbank Management Master Plan (Draft). June 1991. Prepared by Northrop, Devine, & Tarbell, Inc.

included a riverbank erosion survey. A revised Erosion Control Plan was submitted in June of 1999 and accepted by FERC on July 8, 1999. It took 27 years after project operations began to finally get a Plan that committed the Licensee to monitoring and restoring the eroded river banks. This Erosion Control Plan was still in effect as of the beginning of relicensing. Through that entire planning process, the Franklin County Commission, and later when it became FRCOG, along with the CRSEC, were involved in meetings and filing motions to intervene and comment to FERC.

As part of the requirements of the 1999 Erosion Control Plan, FirstLight and its predecessor owners conducted Full River Reconnaissance (FRR) efforts during 2001, 2004, and 2008. The 2004 FRR showed the erosion control efforts were not keeping pace with the rate of erosion. FERC issued a letter on June 28, 2005, requiring Northeast Generating Company (NGC) to submit a plan of action by which it would be able to show a reduction in the rate of erosion by the next FRR. In response to the FERC letter, NGC retained a fluvial geomorphologist to study the Turners Falls pool and make recommendations. On December 12, 2007, NGC filed the geomorphologic study report prepared by Field Geology Services. FERC again required a plan unless the 2008 FRR was able to demonstrate a reduction in the rate of erosion. NGC hired a new consultant, changed some of their methods, and this time, the 2008 FRR demonstrated a reduction. FERC accepted the 2008 FRR without a plan in a letter dated November 17, 2009. The next FRR was completed in 2013 as Relicensing Study 3.1.1, and submitted to FERC in September 2014. The Erosion Control Plan committed the licensee to conduct FRRs every 4-5 years until the end of the license term, which was originally 2018 but has since been administratively continued. No FRR has been completed since 2013, and it has now been almost 11 years since the last survey of the status of the riverbanks in the impoundment.

FERC should continue to include and enforce license articles related to erosion

The plans described in the previous section are due to FERC's enforcement of Article 19 in the Turners Falls license[7] and Article 20 in Northfield Mountain's license.[8] FERC has repeatedly referenced these license articles when issuing orders to the licensee and, when enforced, these conditions have resulted in important information, planning, and bank restoration work. These license articles are still relevant and should remain in place.

[7] Article 19 (which is the same as FERC's standard license article 19) provides: "In the construction, maintenance, or operation of the project, the Licensee shall be responsible for, and shall take reasonable measures to prevent, soil erosion on lands adjacent to streams or other waters, stream sedimentation, and any form of water or air pollution. The Commission, upon request or upon its own motion, may order the Licensee to take such measures as the Commission finds to be necessary for these purposes, after notice and opportunity for hearing."

[8] Article 20 provides: "The Licensee shall be responsible for and shall minimize soil erosion and siltation on lands adjacent to the stream resulting from construction and operation of the project. The Commission upon request, or upon its own motion, may order the Licensee to construct and maintain such preventative works to accomplish this purpose and to revegetate exposed soil surface as the Commission may find to be necessary after notice and opportunity for hearing."

Effects of natural flows and impoundment fluctuations already acknowledged

Erosion is a natural process in rivers, with rivers carving new paths and eroding new areas during high flow events. In addition, increasing erosion from impoundment fluctuations have already been determined to be impacted by the operations of Turners Falls and Northfield Mountain projects. The most comprehensive, and the only truly independent study on erosion on the Connecticut River to date is the 1979 Army Corps study, which was prepared after four years of thorough analysis and hydrologic and geotechnical data collection.[9] This study identified shear stress from high river flow events as the biggest cause of erosion in the Turners Falls pool. On page 67 of the 1979 Army Corps report, it explained that comprehensive studies by experienced engineers and geologists have concluded that 90-99% of all significant erosion occurs during major flood events. This was known going into relicensing. Nevertheless, the study documents that project operations can play a role in exacerbating this natural erosion. In fact, page iv of the 1979 Army report stated,

> Note that forces exerted on the bank of a channel by the flowing water can be increased as much as 60 percent by such factors as flood stage variations, pool fluctuations, boat and wind waves, etc. Evaluation of forces causing bank erosion verifies the relative importance of causative factors. In descending order of importance they are: shear stress (velocity), pool fluctuations, wind waves, ice, flood variations, and freeze-thaw. (emphasis added).

The impacts of fluctuating water levels from hydropower projects has also reported elsewhere. One assessment filed with FERC regarding a hydropower project in Vermont describes the process at run-of-river dams:

> Mass slippage along run-of-river reservoirs is described in the literature and is predicted to occur during fluctuation of the adjacent water level. At low water the pore water pressure at the slip surface is increased and this diminishes the restraining friction along the slip line (and there is increased bank material weight due to the added groundwater). This process commonly leaves the slumped materials at the toe of the bank. Thus, a bank slump involves soil movement along a slip surface: a changed balance of shear stresses and shear strengths occur and a stability threshold is crossed. Also, **both rapid water level rise and fall can affect bank stability**. Consequences of rapid drawdown and the fact that pore pressures are potentially delayed compared to the external water level have been shown to include outward seepage, tension cracks development, and finally slope failure along a rotational slip surface.[10] (emphasis ours)

Field Geology Services also described the process in a report commissioned by the owner of Northfield Mountain Pumped Storage Project:

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[9] Simons, D. B. et al. 1979. Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire, and Vermont. Contract No. DACW 33-78-C-0297. Prepared for U.S. Army Corps of Engineers. Cover letter dated November 21, 1979.

[10] G. Robert Brakenridge, 2021. Run-of-River Hydroelectric Dam Bank Erosion and Cultural Resources in Vermont. Page 25. FERC Accession Number 20220131-5494

> While composition is a very important factor determining the strength of the bank sediment, certain soil moisture conditions can further weaken the bank material and increase the likelihood of bank failure. Quite commonly bank erosion will be greatest during the recession of high flows rather than during the high flow itself. This occurs because the bank sediment becomes saturated with water during the high flow and then the confining pressure exerted on the bank by the river decreases as the river level recedes. **Rapid water level fluctuations in reservoirs can cause similar discrepancies between the water surface and adjacent groundwater levels**. The differences will be most pronounced in less permeable finer grained sediments as groundwater levels will more slowly equilibrate to the changing water surface.[11] (emphasis ours)

The Turners Falls Impoundment is part of a system of hydropower projects

Historically, a common hypothesis about rivers impacted by dams is that the effects of dams attenuate in space and time until a new equilibrium is reached. Recent studies are showing, however, that this may be more complicated on river systems with multiple dams on the mainstem and hundreds or thousands in tributaries, like the Connecticut River -- "We hypothesize that where dams that occur in a longitudinal sequence, their individual effects interact in unique and complex ways with distinct morphodynamic consequences."[12]

In recognition of the importance of evaluating the Connecticut River as a system, FERC has been undertaking the relicensing of five projects on the Connecticut River at the same time, the Wilder, Bellows Falls, and Vernon Dams in Vermont and New Hampshire; and the Northfield Mountain Pumped Storage Project and Turners Falls Dam in Massachusetts. The Scoping Documents from 2013 for these facilities recognized cumulative effects of the projects, and FERC should continue to recognize the interplay between the projects as well as the river system as a whole.

FirstLight's Erosion Causation Study (Study 3.1.2) has flaws that mask the project effects

As part of this relicensing proceeding, FirstLight completed Study 3.1.1 in 2013, the Full River Reconnaissance; and Study 3.1.2 in 2016 and revised in 2017, the "Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report" but commonly referred to as the "Causation Study." FirstLight has been arguing in recent years that the company does not have responsibility for erosion. At the beginning of relicensing, FirstLight filed a biased report that was not part of relicensing, the "Riverbank Erosion Comparison along the Connecticut River" prepared in 2012 by Simons and Associates. This report fits into a pattern of communications in which FirstLight has been discounting the impacts of FirstLight project operations on bank erosion. In the study request

[11] Field Geology Services, 2007. Fluvial Geomorphology Study of the Turners Falls Pool on the Connecticut River Between Turners Falls, MA and Vernon, VT. Prepared for Northfield Mountain Pumped Storage Project. Page 9 and 10.

[12] Skalak, K.J., Benthem, A. J., Schenck, E. R. et cal. 2013. Large dams and alluvial rivers in the Anthropocene: The impacts of the Garrison and Oahe Dams on the Upper Missouri River. Published in Anthropocene, October 2013. Pages 51-64. Online at https://www.sciencedirect.com/science/article/abs/pii/S221330541300026X?via%3Dihub

phase of relicensing in 2013, project stakeholders requested a study documenting the amount of erosion that had taken place over the course of the existing license as well as operational statistics on impoundment fluctuations. Instead of providing this information, FirstLight created a model to determine the cause of erosion. Perhaps unsurprisingly, FirstLight's model concluded that project operations have little impact, and predicted that future operations will also have little effect. Yet, peer reviews of the model and its application to the complex hydrologic and hydraulic conditions in the Turners Falls Impoundment indicate serious flaws in the model and its application. Criticisms include the fact that few caveats regarding the model results were presented, and few inputs and outputs to the model were ever provided to stakeholders, making replication of the model results impossible.

FRCOG hired a peer reviewer in 2014 to look at the study plan for the causation study to be prepared by FirstLight. In the letter from the University of Illinois at Urbana-Champaign to FRCOG dated November 13, 2014, the peer reviewers summarized the current state of understanding of fluvial erosion processes at the time Study 3.1.2 was designed. Their letter identified several weaknesses with the state of understanding and modeling (included here as Attachment A). The reviewers wrote that the objectives of the study, to quantify causative factors in erosion, was daunting if not impossible. They said that, while the Bank Stability and Toe Erosion Model (BSTEM) is a sound practical approach, any findings should be "strongly qualified" and a finding that the pumped storage operations have no impact on bank retreat would "not be defensible given the uncertainties involved." As we have since seen, the Study 3.1.2 Report was not strongly qualified at all, and was instead presented as definitive science by FirstLight, a claim that is not scientifically valid or supported by peer-reviewed literature or the information provided in FirstLight's own report (Study 3.1.2 Report).

The University of Illinois reviewers thought the study would provide insights into which processes were important *in a relative sense*. An additional observation from the University of Illinois reviewers is important to emphasize:

> The presence of the undercut "notches" located near the normal water state with the maximum extent of the cut not extending deeper below the water surface also **suggests other mechanisms are likely acting in concert with fluvial erosion**; note that Table 6.1 of the FRR indicates that approximately 43% of the river banks show evidence of this feature. A notch whose maximum extent is located near the normal water surface suggest the effect of both wave action and sapping associated with the steepest part of the groundwater table following a period of drawdown, and its influence in making the bank material more susceptible to fluvial erosion.

The observation made by the University of Illinois reviewers in the quote referenced above was on display in FirstLight's Study 3.1.2 Appendix D Detailed Study Assessments. As you can see from the figures below at Site 7L and 7R, located 2,500-3,000 feet downstream of Kidds Island, there are notches in the vicinity of the water level that appears to be causing a cascading effect on the entire bank. Both sides of the river at this location have experienced substantial bank loss as shown in FirstLight's cross-sectional surveys. Detailed study sites 7L and 7R were both considered to be affected only by "high flows" in FirstLight's BSTEM modeling (see Figure 1, Map 2 in the 2024 Supplemental BSTEM Report).

The full drawings for these sites and the cross sections from Study 3.1.2 Appendix D are included in Attachment B.

Figure 1. FirstLight Study 3.1.2 Detailed Study Site 7L figure from Appendix D. Note toe undercut at river level.

Observed Erosion Features:

- *Very steep slopes near top of Upper Bank, with little vegetation.*
- *Leaning trees with exposed roots at river level.*
- *Mass wasting with slumping and exposed roots.*
- *Toe undercutting and localized scour holes between trees at river level.*
- *Overhangs with exposed roots of large trees at top of Upper Bank.*

Site Sketch:

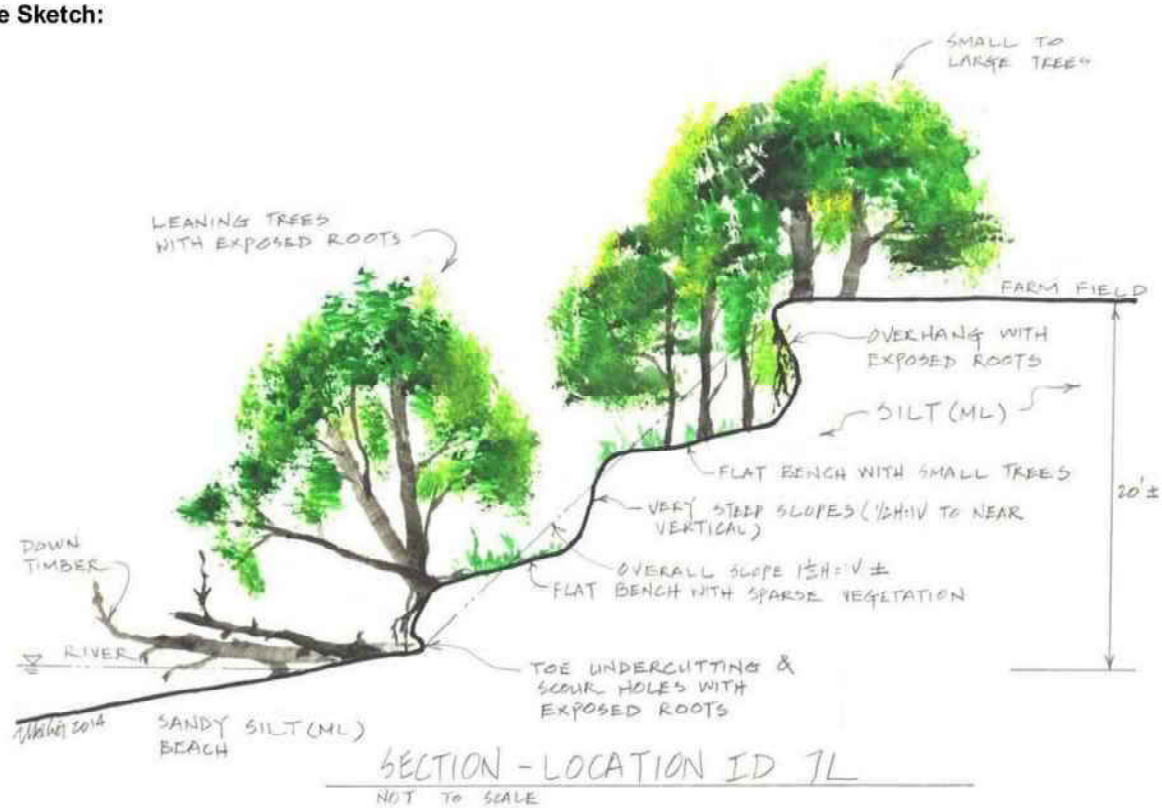
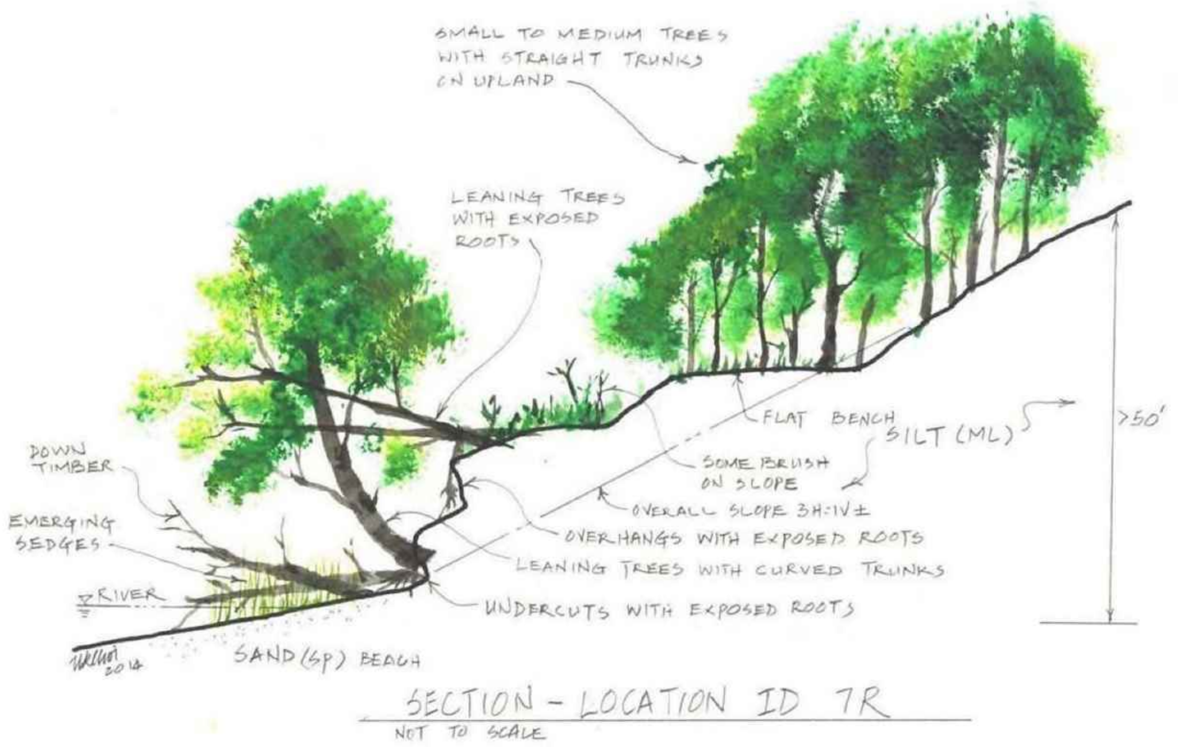


Figure 2. FirstLight Study 3.1.2 Detailed Study Site 7R figure from Appendix D. Note the toe undercut at river level. Also note mention of groundwater flow.

Observed Erosion Features:

- *Undercuts with exposed roots at river level.*
- *Mass-wasting along entire slope.*
- *Trees on upland area have straight trunks, suggesting the trees post-date the mass-wasting movement.*
- *Leaning trees with exposed roots at river level and bottom of Upper Bank, some with curved trunks.*
- *Large scour hole (20' wide x 40' long x 15 feet deep) at mid-slope, with flowing groundwater at bottom of hole.*

Site Sketch:



Given that previous studies, such as the 1979 Army Corps study, identified high flow events as the biggest driver of erosion, it is not surprising that FirstLight's study identified this as well. The question is more about how project operations *also* contribute to erosion. FirstLight arbitrarily defined "dominant" causes of erosion as those that contribute more than 50% of the erosion, and under this definition, high flow events were always going to be the only category meeting that definition. Next, "contributing" causes of erosion were those causing between 5 and less than 50% of erosion. The study identified project operations as being a contributing cause of erosion at 3 of 25 sites along 40 miles of riverbank length, and FirstLight extrapolated data from the 25 sites to label the entire 40-mile length with various causes of erosion. The parsing out of the causes of erosion, with no interplay between these causes, and the rationale for extrapolation, strains credulity.

When Study 3.1.2 came out in 2016, the Connecticut River Watershed Council, now called the Connecticut River Conservancy (CRC), hired Princeton Hydro to conduct a peer review of the study report. Princeton Hydro's peer review memo dated December 7, 2016, further identified several problem areas in the study. The Princeton Hydro memorandum was part of CRC's comments on the Study Report filed with FERC on December 15, 2016. In FirstLight's response to stakeholder comments filed with FERC on January 17, 2017, FirstLight discounted most of these peer review comments. Because the revised document came out after the comment period on the Study Report for 3.1.2, no review by stakeholders ever took place of FirstLight's updated report filed on April 1, 2017, which included their ice analysis.

As part of the NOAA National Marine Fisheries Service's (NMFS's) analysis of relicensing study reports, NMFS requested a review from Eddy Langendoen, a Research Hydraulic Engineer from the U.S. Department of Agriculture. Dr. Langendoen was a principal designer and developer of BSTEM and was well qualified to review the methods and results of Study 3.1.2. Dr. Langendoen's review of Study 3.1.2 was included as Appendix 2 to Attachment A to NMFS's letter to FERC dated December 15, 2016. One of Dr. Langendoen's first comments was that, "to accurately characterize the long-term bank erosion rate, the cyclic process of fluvial erosion and mass wasting must be adequately simulated by BSTEM." He added that it appeared that the period of the cyclic process of erosion in the Turners Falls Impoundment was longer than the 15-year simulation period (2000 to 2014) and that the estimated long-term erosion rates at the study sites would be underestimated. In FirstLight's response to comment document dated January 17, 2017, FirstLight stated that the cyclic processes were adequately modeled during the 15-year period and increasing the length would have produced low annual rates of erosion. Furthermore, the 15-year period is the period for which they had digital operational data and riverbank geometry data. The modeled period may miss mass wasting episodes, making it look like incremental low rates of erosion until the mass wasting episode results. Operational impacts may have been masked by a shorter time period of the modeled study, and none of this was acknowledged by FirstLight.

The Connecticut River Conservancy and FRCOG have collaborated to hire Dr. Evan Dethier to complete another review of Study 3.1.2. Dr. Dethier was able to look more extensively at the BSTEM modeling input values and conclusions than Princeton Hydro's review did. Attachment C includes his review. Dr. Dethier points out a number of flaws in the BSTEM modeling, and offers additional reasons why the study's conclusions, which are presented without any uncertainty, are not credible.

2024 BSTEM Modeling Report is used as predictive tool to evaluate impacts of proposed operations vs. modeled existing operations

On March 22, 2024, FirstLight filed a Supplemental BSTEM Modeling Report Reflecting Operating Conditions in the Flows and Fish Passage Settlement Agreement. This report uses the flawed BSTEM modeling of Study 3.1.2, and now uses the model as a <u>predictive</u> tool to estimate project impacts into the future using modeled existing and modeled future conditions. The results of the Study 3.1.2 scenarios cannot be compared with the 2024 scenario outputs for reasons explained below.

In Study 3.1.2, the BSTEM model compared a "baseline" scenario vs. "S1" scenario. The Study 3.1.2 "baseline" included historic actual flows from Vernon Dam and historic actual Northfield Mountain and Turners Falls Dam operations. "S1" was the same, except Northfield Mountain operations were "turned off." On page 5-53 of Vol II of Study Report 3.1.2, FirstLight asserted that the comparison of the two scenarios allowed them to "tease out" the causes of erosion. However, this is a flawed assertion. Turners Falls operations were never turned off in this scenario (Northfield Mountain idle), which is a serious oversight because the actual Turners Falls Dam operations would have reflected the conditions of Northfield Mountain running. In other words, the "S1" scenario, while perhaps turning off water flowing in and out of the Northfield tailrace, would include TFI elevations as measured at the dam that represent a combination of Turners Falls project effects and Northfield Mountain operations. **As a result, it is not at all clear how FirstLight's assertion that the comparison of the two scenarios would effectively tease out project effects from each project.**

In the 2024 report, the BSTEM model used modeled current operations as "baseline" against modeled conditions of the Flow and Fish Passage (FFP) Settlement Agreement "2023 FFP." The FFP scenario also includes modeled Northfield Mountain operations with an expanded upper reservoir. In other words, the 2024 "baseline" is very different from the Study 3.1.2 "baseline." Table 1 below summarizes the differing input data. In 2024, baseline is a modeled run of river operation for Vernon Dam, and modeled "existing operations" for Northfield and Turners Falls Dam, not historic actual operations. No scenario compares an idle Northfield Mountain against the 2023 FFP scenario, or actual conditions vs. modeled FFP conditions. **Moreover, the 2024 report modeled future conditions based on 2000-2014 flows to predict impacts over the next 50 years, which we consider a serious flaw especially given climate change combined with a rapidly changing electric market.**

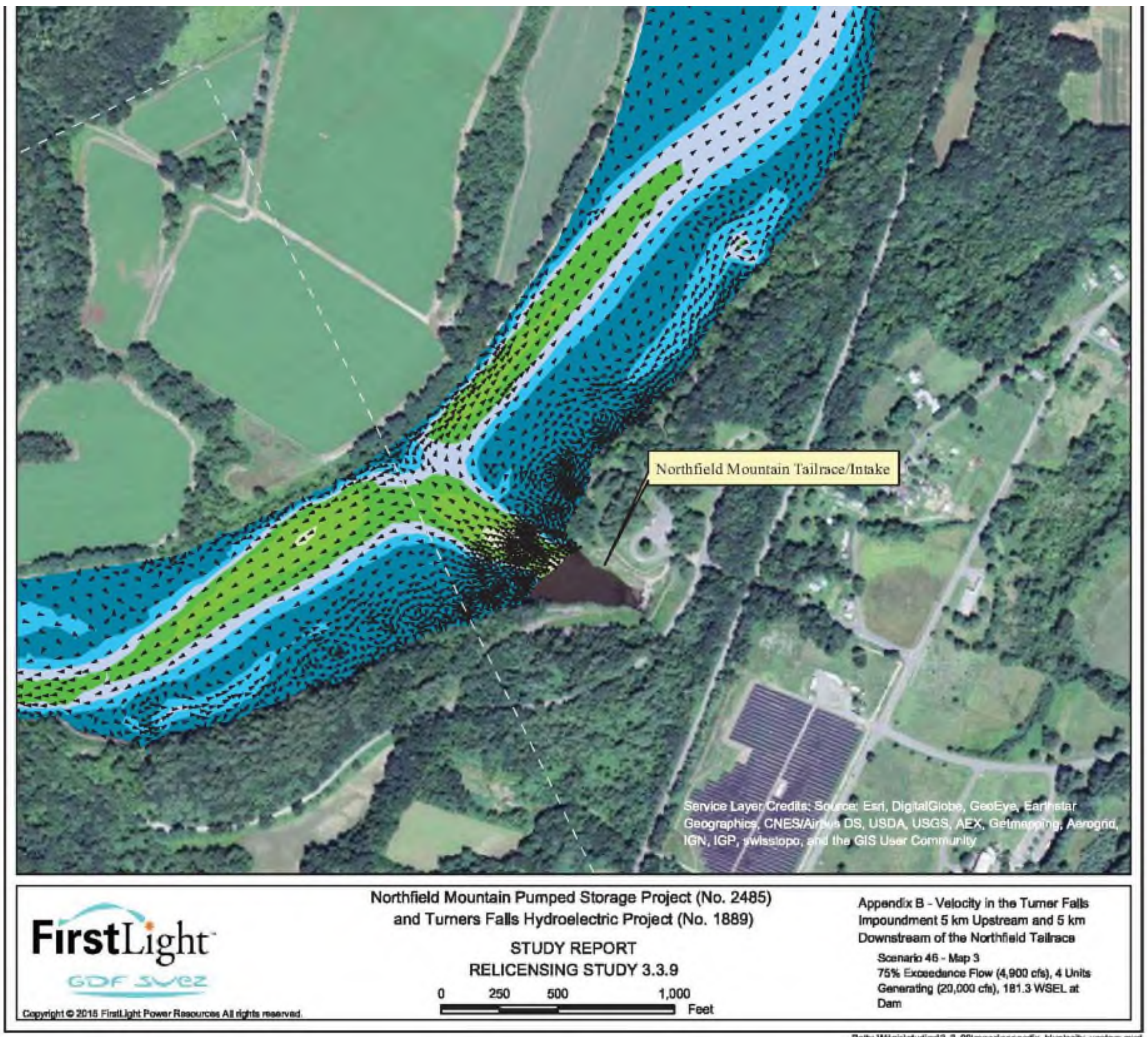
Table 1. Model inputs from Study 3.1.2 and the 2024 Supplemental BSTEM report

Model Scenario	Time step & Time frame	Vernon Operations (flow)	Millers and Ashuelot flows	NFM Operations (flow)	TFD Operations (elevations)
Study 3.1.2 Baseline	Hourly 2000-2014	Historic actual	Historic USGS gage	Historic 2000-2014	Historic 2000-2014
Study 3.1.2 S1	Hourly 2000-2014	Historic actual	Historic USGS gage	Idle	Historic 2000-2014
2024 Baseline	Hourly 2000-2014	Modeled run of river*	Historic USGS gage	Model of existing operation conditions	Not stated, but assumed to be model of existing operation conditions
2023 FFP	Hourly 2000-2014	Modeled run of river*	Historic USGS gage	Expanded upper reservoir and FFP conditions	Modeled FFP operational changes, as if implemented in year 1

* - Great River Hydro's operation agreement allows Vernon to peak and refill the impoundment a certain number of hours per month. Flex peaking has not been modeled in these scenarios.

Moreover, the hydraulic model used for Study 3.2.2 did not appear to look at negative velocities (when the river flows upstream), or the geographic extent of upstream flow during different river elevations and operational scenarios. Study 3.3.9 Appendix B velocity graphs show the river flowing upstream beyond the 5 km-extent of the study area upstream and downstream of the Northfield Mountain tailrace, with swirling patterns against the banks in the vicinity of the tailrace.[13] See Figure 1 example below. In contrast, the 1979 Army Corps Study on page 120 concluded that **flow reversals, turbulence, and changes in river stage** caused by power generation have induced bank erosion.

Figure 3. Cropped map from Relicensing Study 3.3.9, Appendix B Velocity, Scenario 46, Map 3. Dark blue areas have lower velocities and green areas have higher velocities. Triangles indicate direction of flow.



In conclusion, the 2024 Supplemental BSTEM report FirstLight's Streambank Erosion Proposal for the Turners Falls Impoundment, submitted to FERC on March 22, 2024, does not recognize uncertainties in

[13] Despite their own Study 3.3.9 showing otherwise, Study 3.1.2 Volume II states on page 5-210: "In addition, water level fluctuations cause no horizontal impact to the riverbank; **the water level simply rises and falls slowly**."

the model, does not identify factors the model was not able to incorporate, and **instead assumes it is 100% predictive of project operational impacts on bank stability for the next 50 years**. This is not an appropriate use of the modeling results.

Information lacking on modeled TFI levels under proposed FFP conditions

The 2024 Supplemental BSTEM report indicates FirstLight has modeled project operations under the FFP Settlement Agreement conditions. The report, however, did not provide sufficient information to understand predicted TFI impoundment levels, modeled fluctuations, or average impoundment elevations. Figure 2.2-2 in the 2024 Supplemental BSTEM report, which shows modeled water surface elevations at Transect BC-1R in Barton Cove (similar graphs were provided for Transect 75 near the Northfield Mountain tailrace and Transect 4L near the Pauchaug Boat Launch) provides only limited and insufficient information. While this information from the supplemental report may be helpful in comparing elevations between the modeled baseline and the modeled FFP conditions at this transect in Barton Cove, FirstLight's proposal of a TFI elevation range of 176-185 feet mean sea level (msl) is <u>as measured at the dam</u>, not at Transect BC-1R. Transect BC-1R should not be used as a surrogate for elevations as measured at the dam, because Figure 4.3.1.3-7 of the October 2012 Pre-Application Document (PAD) shows a fairly substantial difference between elevations at the dam vs. the boat barrier line, which is not very far from the dam.

FirstLight did not provide sufficient data files with modeled TFI elevations as part of the 2024 Supplemental BSTEM Modeling Report. After the AFLA was submitted in 2020, FERC requested information through several "Additional Information Requests" or AIRs. In AIR#5, FERC requested FirstLight provide simulated hourly water surface elevations in the Turners Falls Impoundment, and other information. On June 21, 2021, FirstLight filed responses to FERC's AIR, which included several Excel spreadsheet files. These Excel files from 2021 included flows from Great River Hydro's Vernon Dam modeled as Run-of-River, but the FFP Settlement Agreement did not yet exist. FERC has not requested similar information for the FFP conditions, nor has FirstLight provided a replacement set of spreadsheets. Therefore, we cannot evaluate the predicted hourly water surface elevations in the TFI under the proposed conditions. In light of these gaps in information, it is not possible to understand typical predicted daily fluctuation ranges or the average river elevation.

Understanding river elevation and fluctuation patterns is important for setting future license conditions

The current license for the projects contains only the 9-foot impoundment fluctuation limit, as measured at the Turners Falls Dam. It is widely accepted that this "full operating range" is different than "normal operations," which involves a narrower fluctuation range. Due to FirstLight's failure to gather or provide the necessary data, we have little understanding of what "normal operations" is in terms of fluctuation ranges and typical elevations, and whether "normal operations" has changed over the course of the existing license. Despite the water quality impairments, FirstLight continues to seek approval of a license that allows this same 9-foot full operating range. The river fluctuations at the dam are smaller than elsewhere in the impoundment because FirstLight can control river elevations from the various gates at the dam, and because of the hydraulic pinch point at French King Gorge upstream.

Again, as a result of FirstLight's failure to collect or share information, we cannot fully evaluate whether the impoundment fluctuations in the vicinity and upstream of the Northfield Mountain tailrace have changed over time. However, we do have some limited data to suggest that normal operations may be shifting to wider daily fluctuations, potentially leading to increased impacts on bank stability.

In 1991, consultants for the project owner, Northrop, Devine, and Tarbell, produced a Riverbank Management Plan, as mentioned earlier in our comments. Table III-2 in the 1991 Riverbank Management Plan listed the normal fluctuation range at Bennett Meadow (adjacent to the Route 10 bridge, approximately 5.7 miles upstream of the Northfield Mountain project intake/tailrace) as within 2.4 feet. This statistic was qualified as being true for the 80% of the time that the river flow is less than 20,000 cubic feet per second (cfs).

In 2017, Figure 5.1.3.1-6 in Volume III of Study 3.1.2 showed modeled historical fluctuations at Transect 5CR, located at Bennett Meadow. These were shown as 2.8 to 3.2 ft for 80% of days during all conditions when flows from Vernon are less than 18,000 cfs and Northfield is operating (and only 0.8 to 1.2 ft for 80% of days when Northfield Mountain is idle). Therefore, it seems possible that "normal operations" have shifted from 2.4-foot daily fluctuation prior to 1991 to 2.8-3.2-foot fluctuations between 2000 and 2014.

River level fluctuations may have increased again since the modeled conditions in Study 3.1.2 (2000-2014). In 2018, the U.S. Geological Services (USGS) installed a river gage on the Connecticut River in the TFI just upstream of the Route 10 Bridge in Northfield MA, which is approximately 5.8 miles upstream of the Northfield Mountain project intake/tailrace.[14] This location is just upstream of the Bennett Meadow site described in the previous two paragraphs. The USGS gage shows river elevations that are subject to a combination of natural river flows with the operations of the Vernon Dam, Turners Falls Dam, and Northfield Mountain Pumped Storage Project. As a result of the installation of this gage, and for the first time, the public could understand how much fluctuation the river was experiencing in the TFI.

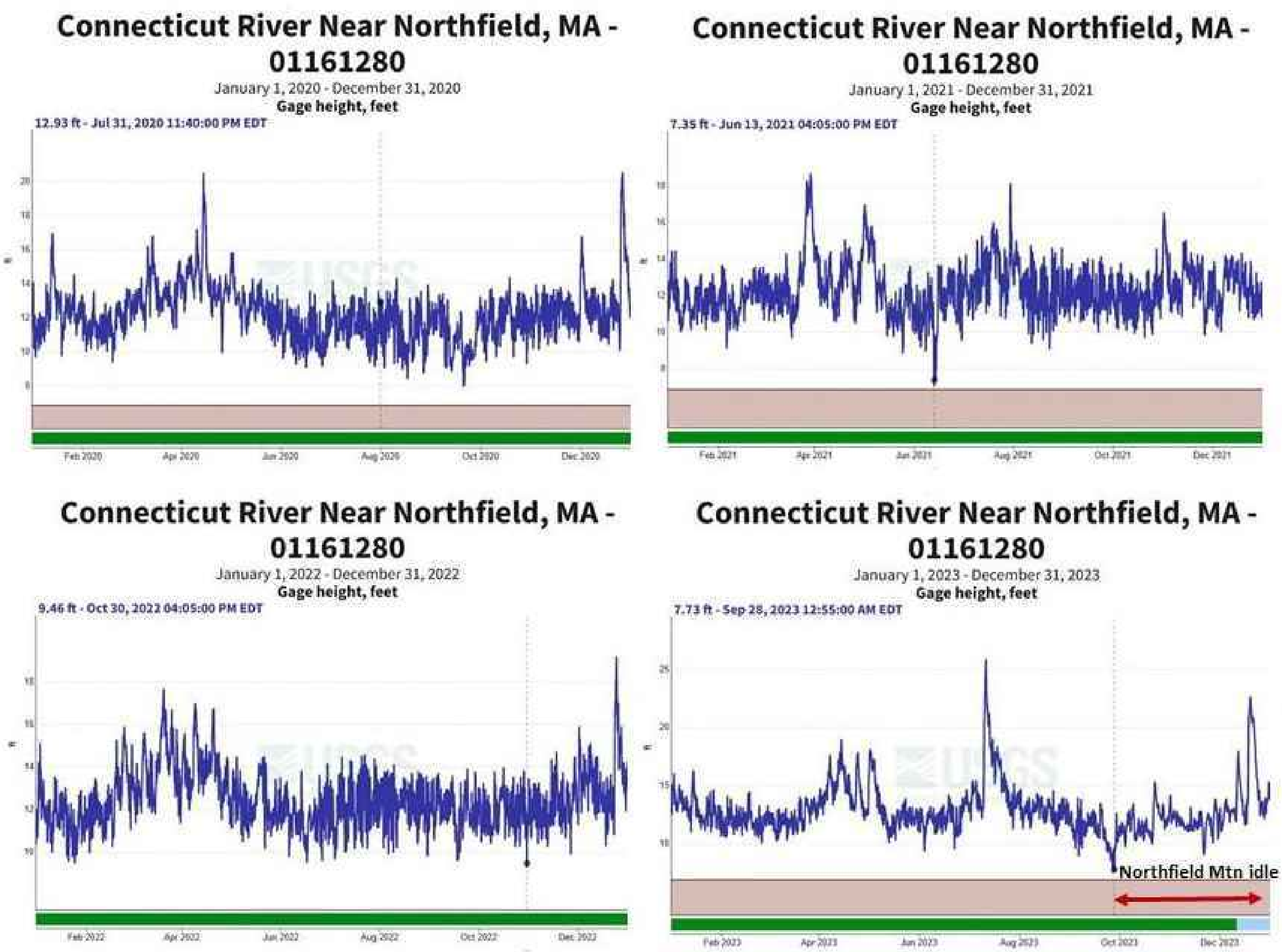
The graphs below show the river elevations at the Northfield USGS gage for the years 2020, 2021, 2022, and 2023. There is no way to screen out only the flows from Vernon that are less than 80,000 cfs, but the graphs show that river elevations typically fluctuate between a ~4-ft range between 10 and 14 ft on the gage in the summer. The year 2022 was a drought, and is a good example of low flow conditions.

Gage heights for these four most recent years vary between a low of 7.35 ft on the Northfield USGS gage in June of 2021 to a high above 25 feet during a flood in July of 2023, representing an approximate range of 18 feet. The low event was caused operationally and led to a FERC letter to FirstLight responding to a

[14] Real-time and past river level information for this site can be accessed online at https://waterdata.usgs.gov/monitoring-location/01161280.

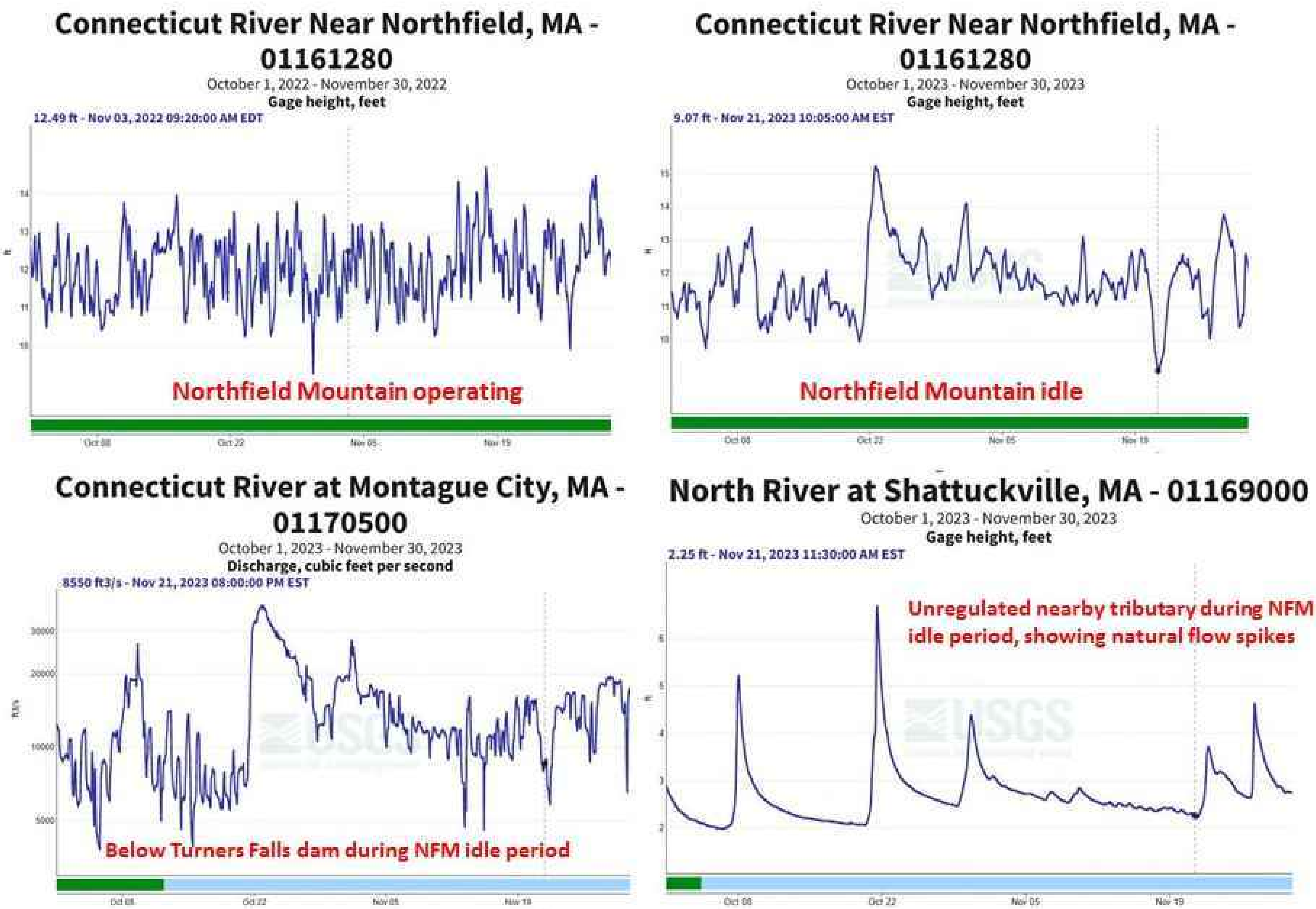
complaint. FirstLight wrote in a response to FERC on June 23, 2021 that the TFI levels reached a low of 177.5 feet as measured at the dam, which was within the range allowed in the license.

Figure 4. Upper left to right Connecticut River hydrograph in the TFI for the period 2020 and 2021. Lower left to right Connecticut River hydrograph in the TFI for the period 2022 and 2023. Note the scales on the y-axes are not the same, due to annual variation in flow levels. Graphs represent gage height in feet as measured at the USGS Gage at Northfield, MA near the Route 10 bridge.



As mentioned previously, Figure 5.1.3.1-6 in Volume III of Study 3.1.2 showed modeled 0.8 to 1.2 foot fluctuations at Transect 5CR at Bennett Meadow when Northfield Mountain was idle. Between sometime in September and December 27, 2023, Northfield Mountain underwent maintenance and was not operating. This provided an opportunity to compare actual USGS gage levels without Northfield project operations near the Route 10 bridge. The upper part of the figure below shows gage levels at the Northfield gage for October 1-November 30 in 2022 (Northfield operating) vs. 2023 (Northfield idle). The lower part of the figures show gage readings for the Connecticut River at Montague City and the North River for October 1 to November 30, 2023, to provide comparison of river manipulations and high flow events (2023 was a wet year). It is striking how steeply the river levels are manipulated when Northfield Mountain is operating.

Figure 5. Upper left: Connecticut River hydrograph in the TFI for the period October 1-November 30, 2022, when Northfield Mountain Pumped Storage Project was operating, showing a daily fluctuation between approximately 10.5 to 13.5 ft. Compare that to Upper right: Same location for the same period of time in 2023, when Northfield Mountain was not operating due to maintenance, and when not flowing high due to rain, fluctuated less. Bottom left shows the 2023 time period at Montague City station, below the Turners Falls Dam. Bottom right shows the 2023 time period at the North River in Colrain, MA. The North River is an unregulated tributary of the Deerfield River that flows from southern VT to Shelburne, MA and experiences similar weather patterns to Northfield.



Historic usage patterns are no longer in place

FirstLight is requesting expanded use of the upper reservoir (FFP Article B100), along with the same 9-ft elevation range in the lower reservoir (FFP Article A190) as is allowed in the current license (176.0 feet to 185.0 feet, as measured at the Turners Falls Dam). FirstLight's 2024 Supplemental BSTEM Report uses modeled future conditions from 2000-2014 data. Past operations do not predict future operations in this rapidly changing landscape of electric generation and distribution. And while operations may have been predictable back in the early 70's and before 401 Water Quality Certificates were even required, the proposed license articles do not provide adequate protection against an *increased* impact from project operations, nor do they reduce present impacts.

When Northfield Mountain first went into operation in the early 1970's, the electric industry was regulated, and pumped storage took advantage of the surplus power available at low prices in the middle of the night when nuclear power plants were generating. The daily and weekly operational patterns were relatively predictable, as described on page III-8 of the Northrop, Devine, and Tarbell 1991 Riverbank Management Plan:

> "The basic operating principle of the Project is to provide electricity to the public during periods of peak electrical use. The Project operation consists of pumping water from the Turners Falls pool to the upper reservoir during periods of low electrical demand, then releasing this water for power generation back to the lower reservoir during peak demand periods. During hours of low, off-peak power use, the pumping facility moves water from the lower reservoir to the upper reservoir. In the case of the Northfield facility, this is usually between the hours of 12:00 am and 6:00 am. At the beginning of each work day, when the regional consumption of energy increases, water is released from the upper reservoir through the underground penstock to the pump/turbines which generate the electricity required to meet the energy demands of the public… The Northfield facility is operated on a weekly cycle under the premise that the upper reservoir will be at full capacity on Monday mornings."

Electric markets in Massachusetts were restructured in the mid 1990's, and Northfield Mountain's original owner was required to separate energy generation from energy transmission, later selling off its generation facilities. During the 1980's to 2000's, there was more and more deregulation of electric utility corporate structures.[15] Northfield Mountain project and the Turners Falls Dam projects were sold in 2006, 2008, and 2016. In 2019, each FirstLight project was split into separate LLCs, with several levels of LLCs between the project and the owner Public Sector Pension (PSP) Investment Board. After 2006 and since then, anecdotally, residents on the river spoke of each new corporate owner "running the river harder," which could be interpreted as changing the river levels in some noticeably different way.

FirstLight's application materials did not contain historic information showing typical river elevations, or daily elevation ranges, prior to the study period of 2000-2014. FRCOG was able to find a reference for elevations at the Northfield Mountain tailrace indicating that the river elevation at the tailrace was kept 6 inches higher during the relicensing studies than prior to 1991, and elevations experienced more frequent low levels than in 1991. See Table 2 following.

[15] Eve Vogel, 2021. Legacies of Electric Restructuring for A New Electric Transition: Neoliberal Paths for Canadian Hydropower. Published in Northeastern Geographer. See https://works.bepress.com/eve_vogel/24/

Table 2. Summary of elevation duration curves at the Northfield Mountain Tailrace for two different time periods

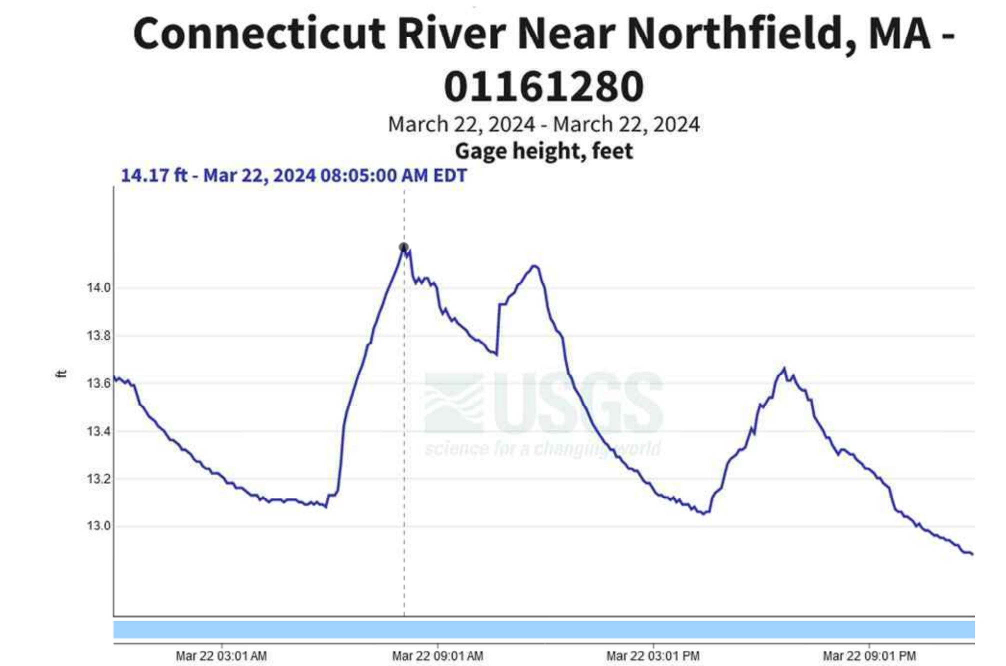
Measurement	Location of Measurement	Reference
Annual Elevation Duration Curve at 50% = 183.5 ft. Statistically, the river elevation never went below 181 ft.	Northfield Mountain Tailrace	1991 Riverbank Management Plan produced by Northrop, Devine and Tarbell. Figure III-6.
Annual Elevation Duration Curve at 50% = 183.0 ft. Graph shows river levels below 181 ft approximately 10% of the time.	Northfield Mountain Tailrace	2020 AFLA Exhibit B, Figure 2.5-1 for the time period 2000-2010.

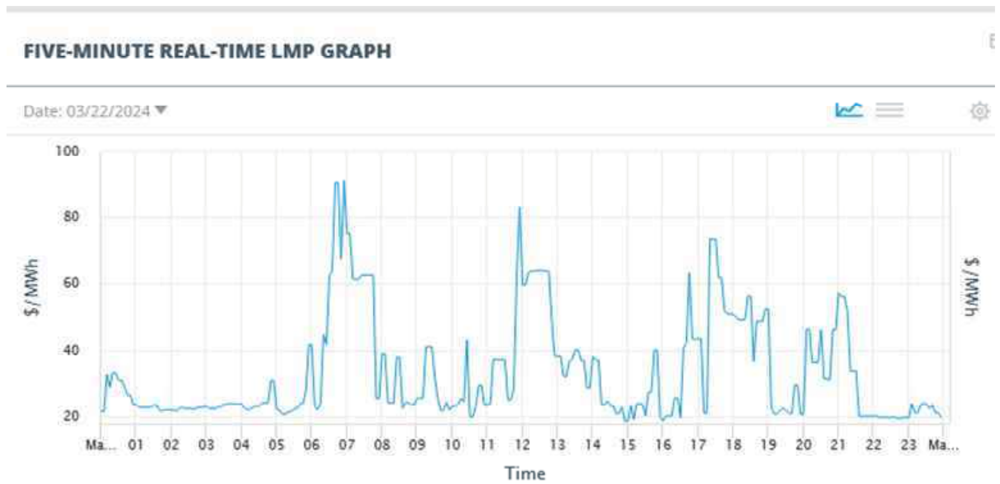
The historical daily and weekly operation pattern described above from 1991 has changed. It probably has changed some even *since* the relicensing studies took place, as more and more renewable energy has been added into the regional energy grid over the last nine years. Northfield Mountain Pumped Storage Project today operates according to price fluctuations, and low energy prices are not always lowest in the middle of the night. For example, conditions on March 22, 2024 show how the old patterns are no longer in place.

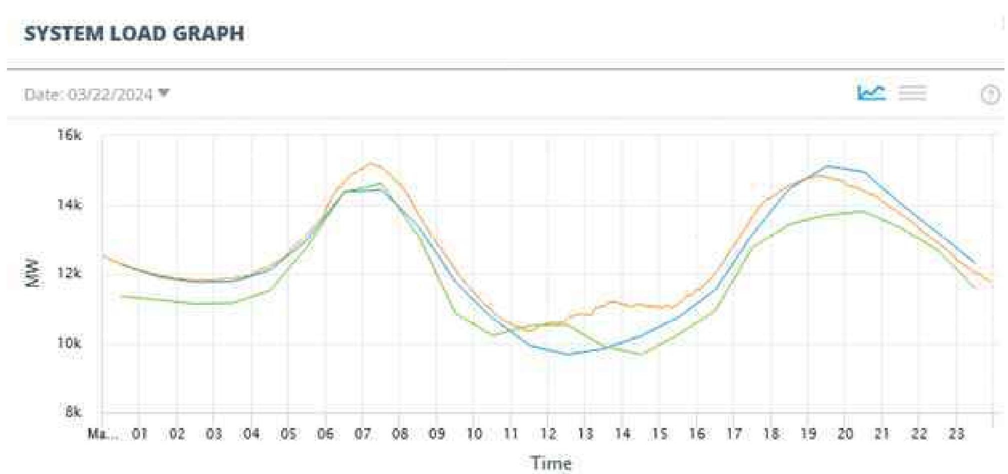
As shown in the figure below, the stage readings for the USGS gage located on the Connecticut River in Northfield MA near the Route 10 bridge shows that Northfield Mountain may have been pumping four times and generating three times during the 24-hour period of March 22. After generating for a few hours in the morning, pumping starting at 8 AM (not the middle of the night). There was a brief time of generation that morning, before pumping again until the late afternoon. Generation resumed in the evening, when solar power generation declined. The ISO-New England real-time price fluctuations for that day hint at the reason for the operational pattern that day: energy prices increased at about 7 AM, then dropped during the late morning, increased again at noon, and dropped in the afternoon. The ISO-New England system load graph (available on the ISO-NE website at https://www.iso-ne.com/) for that day is shown below that for additional information. Although the example shown below shows the river level varying within only one foot of water surface elevation (elevation changes are more severe during peak heating and cooling seasons), it's illustrative of a changing pattern of pumping and generating that tracks hourly energy pricing. The old pattern described in 1991 and quoted earlier in this letter is no longer in effect.

Figure 6. Top figure shows the USGS gage readings at the Route 10 Bridge in Northfield MA (within the TFI) for March 22, 2024. Middle graph shows the $/MWH pricing from ISO-New England's website, and the bottom graph shows the system load graph for power generation from ISO-New England's website.

FRCOG Comments and Recommendations
May 22, 2024







With so much change occurring in the transition to renewable energy generation, along with other financial incentives at the state, regional grid, and federal levels over the life of the next license, there is no way to accurately predict how Northfield Mountain will be run between 2025 and 2075, or what the project's profit margin will be. As a result, given the relationship between Project flow fluctuations and erosion, it is increasing difficult to accurately predict specific impacts on riverbank erosion.

Given the variability over the next 10-50 years, it seems clear that the license terms put in place prior to the Clean Water Act in 1968 were not protective of water quality then, and are not going to be sufficiently protective now. Continuing to allow a 9-foot impoundment fluctuation range, as measured at the Turners Falls Dam, with no other limits, fails to protect the riverbanks, archaeological resources, riparian habitat, infrastructure, and water quality.

FirstLight's Streambank Erosion Proposal is Grossly Inadequate

On March 22, 2024, FirstLight submitted a "FirstLight Streambank Erosion Proposal for the Turners Falls Impoundment." FirstLight has used the BSTEM modeling results as being predictive of future causes of erosion and proposes to monitor shoreline erosion for the TFI reaches in Massachusetts only where the 2024 BSTEM modeling showed that proposed project operations are a contributing cause of erosion. FirstLight has eliminated the reach in Vermont and New Hampshire that showed project operations as a contributing cause. The proposed monitoring is to take place five times over 50 years. FirstLight proposes to complete stabilization or repair projects only in these areas.

FRCOG has already outlined our disagreement with the BSTEM modeling, and we have the following comments on FirstLight's Erosion Proposal:

1. FirstLight says it will establish Conservation Easements along the TFI riparian corridor on FirstLight-owned land. FRCOG was a signatory to the Recreation Settlement Agreement and we support this provision. Since it is already in the Settlement Agreement as a recreation provision, it does not belong here as an erosion "proposal." Further, the relationship of a Conservation Easement to Protection, Mitigation and Enhancement measures for erosion is not clear, especially if FirstLight will be allowed to continue eroding the banks.

2. FirstLight proposes to coordinate with the MA Department of Conservation and Recreation (MassDCR) to establish a boat wake restriction from the Turners Falls Dam upstream approximately two miles where the TFI narrows. We assume this means the location of the French King Bridge (Route 2), but this is not specified. A boat wake restriction could be implemented any time, and may require a public hearing by MassDCR and the Environmental Police to garner public comments and for the agencies to weigh how enforceable this restriction. It is unclear who will pay for the staff, equipment, and enforcement of the proposed boat wake restriction. The outcome of this proposal is not within FirstLight's control. Additionally, **motor boating must be considered a secondary project effect that impacts the entire impoundment**, because motor boating, and boats of the size that are popular in the TFI,

would not be possible on this river if the dam was not in place or if the elevation of the dam had not been raised 5.9 ft. to accommodate Northfield Mountain's operations.

3. FirstLight proposes a shoreline erosion monitoring program for TFI reaches in Massachusetts where BSTEM modeling showed Project operations are a contributing cause of erosion. First, for the reasons described above, BSTEM modeling should not be used as a predictive tool to allow FirstLight to avoid responsibility for the rest of the TFI shoreline for the next 50 years. Second, the shoreline extends into NH and VT. Shoreline surveys every 10 years is not often enough to understand when changes are occurring. The existing 1999 Erosion Control Plan required shoreline surveys every five years, and this should continue to be the frequency for future shoreline surveys.

4. The proposal commits FirstLight to stabilization and repair within 5 years of the shoreline survey reports, and the stabilization measures must be approved by MassDEP. FirstLight proposes no role for CRSEC. Making repairs only in this limited area, only after the reports come out every 10 years, is an inadequate level of stewardship for a property owner in charge of maintaining shoreline for so much of the TFI. As noted below, the license should require surveys every five years and CRSEC should be a participant in the process of determining response measures.

FRCOG license recommendations are included later in this comment letter.

Summary of Erosion Comments

Northfield Mountain has been operating for the last 52 years, and despite its importance in providing power at peak demand periods using long-lasting turbine technology, the impacts on the Connecticut River and its banks have been large. The river's banks have drastically changed during that time period, aquatic habitat has degraded, and Barton Cove has filled with sediment. The Northfield Mountain Project proposed operations would expand the facility's operational flexibility and allow FirstLight to move larger quantities of water into and out of the Connecticut River during pumping and generation cycles, resulting in more riverbank exposed to destabilizing wetting and drying cycles.

No modeling can adequately capture all of the nuances of what is going on in this large and highly manipulated river system. Study 3.1.2 did not adequately capture the interplay between all causes of erosion in the TFI. It mainly identified what we already knew, that erosion happens during high flow events. Summaries of Pumped Storage Hydropower, like the U.S. Department of Energy's 2020 "A Comparison of the Environmental Effects of Open-Loop and Closed-Loop Pumped Storage Hydropower" recognizes the higher relative impacts of open-loop facilities compared to closed-loop facilities on environmental qualities like erosion.[16] It is illogical to think that Northfield Mountain, an open-loop facility built along a river with fine-grained, erodible soils, is free from the significant impacts of other open-loop pumped storage facilities.

[16] https://www.energy.gov/sites/prod/files/2020/04/f73/comparison-of-environmental-effects-open-loop-closed-loop-psh-1.pdf

FRCOG disputes FirstLight's use of BSTEM modeling as being fully capable of accurately teasing out causation in a complex river system like this and we dispute its use as a predictive tool. Questionable model outputs and applications cannot mask the rational (and scientific) notion that manipulating and drastically fluctuating river levels every day, to the point that the River's flow is reversed, is a significant cause of, and increase in, erosion.

Reducing the amount of river level fluctuation would reduce erosion impacts. Page v of the 1979 Army Corps report recognized this relationship: "… the success of all non-structural measures depends on the lower bank stability. That is, by controlling boat waves and wind waves, **by limiting pool fluctuations** and by encouraging growth of vegetation on the upper banks, the **upper bank erosion problems can be significantly reduced**. However, during periods of flooding the lower banks may yield to the attack of the tractive force exerted on the banks by the flowing water. If this occurs, the upper bank will be subject to erosion." (emphasis ours)

There is much more uncertainly about future project operations than when the project first began, and there is ample justification for limiting impoundment levels more in the future license because it is known that rising and falling impoundment levels impact erosion, and it seems likely that future project operations could mean wider and more frequent fluctuations. FERC should continue to hold the licensee responsible for addressing some of the erosion and being a responsible steward of the Connecticut River. **It is not necessary, nor scientifically feasible or defensible, to precisely determine the percentage of responsibility: Northfield Mountain Pumped Storage Project has had a large impact on the Connecticut River and those impacts should be minimized and mitigated**.

Erosion Recommendations

FRCOG's recommendations for terms of the new license are based on the following values:

- The future license conditions should be set to reduce project impacts. Reducing river level fluctuations will reduce project impacts.
- FirstLight should provide good stewardship of project lands along the Connecticut River, promoting a diverse vegetative riparian buffer.
- FirstLight should conduct and make public more and better monitoring of project operations and river conditions.

To achieve this, FRCOG expects FERC and MassDEP to develop a set of conditions that establish the following requirements.

1. Target TFI elevation and typical operating range

Together with the full operating range of 176-185 ft msl as measured at the dam, there should be a management goal for the Turners Falls Impoundment similar to that in the Great River Hydro agreement, which is "creating more stable impoundment water surface elevations." Great River Hydro's agreement #9 limits a fluctuation range per project (no more than a 1.5 ft) and #21 sets a target elevation and target 1.0-ft water surface elevation bandwidth. Because Northfield Mountain is a pumped storage project, the bandwidth would need to be wider.

A target elevation and target water surface elevation bandwidth should be established for the location at the Turners Falls Dam where the current license limit is measured, as well as at a new location at the USGS Gage at the Route 10 bridge in Northfield. The target elevation should be the same as what has been typical in the past, and the target bandwidth should be no more, ideally less, than what was typical between 2000 and 2014, to ensure that operations do not instigate a new increased round of erosion. "Target bandwidth" would mean that the river elevation as measured at the dam would stay within the bandwidth a high percentage of the time (such as 85%), and at the USGS gage would stay within the bandwidth a different percentage of time, assuming it's harder to control river fluctuations coming from upstream (70% of the time, for example).

FRCOG is not suggesting specific numbers in this comment letter, as we are hindered by a lack of information about historic, existing, and predicted future TFI fluctuations. Page 3-24 of the Pre-Application Document (PAD) cited a "target" TFI elevation of 180.3[17] and page 3-25 cites typical elevation of 180.5 feet msl.[18] Study Report 3.3.9 stated on page iii that the median elevation as measured at the dam for 2000 to 2010 was 181.3 msl. In the AFLA Exhibit E, Figure 3.3.2.2.1-8 showed an Annual Maximum Daily Change Histogram at the Turners Falls Dam for "baseline" and "FL AFLA Proposal." However, the graph does not show what years the baseline was based on. Additionally, the number of days shown on the graph far exceed the number of days in a year, and with the title being "annual," it is not clear how to interpret this graph. Nevertheless, it shows the most frequent maximum daily change is in the 1.2 to 1.6 foot range. License conditions should ensure that the frequency of daily water surface elevation fluctuations be reduced and not skew higher.

The following language could be refined with access to more information:

> The Turners Falls Impoundment (TFI) will be operated with a target average elevation (50% exceedance) of [example: 181 ft.] as measured at the dam. The TFI elevation will be maintained between [example: 180 and 182 feet] more than [example: 50%] of the hours each year.
>
> Additionally TFI elevations will be above [example: 179 ft. at least 95%] of the hours each year and 100% of daylight hours between Memorial Day weekend and October 31. TFI elevations will be below [example: 184 ft. at least 95%] of the time.

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[17] "Under most common operating scenarios, FirstLight targets an impoundment elevation of 181.3 msl at the dam and 173.5 feet msl in the power canal (as measured in the Cabot forebay)."

[18] "Under moderate flow conditions, i.e., naturally routed flows are between 1,433 cfs and 13,728 cfs (river flow exceeds 13,728 cfs approximately 34% of the time), the Turners Falls Impoundment elevation is typically managed around elevation 180.5 feet msl, but fluctuates under these inflow conditions due to Cabot peaking operations and the pumping/generating cycle at the Northfield Mountain Project."

A similar requirement would be set for the USGS gage at the Route 10 bridge in Northfield, using data available since 2018.

2. Monitoring

A. Project Operation, Monitoring, and Reporting Plan

FRCOG recommends that the language about the Project Operation, Monitoring, and Reporting Plan as contemplated in A200 of the FFP Settlement Agreement be modified to include the following TFI statistics in the annual compliance reports until the end of the license: for each month of the year, the average TFI elevation as measured at the Turners Falls Dam, the average daily elevation change (maximum elevation minus the minimum daily elevation, averaged over the month), the highest elevation of the month, and the lowest elevation of the month. This report will also demonstrate compliance with any TFI target ranges that are developed.

B. Transect Surveys

FirstLight is currently required to conduct annual transect surveys. FRCOG recommends that this requirement continue into the next license. Based on our experience reviewing previous cross-sectional charts provided by FirstLight, we have the following recommendations. Cross-sectional surveys will be conducted by a Licensed Surveyor at the 22 historical transect locations and 9 new locations established for relicensing studies 3.1.1 and 3.1.2 locations. Annual reports will be submitted to FERC, showing a cross-sectional view with consistent vertical and horizontal scales that do not obscure the horizontal bank changes. The previous 10 years' worth of cross-section survey lines should be provided on each graph in a line color or pattern that is easy to see from one survey-year to another. The maximum and minimum water surface elevations (for flows less than 18,000 cfs) for each transect location should be provided on each cross-section chart. Right and left bank (looking downstream) should be clearly identified. Each transect chart in the report shall have the licensed surveyor's business name on the chart. The raw data from the transect surveys shall be made available if requested by the public.

C. Full River Reconnaissance

The Full River Reconnaissance should continue to be required. The methods of the FRR should be determined by an independent consultant hired and managed by an outside agency that is not the licensee. Methods that are less subjective and more objective, such as LiDAR surveys, should be employed (methodology changes made during previous FRR efforts led to various problems with comparing results). Ideally, a LiDAR survey should be done once per year, with the TFI level held at the same level each survey – the elevation should be relatively low so that the banks can be exposed and surveyed. The methodology of the FRR should be written and viewable by the public, and there should be a Quality Assurance Project Plan reviewed and approved by MassDEP and the U.S. Environmental Protection Agency. The first FRR should be completed in the first year of the new license to establish baseline conditions for the new license.

D. Contribution to USGS gage at Route 10 bridge

FirstLight should fund annual operational costs to continue the USGS gage (gage level data only) near the Route 10 bridge, separate from other funding. This is gage 01161280. The estimated cost to operate is $25,000 in 2020 dollars based on personal contact with MassDEP. The funding contribution should continue for the duration of the license and data will be publicly available in real-time via the USGS. This is consistent with Standard License Article 8 under FERC's L-3: Terms and Conditions of License for Constructed Major Projects on Navigable Waters of the United States.

3. License Articles

Articles 19 and 20 from the existing Turners Falls and Northfield Mountain Project licenses, respectively, should continue to be in the new FERC licenses: "The Licensee shall be responsible for and shall minimize soil erosion and siltation on lands adjacent to the stream resulting from construction and operation of the project."

4. Maintenance of Previously Repaired Sites

FirstLight should continue to be responsible for maintenance and repair of all bank restoration projects started and/or completed under the prior/currently existing license.

5. Shoreline Management and Erosion Control

An update to the 1999 Erosion Control Plan is needed. The Plan should be modified to indicate a more holistic approach to managing the riverbank and riparian area, and could be called a Shoreline Erosion Control Management Plan. FRCOG would not be opposed if a single plan was developed for all five projects Connecticut River projects undergoing relicensing, which would potentially recognize cumulative effects of the projects, setting wider management goals, and an agreement for many parties to work collaboratively. However, the MA projects will be geared towards restoring conditions to meet MA State Surface Water Quality Standards. The new plan should have the following elements:

A. Interested party involvement. It took more than 20 years for the formation and recognition of the Connecticut River Streambank Erosion Committee (CRSEC), which was then recognized as an ad-hoc group by FERC. The licensee should continue to meet and consult with CRSEC into the next license.

B. Full River Reconnaissance. The licensee should continue to be responsible for conducting a reconnaissance survey of bank erosion at regular intervals throughout the license term. See previous recommendation details in #2C.

C. Mitigation Projects. FirstLight will work with the CRSEC, town Historical Commissions, and indigenous groups to commit to riverbank and riparian projects to reduce and mitigate project effects. Particular attention must be given to preserving farmland, infrastructure, and historical and cultural artifacts.

D. Invasive Species Management. See our comments in the next section regarding FirstLight's responsibilities as steward of riparian lands. These recommendations are very much tied to erosion concerns.

Invasive Species Plan Comments

The Franklin County towns in the project area have all completed local Hazard Mitigation Plans. These plans follow the format of the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan by identifying vulnerabilities from invasive species as one of 14 hazard types to consider.[19] The Massachusetts state and local hazard mitigation plans recognize that invasive species are a threat to a climate-resilient landscape. Moreover, a recent meta-analysis of data from thousands of observations showed that *biodiversity loss* and *introduced species* are both associated with *increases in infectious disease* (along with chemical pollution and climate change).[20]

FirstLight is owner and steward of significant acreage of land in the project area. The Recreation Management Plan (RMP) submitted as part of the Recreation Settlement Agreement (Sections 4.2.1 and 4.3.1) provide that FirstLight will place 761.4 acres (of the 4,599 acres of lands it owns within the Project boundaries) into conservation restrictions. Invasive species management is a critical part of conservation stewardship. Furthermore, the impoundment and power canal create artificial lake-like areas that provide the opportunity for aquatic invasive plant species to become established.

On March 22, 2024, FirstLight filed a revised set of Invasive Plant Species Management Plans ("Invasive Species Plans") for each project dated March 2024. The 2024 Invasive Plans supersede the Plans included as part of the 2020 AFLA, which had no public comment period. The Invasive Plans list the 5 invasive aquatic plant species in the Turners Falls impoundment and 21 upland invasive plant species found in the study area during the 2014 and 2015 field surveys. The Invasive Plans have the following multiple shortcomings.

1. There is no commitment to conduct additional upland plant surveys at any time during the life of the new license.

2. There is no commitment to monitor or track invasive aquatic plant species surveys in the Turners Falls canal.

3. FirstLight commits to invasive aquatic species control measures in the Turners Falls Impoundment (TFI) and bypass reach (not the canal), but only "*if the U.S. Fish and Wildlife Service (USFWS) and/or the Massachusetts Natural Heritage and Endangered Species Program (NHESP) demonstrate that the invasive species are 'significantly affecting fish and wildlife populations.'*" Such a demonstration would require extensive field studies and would be difficult for either agency to establish. Given that Barton Cove is already listed in the

[19] https://www.mass.gov/doc/shmcap-executive-summary/download

[20] Mahon, M.B., et al. 2024. A meta-analysis in global change drivers and the risk of infectious disease. *Nature*. Published May 8, 2024.

Massachusetts Integrated List of Waters as being water quality impaired due to the presence of aquatic invasive species, this limitation on the obligation of FirstLight to control invasive species is not appropriate.

4. There is no commitment to manage invasive plants in upland areas other than preventing the spread of invasive plants during daily operations, routine maintenance, construction, and major maintenance. The Plan does not recognize the impacts of a no-control approach to invasives on native species diversity, riparian habitat, riverbank stability, aesthetics, or recreation. According to Table 4.1-2 in Study 3.6.5, the project boundaries encompass 7,246 acres, with 2,647 of those acres being open water. This means FL has ownership or flowage rights of approximately 4,599 acres of land in the project areas. As stewards of this land, there should be more of a commitment to promoting a healthy and diverse riparian habitat. Oriental bittersweet, for example, is impacting mature trees along the river's edge, and if trees are toppled because of being overtaken by vines, this removes valuable vegetation and roots along the banks of the river. Allowing the spread of bittersweet with no control will make the banks more vulnerable to erosion and contribute to bank instability.

5. None of the multiple state agencies and consortiums in Massachusetts that are involved with the identification, tracking, and removal of aquatic and upland invasive plants, are mentioned in the Invasive Species Plans. These agencies include but are not limited to the Massachusetts Department of Agriculture Resources (DAR) and the Department of Conservation and Recreation (DCR). The Department of Environmental Protection (DEP) also plays a role because aquatic plants are the reason for an impairment listing for Barton Cove.

Invasive Species Plan Recommendations

FRCOG recommends that FirstLight be required to prepare a revised Invasive Plant Species Management Plan that spans both projects and involves a public comment period. A draft should be distributed to all relevant federal and state agencies, including consortiums that are involved in invasive plant identification and removal, as well as parties intervening in the relicensing effort.

The format of a revised Plan should be closer to that developed by another land conservation organization, The Trustees of Reservations, or from Army Corps of Engineers guidance.[21, 22] The revised plan should commit FirstLight to early detection and response, in partnership with volunteers, agencies, and nonprofits. Management guidelines and a guide for prioritization should be developed. Invasive species control has been part of other Invasive Species Management Plans for other FERC-licensed projects.

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[21] https://thetrustees.org/wp-content/uploads/2020/07/Invasive-Plant-Management-GUIDELINES-AND-BEST-PRACTICES.pdf
[22] https://www.nae.usace.army.mil/portals/74/docs/regulatory/invasivespecies/iscpguidance.pdf

FirstLight should commit to the following, at a minimum:

1. Early detection and removal of new invasive species in the project area, both aquatic and upland, in coordination with relevant agencies and organizations. This commitment may include species beyond plants.
2. Continued participation, which includes staff assistance and expenses, in managing and removing aquatic invasive plants in the entire project area.
3. A priority set of upland invasive plants should be monitored in the project area at regular intervals throughout the term of the license (once every 5 or so years).
4. FirstLight should commit to controlling and reducing the further increase of established priority invasive plants in priority areas that are identified in coordination with interested parties.
5. FirstLight should coordinate with agencies on any non-plant invasive species, when they become an active threat.
6. FirstLight should host a meeting with agencies and other interested parties once every 5 years, after the results of the surveys are completed. These meetings should include a summary of the current state of invasive species, management techniques, and input on the upcoming efforts of the next five years in coordination with parties attending. Such meetings will allow the licensee and interested parties to adjust to any unanticipated issues over the term of the license.

Traditional Cultural Properties (TCP) and Historical Properties Management Plan (HPMP) Comments

FERC required FirstLight to conduct a Traditional Cultural Property (TCP) study (Relicensing Study 3.7.3). Under Section 106 of the National Historic Preservation Act, Section 106, FirstLight is required to have consulted and actively engaged with cultural/indigenous groups actively involved in the Project area. For various reasons, active engagement did not happen, and the resulting TCP Study Report was simply a literature survey. Without a meaningful engagement between FirstLight and indigenous groups, both the TCP and the Historical Properties Management Plan are incomplete. Additionally, FRCOG recognizes that we participated in negotiating the recreation settlement agreement with FirstLight without having the benefit of understanding recreational impacts to culturally sensitive locations.

FirstLight prepared two HPMPs that were filed with FERC as non-public documents. FRCOG does not have a copy of them, and we did not review them. The TCP and HPMPs are outside of FRCOG's areas of expertise, but are important to our Towns, to tribes, and to the area's indigenous heritage and culture. The non-public status of the HPMP has presented difficulties for town Historical Commissions to access the HPMP and then discuss in a public meeting, since they are required to follow the Open Meeting Law in Massachusetts. We support comments submitted by town Historical Commissions, as well as the Nolumbeka Project, the Elnu Abenaki, the Nipmucs, and any of the federally recognized tribes that may provide comments.

Traditional Cultural Properties (TCP) and Historical Properties Management Plan (HPMP) Recommendations

FRCOG recommends that FERC meet with FirstLight and indigenous groups to identify a path forward to completing a TCP. Once a revised TCP has been finalized, the HPMPs should be revised with input from Town historical commissions and indigenous groups. A public, redacted version of the revised draft HPMPs should be submitted to FERC with a public comment period.

Nonproject Use of Project Lands Comments

Section 3.3.7.1.5 in the 2020 AFLA addressed Non-Project Uses of Project Lands. This section stated that FirstLight has an established Permit Program through which it administers non-project uses of lands within the Project boundaries including lands it owns in fee, or in which it has an interest. This includes private recreational clubs, private seasonal or year-round dwellings or "camps," water withdrawals, and boat docks. It cited a non-public document attributed to FirstLight employee John Howard that was dated 2008 as spelling out the details of this Permit Program. Page E-547 provides a list of common elements in the license agreements for these uses.

FirstLight requested authorization from FERC on October 10, 2008 to issue licenses for residential and private structures at 24 sites within the project boundaries. FERC issued an Order Modifying and Approving these Non-Project Use of Project Lands on October 28, 2009. In its Order, FERC required FirstLight to provide a report including baseline data and an evaluation of erosion and runoff potential at each site. This report was filed with FERC on December 21, 2010. FirstLight provided federal and state agencies with a copy of this report (no comments were received), but the CRSEC was not consulted despite erosion being one of the things evaluated at each site. FERC issued an Order Approving of the report on May 13, 2013.[23]

With regard to the evaluation of erosion and runoff at each site, it is unclear whether there has been follow up observation of these properties since 2010. It is also unclear whether FirstLight proposes any new activity into the next license. Were all of the actions that FirstLight committed to completed? FirstLight stated in its 2010 report that it will "formalize" a 10-foot wide vegetated buffer at the shoreline edge. What is the status of this formalization, and is this requirement actively monitored? Does FirstLight use that same guideline on other project properties it owns? How was the buffer width of 10 feet chosen, and what was it based on? FRCOG wishes to understand as part of our concern for erosion and health of riparian habitat.

FRCOG has reviewed the financial information submitted in the AFLA Exhibit D and we do not know if the licensing fees FirstLight charges were included in the revenues that were reported Exhibit D.

[23] FERC Document Accession #: 20130513-3024.

Nonproject Use of Project Lands Recommendations

FRCOG recommends that FERC require FirstLight to draft a Land Use Management Plan (with a review and solicitation of public comments) that includes the information in FirstLight's 2008 (currently non-public) permit program document for nonproject use of project lands, and a plan to regularly evaluate shoreline buffer maintenance and erosion on project lands and monitor other issues as they arise. This will help the public and affected parties understand FirstLight's Permit Program for the next several decades, and how it relates to any other local or state permitting programs.

Conclusion

Thank you for this opportunity to review and provide comments on this Notice. If you have any questions, please do not hesitate to contact myself or Kimberly Noake MacPhee (kmacphee@frcog.org).

Sincerely,

Linda Dunlavy
Executive Director

ATTACHMENTS

Attachment A: University of Illinois at Urbana-Champaign review of Study Plan for Study 3.1.2 dated November 13, 2014

Attachment B: Detailed Study Site 7L and 7R from Study 3.1.2 Appendices D (field drawing and observation) and E (cross-section plots)

Attachment C: Evan Dethier review of Erosion in the Turners Falls Impoundment

CERTIFICATE OF SERVICE

I hereby certify that I have caused the foregoing document to be served via the Commission's electronic service system upon each person designated on the official service lists compiled by the Secretary in these proceedings this 22nd day of May, 2024.

S/ Kimberly Noake MacPhee
Land Use and Natural Resources Program Manager

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November 13, 2014

Kimberly Noake MacPhee
Land Use & Natural Resources Planning Program Manager
Franklin Regional Council of Governments
12 Olive Street, Suite 2
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Dear Ms. Noake MacPhee:

At your request, we have performed a review of various materials prepared as part of the FERC relicensing of the Northfield Mountain / Turners Falls operations on the Connecticut River. In particular, our review has focused on the analyses pertaining to river hydraulics and bank retreat included in the following documents:

- Revised Study Plan (FirstLight Power Resources, 2013a), Sections 3.1.2 and Sections 3.2.2.
- Initial Study Report Summary for Section 3.1.2 (Choi, 2014a)
- Initial Study Report Summary for Section 3.2.2 (Gomez and Sullivan Engineers, 2014)

For additional background information regarding the river characteristics, we also reviewed the following project documents that were provided:

- Fluvial Geomorphology Study of the Turners Falls Pool on the Connecticut River Between Turners Falls, MA and Vernon, VT (Field Geological Services, 2007)
- Hydraulic Modeling Assessment Of The Turner Falls Impoundment (FirstLight Power Resources, 2013b)
- 2013 Full River Reconnaissance report (Choi, 2014b)

Our review has primarily focused on the models (BSTEM, HEC-RAS, RIVER2D) and the data collection methods used by the project consultants. We need to preface our analysis by clearly stating that we have not performed any onsite analysis of the Connecticut River; we also have not performed a thorough review of the abundant analyses that have been completed dating back to the 1970s associated with bank retreat for this reach of the river. Our site-specific knowledge pertaining to the river is derived from a review of the above-referenced documents.

We deem the following physical river characteristics particularly important to our assessment of the bank retreat issue in the Turner Falls impoundment:

- The river banks in the reaches that have experienced the most pronounced bank retreat are alluvial deposits of predominantly sand and silt; stratigraphic analysis reveals inter-bedded layers of sand and silt (Field Geological Services, 2007; p.18, p.25, p.66)
- Narrow "beach" landforms are common - these are described as mild transverse slopes extending riverward from the toe of the steep portion of the river bank and extending out a short distance from the bank before dropping off more steeply into the deeper part of the channel (Field Geological Services, 2007; p.17, p. 43)

- Bank retreat is occurring in locations that are apparently independent of high boundary shear stresses (Field Geological Services, 2007; p.20, p. 25)

The majority of our analysis will discuss the proposed modeling of bank retreat per Section 3.1.2 of the Revised Study Plan (RSP). The suitability of any model is dependent on the objectives of the modeling effort; the most sophisticated model is not necessarily the most appropriate for all purposes. In this case, the objective has been defined as evaluating and identifying the causes of erosion in the impoundment and determining to what extent they are related to project operations; the modeling is one part of an effort to satisfy that objective. We recognize that this is an extremely challenging task, due to the inter-related nature of the various causes of bank retreat. The BSTEM model has been proposed to quantify the effect of two of the identified causative factors in bank retreat: fluctuating water levels and fluvial boundary shear stresses. BSTEM was designed to couple the processes of fluvial erosion and mass failure that are both integral to bank erosion analyses; to our knowledge, that model (along with its predecessor, the ARS Bank Stability Model) was the first model available for engineering practice outside an academic research setting to couple those processes using physics-based formulations. The model was developed at the USDA National Sedimentation Laboratory; for the last several decades that group has been at the forefront of developing techniques to quantify bank erosion and develop models for practical usage. We will discuss the model's suitability and limitations with respect to the unique conditions in the Turners Falls impoundment.

The issue of fluctuating water levels, in its most basic form, is a rapid drawdown problem that has conventionally been treated by geotechnical engineers considering earthen embankments (Morgenstern, 1963; Desai, 1977; Lane and Griffiths, 2000). When the water level is drawn down, pore water remains in the embankment which maintains the weight of the soil (the gravitational force is the primary driving force behind potential failures) while the confining pressure acting on the surface of the soil mass is removed, thus reducing the factor of safety. An integral part of the problem is the knowledge of the water level in the water body and the phreatic surface (or more accurately, the pore pressure distribution) of the groundwater. The BSTEM model includes the effect of the water level difference that is of primary importance to the problem, but the water levels are specified as parameters. Therefore how the water level difference is specified in the proposed analysis is very important. Accurate treatment involves not only the magnitude of the drawdown but also the rate of drawdown, as the water table does not adjust at the same rate as the stage of the water body. An appropriate treatment would involve an unsteady state 2D groundwater model (e.g., SEEP/W) applied to a cross-section using the maximum drawdown rate over the maximum magnitude of drawdown (the boundary conditions of the groundwater model) to determine the appropriate values of the input parameters pertaining to the water levels used in BSTEM. In review of the Revised Study Plan (RSP), there is no mention of proposed groundwater modeling; mention is made that a single transect of three piezometers was established and monitored at a site and that the groundwater responded to the river water stage quickly. We would recommend that such data be used with caution in the absence of a site-specific model on which such data would serve as calibration, which could then allow the full range of potential boundary conditions to be evaluated. We would also caution that such data should not be extrapolated to all sites in the system as the stratification and hydraulic conductivities along the ~20-mile long impoundment are certainly not uniform. For example, the 2013 Full River Reconnaissance (FRR) includes geotechnical site data sheets that include sites where the bank profile is dominated by sand (USCS classification SM) and profiles dominated by silt (USCS classification ML); the hydraulic conductivities of such soils are likely to differ by an order of magnitude or more. In the absence of a groundwater model to establish the appropriate water level difference used in BSTEM, then conservative assumptions would be required regarding how fast the groundwater table responds to the river water level. For example, in the analysis of Morgenstern (1963), the pore water pressure distribution (a linear function of the groundwater level in a free-draining incompressible material) was assumed to be maintained at its pre-drawdown level throughout much of the embankment for the stability analyses. In more sophisticated analyses such as Lane and Griffiths (2000), the pore pressure distribution is solved numerically before the stability calculation proceeds. Some justification will need to be provided for conservative estimates of groundwater table levels in the absence of calibrated groundwater models. Note that in all of the cited conventional geotechnical analyses, the seepage forces are neglected; the significance of seepage forces are discussed later in this letter.

In terms of the magnitude and rates of variation in the river stage (the river stage input as a parameter in the BSTEM model), we understand that an unsteady state HEC-RAS model will be developed and calibrated. We feel that HEC-RAS is an appropriate model for this purpose. Even though impounded, the river is generally curvilinear and the flows can be reasonably approximated as 1D for the purpose of determining stage. The primary data used in HEC-RAS is the bathymetry and bank/floodplain topography. Cross-sections are spaced more closely in steep rivers and where the geometry changes significantly over short distances. The modeling proposed includes cross-sections at 500 feet longitudinal spacing sampled from longitudinal bathymetric transects. For a river with mild slopes such as the Connecticut River where the bankfull width is typically 600 to 700 feet, having cross-sections spaced at 500 feet is quite resolute for a 1D model and will characterize spatial geometry variations at an appropriate scale. Utilizing stage recorders to obtain calibration data as proposed is also appropriate. Calibration of roughness coefficients using the steady flow calculation procedure as indicated in the RSP should be performed when flow through the system is confirmed to be steady (flow input equal to flow output from the system).

Regarding other aspects of the geotechnical slope stability calculations used in BSTEM, beyond the issue of rapid drawdown, we feel it would be appropriate if the project geotechnical engineer confirmed that the factor of safety values calculated by BSTEM for planar failure are indeed less than that calculated from the analysis of rotational failure. BSTEM was designed for use on short steep slopes typical of most river banks where planar failures and cantilever failures resulting from undercutting are the dominant modes of failure. In some areas in the Turners Falls impoundment there are fairly high slopes (some reported >50 feet in height) and some of these areas have soils classified as being silt-dominated (ML classification). If the cohesiveness of these silty soils turns out to be substantial, a more deep-seated rotational failure might be the actual mode of failure as opposed to shallow planar failures. In fact, on Table 7-2 of the Initial Study Plan Summary for 3.1.2, a number of the representative and calibration sites have indicated rotational failures.

Proceeding to the issue of fluvial erosion of the bank toe used by BSTEM, we feel that the proposed use of RIVER2D for the determination of boundary shear stresses is appropriate. While a 1D model such as HEC-RAS will provide cross-sectional average values, RIVER2D will provide variation across the cross-section, including in the near-bank region, which is the preferable approach. The domain of RIVER2D modeling would preferably include the entire impoundment; however, if local domains are used for each of the calibration sites, the domain should be confirmed to be sufficiently long both upstream and downstream of the calibration sites such that the velocity field calculated at the calibration site is relatively insensitive to the specific velocity fields specified for the upstream and downstream boundaries.

Quantifying the parameters used in the fluvial entrainment routine of BSTEM has been proposed using both a submerged jet test in the field and by determining grain-size distributions which can then be used to specify the critical shear stress parameter when the soil is non-cohesive. The submerged jet test is generally considered to be the standard to quantify the parameters used in the entrainment rate formulation for bank erosion. The field methods proposed and the specific formulations used by BSTEM are the best that are currently available to quantify the fluvial entrainment of bank materials. However, the entrainment rates thus determined must be understood to still involve substantial uncertainty. Thus the issue of calibration as proposed in the study becomes important.

The issue of calibration must be treated with some caution in a study where causality is intended to be quantified (as specified in the objectives). For example, it has been observed that areas of significant bank retreat exist in areas of low boundary shear stress. One approach of calibration would be to modify the critical shear stress parameter to a very low value and modify the erodibility coefficient to a very high value in the entrainment rate formulation to achieve the magnitude of fluvial entrainment and subsequent mass failure observed in the low fluvial shear areas – thus achieving a calibrated model. However, a calibrated model does not guarantee that the physics of the model is correct; in other words, if the original values used in the model did not yield the observed bank deformation, it is also possible that other causative factors are involved that are not accounted for in the models. With this in mind, one causative factor that we feel is of high importance pertaining to the issue of bank retreat and not incorporated into the modeling is erosion associated with seepage from water continually being transported into and out of the banks associated with frequent stage changes; (note that this is a separate issue from the rapid drawdown problem described previously, but it is a related issue). The processes where the seepage forces are dominant involve the gradual sapping of soil grains from a soil stratum, potential development of soil pipes, and the associated structural weakening of the soil; the processes are discussed in limited detail in the following paragraphs. This physical factor is not accounted for in the BSTEM model - although this is not a fault of the model or the choice of model, but rather a limitation in the current state of the science. This makes the issue of assigning causality to various factors very difficult.

In geotechnical engineering practice, seepage forces are typically accounted for by ensuring that a critical hydraulic gradient is not exceeded along a flow path through the soil, which is particularly important when considering groundwater flow beneath dams or excavations below the water table (e.g., Terzaghi et al., 1996). In sophisticated models analyzing slope stability, the seepage forces may be accounted for with respect to their reduction of the effective stress and thus the frictional shear resistance along potential failure planes. However, quantifying processes associated with gradual sapping of soil grains which may eventually lead to the development of piping is still a developing field. The following statement in Terzaghi et al. (1996, p.475) is particularly pertinent to the current discussion: "*In nonhomogeneous material the locations of lines of least resistance against subsurface erosion and the hydraulic gradient required to produce a continuous channel along these lines depend on geologic details that cannot be ascertained by any practicable means.*" Advances are currently being made in this field of research as it relates to stream bank erosion, including substantial contributions by the USDA National Sedimentation Laboratory (the agency that developed the BSTEM model); but to our knowledge, quantitative models are still in the research stage and have not advanced to the level of practical engineering usage.

The current state of the science associated with bank retreat due to seepage forces is well described in a review paper by Fox and Wilson (2010). The essential aspects are that the hydraulic gradient of the groundwater is associated with a pressure force that reduces grain-to-grain friction, which can lead to entrainment of particles into the groundwater flow path. In its most extreme form, the seepage forces can exceed the weight of soil grains and cause a non-cohesive soil mass to fully liquefy. However, in cases of bank erosion, where hydraulic head gradients are generally more limited, the gradual process of grain by grain entrainment is the expected mode. Fox and Wilson (2010) use the term seepage erosion to describe this entrainment process. In its most developed condition, it can lead to development of soil pipes and cavities and collapse of overlying soil strata as described in Hagerty (1991a; 1991b); in those papers, the terms piping and sapping are used to describe the removal of soils by seepage exfiltration from a bank face. Hagerty (1991a) indicates the issue to be most prevalent in alluvial soil deposits where the natural layering favors concentration of groundwater flow in the more pervious strata; he also indicates the necessary conditions for the process to occur, which include the presence of a free exfiltration face, a source of water, and stratification of layers of different hydraulic conductivity that promotes flow concentration. Hagerty (1991a) states: "*The variations in texture and porosity among alluvial strata in a bank may not be noticeable and may appear to be slight, but even seemingly minor changes in soil texture can change hydraulic conductivity by orders of magnitude……a silty sand may be 100 times more pervious than a sandy silt, even though both soils look and feel very similar*." Fox et al. (2007) provide evidence that lateral flow can be generated in more pervious strata when the vertical component of the hydraulic conductivity between layers is less than an order of magnitude different. The hydraulic gradient, and thus the seepage force, will generally be steepest at the free exfiltration face as a groundwater level adjusts to a new surface water level; thus the tendency for particle entrainment will be greatest at the exposed face and may not necessarily be maintained deeper into the bank. The sapping of grains from a strata, particularly when the grains being removed are fine-grained and provide some cohesion to the strata, is also expected to reduce the resistance of the surface to fluvial erosion. Therefore fluvial erosion may still be eroding the toe of the bank, but the effect of stage changes on sapping grains from strata and its effect on fluvial erosion cannot currently be decoupled.

Due to the fact that the science has not yet advanced sufficiently to quantitatively model the process of seepage erosion and its effect on bank retreat, correlation to other sites where this process has been observed to be a dominant process is appropriate. The shape of the Connecticut River near-bank region described by Field Geology Services (2007) and bulleted above on p.1-2 of this letter warrants special consideration and provides an indication of the dominant processes occurring in the near-bank region. Hagerty et al. (1995) considered a gently sloping bench just below the ordinary low water level to be characteristic of rivers having controlled stage; the particular case considered was navigation pools on the Ohio River, although examples were also provided from observations elsewhere in the country. They clearly state that the process of bench formation is not fully demonstrated, but that the evidence suggests a process whereby the permanently submerged portion of the bank becomes more stable, and the above-water portion of the bank migrates at a faster rate than the below-water portion of the bank – even though both may be migrating more slowly than the pre-controlled condition. In each of the cases described by Hagerty et al. (1995), a primary cause of bank migration in the portion of the bank above the maintained low water stage was associated with the piping / sapping mechanism. A stable bench at a migrating bank is not a typical landform in an unregulated river. When a bank is eroding due to fluvial entrainment, migration of the deeper portions of the bank will generally drive the migration of the upper portion of the bank because the shear stresses generally increase with depth. Therefore, for a bench to form on or above the lower bank, at some point in time the lower portion of the bank must not be driving migration of the upper portion of the bank. This is not meant to imply that fluvial action cannot still erode the toe of the bank above the bench; rather it is simply meant to point out that the process is not typical of a migrating bank and that other processes may be involved. The presence of the undercut "notches" located near the normal water stage with the maximum extent of the cut not extending deeper below the water surface also suggests other mechanisms are likely acting in concert with fluvial erosion; note that Table 6.1 of the FRR indicates that approximately 43% of the river banks show evidence of this feature. A notch whose maximum extent is located near the normal water surface suggests the effect of both wave action and sapping associated with the steepest part of the groundwater table following a period of drawdown, and its influence in making the bank material more susceptible to fluvial erosion.

Finally, we would like to reiterate that the objectives for which the modeling is intended to satisfy (decoupling and quantifying the various causative factors) is daunting, if not impossible in a strict sense, given the current state of the science regarding the physical processes and our ability to contend with physics occurring at a variety of spatial scales and with high spatial heterogeneity. This does not imply that a modeling approach, which will always require simplifications, is without value. In general, we feel the proposed approach of using BSTEM is a sound practical approach that will provide insights into which processes are important in a relative sense. However, such findings should be strongly qualified; a finding that suggests that the fluctuating stages associated with the pumped storage operations has no impact on the bank retreat or, conversely, that it is entirely responsible for the bank retreat would not be defensible given the uncertainties involved.

Sincerely,

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Appendix A: References

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Education

National Litoral University, Argentina,	Water Resources	Dipl. Ing.	1982
University of Minnesota	Civil Engineering	M.S.	1985
University of Minnesota	Civil Engineering	Ph.D.	1989

Academic Experience

2012-present	Faculty Fellow, National Great Rivers Res. and Ed. Center, Alton, Illinois
2006-present	Professor of Geology (adjunct), Department of Geology, University of Illinois
2001-2014	Chester and Helen Siess Endowed Professor of Civil Eng., University of Illinois
2000 – present	Professor, Dept. of Civil and Environmental Eng., University of Illinois
1999 (1 month)	Visiting Assoc. Prof., Ecole Polytech. Federale de Lausanne, Switzerland
1997 (4 months)	Visiting Associate Professor, California Institute of Technology
1997 – present	Director, Ven Te Chow Hydrosystems Laboratory, University of Illinois
1996 - 2000	Associate Professor, Dept. of Civil and Env. Eng., University of Illinois
1990 - 1996	Assistant Professor, Department of Civil Eng., University of Illinois
1993 - present	Visiting Professor, School of Water Resources Eng., UNL, Santa Fe, Argentina
1993 (4 months)	Contract Professor, Istituto di Idraulica, University of Genoa, Italy
1988 - 1989	Research Fellow, St. Anthony Falls Hydraulic Lab., Univ. of Minnesota
1983 – 1987	Research Assistant, St. Anthony Falls Hydraulic Lab., Univ. of Minnesota

Honors: : ASCE Hilgard Prize (1996, 1999), Huber Research Prize (1998), H.A. Einstein (2006), Housner Award (2012), Rouse Award Lecture (2012); Borland Lecture (2009), IAHR Ippen Award ('01); National Academy of Engineering, Argentina (2005), Enrico Marchi Lecture (2012), Distinguished Member, American Society of Civil Engineers (2013), Yeh Chair (2014).

Five Relevant Publications (total of 130 archive journal publications)

1. Motta, D., Abad, J.D., Langendoen, E., and M.H. Garcia (2012). A simplified 2D model for meander migration with physically-based bank evolution, Geomorphology 163–164, 10–25. doi:10.1016.
2. Motta, D., Abad, J.D., Langendoen, E., and M.H. Garcia (2012). The effects of floodplain soil heterogeneity on meander planform shape, Water Resources Research, AGU, DOI:10.1029.
3. Czuba, J A.; Best, J.L.; Oberg, K.A.; Parsons, D. R.; Jackson, P. R.; Garcia, M. H.; Ashmore, P. (2011) "Bed morphology, flow structure, and sediment transport at the outlet of Lake Huron and in the upper St. Clair River." Journal of Great Lakes Resarch, 37(3), 480-493. Recognized with the IAGLR Chandler-Misener Award for most notable paper published in Journal of Great Lakes Research in 2011.
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5. Fernandez, R.L.; Cauchon-Voyer, G.; Locat, J.; Dai, H.; Garcia, M. H.; Parker, G. (2011) "Co-evolving delta faces under the condition of a moving sediment source."Journal of Hydraulic Research, 49(1), 42-54.

Five Other Publications

1. Abad, J. D., Rhoads, B. L., Guneralp, I., García, M. H. (2008) "*Flow structure at different stages in a meander-bend with bendway weirs*". Journal of Hydraulic Engineering, 138 (8): 1052-1053.
2. Abad J. D. and García, M. H. *RVR Meander: A toolbox for re-meandering of channelized streams.* Computers & Geosciences, 32: 92-101, 2006.
3. Abad, J. D., Buscaglia, G. and Garcia, M. H. (2008) "*2D Stream Hydrodynamic, sediment transport and bed morphology model for engineering applications*". Hydrological Processes, 22: 1443-1459.
4. Motta, Davide; Abad, Jorge D.; Garcia, Marcelo H.(2010) "Modeling Framework for Organic Sediment Resuspension and Oxygen Demand: Case of Bubbly Creek in Chicago." Journal of Hydraulic Engineering - ASCE, 136(9), 952-964. Recognized with the ASCE 2012 Wesley Horner Award for best publication.
5. García, M. H., "Modelling Sediment Entrainment into Suspension, Transport, and Deposition in Rivers," Chapter 15 in *Model Validation: Perspectives in Hydrological Science*, M.G. Anderson and P.D. Bates (Editors), 389-412, John Wiley & Sons, England, 2001.

Synergistic Activities

Member, Steering Committee, Community Surface Dynamics Modeling System (CSDMS), 2013-2018.
Editor-in-Chief, ASCE/EWRI "Sedimentation Engineering," Manual of Practice 110, May 2008.
Member, National Research Council Panel on "River Science at the US Geological Survey." 2005-2006.
Expert Panel Member, Mississippi River Hydrodynamic and Sediment Transport Modeling, Battelle & US Army Corps of Engineers, 2013-2016.
International Scientific Committee on Flooding, Firenze 2016, Florence, Italy, 2014-2016.

Ph.D. Advisees(total: 27): Yarko Niño (Prof., University of Chile); Fabian López, (Minister for Public Works, Cordoba, Argentina); Sung-Uk Choi (Prof., Yonsei University, South Korea); Jeffrey Parsons (Consultant, WA); David Admiraal (Assoc. Prof., University of Nebraska-Lincoln), Xin Huang (Software Engineer, Motorola, Inc.), Fabian Bombardelli (Assoc. Prof., University of California-Davis), Jose Rodriguez (Senior Lecturer University of Newcastle, Australia), Michelle Guala (PhD, Univ. of Genoa; Asst. Prof. Minnesota), Robert Holmes,Jr. (National Flood Hazard Coordinator, USGS), Arthur Schmidt (Res. Asst. Prof., University of Illinois), Juan Fedele (ExxonMobil), Yovanni Catano (Sr.Eng., Alden Research Lab, MA), Michael Yang (Consulting, Shaw Group), Octavio Sequeiros (Researcher, Shell Co, The Netherlands, w/ Gary Parker), Carlos M. Garcia (Prof. Universidad Nacional de Cordoba), Mariano Cantero (Asst. Prof., Instituto Balseiro, Argentina), Jorge Abad (Asst. Prof., Univ. of Pittsburgh), Albert Dai (Asst. Prof., Tamkang University, Taiwan); Xiaofeng Liu (Asst. Prof., Penn State), Arturo Leon (Asst. Prof ., Oregon State University), Francisco Pedocchi (Asst. Prof., Universidad de la Republica, Uruguay), J. Ezequiel Martin (Res. Assoc., Univ. of Iowa), Blake Landry (Post-Doc, UIUC), Sumit Sinha (Res. Assoc., Helmholtz Inst., Germany), Davide Motta (Cons. PA), Tatiana Garcia (PostDoc USGS).

Currently: 12 graduate students. MS Thesis Students Advised to date: 40

Graduate Studies Advisor: Gary Parker, University of Minnesota (currently at UIUC)

List of Collaborators: Bruce Rhoads, Jim Best, Gary Parker, University of Illinois, Eddy Langendoen (USDA), S. Balachandar, University of Florida, Colin Stark, Columbia University, Mohamed Ghidaoui, Hong Kong University of Science and Technology, Mario Amsler and Ricardo Szupiany, Universidad Nacional del Litoral, Argentina, Daniel Brea, Instituto Nacional del Agua, Argentina, Kevin Oberg and Ryan Jackson (Hydroacoustics, USGS), Faith Fitzpatrick (USGS).

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EDUCATION

Bachelor of Science, Engineering (BSE), 1996
Interdisciplinary Engineering program; Ecological Engineering option
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Master of Science, Civil Engineering, 2011
Environmental Hydrology and Hydraulic Engineering program
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Currently in PhD program, Civil Engineering, 2011-present
Environmental Hydrology and Hydraulic Engineering program
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

HONORS

Ben Chie Yen Fellowship Award, 2012

ACADEMIC EXPERIENCE

Graduate Research Assistant, *University of Illinois at Urbana Champaign* *2009-present*

- Bubbly Creek sediment oxygen demand study [Masters project]

  Waterman, D. M., Waratuke, A. R., Motta, D., Cataño-Lopera, Y. A., Zhang, H., & García, M. H. (2011). In situ characterization of resuspended-sediment oxygen demand in Bubbly Creek, Chicago, Illinois. *Journal of Environmental Engineering*, 137(8), 717-730.
- Physical modeling of stepped canoe chute / fish passage facility; Arkansas River, KS
- Field and laboratory experiments on oil-sediment aggregation processes associated with submerged oil; Kalamazoo River, MI
- Physically-based bank erosion formulation implementation into the model RVR Meander model; Mackinaw River, IL
- Morphodynamics of bank accretion; Green River, UT

PROFESSIONAL EXPERIENCE

Environmental Scientist / Project Engineer / Project Manager, *Environmental Technology Consultants (A Division of Sisul Enterprises, Inc.), Vancouver, WA* *1996-2008*

- Performed civil engineering design and plan preparation for residential and commercial development projects.
- Performed modeling of open channel systems using HEC-RAS as part of conveyance design and floodway / floodplain analysis.
- Performed wetland delineations in a variety of ecoregions throughout the Pacific Northwest
- Performed all aspects of Section 404 wetland/stream permitting.

CONTINUED…

Civil Engineering Technician, *US Army Corps of Engineers, Operations Division, Navigation Section; Louisville, KY* *1994-1995 (Summer)*

- Produced hydrographic survey maps from raw field data for channel maintenance dredging.

Geotechnical Engineering Technician, *Greenbaum Associates, Inc., Louisville, KY* *1993 (Summer)*

- Assisted drill operator in soil core sampling and installation of monitoring wells. Prepared well logs.
- Inspected structural foundations at construction sites.

Connecticut River – Turners Falls Impoundment Riverbank Detailed Site Assessments

Location ID: *7L*

Personnel: *YKC, CM, RKS*

Date: *September 25, 2014*

Time: *8:00 AM*

Photo Reference Numbers: *871 - 877*

Station Number : *375+00*

Latitude: *42.63684*

Longitude: *-72.48664*

Left or Right Bank (Looking Downstream): *Left*

Previously Stabilized? *No*

Geologic / Geotechnical Observations:

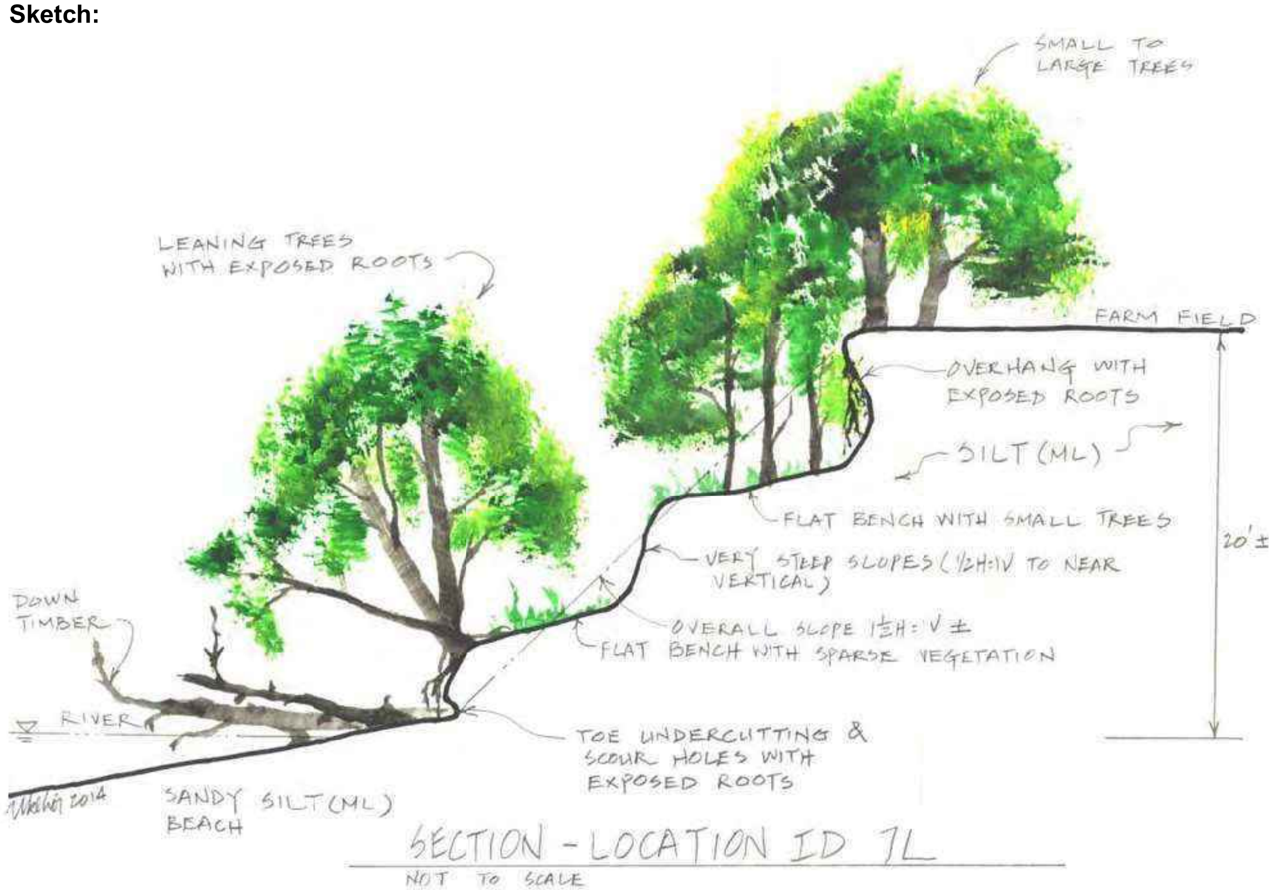
Stratigraphy:
(Refer to Site Sketch below for locations of soil/rock layers
Notations in parentheses are based on Unified Soil Classification System)

Upper Bank: SILT (ML) – Low plasticity, approx.10% - 20% fine sand, gray.
Lower Bank: SANDY SILT (ML) – Low plasticity, approx. 40% to 50 % fine sand, gray.

Observed Erosion Features:

- *Very steep slopes near top of Upper Bank, with little vegetation.*
- *Leaning trees with exposed roots at river level.*
- *Mass wasting with slumping and exposed roots.*
- *Toe undercutting and localized scour holes between trees at river level.*
- *Overhangs with exposed roots of large trees at top of Upper Bank.*

Site Sketch:



Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: 7L **Date:** *September 25, 2014*

Station Number : *375+00*

Bank Vegetation:

Top: Heavy (>50%) cover – Broad leaved deciduous tree

Tree (60%): red oak, white oak, basswood, elm*
Shrub (50%): morrow's honeysuckle, raspberry, sumac, elm, dogwoods*
Vine (40%): bittersweet, grape, Virginia creeper*
Herbaceous (15%): poison ivy, Solidago spp *., mixed grasses & asters*

Face: Heavy (>50%) cover – Broad leaved deciduous tree

Tree (60%): basswood, elm, ash, red oak, white oak, cottonwood, ashleaf maple*
Shrub (20%): elm, red oak sapling, white oak sapling, ash sapling, basswood sapling, barberry, honeysuckle,*
Vine (35%): bittersweet, Virginia creeper, grape*
Herbaceous (<10%): garlic mustard, cinnamon fern, mixed goldenrods (Solidago spp *.), mixed asters & mixed grasses*

Toe: sparse (<5%) cover – Broad leaved deciduous (mixed)

Tree (<5%): basswood, elm, red oak, white oak (partly fallen, overhanging trees)*
Shrub (<10%): honeysuckle, basswood sapling, elm*
Vine (30%): bittersweet with some grape and creeper*
Herbaceous: none

** Dominant species in each vegetative strata is marked with an **

The dominant vegetative strata is the tallest strata with >30% cover

Adjacent Land Use:

Very thin riparian buffer (1 tree width) with agricultural land use at the top of the bank

Sensitive Receptor:

No

Notes :

Lots of invasive species here: barberry, morrow's honeysuckle, garlic mustard, Virginia creeper, and oriental bittersweet is very prevalent, covering everything

Connecticut River – Turners Falls Impoundment Riverbank Detailed Site Assessments

Location ID: *7R* **Personnel:** *YKC, CM, RKS*

Date: *September 25, 2014* **Time:** *9:00 AM* **Photo Reference Numbers:** *879 - 884*

Station Number : *375+00* **Latitude:** *42.63824* **Longitude:** *-72.49010*

Left or Right Bank (Looking Downstream): *Right*

Previously Stabilized? *No*

Geologic / Geotechnical Observations:

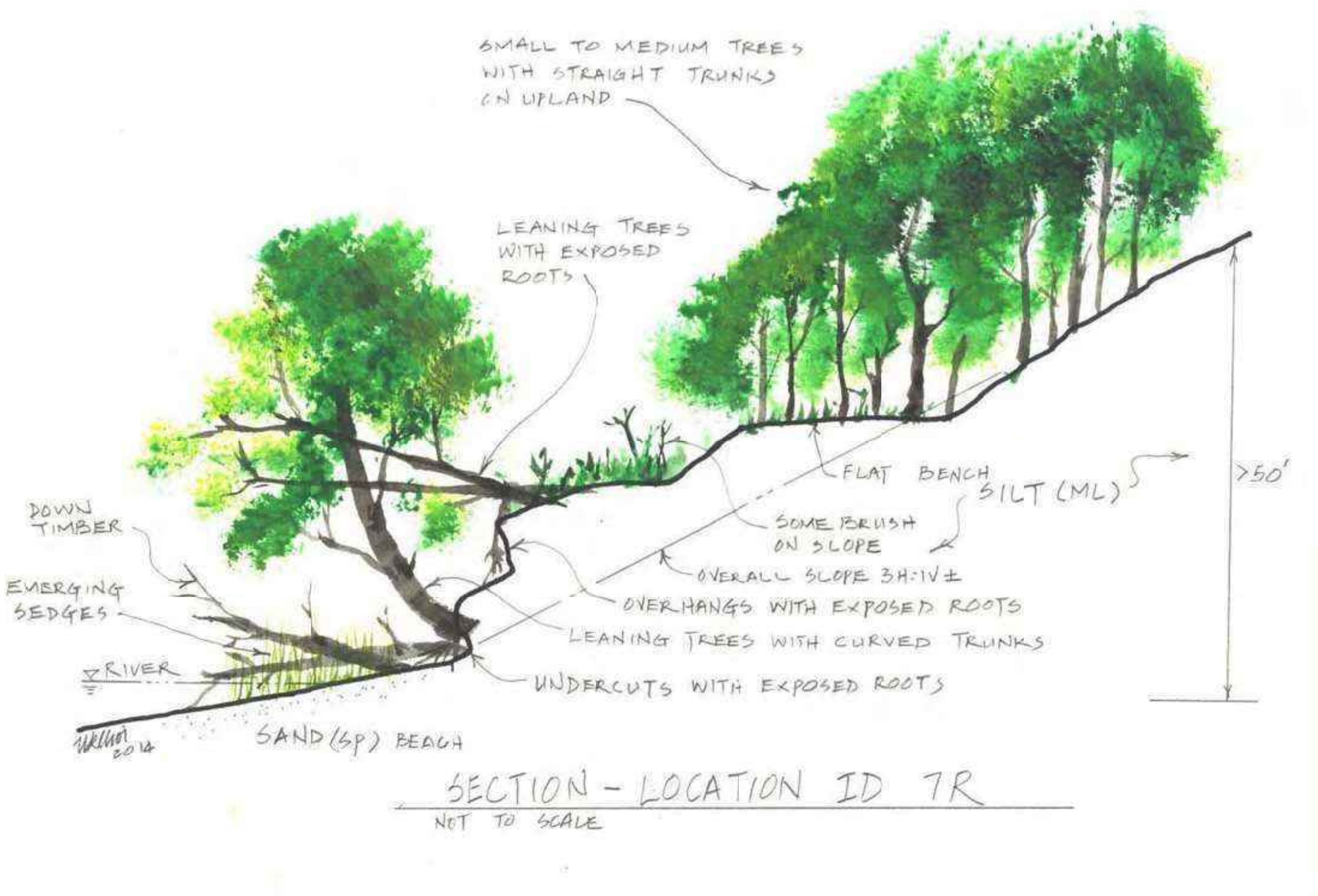
<u>Stratigraphy:</u>
(Refer to Site Sketch below for locations of soil/rock layers
Notations in parentheses are based on Unified Soil Classification System)

Upper Bank: SILT (ML) – Low plasticity, approx.20% - 30% fine sand, gray.
Lower Bank: SAND (SP) – Fine to medium sand, <5 % nonplastic fines, brown and gray.

Observed Erosion Features:

- *Undercuts with exposed roots at river level.*
- *Mass-wasting along entire slope.*
- *Trees on upland are a have straight trunks, suggesting the trees post-date the mass-wasting movement.*
- *Leaning trees with exposed roots at river level and bottom of Upper Bank, some with curved trunks.*
- *Large scour hole (20' wide x 40' long x 15 feet deep) at mid-slope, with flowing groundwater at bottom of hole.*

Site Sketch:



Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: 7R **Date:** *September 25, 2014*

Station Number : *375+00*

Bank Vegetation:

Top: Heavy (>50%) cover – Broad leaved deciduous tree

Tree (80%): sugar maple, eastern white pine, hemlock, black birch, ash, white oak*
Shrub (2%): black birch sapling, barberry, honeysuckle, sugar maple sapling*
Vine (2%): bittersweet, grape*
Herbaceous (10%): mixed ferns (inc. Christmas fern, ostrich fern, Dryopteris spp., sensitive fern), poison ivy, asters

Face: Heavy (>50%) cover – Broad leaved deciduous shrub

Tree (40%): black birch, sugar maple, eastern white pine, hemlock, ash*
Shrub (60%): barberry, honeysuckle, hemlock, ash sapling, sugar maple sapling, poison ivy shrub, white oak sapling
Vine: bittersweet, Virginia creeper, grape*
Herbaceous (<5%): poison ivy, Christmas fern, asters

Toe: sparse (<5%) cover – narrow leaved persistent emergent

Tree (10%): ash, sugar maple, eastern white pine, red oak, black birch (partly fallen, overhanging trees)*
*Shrub (<10%): honeysuckle**
Vine (5%): bittersweet, grape*
Herbaceous (50%): three square sedge (Scirpus americanus *)*

** Dominant species in each vegetative strata is marked with an **

The dominant vegetative strata is the tallest strata with >30% cover

Adjacent Land Use:

Forested

Sensitive Receptor:

No

Notes :

There is a section on the bench where rock has been placed (see photos)

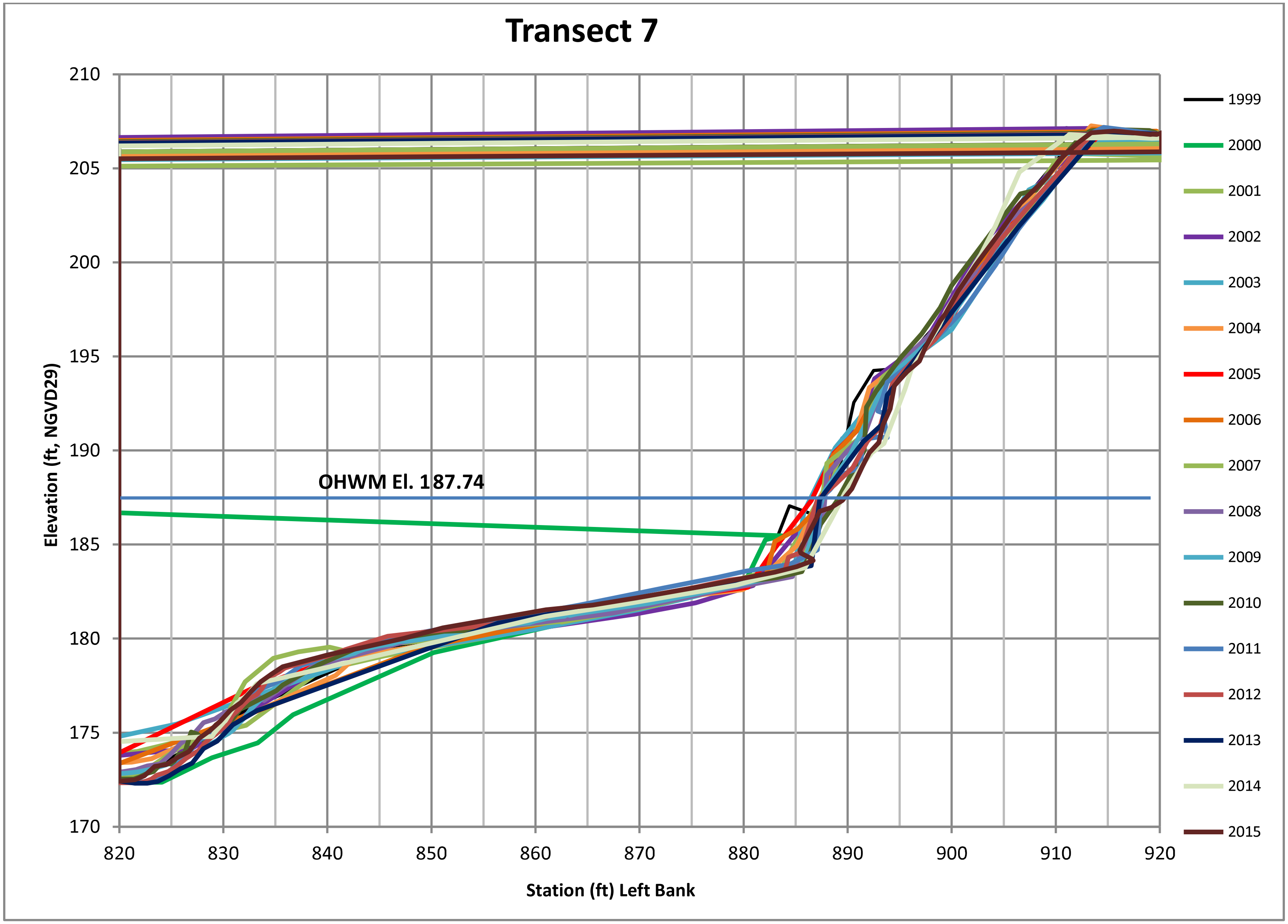
Approx. 3 m upstream there is a small patch of three square *, ~5m x 5m in size (CM photo 50)*

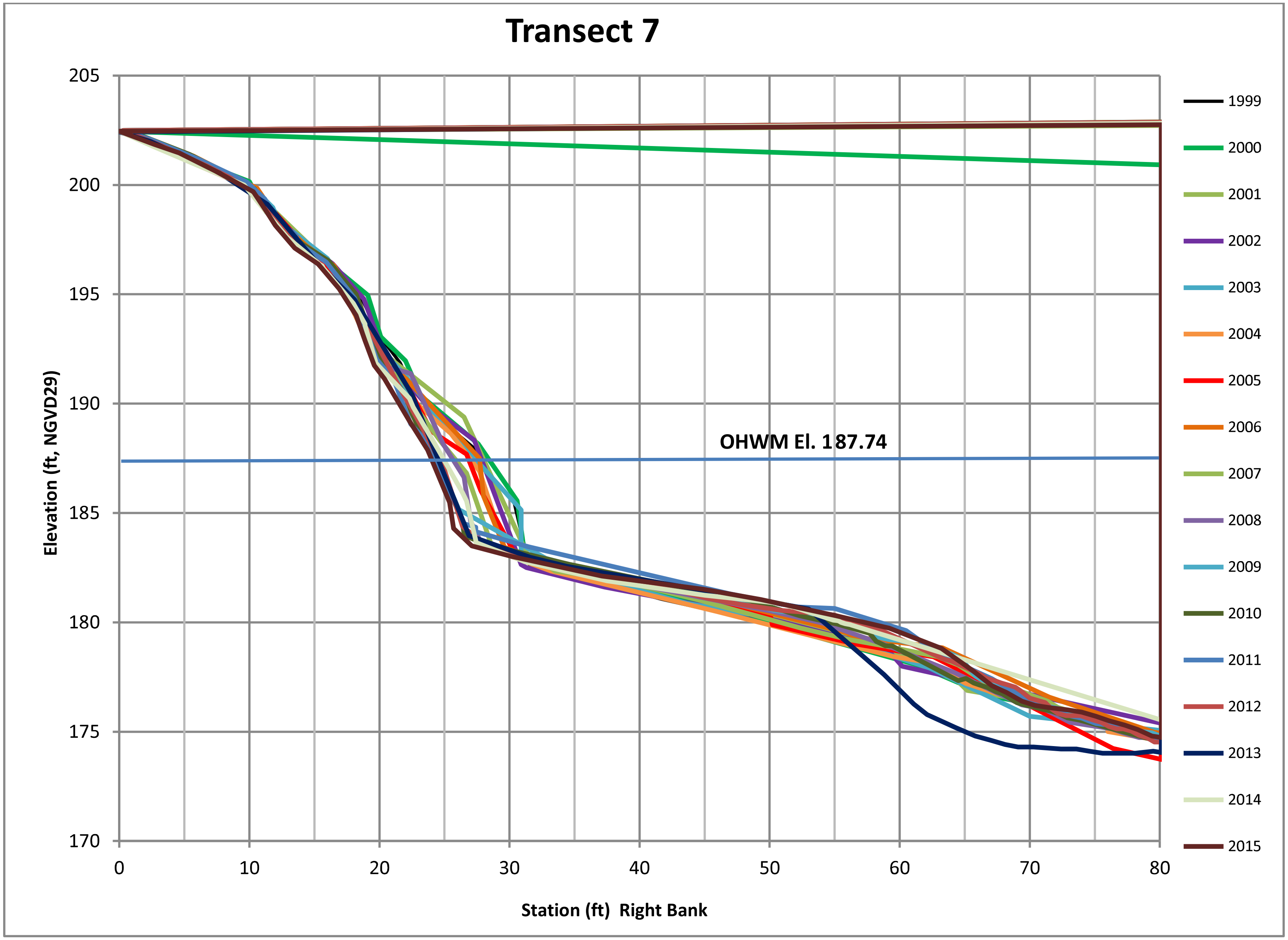
There is a gully where a tree fell mid slope up the hill (CM photo 051)

Very high bank

Mid slope is very steep – too steep to support much vegetation

Invasive species are present here, including: Japanese barberry, oriental bittersweet, and honeysuckle. However, none are dominating. The bittersweet is covering everything mid-bank but is absent from the denser forested area at the top of the bank; the barberry is sparse at the top of the bank, ~1%. Honeysuckle is denser at the lower mid slope.


Transect 7
Elevation (ft, NGVD29)
Station (ft) Left Bank
OHWM El. 187.74
210
205
200
195
190
185
180
175
170
820
830
840
850
860
870
880
890
900
910
920
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015


Transect 7
Elevation (ft, NGVD29)
205
200
195
190
185
180
175
170
0
10
20
30
40
50
60
70
80
Station (ft) Right Bank
OHWM El. 187.74
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015

Review of Erosion in the Turners Falls Impoundment

Prepared 19 May 2024 by Dr. Evan Dethier for the Connecticut River Conservancy and Franklin Regional Council of Governments

TABLE OF CONTENTS

Short Biography
Evan Dethier holds a Masters and PhD in Earth Science from Dartmouth College. He is an assistant professor of Geology at Colby College in Waterville, Maine. Evan is a fluvial geomorphologist who has studied erosion in New England rivers for the past decade. He uses field and remote-sensing methods to monitor and improve understanding of natural and anthropogenic disturbance to these rivers and those around the world, including by floods, landslides, mining, and dams.

Dr. Dethier’s CV is attached at the end of this report for reference.

i. Executive Summary

Erosion in the Turners Falls Impoundment

There is substantial evidence of erosion in the Turners Falls Impoundment (TFI), much of it consistent with fluctuations in water level due to dam operations. Several reports and memos, including by the US Army Corps of Engineers, Field Geology Services, and Princeton Hydro, have already established that water level fluctuations in the TFI can, and likely do, enhance erosion in the reservoir.

Reports by FirstLight have repeatedly denied the connection between fluctuating water level and erosion. These denials defy direct observations, including those presented by FirstLight, showing the likely links between FirstLight operations and erosion in the TFI.

- Water fluctuations in the TFI result from a combination of natural flows, which are regulated to some extent by upstream dams, and approximately daily fluctuations that a) move water between the River as lower reservoir and Northfield Mountain's upper reservoir (pumping withdraws water from the river and generation returns water to the river) and b) regulate flow through the Turners Falls Dam and power canal for conventional hydropower. The combination of a) and b) are termed "Project operations" in this report.

- Erosion is clearly documented in both data and images produced by FirstLight.

- Erosion occurs with very few signs of deposition. In its pre-dam state much of the TFI may have been a net-depositional zone, given that the TFI is in a mostly alluvial reach of the Connecticut River, with limited bedrock, a well-developed floodplain, and decreasing stream power.

- River flows have rarely inundated floodplains since flood control dams were established in the mid-20th century, eliminating the possibility of replenishing overbank sediment.

- Observations and measurements included in the FirstLight Full River Reconnaissance and Erosion Causation Study point to numerous mechanisms that could enhance erosion in the TFI due to Project operations.

- FirstLight has not presented credible, reproducible evidence that their operations do not increase erosion in the TFI. Absent targeted mitigation, increase in the water-level range of typical Project operations may increase erosion in the impoundment.

Flaws in FirstLights Erosion Attribution Analyses

FirstLight's two relicensing studies, Study 3.1.1, the Full River Reconnaissance (FRR), and Study 3.1.2, Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report (commonly called the Erosion Causation Study) have numerous methodological flaws and gaps in reporting. These studies document widespread erosion in the TFI, but downplay this erosion in the text and summaries. Other studies and reviews prepared by scientists, including the 2007 and 2013 reports by Field Geology Services and the Princeton Hydro peer review, point out flaws in FirstLight's analyses and highlight the likelihood that FirstLight operations contribute to erosion.

- FirstLight documents substantial evidence of erosion, even attributing some of it to changing water levels due to dam operations. However, this finding is discounted in their text, conclusions, and executive summary.

- There is no mention of the inability of vegetation to colonize lower banks because of water level fluctuations, leaving them prone to erosion.

- There is no mention of freeze-thaw effects causing erosion on unvegetated, steep banks created and maintained (in their unvegetated state) by frequent inundation and erosion. Freeze-thaw erosion does not require ice floes, which FirstLight does address, but can occur from frost wedging and liquefaction on steep banks. In addition, FirstLight's dismissal of erosion by ice jams is not evidence-based.

- The BSTEM model used by the consultants was developed by them. The report has a lack of transparency in model inputs that makes it impossible to judge its appropriateness.

- The version of the BSTEM model used in the Erosion Causation Study is not publicly available and thus the results cannot be understood or replicated.

- Despite high-resolution cross sections available to the model, only a simple parameterization is used (as far as can be understood from the summary). Average slopes for upper and lower banks are used, potentially diminishing estimates of erosion except during floods.

- Groundwater saturation is integral to the model, but almost no data was collected to inform its parameterization.

- Root cohesion data was only collected for large trees. There is no information on grasses and smaller vegetation that does much of the work of bank stability and velocity reduction. Cohesion does not vary through the model run, despite likely lower cohesion during late winter and spring, when soils are saturated and vegetation has not taken root for the season.

Erosion along the banks of the Turners Falls Impoundment has been documented since the construction of the reservoir. A series of independent, expert scientists have attributed at least part of this erosion to Project operations, which raise and lower the water level in the TFI or Connecticut River, exposing different parts of the bank to erosion.

The results of expert analysis—that erosion in the Turners Falls Impoundment is increased by Project operations—conform with the general scientific consensus about shoreline erosion in human-controlled impoundments, particularly in those with fluctuating water levels.

1. Background

1.1 Summary

Erosion is a natural process along any shoreline. Human activities can accelerate erosion processes, causing erosion to occur in excess of natural rates or at different seasons than is normal. Because natural processes generally continue, at least to some extent, after human intervention, and natural and human processes interact with each other, quantifying the precise contribution of natural and human processes to erosion is a difficult task. Over the past several decades, various analyses have attempted to do so. However, as Field Geology Services noted in 2007 (working as a consultant for FirstLight's predecessor), accurately separating human and natural contributions to the erosion in the Turners Falls Impoundment is not possible without more detailed and accurate monitoring than has yet been undertaken[1]. This remains true.

Monitoring recommended by Field Geology Services in 2007 and 2012 (working as a consultant to a landowner group), such as annual lidar surveys[2,3], would address inconsistencies and gaps in historical monitoring efforts, but have not yet been undertaken. Stymied by this lack of certainty, the Field Geology Services Report from 2007 detailed the many potential sources of human and natural erosion and the challenge of separating them, given the interconnected natural and human processes in the TFI[4]. In this report, I summarize peer-reviewed literature about the TFI and similar reservoirs, as well as non-peer-reviewed reports and observations. I also discuss shortcomings in FirstLight's recent analyses of erosion in the reservoir: Study 3.1.1 (the Full River Reconnaissance), Study 3.1.2 (aka the Erosion Causation Study), and several other FirstLight publications. This review should provide insight into the likely contribution of FirstLight operations to erosion on the TFI shorelines, while making clear that FirstLight claims that they are not contributing to erosion are much more certain than is scientifically supported.

1.2 Erosion on reservoir shorelines

1.2.1 Overview

For decades, the technical and scientific community has measured anomalous erosion on the banks of impounded reservoirs. Several studies have shown that erosion occurs or is increased due to reservoir construction and operation. Numerous scientists have found that such erosion can persist well into the lifespan of the dam.

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[1] Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. p. 42 ("Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space.")

[2] Kaczmarek, H., Tyszkowski, S., Bartczak, A., Kramkowski, M., & Wasak, K. (2019). The role of freeze-thaw action in dam reservoir cliff degradation assessed by terrestrial laser scanning: A case study of Jeziorsko Reservoir (central Poland). Science of the total environment, 690, 1140-1150.

[3] Field (Field Geology Services), 2012, Rebuttal of FirstLight's Response to Landowner Filing: Unpublished report prepared for Landowners and Concerned Citizens for License Compliance Turners Falls Pool, 12 p. p. 10 ("Given that both Landowners and Simons (2012) agree that the FRR methodology cannot be used to make comparisons of erosion from year to year, FERC should insist that FirstLight and its agents make no further representations that the 2008 FRR demonstrates a decline in erosion levels between 2004 and 2008. Since FirstLight (2012) makes clear that the objective of the 2013 FRR is, in part, to "analyze any change in the condition of the riverbank since the last FRR" (FirstLight, 2012, Appendix 1, p. 2), FERC should further insist that future FRRs be designed in a manner that allows for detailed site-by-site comparisons from year to year.")

[4] Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. p. 42 ("Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space.")

The Turners Falls Impoundment is relatively long and narrow, resembling both a river and a typical ponded reservoir. Nonetheless, it does not appear to be an exception to this general pattern of increased erosion, because it experiences many of the same processes that enhance erosion in wider reservoirs. Indeed, its non-cohesive sediment banks, location in a freeze/thaw climate, and fluctuations from pump-storage operations increase its likelihood of increased erosion due to Project operations.

1.2.2 Why is there erosion along reservoir shorelines?

The area along a reservoir shoreline that is exposed to changing water level has been termed the “reservoir disturbance zone” due to “the cyclic submergence and exposure caused by the reservoir operation”[5]. Prior to reservoir construction, these elevations usually remain well above the high-water line. They would generally be inundated only during floods, if at all. After the reservoir is completed, frequent water inundation occurs in the reservoir disturbance zone, between the base and peak of normal dam operations. This inundation in the reservoir disturbance zone disrupts soils, vegetation, and fauna. In many cases, these disruptions contribute to erosion[6].

A US Army Corps of Engineers review of ten reservoirs found wind-wave erosion, groundwater-induced sliding, freeze-thaw effects, and landsliding to be the dominant processes after the period of initial reservoir filling[7]. Each of these processes occurs in the reservoir disturbance zone and is caused or accentuated by the inundation of shoreline sediments. Consistent or intense wave action from wind and waves[8] subjects the previously high-and-dry banks to the erosive action of water, leading to sediment removal. Flooding can increase flow velocity and increase erosion. In some cases, previous erosion at the “toe” (base) of steep banks can undercut the bank slope or soil saturation can reduce soil strength during to high-water fluctuations. These events can lead to mass sediment failure farther up the bank and above the disturbance zone[9], as has been found in the Wilder Dam reservoir farther upstream on the Connecticut River[10].

[5] Bao, Y., Gao, P., & He, X. (2015). The water-level fluctuation zone of Three Gorges Reservoir—A unique geomorphological unit. *Earth-Science Reviews*, *150*, 14-24. p. 15.

[6] Bao, Y., He, X., Wen, A., Gao, P., Tang, Q., Yan, D., & Long, Y. (2018). Dynamic changes of soil erosion in a typical disturbance zone of China's Three Gorges Reservoir. *Catena*, *169*, 128-139. p. 136 (“Influenced by this new hydrological regime, the abundance of the original plant species within the [Disturbance Zone] has been drastically reduced”).

[7] Gatto, L. W., & Doe III, W. W. (1987). Bank conditions and erosion along selected reservoirs. Environmental Geology and Water Sciences, 9(3), 143-154. p. 143 “However, freezing can disrupt soil structure and draw pore water to the freezing zone, which may make bank sediment more susceptible to erosion alter thaw.”

[8] Vilmundardóttir, O. K., Magnússon, B., Gísladóttir, G., & Thorsteinsson, T. (2010). Shoreline erosion and aeolian deposition along a recently formed hydro-electric reservoir, Blöndulón, Iceland. Geomorphology, 114(4), 542-555. p. 550 (“After the formation of the Blöndulón Reservoir the most rapid initial erosion rate occurred on bluffs on the northern and western shores, comprising about one third of the shoreline of the reservoir, where the available wave energy was high. This is evident from the high cumulative wave power at those sites due to the long fetch towards the south and east and frequent south to south-easterly storms occurring during high water levels.”)

[9] Kaczmarek, H., Mazaeva, O. A., Kozyreva, E. A., Babicheva, V. A., Tyszkowski, S., Rybchenko, A. A., ... & Słowiński, M. (2016). Impact of large water level fluctuations on geomorphological processes and their interactions in the shore zone of a dam reservoir. Journal of Great Lakes Research, 42(5), 926-941. p. 933 (“Landslide activation took place in 2004, 2006, and 2009, in periods of high water level in the reservoir, reaching 400 m a. s. l. or more”).

[10] https://www.lymenh.gov/sites/g/files/vyhlif4636/f/uploads/lyme_hmp_finalforadopt_apr3_17.pdf

Inundation also increases the susceptibility of the reservoir banks to erosion. Devegetation due to inundation and erosion[11] reduces bank sediment cohesion, especially in silty and sandy soils like those present in the TFI[12], leading to easier removal by reservoir waters. Freeze-thaw erosive processes can physically separate blocks of soil from the bank[13]. Increased water saturation due to reservoir inundation can enhance these processes. Each of these erosion-increasing processes occurs in the Turners Falls Impoundment.

1.2.3 Where does erosion occur in reservoirs?

Despite investigating 32 causes of erosion in reservoirs, the US Army Corps of Engineers study makes virtually no mention of river flooding as an important factor[14], nor do most of the other peer reviewed studies of reservoir erosion. Instead they find the importance of water fluctuations, combined with processes that occur consistently at the reservoir shoreline, facilitated by inundation and wave action[15]. The riverine geometry and flow characteristics of the TFI, especially its upper reaches, makes it susceptible to erosion by flooding, which is most likely a cause and perpetuator of erosion along the shoreline[16]. However, as these studies show, many processes contribute to erosion in a reservoir, and rarely can erosion be distilled to a single cause.

Which of the above processes is dominant in a given reservoir depends on the make-up, orientation, and slope of the reservoir banks, slope and vegetation, dam operations, the prevailing hydrology and climatology, and reservoir activity[17]. The primary cause of erosion may vary within a reservoir due to variations in current, exposure, or bank material. However, in each case erosion mostly occurs in the reservoir disturbance zone, which is largely determined by the dam or project operations[18,19].

In a given moment, erosion primarily occurs within a few vertical meters of the waterline[20], usually when waves or currents transport sediment away from banks[21,22]. Because reservoir levels change with seasons, natural floods, and dam operations, the erosion band moves up and

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[11] Bao, Y. et al. (2018). p. 136 ("Influenced by this new hydrological regime, the abundance of the original plant species within the [Disturbance Zone] has been drastically reduced"); Fig. 7.

[12] Kaczmarek et al. (2016) p. 927 ("Depending on rock resistance, the mean width of eroded shore varies from 80 m in sandstones to 140–200 m in silty deposits")

[13] Gatto, L. W., & Doe III, W. W. (1987). Bank conditions and erosion along selected reservoirs. Environmental Geology and Water Sciences, 9(3), 143-154. p. 143 "However, freezing can disrupt soil structure and draw pore water to the freezing zone, which may make bank sediment more susceptible to erosion alter thaw."

[14] *Id.* at p. 147 Table 2 ("Summary of historical recession").

[15] Vilmundardóttir et al. (2010) p. 554 ("Bluff erosion and aeolian reworking of sediments at the Blöndulón Reservoir are closely linked to water level fluctuations.")

[16] U.S. Army Corps of Engineers, 1979, Report on Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire and Vermont: Department of the Army New England Division Corps of Engineers: Waltham, MA, 185 p.

[17] Gatto and Doe III (1987) p. 143 ("The importance of a process or a set of processes or factors will vary at different sites and different times").

[18] Bao, Y. et al.(2018). p. 135 ("the fluctuation pattern of soil erosion rates in the DZ was consistent with that of the specific water level residence time. The residence times around the minimum and maximum levels were significantly longer than those at the other levels.")

[19] Newbury, R. W., & McCullough, G. K. (1984). Shoreline erosion and restabilization in the Southern Indian Lake reservoir. Canadian Journal of Fisheries and Aquatic Sciences, 41(4), 558-566. p. 561 ("melting occurs below and slightly above the water surface.")

Gatto and Doe III (1987) p. 143 ("The importance of a process or a set of processes or fctors will vary at different sites and different times"). p. 152 ("much of the bank erosion along most of the" reservoirs is caused by water action at the bank toe")

[21] Bao, Y. et al.(2018). p. 128.

[22] Vilmundardóttir et al. (2010) p. 552 Fig. 11.

down throughout the year. The wider the band of water-level variation, the more area that is subject to inundation, scour, devegetation, and thus erosion, and the wider the reservoir disturbance zone.

The physical properties of the reservoir bank sediments are another important control on their erodibility. Where banks are comprised of sandy or silty sediments, they are less likely to be stable than banks made of coarser material or bedrock. Several studies of reservoir erosion have found that, within a reservoir, bank sediment is the most important spatial control on erosion rate. Where sediments are sandy or silty, similar to those in the TFI[23,24], banks are most susceptible to erosion during reservoir water fluctuations since they “lack cohesion and grains of boulder and cobble size”[25].

High slopes at or near the waterline are correlated with higher erosion rates[26]. Although some studies have found elevated erosion even at low slope[27], in general steep banks like those found in glacial and floodplain sediments along much of the TFI are thought to be most susceptible to water-fluctuation erosion (and erosion in general).

Project operations in the TFI frequently raise and lower the water level. Thus, the local area of possible erosion is a dynamically changing band that spans normal pump-storage operations and moves up and down with natural variations in river flow (Figure 1). As opposed to other reservoirs where fluctuations might occur on a seasonal basis and/or with occasional flood events, fluctuations in the TFI occur daily or even multiple times in a day. Rapid erosion throughout the reservoir has occurred in and above this erosion band. FirstLight itself has documented this erosion, including wave-cut banks and bars, bank undercutting and failure, bank retreat, and rotational landslides and slumps[28]. Erosion has encroached on land surrounding the reservoir, removing soil and acreage and threatening roads and infrastructure.

[23] Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. p. 50 (“Most of the riverbank sediments in the Turners Falls Pool are naturally susceptible to erosion given their noncohesiveness and fine-grained texture”)

[24] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Table 4.2.6.3-4: Particle-size Data of the Bank Materials along the Turners Falls Impoundment

[25] Vilmundardóttir et al. (2010) p. 552 (“The current erosion rate is due to loose fluvioglacial substrate material; the texture of the fluvioglacial sediments did not create stable bluffs since it lacked cohesion and grains of boulder and cobble size. We suggest that the nature of the substrate material is the most important environmental factor affecting the development of bluffs towards equilibrium.”).

[26] Bao, Y. et al. (2018). p. 136 (“that the soil erosion rate was positively correlated with the slope gradient”); Fig. 6.

[27] Vilmundardóttir et al. (2010)

[28] FirstLight Relicensing Study 3.1.2 2017 Erosion Causation, Appendix M – 2013 Full River Reconnaissance Riverbank Segments With Causes Of Erosion

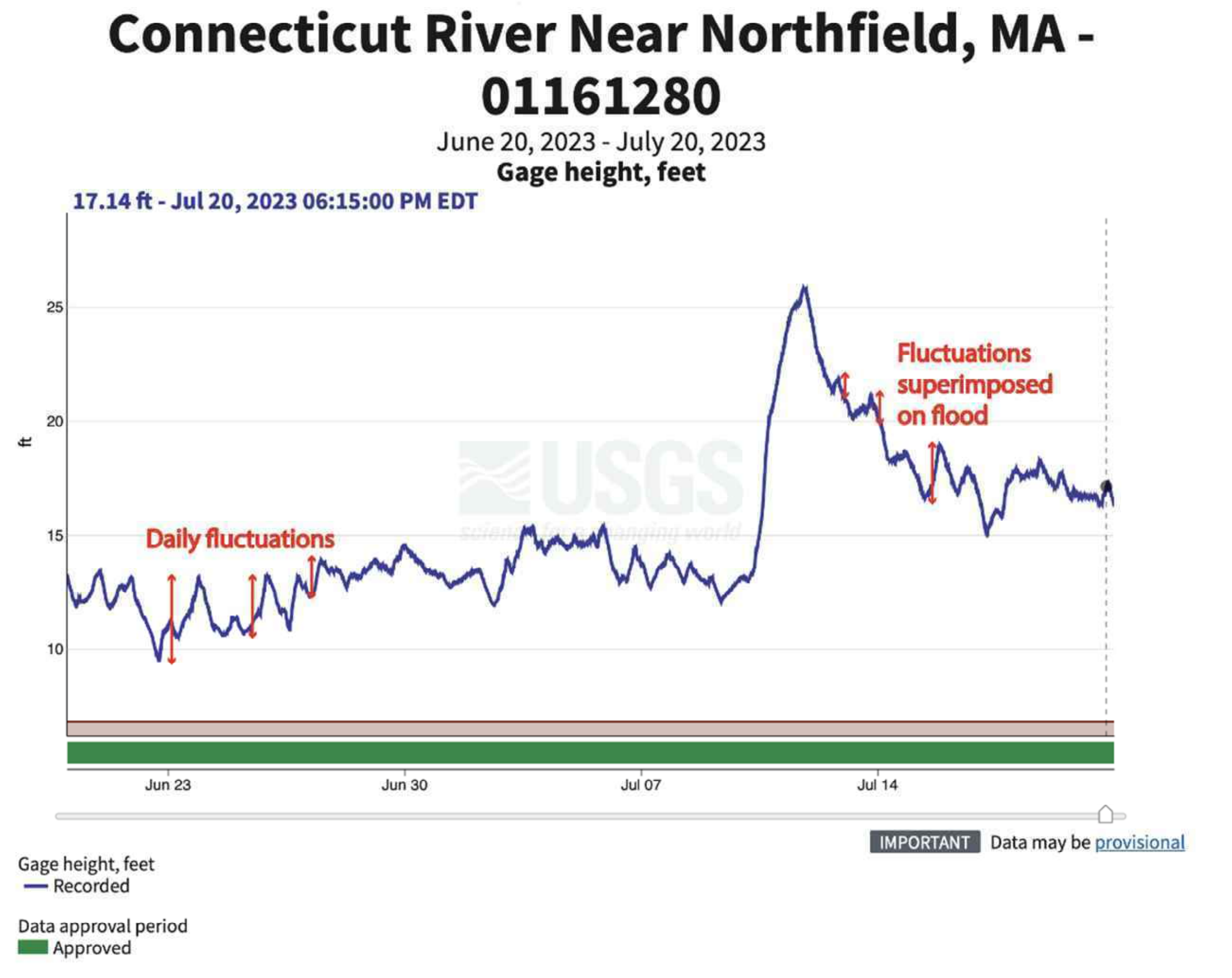

Figure 1. A hydrograph from the United States Geological Survey gage in the Turners Falls Impoundment[29], annotated to highlight normal daily fluctuations by pumped storage operations, as well as how these operations are superimposed on a significant flood event in July, 2023. Although the flood elevated the water levels to the hydrograph peak, fluctuations due to pumped storage increased the residence time of water at certain stage levels during the recessional limb of the flood peak.

1.2.4 Are there close analogues for the Turners Falls Impoundment?

As discussed above, the Turners Falls Impoundment is a narrow, riverine reservoir, especially in its upper reaches. Thus, it is somewhat different from many of the reservoirs that have been studied for erosion, which tend to be broader. River currents are likely higher, especially in the upper sections of the reservoir, than is typical in large, ponded reservoirs.

Nonetheless, it is a reservoir with sub-daily water-level fluctuations, and with banks that are steep, sandy and silty. Reservoirs with these characteristics are highly prone to erosion from

[29] https://waterdata.usgs.gov/monitoring-location/01161280/#parameterCode=00065&period=P7D&showMedian=false

water fluctuations.[30] Its lower section near Bartons Cove, also much more resembles a ponded reservoir, with a maximum width of more than 4,000 feet. Flow velocities there must thus be much lower, even during floods. Despite the lower flow velocities, this section of the reservoir generally experiences comparable erosion rates to the upstream reaches[31], suggesting that water fluctuations may play a larger role in erosion.

In Quebec, erosion rates of 10–30 meters over 20 years were found in similar sediments to those at TFI[32]. The erosion processes are very similar to those in the Turners Falls Impoundment, consistent with understand of geomorphology along sandy shorelines. They are described by Saint-Laurent et al., 2001:

> "The mechanism of bank recession is ruled by shore dynamics and slope rheology (Whalen et al. 1995). The breaking waves dissipate energy and disperse weathering fine particles such as sand and silt towards deep water. The shore is thus depleted and further exposes the foot of the slope to the action of the waves. The sapping of the waves at the foot of the slope progressively removes material at the base until the breakpoint of the slope. The debris join the bottom part of the shore and form a sort of rampart against the effect of the waves. The erosion process thus continues and starts up again year after year (mobilization of shore material by the waves, sapping, and collapse, etc.)." (p. 491)

Photographs and descriptions from Saint-Laurent et al. document similar landforms and erosional features as are present in the TFI (Figure 2), suggesting similar and/or identical processes are at work in the TFI. Saint-Laurent et al., 2001 noted that fluctuations accentuated this erosion: "the equilibrium obtained at a relatively constant level is somehow lost with fluctuations in reservoir water levels."

[30] *e.g.,* Saint-Laurent, D., Touileb, B. N., Saucet, J. P., Whalen, A., Gagnon, B., & Nzakimuena, T. (2001). Effects of simulated water level management on shore erosion rates. Case study: Baskatong Reservoir, Québec, Canada. Canadian Journal of Civil Engineering, 28(3), 482–495. p. 490 ("Proglacial sandy deposits, such as those observed around the Bras Nord and Du Diable Bay, are particularly prone to erosion, especially when exposed to wave action.").

[31] Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. Table 5; Table 6.

[32] *Id.* at p. 492 ("Windigo Bay (20–30 m over 20 years) and Du Diable Bay (10–15 m over 20 years)")

Figure 2. Figure 6a. from Saint-Laurent et al., 2001 shows a shoreline bank failure that strongly resembles failures along the TFI shorelines.

In a study in Poland, silty glacial sediments similar to those at the TFI experienced 1.4–3 m of erosion per year[33]. Another reservoir in Iceland with glacial sediments along its shoreline experienced erosion along its banks of 0–1.7 m per year[34]. Erosion in the TFI is similar to these rates for some banks, with bank losses of >1 ft/yr at some cross sections[35].

The primary mechanism for erosion in each of these reservoirs is likely wave or frost action, as opposed to in the Turners Falls Impoundment, where it may be flood flows. Yet where the erosion occurs and, at least to some degree how much erosion occurs, is set by the reservoir water level. Erosion is highest in the reservoir disturbance zone, where the banks are subject to wave action, inundated or saturated, devegetated; because the reservoir exists, erosion likely occurs at higher rates than if it did not.

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[33] Kaczmarek et al. (2016) p. 930 ("The rate of bluff recession was the highest in the initial period of reservoir use: on average 3 m/year in 1969–1980, compared to 1.4 m/year in 1980–2013.")
[34] Vilmundardóttir et al. (2010) p. 547 ("The bluff retreat measured 1.3 m in 1997, while no erosion was measured in 1998 and 1999 (Table 3) when the water level was low and did not reach overflow level (Fig. 3). Erosion of 0.4 m was measured in 2000 but in 2001 again there was no erosion measured. The most rapid erosion period occurred in 2002 when the bluff receded 1.7 m. Since 2003 the erosion rate has greatly decreased to < 0.2 m yr− 1.")
[35] Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. Table 5; Table 6.

1.2.5 Will erosion naturally slow in the TFI, or has it already?

The Turners Falls Impoundment is an old reservoir, with operations at the present levels initiated in 1970 (the dam was raised first, before Project operations began in 1972). Reservoir shoreline erosion documented in some studies is rapid after initial inundation, then dramatically slows as erodible material is removed. Given the rapid initial erosion in the TFI after reservoir levels were raised in 1970 and the possible slowdown in the 1990s and early 2000s[36], it is reasonable to wonder whether this initial adjustment period has ended and erosion is no longer an issue. However, cessation of shoreline erosion principally occurs when shorelines are eroded to bedrock[37] or beaches can be established[38], protecting against wave action and inundation[39]. Once easily eroded sediments are removed or protected, erosion rates plummet. However, these conditions are generally not present in the TFI. There is limited bedrock that might stabilize the channel, and beaches that might provide a buffer against bank erosion may be destroyed by high flows, limiting bank protection[40] (see below, Figures 6–8).

Reservoirs like the TFI, with shorelines primarily comprised of unconsolidated sediments, tend to maintain higher erosion rates for the reservoir lifespan[41]. Although some slowing usually occurs, as may be the case in the TFI, its sandy and silty banks and general lack of bedrock shoreline means that erosion can essentially continue unchecked[42]. This is particularly true if water level fluctuations remain the same or are increased.[43] In the TFI, if Project operations use a wider range than has been typical during the past 50 years, it is possible that a new wave of erosion will occur, as slopes on the upper bank are inundated for longer periods of the year[44], similar to the initial cycle of erosion that occurred when the reservoir levels were raised in the 1970s.

1.3 Past studies of erosion in the Turners Falls Impoundment

While the existing peer-reviewed literature on reservoir erosion clearly shows that water level fluctuations can cause or contribute to erosion, there is also a decades-long history of studies making a similar conclusion for the TFI specifically. In 1979 and 1991, the US Army Corps of

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[36] Field (2007). p. 27 ("South of the Massachusetts state line, the data reveal an 18 percent increase in the amount of mapped erosion between 1978 and 1990, a 6 percent decline between 1990 and 2001, and a 3 percent decline between 2001 and 2004"); Figure 28a.

[37] Newbury, R. W., & McCullough, G. K. (1984). Shoreline erosion and restabilization in the Southern Indian Lake reservoir. Canadian Journal of Fisheries and Aquatic Sciences, 41(4), 558-566. p. 561 ("If bedrock is encountered at the eroding face, erosion at the water level ceases. In the wave-washed zone overlying the bedrock, erosion continues until a bedrock backshore zone is exposed up to the maximum wave upwash elevation.").

[38] Field (2007)

[39] Vilmundardóttir et al. (2010)

[40] Field (2007). p. 43 ("The presence of higher beach deposits preserved at the base of the bank, particularly in protected areas, suggest prior beaches have been removed by scour")

[41] *Id*. at p. 551 ("Despite the low energy at the south-east shore (R13 and R15) the erosive substrate has prevented the shore from reaching even close to equilibrium.").

[42] Kaczmarek et al. (2016) p. 940 ("Although the reservoir has been operated for several dozen years, the activity of geomorphological processes in its shore zone, initiated or intensified by its creation, is still high."); p. 940 ("Their activity has not decreased after several decades and the affected area is often gradually extended.").

[43] *Id* at p. 940 ("The course of geomorphological evolution is closely linked to large water level fluctuations. The intensity of their development is characterized by remarkable variation between years and within years, conditioned by high water level fluctuations… In periods of high water levels, which reach the base of the bluff, as a result of subaqueous coastal processes result and intensive bluff recession is observed.").

[44] Bao, Y. et al.(2018). p. 135 ("the fluctuation pattern of soil erosion rates in the DZ was consistent with that of the specific water level residence time. The residence times around the minimum and maximum levels were significantly longer than those at the other levels.")

Engineers identified flooding, seepage, project-caused water fluctuations, and boat wakes as possible causes of erosion[45,46]. In 2007, Field Geology Services was hired by FirstLight to study erosion in the reservoir, and provided the most comprehensive summary of erosional processes in the TFI. They found that a combination of erosional processes, contingent on one another, most likely collectively cause erosion in the reservoir[47].

The 2007 Field Geology Services report, summarizing likely erosion processes occurring in the TFI, included natural erosion processes that may occur regardless of Project operations, including flood flows, undercutting and seepage, boat waves, freeze-thaw processes, and landsliding and slumping. However, it also discusses how pool fluctuations due to Project operations likely cause erosion themselves while also potentially initiating or perpetuating the “erosion sequence”. Field Geology Services added that “erosion is likely to persist as flood flows rework beach deposits and inundate the beach face, enabling boat waves, ***pool fluctuations***, and natural river currents to remain active at the base of the banks” (emphasis added).

Since then, in FirstLight’s Full River Reconnaissance in 2008, Full River Reconnaissance in 2013, the Erosion Causation Study in 2017, and several other documents and rebuttals, FirstLight has scrupulously denied taking responsibility for almost any erosion in the reservoir, despite repeated reports and letters by independent scientists and community groups. Field Geology Services, who was considered a sufficiently reputable scientist to be hired by FirstLight in 2007, summarized this avoidance of responsibility and deflection in their 2012 critique of FirstLight’s approach[48]:

> “However, as detailed below, the supporting evidence for making such a strong charge is found wanting in accuracy, relevance, and evenhandedness in application. Simons (2012) uses six oft-repeated strategies to give the appearance of refuting Field’s (2011) claims without providing sufficiently compelling evidence to do so: 1) providing information that in fact contradicts the assertion being made, 2) presenting information that is inaccurate, misleading, or misrepresents the work of others, 3) presenting information that is factually correct but irrelevant in regards to changing erosion levels in the Pool, 4) presenting information that is not readily verifiable, 5) presenting new information that further calls into question findings of the 2008 [Full River Reconnaissance (FRR)], and 6) making assertions that if applied evenly would discredit Simons’ (2009) conclusion that erosion levels decreased between the 2004 FRR and 2008 FRR.” (p. 5)

These are strong rebukes from a respected scientist, and call into question the claims made by FirstLight. Nonetheless, in subsequent reports, FirstLight has persisted in this pattern of denial, rejecting even the possibility that Project operations are meaningfully contributing to erosion in the TFI.

The erosion sequence as proposed by Field (2007) (similar to the stages of erosion discussed in this report), describes processes and feedbacks potentially caused by Project operations that

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[45] U.S. Army Corps of Engineers, 1979, Report on Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire and Vermont: Department of the Army New England Division Corps of Engineers: Waltham, MA, 185 p.
[46] Field (2007)
[47] *Id.* at p. 42 (“Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space.”)
[48] Field (2012)

accentuate natural erosion processes and perpetuate a cycle of erosion in the reservoir[49]. The original Field Geology Services report is still valid, and the processes it details refute the FirstLight claim that erosion cannot be attributed to Project operations. Field Geology Services provides numerous illustrations and photographs showing erosional landforms that could be caused or accentuated by Project operations (e.g., Figure 3, 4). In their reports, FirstLight provides many images showing the same erosional features, yet denies that Project operations could contribute to their formation.

b)

Figure 8: a) Active beach face and b) remnants of a higher beach.

Figure 3. Figure 8 from Field Geology Services' 2007 Fluvial Geomorphology Study of Connecticut River[50] shows erosion that is consistent with changing water levels forming and eroding beaches along a sandy bank of the TFI. Each "step" in the beach is consistent with water levels being at that height, possibly due to water level fluctuations, with wave-cut faces and ripples showing evidence of sediment transport away from each face.

[49] *Id.* at p. 42 ("boat waves and pool fluctuations play a role in the creation of undercuts that begin the erosion sequence")
[50] Field (2007)

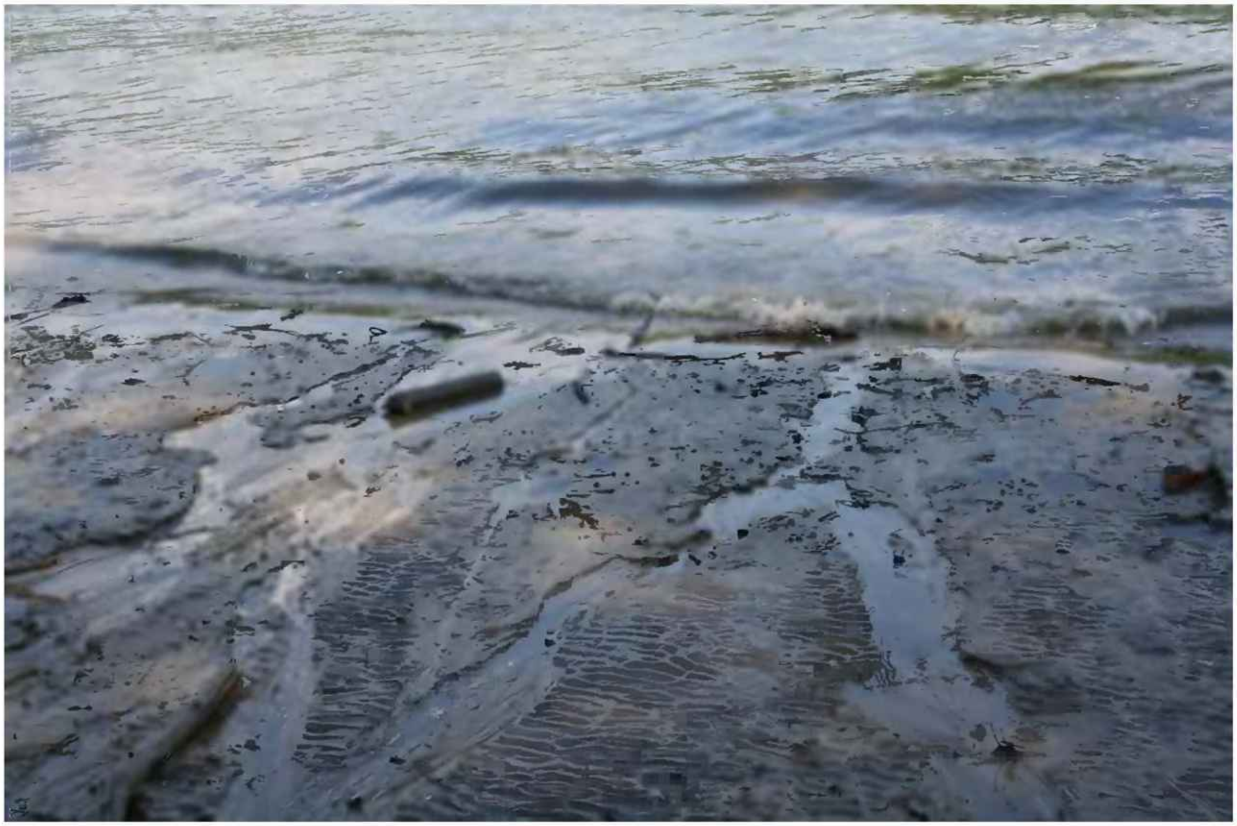

Figure 43: Seepage channels forming across a beach face.

Figure 4. Figure 43 from Field Geology Services's 2007 Fluvial Geomorphology Study of Connecticut River[51] shows erosion that is consistent with changing water levels forming and eroding beaches along a sandy bank of the TFI. In this case, Field Geology Service identified seepage channels, clearly transporting sediment away from the beach. FirstLight has denied the importance of this process and not included it in BSTEM modeling. However, its documentation has not been thorough in the reservoir.

Despite the well-reasoned and reasonable conclusions by these scientists, FirstLight has consistently contradicted independent, expert conclusions and does not acknowledge that dam operations most likely contribute to erosion in the reservoir. Instead, FirstLight has repeatedly attributed erosion to other factors and downplayed the amount of erosion occurring.

Most recently, the Erosion Causation Study is the latest report by FirstLight that selectively interprets or overinterpret results that downplay erosion in the TFI in general, and erosion attributable to Project operations specifically. FirstLight has used a proprietary software to claim that erosion is primarily due to natural flood flows through the reservoir. This computer software, BSTEM, attempts to model the erosion conditions in the reservoir. Although modeling of such dynamic systems is well known to be highly uncertain, particularly absent rigorous site-specific calibration and testing[52], FirstLight claims a certainty from the model that is not

[51] Field (2007)
[52] Klavon, K., Fox, G., Guertault, L., Langendoen, E., Enlow, H., Miller, R., & Khanal, A. (2017). Evaluating a process-based model for use in streambank stabilization: insights on the Bank Stability and Toe Erosion Model (BSTEM). Earth Surface

credible. There are large uncertainties in its inputs and many "dial settings" that allow the model to be adjusted to achieve a range of results. The results do not sufficiently rule out the possibility of erosion due to water level fluctuations, which has been raised by many scientists, documented by landowners[53], and is supported by field observations from decades of monitoring in the reservoir.

More recently, Princeton Hydro[54] provided a systematic critique of the FirstLight Erosion Causation Study, particularly its reliance on BSTEM, which FirstLight has used to deny responsibility of erosion. The parameterization of BSTEM, and thus its results, has been similarly critiqued by an independent scientist for the US Department of Agriculture[55] and several peer-reviewed scientific papers, summarized by Klavon (2017)[56]. Each of these independent experts find serious problems with the methods and results produced by BSTEM, which calls into question any interpretations by FirstLight.

1.4 Report objectives

In the remainder of this report, I summarize the ongoing erosion that is likely at least partly attributable to Project operations in the Turners Falls Impoundment (section 1). Much of this erosion analysis builds on past work by scientific experts and peer-reviewed literature about reservoir shoreline erosion. It also relies heavily on observations made by FirstLight and its consultants. For decades, scientists have presented such evidence, showing that FirstLight operations are most likely contributing to excess erosion in the TFI while acknowledging that the complexities in the reservoir prevent detailed, specific attribution to FirstLight, recreational, and natural process.

In contrast, FirstLight and its consultants have claimed to be *certain* that Project operations are not meaningfully contributing to erosion in the TFI. As a result, in Section 3 I also address the failings of the BSTEM model, which FirstLight claims shows they are not the "dominant, primary cause of erosion" [57] anywhere in the impoundment and only a "contributing cause of erosion" along 1.5 miles of shoreline (out of 44 miles) [58]. Absent accurate, repeatable *documentation* of the erosional processes they favor, this modeling is not credible.

Processes and Landforms, 42(1), 191-213. p. 191 ("The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters.")

[53] Landowners and Concerned Citizens for License Compliance Connecticut River, Turners Falls Pool, Massachusetts. August 2nd, 2012.

[54] Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

[55] Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p.

[56] Klavon, K., Fox, G., Guertault, L., Langendoen, E., Enlow, H., Miller, R., & Khanal, A. (2017). Evaluating a process-based model for use in streambank stabilization: insights on the Bank Stability and Toe Erosion Model (BSTEM). Earth Surface Processes and Landforms, 42(1), 191-213. p. 191 ("The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters.")

[57] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume I – Executive Summary and Summary. p. vii.

[58] *Id*. p. viii

2. Evidence of erosion in the Turners Falls Impoundment

2.1 Summary

Evidence from the Turners Falls Impoundment (TFI) indicates that FirstLight operations likely contribute to erosion in the TFI. Project operations set the likely height of erosional impacts, contribute to processes that directly cause erosion on banks in the impoundment, and most likely prevent natural recovery and re-stabilization from occurring.

This evidence, summarized both here and in past studies[59,60], consistently points toward FirstLight operations contributing to anomalously high erosion rates throughout the impoundment. These erosional processes occur in five primary ways, which are all interrelated and very likely attributable to FirstLight operations, as supported by direct observations in the TFI, past reports from various stakeholders, and decades of peer-reviewed research on erosion.

One note: these erosion mechanisms resemble closely the proposed 'sequence of erosion" proposed by Field (2007)[61]. They align with clearly established geomorphic processes on shorelines, specifically of reservoirs with fluctuating water levels.

2.1.1 Overview of likely erosion mechanisms or "sequence of erosion" in the Turners Falls Impoundment

1. Operations of the TFI reservoir (pumped storage and conventional hydro) cause water level in the impoundment to be repeatedly raised and lowered. Water levels are also subject to natural variability and upstream projects, including Vernon Dam immediately upstream. The year-round undercutting of the bank from sub-daily river fluctuations may decrease upper slope stability. Trees are undermined throughout the reservoir, indicating further reduced stability in a feedback loop.
2. Vegetation likely cannot colonize because of repeated inundation by fluctuating water in the impoundment during the growing season.
3. Daily FirstLight fluctuations likely saturate banks and toe slopes, reducing internal strength and accelerating erosion.
4. Moderate and flood flows transport eroded sediment away from toeslopes and bars, destroying beaches that might stabilize bank erosion.
5. Overbank and bank deposition is limited, so net change *on both banks* is erosional.In a river in equilibrium, erosion occurs but is approximately balanced by deposition on the opposite bank. In the TFI, upstream flood control and sediment trapping (not by FirstLight), sediment settling in the reservoir, and loss of vegetation due to FirstLight operations likely limit such balancing deposition.

Each of these erosion mechanisms is likely directly caused or accentuated by FirstLight operations. There is no doubt that flood flows contribute to erosion in the Turners Falls Impoundment, as they do in all natural rivers. However, FirstLight operations likely also

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[59] Field (2007)

[60] Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

[61] Field (2007) p. 11 ("FRR methodology cannot be used to make comparisons of erosion from year to year")

contribute to erosion and allow flood flows to be more erosional than they would be in a natural river.

Rather than taking steps to mitigate ongoing erosion in the TFI, FirstLight claims that it will continue similar fluctuation of water levels and has left open the possibility of increasing fluctuations.

FirstLight justifies this potential change by claiming[62]:

> "FirstLight's proposed changes in operations under the Agreement do not change the basic finding that FirstLight's operations are an insignificant cause of bank erosion in the TFI. Because FirstLight's operations under the Agreement will not be a significant cause of erosion, it is not within FirstLight's control to prevent it; and neither should FirstLight be responsible for remediating it." (p. 14)

The magnitude of erosion attributable FirstLight operations ("significant" vs. "insignificant") cannot be credibly quantified due to the lack of rigor in FirstLight monitoring[63,64,65] and unacknowledged uncertainties in the BSTEM model approach[66]. However, FirstLight studies *do* document numerous field instances of bank erosion that is likely ongoing due to, and/or accentuated by, FirstLight operations. Much of the erosion documented in each study commissioned by FirstLight is consistent with regular, repeated cycles of inundation and exposure of river bars and banks that occurs at least partly as a result of Project operations. An increase in the frequent range of this inundation would likely increase erosion in the TFI. FirstLight's arguments that it will not shows an unscientific and unsupported degree of certainty about uncertain processes, while also defying evidence in its own reports and decades of geomorphology and reservoir study.

Below, each point is explained and evidence for project operation contribution to these erosional processes is presented. In each case, the findings show that the BSTEM model is not modeling the full suite of erosional processes occurring in the Turners Falls Impoundment. The BSTEM model and FirstLight reports consistently discount or ignore erosional processes that can be attributed to FirstLight operations. BSTEM is not adequately capturing erosion processes in the TFI, nor is uncertainty reported in its presentation; accordingly, its results cannot be treated as definitive.

Several scientists have described these erosion processes and demonstrated critical failings in scientific methods and inference made by FirstLight consultants, including the most recent

[62] Response of Firstlight MA Hydro LLC And Northfield Mountain LLC to Comments on Flows and Fish Passage Settlement Agreement. June 12, 2023. 49 p. p. 14.
[63] Field (2007) p. 7 ("Many areas of additional study are necessary including surveys of erosion using a systematic and explicit method for mapping the types of erosion present in order to eliminate artifacts in the mapping process.")
[64] Field (2012) p. 11 ("FRR methodology cannot be used to make comparisons of erosion from year to year")
[65] Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. p. 5 ("Large Portions of the Turners Falls Impoundment Remain Unassessed")
[66] Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

BSTEM Model. These include two reviews since 2010 [67,68], which are both rigorous and document failings in erosion attribution by FirstLight.

2.2 Repeated undercutting of the bank decreases upper slope stability. Trees are undermined, further reducing stability in a feedback loop

FirstLight claims several times that the upper slopes of river banks are not wetted by their operations, and only experience erosional flows during floods. However, it is clear from FirstLight's reports that Project operations regularly inundate steep banks along the TFI reservoir shoreline. Plots of water surface elevation show as much as 6 ft of daily water surface elevation changes during just one example period[69]. In addition, pumping and release occurs during high-flow events. Fluctuations are thus superimposed on larger fluctuations in the hydrograph, potentially amplifying the erosional effects of those events (Figure 1, Figure 5).

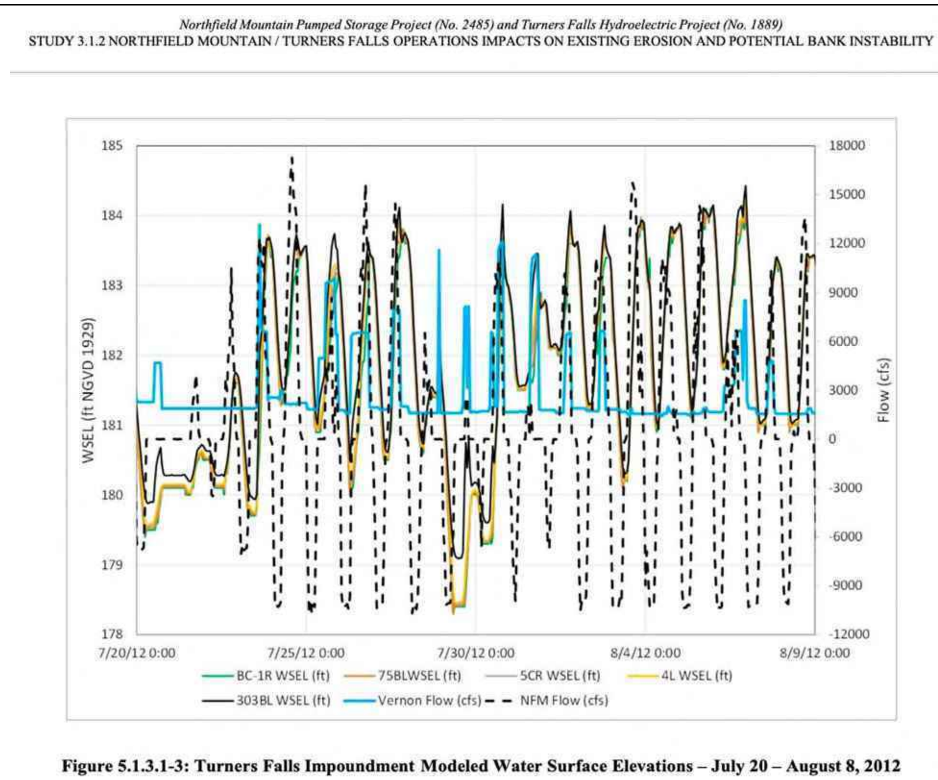

Figure 5. A plot of modeled water surface elevation from Study 3.1.2[70] shows up to 6 feet of elevation variation in an approximately weeklong stretch, with similar elevation differences at several cross-section locations in the reservoir.

[67] Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

[68] Field (Field Geology Services), 2012, Rebuttal of FirstLight's Response to Landowner Filing: Unpublished report prepared for Landowners and Concerned Citizens for License Compliance Turners Falls Pool, 12 p.

[69] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Figure 5.1.3.1-3: Turners Falls Impoundment Modeled Water Surface Elevations – July 20 – August 8, 2012

[70] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Figure 5.1.3.1-3: Turners Falls Impoundment Modeled Water Surface Elevations – July 20 – August 8, 2012

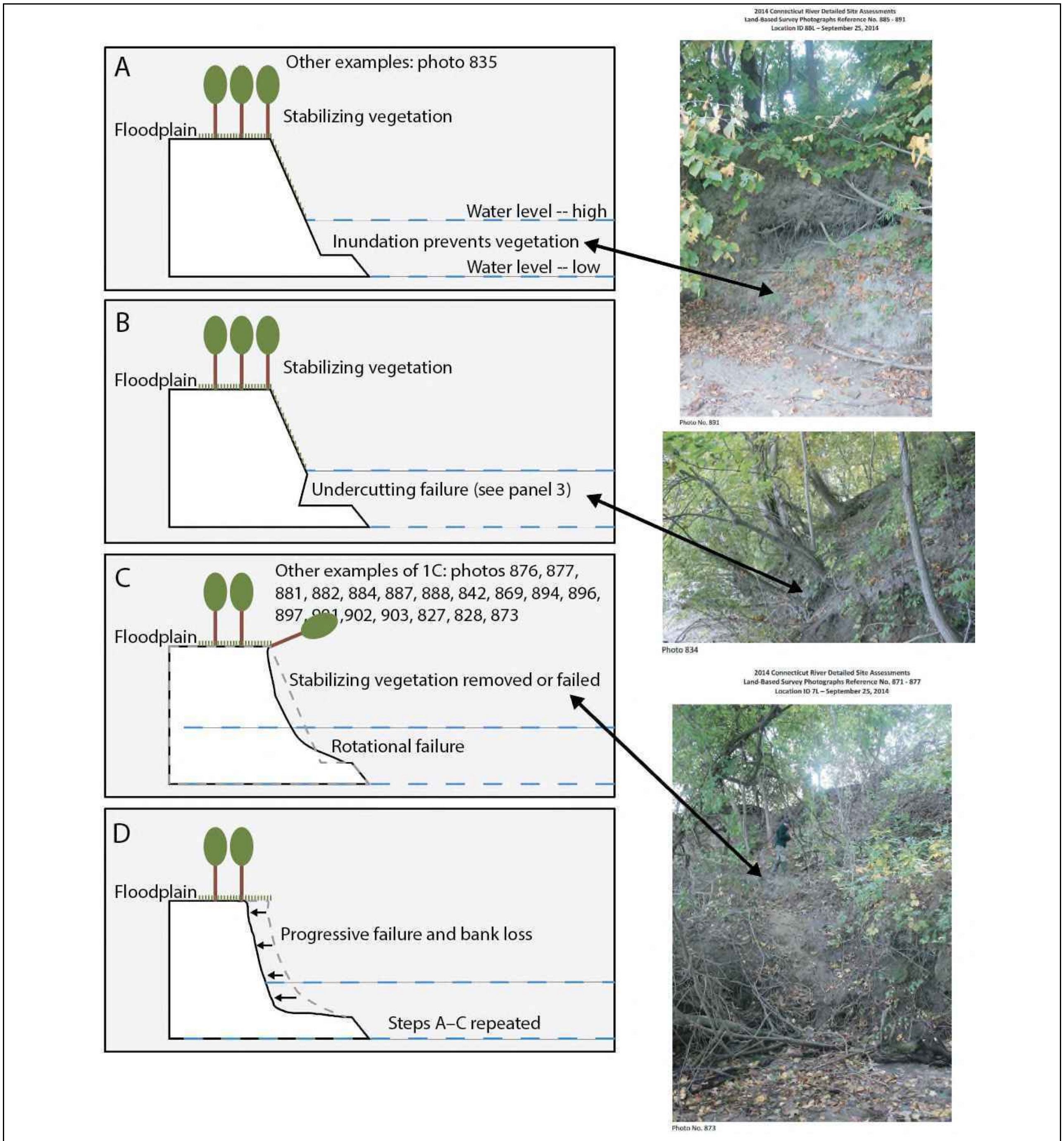

Figure 6. A diagram showing mechanisms for erosion in the Turners Falls Impoundment, specifically illustrating how water fluctuations could contribute or cause erosion of steep banks. Images from the FirstLight Erosion Causation Study on the right illustrate the erosional landforms in the diagram. Photographs are from the Study 3.1.2, Volume III, Connecticut River – Turners Falls Impoundment Riverbank Detailed Site Assessments.

Figure 6 illustrates a sequence of bank undercutting that is likely accentuated by Project operations continually fluctuating water levels up and down, saturating the bank sediments and exposing them to currents and wave action (Figure 6, A). Sediment is eroded when water levels are high, transported away from river banks, tree roots, and beaches. When the reservoir level drops, the undercut sediment may also fail as the water's confining pressure is removed. It is also more susceptible to wave and current erosion because it has been saturated. In each case, because sediment buttresses the banks, its removal destabilizes those banks (Figure 6, B). Community members have observed these processes occurring in the reservoir[71]:

> "When the boats go by, the erosion is worse because the river's been lowered to the point where there are drop-offs from the erosion, so when the waves hit, it hits the drop off and pulls the mud down. This is wreaking havoc. ***Those of us who live on the river, we see it on a daily basis***." (p. 2) (emphasis added)

As the community members have observed, this process may occur almost daily in some places on the TFI shoreline during reservoir storage and release. Vegetation is sporadic in the lower banks, where undercutting is very common, limiting the cohesive strength of bank sediments (see Section 2, below). Undercutting of the banks can lead to failure during rain events and snowmelt periods, as has been observed by landowners[72]:

> "Those of us who live on the river, we see the erosion. We see it every winter, when they lower it down...(with) the mud literally falling into the river." (p. 2)

Erosion of this nature has been documented at other reservoirs, including in similar temperate climates where reservoir bank substrate is glacial sediment. Reid (1985)[73] found that:

> "During high pool levels, waves pound that area, exposing this sand unit, resulting in rapid undercutting of the overlying till. Upon lowering of the pool level, the undercut till quickly fails". (p. 783)

Field evidence presented in the Erosion Causation Study[74] shows similar processes are active in TFI. The combination of fluctuating reservoirs and wave and current erosion (driven by flow, wind, and/or boat wakes) leads to undercutting of steep, unvegetated banks. Upper slope destabilization consistent with consistent lower bank erosion and undercutting is documented in numerous photographs in the Full River Reconnaissance[75] (see photos 876, 877, 881, 882, 884, 887, 888, 842, 869, 894, 896, 897, 901,902, 903, 827, 828, 873) (Figures 6–9). Three examples are provided here, showing undercutting and undermining of bank-stabilizing tree roots (Figure 7), and high bank failures above evidence of lower bank undercutting (Figure 8 and Figure 9).

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[71] Landowners and Concerned Citizens for License Compliance Connecticut River, Turners Falls Pool, Massachusetts. August 2nd, 2012. p. 2
[72] *Id*.
[73] Reid Jr., J. R. (1985). Bank-erosion processes in a cool-temperate environment, Orwell Lake, Minnesota. Geological Society of America Bulletin, 96(6), 781-792.
[74] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.
[75] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.

2014 Connecticut River Detailed Site Assessments
Land-Based Survey Photographs Reference No. 885 - 891
Location ID 8BL – September 25, 2014

Photo No. 887

Figure 7. An image from the FirstLight Study 3.1.2, Volume III Appendix D (pdf page 200) shows undercutting of a lower bank has stripped vegetation, removed vegetation under tree roots, and undermined sediments on the upper bank.

2014 Photo: Montague

Observations: Erosion has been ongoing at this site for quite some time and has been recommended for preventative maintenance and/or bank stabilization work in the 2013 FRR report.

Figure 8. An image from the FirstLight Causation Study Volume II shows minimal protection by a beach of a slope failure in the reservoir disturbance zone.

Observations: This site has been eroded for some time and was recommended for preventative maintenance and/or bank stabilization work in the 2013 FRR report.

Figure 9. An image from the FirstLight Causation Study Volume II shows that undercutting erosion can occur on steep banks even when there is a well-developed beach protecting them.

FIG. 2. Erosion in frozen lacustrine clay at site 1.

Figure 10. An image from Southern Indian Lake in Manitoba, Canada shows erosion that strongly resembles erosion depicted in images of the shoreline of the Turners Falls Impoundment.[76] Researchers attributed Southern Indian Lake erosion partly to inundation and devegetation of the banks, which combined to reduce sediment cohesion.

Other researchers have reported on reservoir shoreline erosion attributable to lack of bank cohesion that strongly resembles erosion at TFI (Figure 10). At Southern Indian Lake, a dam-regulated reservoir in Manitoba, shoreline substrate, although frozen, is unconsolidated glacial sediment similar to that in the TFI, with grassy vegetation and trees providing some strength[77]. Researchers found that wave energy and inundation were found to cause an erosional feedback loop, with an anticipated 35 meters of horizontal erosion forecast before bedrock would be encountered. The researchers observed the inundation of frozen sediments, after which “bank materials become oversaturated with water and form a slurry-like mixture. The partially thawed materials flow out” and are subsequently “completely removed during storms”[78]. The processes and feedback loop described here are very similar to the “sequence of erosion” described by Field Geology Services (2007) [79] and here in the five-step erosion feedback loop.

[76] Newbury, R. W., & McCullough, G. K. (1984). Shoreline erosion and restabilization in the Southern Indian Lake reservoir. Canadian Journal of Fisheries and Aquatic Sciences, 41(4), 558-566. p. 561 Fig. 2.
[77] Newbury, R. W., & McCullough, G. K. (1984). p. 561 Fig. 2.
[78] Newbury, R. W., & McCullough, G. K. (1984). p. 561 (“melting occurs below and slightly above the water surface.”).
[79] Field (2007) p. 11 (“FRR methodology cannot be used to make comparisons of erosion from year to year”)

In addition, FirstLight downplays the magnitude of existing fluctuations in the TFI. For all of the days (other than May – November 2010) that were modeled, they report that 15% of the daily water surface elevation variations were less than 1.6 feet and about 95% were less than 4.0 feet. However, this means that 85% of days have > 1.6 feet of variation – constant rise and fall of water level consistent with erosion on beaches, bars, and steep banks that are not protected by beaches. The 5% of days with more than 4.0 feet of elevation change likely accentuated erosion further.

2.3 Vegetation cannot colonize because of repeated inundation during the growing season. The second component of the erosion feedback loop is the removal of vegetation along beaches, benches, and steep banks of the reservoir shoreline by frequent inundation. In the Connecticut River watershed, erosion is generally low compared to other regions[80] despite abundant unconsolidated glacial sediments in the river valley. The general stability of riverbanks in the Connecticut River watershed, and New England generally, is mostly explained by the presence of abundant stabilizing vegetation in the region, which has approximately 80% forest cover and pervasive riparian vegetation.

Many plant species not suited to water are threatened by any inundation, and substantial loss of vegetation due to inundation in the reservoir disturbance zone has been documented along other reservoir shorelines[81]. FirstLight's own HEC-RAS modeling shows that flows rest on the upper bank between 1–22% of the time for selected reaches—10–20% of the time is substantial and consistent with numerous images in the FirstLight Full River Reconnaissance, as well as the 2007 Field Report, showing bare tree root balls, devegetated banks and bars, and undercut slopes[82] (Figure 11).

Figure 11 shows the cycle of devegetation that can occur from frequent inundation. As FirstLight stated in their Full River Reconnaissance in 2008[83]:

> "Vegetation plays a significant role in the stability of riverbanks. Vegetation colonizing and expanding onto a riverbank where vegetation did not exist or was sparse indicates that the riverbank is becoming more stable. As vegetation expands and matures, it offers greater protection against erosion."

Vegetation is not able to colonize banks in the reservoir disturbance zone due to unsuitable conditions. Lack of vegetation prevents sediment trapping, leading to beach and bank instability and further erosion. The absence of root cohesion also limits shoreline resistance to erosion.

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80 Rainwater, F.H., Stream Composition of the Conterminous United States, USGS Atlas HA 61, Washington, D.C., 1962.

81 Bao, Y. et al.(2018). p. 136 ("Influenced by this new hydrological regime, the abundance of the original plant species within the [Disturbance Zone] has been drastically reduced"); Fig. 7.

82 FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.

83 FirstLight Full River Reconnaissance. 2008 TURNERS FALLS POOL, CONNECTICUT RIVER. p. 27.

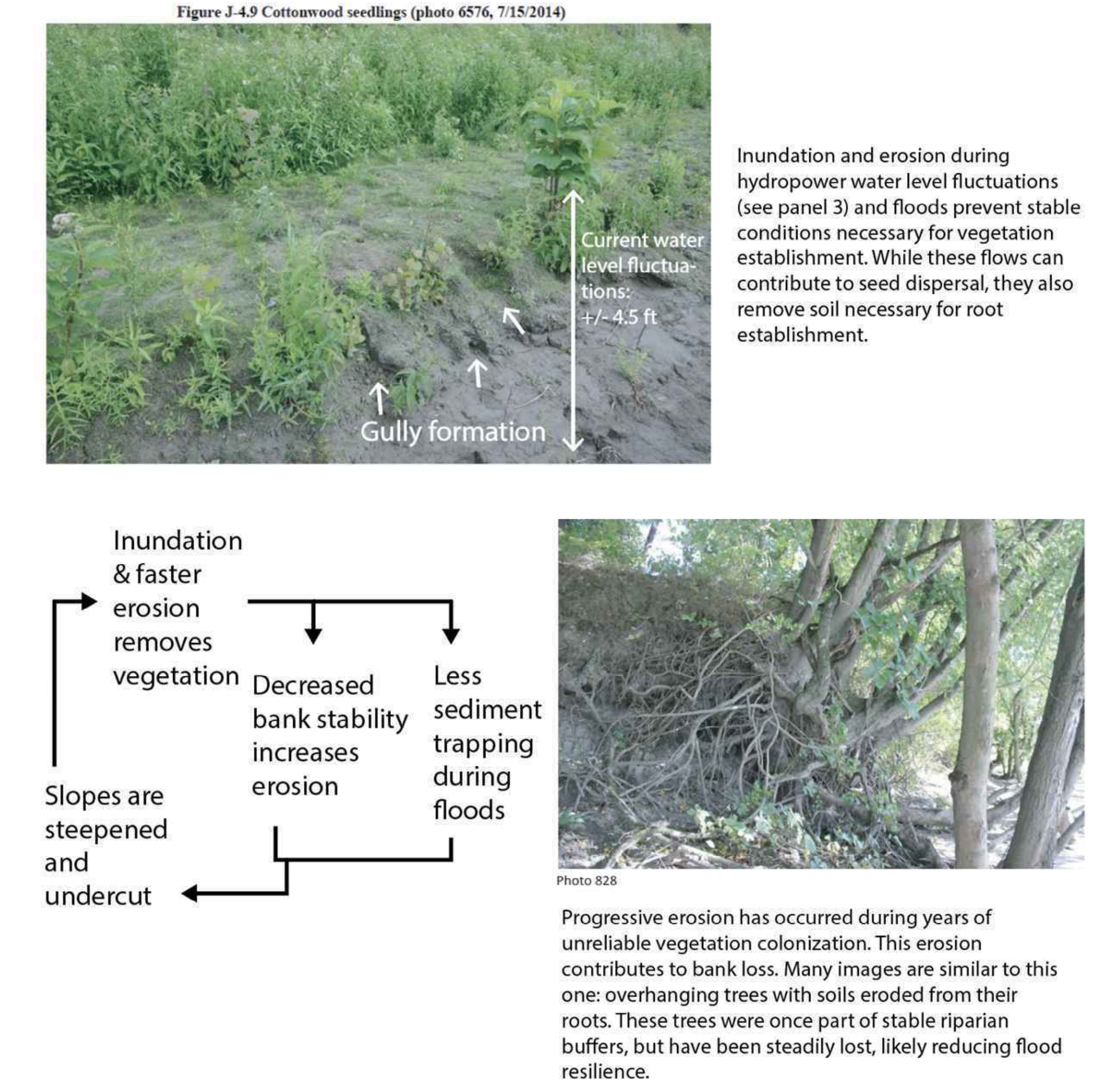

Figure 11. A diagram showing the erosion feedback loop that occurs with devegetation. Inundation removes vegetation or prevents vegetation from successfully growing. Upper[84] and lower[85] images are from FirstLight surveys; annotations and text are from this report. Lack of vegetation lowers root-based cohesion of the banks and traps sediment less effectively, leading to further destabilization and heightened erosion. This diagram is illustrated by ongoing, linked erosional and devegetation processes in the Turners Falls Impoundment, each of which is consistent with erosion caused or aided by fluctuating water levels due to Project operations.

[84] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix J.
[85] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.

Vegetation that does colonize steep reservoir banks during the summer may not persist through the late fall and winter, leaving slopes susceptible to erosion especially during those months. Even where trees have maintained root structure, frequent inundation likely limits understory growth, allow rapid erosion and progressive undermining of larger trees. Lack of understory was documented at least at two sites by FirstLight and reported in the Erosion Causation Study[86]:

> "It should be noted that although the tree cover is 95% and 70% at sites 75BL and BC-1R respectively, the understory data at these locations indicates a high percentage (80%) of the soil under the trees is bare. In these cases, although the trees are contributing to root-reinforcement within the banks themselves, there is less surface protection from hydraulic forces." (p. 4-113)

However, in FirstLight's response to the Princeton Hydro letter, they defend the BSTEM model inputs by directly contradicting their own field observations, saying "BSTEM was run with the appropriate amount of vegetation according to conditions at the start of the simulation. These were based on photos. ***Most of the banks were vegetated to some degree***"[87] (emphasis added). The banks are only vegetated sporadically, and are mostly unvegetated in many of the critical erosion locations. The inputs to BSTEM are thus both flawed and incomplete, casting doubt on its results.

Revegetation is also a primary factor in the recovery of destabilized slopes. In the case of bank failure caused by flooding, undercutting, freeze-thaw processes, or other causes, revegetation can stop the sequence of erosion, preventing the erosion feedback loop from running unchecked. In its analysis of erosion sources, FirstLight does not account for how the lack of stabilizing vegetation prevents banks from recovering once they are perturbed. Similarly, BSTEM only uses a one-time vegetation parameter. Because it does not seem as though vegetation is allowed to vary or evolve during the model, BSTEM is not accounting for critical changes in bank cohesion and thus erodibility that may be attributable to FirstLight Project operations.

2.4 Daily FirstLight fluctuations likely saturate banks and toe slopes, reducing internal strength and accelerating erosion.

2.4.1 Fluctuations can cause sapping, rilling, and gullying in bank sediments

As water levels rise and fall over unconsolidated sediments, progressive erosion can occur on beaches, bars, and banks – even those that are not as steep as the undercut banks in (Section 1). Sapping occurs when confining pressure from surrounding water is removed from saturated sediments. Resulting flow through the sediments can "sap" the bank of its water and sediment, transporting eroded sediment toward the receding water. Rilling, gullying, and knickpoint propagation can also occur. These processes occur in natural circumstances by runoff over the ground during precipitation or melting events. The erosional power of this runoff is focused where the bank or beach slope is locally steep (Figure 12).

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[86] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 4-113

[87] FirstLight Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary. January 17, 2017. p. 2

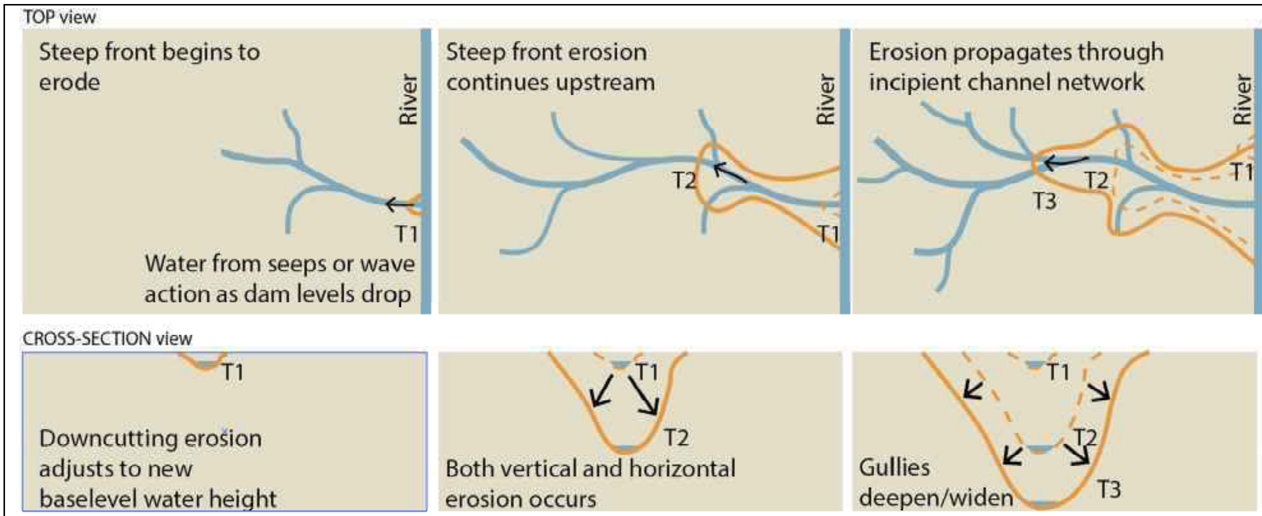

Figure 12. Schematic of erosion by knickpoint propagation, which can focus erosion at a locally steep zone, which propagates uphill. The scale of these features can vary from centimeters to tens of meters.

Sapping and local oversteepening of the bank can occur during rapid water level recession, which is often called “baselevel fall”. Kaczmarek et al., (2016) found evolution of gullies to be strongly related to reservoir water fluctuations[88]:

> “In periods of high water levels, due to coastal erosion of the bluff, the terminal, flattest parts of the gully were destroyed, which triggered their further development. In contrast, declining water level in the reservoir is a cause of intensified deep erosion in the gully bottom, which consequently initiates backward erosion at the bottom of these forms.” (p. 937)

Gullying, rilling, and knickpoint erosion are part of strong erosional feedback loops, as the locally oversteepened point progressively moves uphill, cutting farther into the bank. This process is illustrated in Figure 12 (diagram) and Figure 13 (annotated photograph), which show the process of gully development as it appears to occur along the shoreline of the TFI.

[88] Kaczmarek et al. (2016)

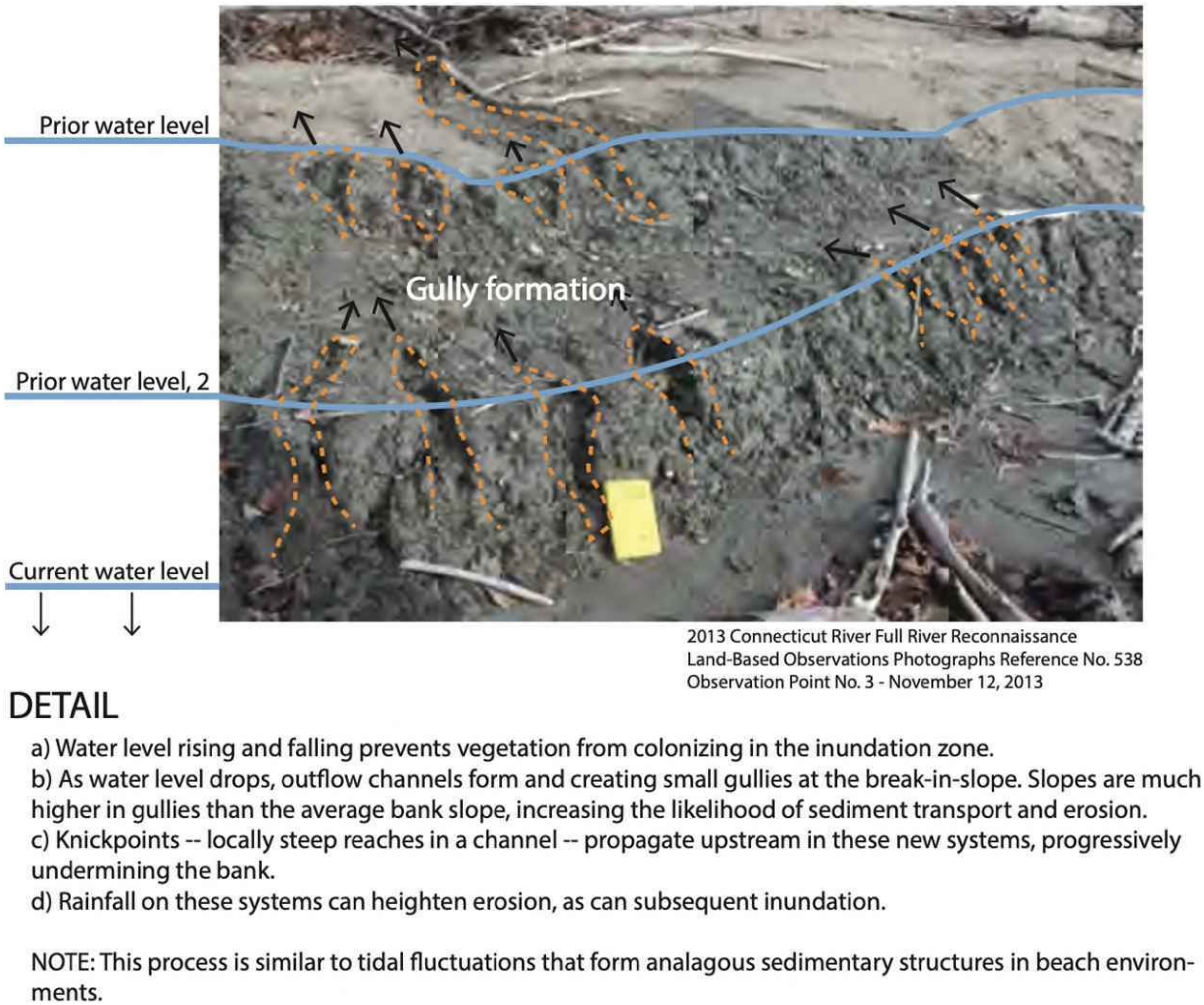

Figure 13. An annotation of an image from the FirstLight Full River Reconnaissance Study 3.1.1 showing gully formation and likely knickpoint propagation. This appears to be occurring on a beach or low bench, where different water levels have allowed wave-cut vertical slopes to form. Notches in these slopes provide the initial node for knickpoint erosion (see Figure 12).

The "FL Response to Study Comments" states: "BSTEM results found that ***minimal to no erosion occurs on the flat, beach-like lower bank*** that could instigate erosion of the upper bank during low flow periods when hydropower operations control flow and water levels in the TFI."

However, numerous photographs provided by FirstLight consultants in the Erosion Causation Study directly contradict this claim that there is minimal erosion in the flat, beach-like lower bank. This includes the photograph in Figure 13, as well as photos 583 (Figure 14), 638 (Figure 15), 698 (Figure 16), 709 (Figure 17), 833, 834, 882, 796[89], J-4.1 (Figure 18), and J-4.9[90] from

[89] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.
[90] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix J -- Ice Data And Supplemental Information.

the 2017 FirstLight Erosion Causation Study. These photographs show significant erosion, including rilling, bank failure, devegetation, and winnowing of sediment in the lower bank zone. They also include successive benches on beaches, each showing gullying that was likely initiated by dropping water levels. As was noted by the Princeton Hydro review[91], ***the fact that the BSTEM model failed to capture sediment transport or significant erosion in these lower bank zones indicates its failure to capture critical erosion dynamics in the TFI.***

These landforms and features are not all necessarily caused by Project water level fluctuations. However, they are clearly consistent with erosion by water level fluctuations and occur at elevations set by Project-determined water levels. Gullying has been consistently identified as a result of shoreline erosion related to changing water levels[92]. In Poland, erosion in glacial sediments similar to those in the TFI caused gullying on a variety of scales, with development strongly resembling gullies documented by FirstLight in the TFI[93]:

> "…gullies disturbed the stability of the bluff by developing in the easily degraded sandy-silty de-posits, their dense network deeply indents the bluff and disrupts its continuity. Their development is cyclic and ***strongly related to water level fluctuations in the reservoir***." (p. 932) (emphasis added)

This passage highlights the challenges with gully erosion if it is left unchecked. The local steepening of slopes continues to propagate into the bank and perpetuate the cycle of erosion being outlined here. Especially absent stabilizing vegetation (See Section 2) or the presence of bedrock[94], this propagation can also contribute to undercutting of steeper banks or undermining of upper banks (See Section 1), leading to mass failure.

Significant erosion at or near the low-flow water line is shown in the following photos and many others. In Figures 13–16, low, steep banks on several beaches show evidence of notching, which can be an initiation point for knickpoint erosion. In several instances, these steep banks have multiple wave-cut elevations, consistent with water levels fluctuating and thus focusing erosion at a certain beach elevation.

2.4.2 High water levels can exacerbate bank erosion during spring snowmelt

Saturation of sediments along the reservoir shoreline, especially given the lack of vegetation and root cohesion, also increases bank susceptibility to erosion during the spring snowmelt period. Freeze-thaw processes can physically wedge apart the banks, in processes similar to the ones that cause frost heaves in roads. Water that percolates into sediment pore space freezes and expands, wedging apart sediment. This can either cause erosion directly or make extra space for more

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[91] Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. p. 13 ("does not seem to support the conclusion that the WSE fluctuation is almost always on the lower bank, which they have stated is bedrock dominated. If in fact, the WSE fluctuation is not all limited to the lower bank, as seems to be demonstrated in Figure 5.4.1.1-4, then the study's concluding assumptions may not be valid.")

[92] Kaczmarek et al. (2016) p. 937 ("In periods of high water levels, due to coastal erosion of the bluff, the terminal, flat- test parts of the gully were destroyed, which triggered their further development. In contrast, declining water level in the reservoir is a cause of intensified deep erosion in the gully bottom, which consequently initiates backward erosion at the bottom of these forms.").

[93] Kaczmarek et al. (2016). p. 932 ("Gully development is also partly due to linear erosion, which is particularly important during summer rainstorms. Such forms appear frequently on primary pathways of surface runoff from local microcatchments.").

[94] Newbury, R. W., & McCullough, G. K. (1984). p. 561 Fig. 2.

water to intrude, leading to more "frost wedging" and/or increasing the potential saturation of the banks during the spring. If the bank remains intact through the frost-wedging period, the extra water it retains can cause it to liquefy when the ice melts because of the loss of internal sediment grain contact and cohesion. Each of these well-known erosion processes may be increased by frequent saturation because of Project operations fluctuating water levels in the reservoir.

The FirstLight Erosion Causation Study does not account for freeze-thaw erosion of steep banks. The Causation Study and BSTEM also do not specifically model winter and spring snowmelt conditions, which, due to the processes described above, are both complex and lead to far higher erosion susceptibility than summer in the Connecticut River.

The Erosion Causation Study makes two admissions about freeze-thaw erosion. The first is that these processes have mostly been ignored by FirstLight studies of the reservoir, despite the importance of the snowmelt period in erosion in the Connecticut River watershed[95]:

> "No actual data exist that allows quantification of the effect of freeze-thaw cycles on riverbank stability in the TFI. Freeze-thaw is a natural process that is primarily influenced by weather and climatic cycles and is not considered a primary factor in riverbank erosion processes in the TFI, nonetheless it is likely to contribute to riverbank instability to some lesser degree." (p. 5-271)

As this passage states, although FirstLight acknowledges the likely contribution of freeze-thaw to erosion processes, they have not collected any data about it. As a result, all of the claims about erosion in the TFI are at least partly based on conjecture.

The second admission is the possible importance of ice processes in killing vegetation in the reservoir[96]:

> "Ice both destroys riparian vegetation and limits its establishment and growth as demonstrated by various analyses and observations (and has been quantitatively demonstrated by vegetation demography studies, analysis and computer modeling that ice plays a *"significant, if not dominant"* role in removing and limiting riparian vegetation on the Platte River). As shown in the erosion causation study, riparian vegetation plays a significant role in riverbank stability" (p. 5-303)

Indeed, the contribution of freeze-thaw processes may be substantial. As noted in a similar geologic setting in Poland by a high-resolution study by Kaczmarek et al (2019)[97]:

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[95] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report.

[96] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report.

[97] Kaczmarek, H., Tyszkowski, S., Bartczak, A., Kramkowski, M., & Wasak, K. (2019). The role of freeze-thaw action in dam reservoir cliff degradation assessed by terrestrial laser scanning: A case study of Jeziorsko Reservoir (central Poland). Science of the total environment, 690, 1140-1150.

FRCOG Attachment to FRCOG Comments

> "As a result of the creation and operation of this water body, the formation of bare, nearly vertical cliff faces (which were absent in this location before the impoundment) facilitated the frost processes, and their course is specific, having no equivalent in natural conditions. When the water level is high, the periodical wave erosion at the bluff toe does not allow stabilization of the transformed cliff and long-term accumulation of talus slopes protecting the bluff toe. In such conditions, the whole cliff face is subject to frost processes." (p. 1149)

In this reservoir in Poland, on years when water levels are high and wave action can contribute to erosion, frost action contributes approximately 20% of annual erosion. When water levels are low, frost action contributes approximately 70% of annual erosion.

FirstLight thus acknowledges that freeze-thaw erosion processes may be important contributors to reservoir erosion, that no data have been collected about them, and that riparian vegetation may be destroyed by ice processes related to Project operations. However, these are relegated to a section mostly devoted to abrasion and gouging by ice floes.

In their rebuttal to the Princeton Hydro memo, FirstLight states that "BSTEM results found that the vast majority of all erosion (i.e., hydraulic and geotechnical erosion) occurs at flows greater than 30,000 cfs; this includes both minor particle by particle erosion at the toe of the bank and large mass wasting events."[98] Yet its reports do not sufficiently measure or model erosion during this critical period: snowmelt in the winter and spring. Despite the importance of this period in cold climates, processes associated with snowmelt and freeze-thaw are discounted and/or not measured by FirstLight[99]:

> "it was noted that ice typically does not cause erosion if the ice simply melts in place without significant break-up and if ice floes moving down river causing ice jams and impacting banks do not occur. This is consistent with the findings of the historic analysis conducted and with observations made during field monitoring which occurred during the 2014/2015 winter when much of the TFI was frozen over but the ice simply melted in place during the later winter, early spring of 2015. If, on the other hand, there is significant break-up, ice floes moving down river with the potential for ice jams that are pushed against and scrape along the banks; then such an event could potentially cause erosion and damage to the riverbanks." (p. 5-245)

This ice jam dismissal is cursory and not scientific, but also misses an important point: freeze-thaw processes can contribute to erosion even without ice flows. Landowners along the river have observed such erosion, potentially magnified by boat wakes, as they documented in a 2016 letter[100]:

> "Those of us who live on the river, we see the erosion. We see it every winter, when they lower it down...(with) the mud literally falling into the river… When the boats go by, the erosion is worse because the river's been lowered to the point where there are drop-offs from the erosion, so when the waves hit, it hits the drop off and pulls the mud down. This is wreaking havoc. Those of us

[98] FirstLight Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary. January 17, 2017. p. 2
[99] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 5-245
[100] Bathory letter (2016) p. 2

who live on the river, we see it on a daily basis." When the consultants were asked about this observation, they said that the BSTEM model does not measure this." (p. 2)

In not measuring or considering freeze-thaw processes[101] and ignoring these first-hand observations, FirstLight is potentially missing a major source of erosion, which Project-caused water fluctuations and devegetation could accentuate. Their contribution to erosion in the TFI must be rigorously quantified in order for the claims of erosion timing and attribution to be considered valid.

Figure 14. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 11 showing a wave-cut beach and incipient gullying.

[101] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume I – Executive Summary and Summary. p. vii ("a quantitative analysis of the impact of ice as a cause of erosion was not possible given weather conditions during the monitoring period and available historic data")

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 638 - 641
Observation Point No. 17 - November 15, 2013

Photo No. 638

Figure 15. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 17 showing a wave-cut bench, fallen-down sediment blocks, and incipient gullying.

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 691 – 696, 698 - 699
Observation Point No. 24 - November 16, 2013

Photo No. 698

Figure 16. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 24 showing a wave-cut bench, fallen-down sediment blocks, and incipient gullying.

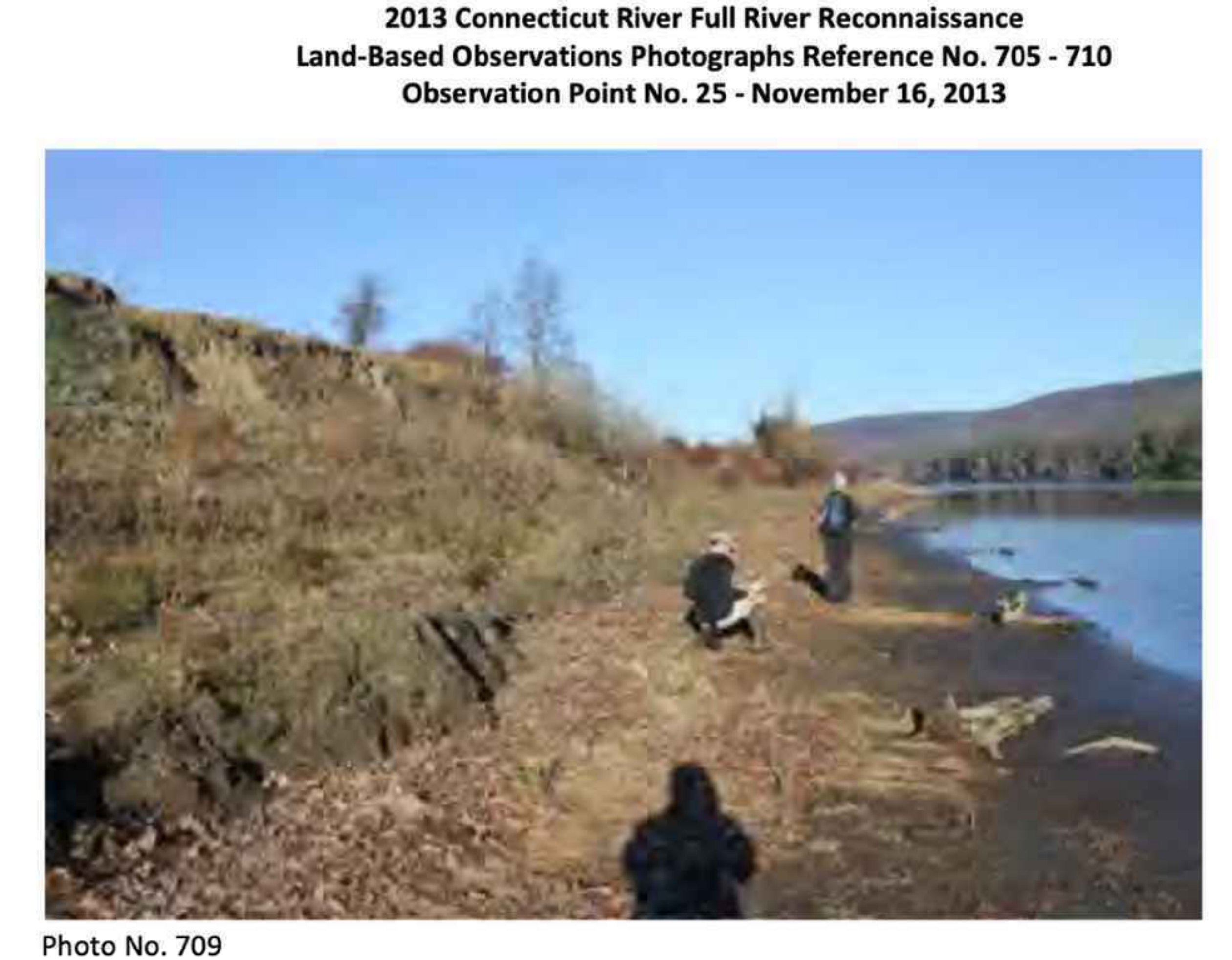

Figure 17. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 25 showing a wave-cut bench, fallen-down sediment blocks, and incipient gullying.

STUDY 3.1.2 NORTHFIELD MOUNTAIN / TURNERS FALLS OPERATIONS IMPACTS ON EXISTING EROSION AND POTENTIAL BANK INSTABILITY

Figure J-4.1 Maple seeds (photo 0202, 9/28/2015)

Figure J-4.2 Location of photo #0202

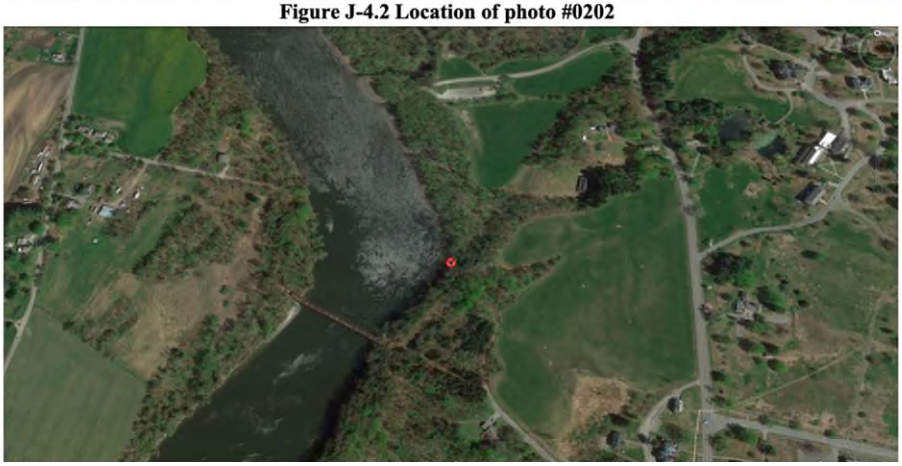

Figure 18. Photograph from the FirstLight Relicensing Study 3.1.2 Appendix J, showing maple seed dispersal but also challenges with vegetation establishment, given frequent inundation and signs of incipient gullying.

2.5 Moderate and flood flows transport eroded sediment away from toeslopes, beaches, and bars.

In the alluvial sections of the Connecticut River watershed, where the Turners Falls Dam is located, the substrate is mostly comprised of erosion-prone sediments and occasional bedrock[102]. Although Connecticut River streams and rivers generally erode slowly, sediment is mobilized during flooding that is endemic to the region. Moderate floods transport sediment that is not

[102] Field (2007)

secured by vegetation[103]. Larger floods can strip vegetation and undermine steep banks, leading to much more erosion. Even without high flows, riverbanks without perennial vegetation can erode as snowpack melts in the spring (typically March and April). However, during the summer low-water season, very little erosion occurs unless a flood occurs.

The role of flood flows in erosion in the TFI is summarized in Figure 19. The annotated images illustrate erosional processes consistent with flood transport. Erosion is a natural process that occurs along all rivers and does not, by itself, indicate compromised river health or processes. However, as is shown in the figure, natural erosion processes may be accentuated by Project operations, including steep or overhanging banks that are prone to erosion and lack of vegetation that can provide cohesion for sediments and slow flood flows, leading to deposition rather than erosion.

[103] Renshaw, C. E., Dethier, E. N., Landis, J. D., & Kaste, J. M. (2022). Seasonal and longitudinal variations in suspended load connectivity between river channels and their margins. Water Resources Research, 58(4), e2021WR031212.

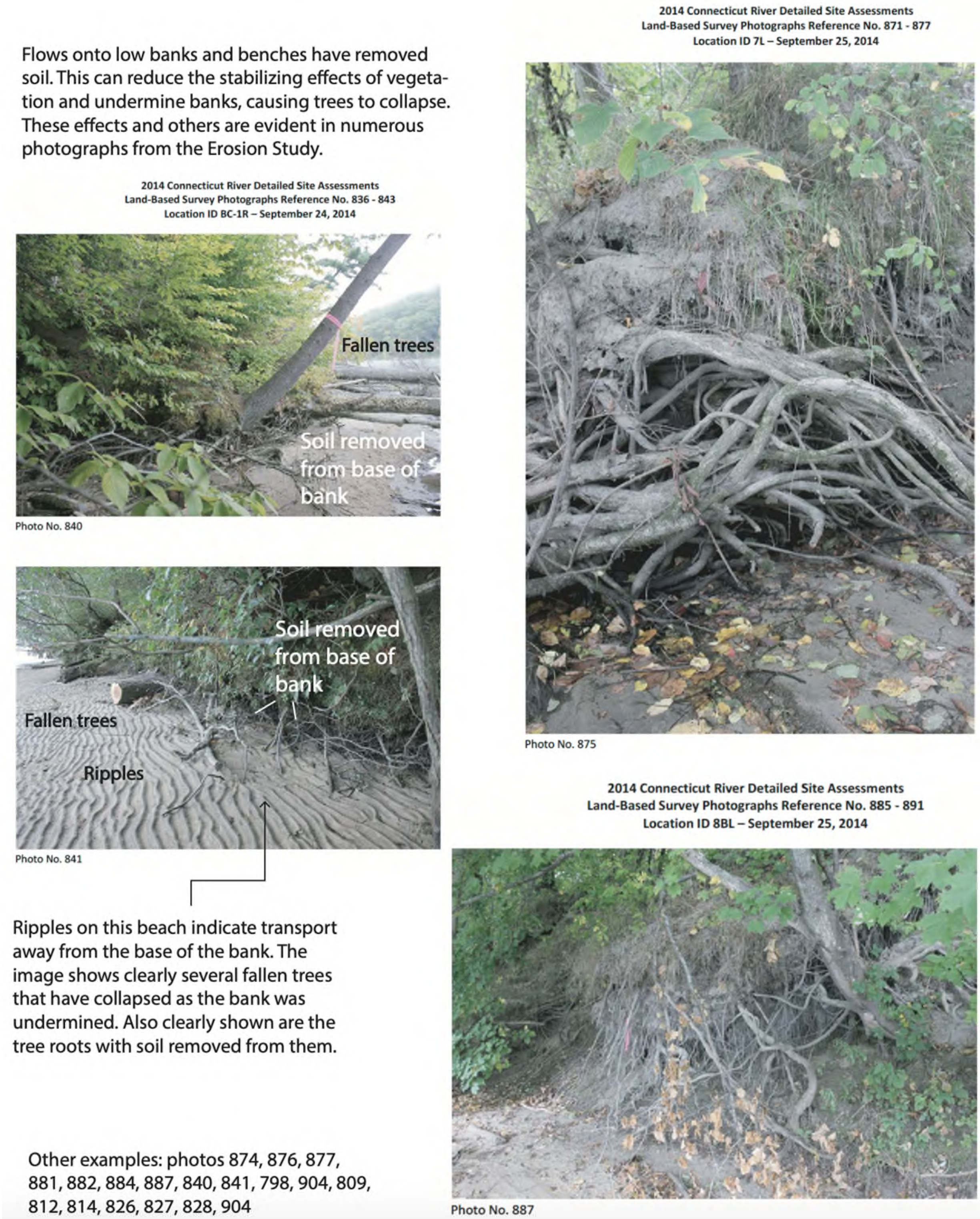

Figure 19. Annotated photographs from FirstLight Relicensing Study 3.1.2, Locations 8C-1R (left), 7L (upper right), and 8BL (lower right), showing evidence of bank undercutting, sediment transport, and vegetation removal that are consistent with Project-caused water-level fluctuations.

In the Turners Falls Impoundment floods likely transport sediment in processes that resemble unregulated river reaches in the region. FirstLight identifies these floods as the sole "significant" or "dominant" cause of erosion in the TFI. Floods may be the largest cause of erosion in the reservoir[104]. However, the geomorphic effectiveness of these floods is likely accentuated by the bank destabilization due to devegetation and saturation described above and in prior reviews by independent scientists[105,106].

The challenge of attributing erosion to flood flows alone was highlighted by Field (2007), who analyzed annual erosion at monumented cross sections in the TFI, relative to flood magnitudes for those years. They found that peak annual discharge did not have a direct relationship with measured erosion[107]:

> "The year with the highest peak discharge since 1990 at the Montague gauge was 1998, a year in which the greatest one-year change in bank position did not occur at any of the cross sections. A careful analysis of rainfall in the area preceding these flood events would be needed to determine if variations in soil moisture can explain the variations in response to these larger flood events. The most significant period of bank recession for several cross sections occurred in the early 1990's with average rates of recession ranging between 1.7 and 4.5 ft/yr during this short time period (Table 5). No high flood discharges were recorded during this period (Figure 4)." (p. 30)

In addition, a raised water level allows floods to erode higher on the bank. Flood water levels will be elevated by the number of feet the water level is raised. Although FirstLight claims that there is minimal effect of Northfield Mountain generation during high flows, they actually report that flood heights are raised by as much as 1.5 feet when generation is at 10,000 cfs and river flows are 30,000; 40,000; 50,000; and 60,000 cfs. This is equivalent to 20–30% additional discharge during some floods[108]. The erosional impact of this additional discharge and flood elevation is not quantified by FirstLight, nor do they claim responsibility for any additional erosion that may occur.

Project operations may also limit recovery. After an erosional event, relatively rapid revegetation can restabilize sediments, preventing chronic erosion. However, the normal recovery processes that follow floods are also consistently disrupted by post-flood inundation/exposure cycles during Project operations, extending the erosional sequence. These are summarized above in sections 1–3.

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104 U.S. Army Corps of Engineers, 1979, Report on Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire and Vermont: Department of the Army New England Division Corps of Engineers: Waltham, MA, 185 p.

105 Field (2007) p. 42. "Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space."

106 Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

107 Field (2007) p. 30.

108 FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 5-30 and accompanying figures.

2.6 Flood control and loss of vegetation limits overbank and bank deposition, so net change is erosional.

Prior to flow regulation by dams, the Connecticut River would regularly overtop its banks, replenishing floodplain sediments. Since flood-control dams were constructed in the mid-20th century, this natural floodplain exchange has been reduced. From 1961–present, the Connecticut River has only had substantial flow (> 3 ft) onto its floodplains 12 times (Figure 20).

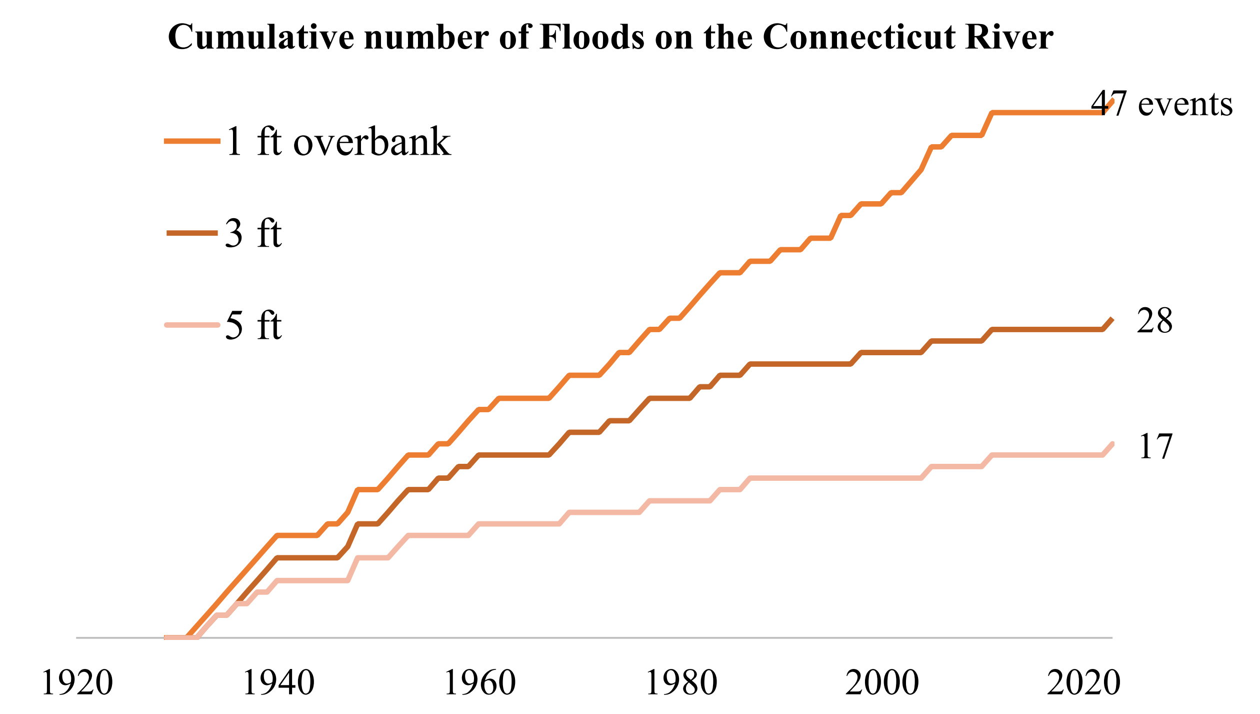

Figure 20. The cumulative number of overbank flooding events on the Connecticut River near Turners Falls has been reduced significantly since flood control began, especially for larger events (3 ft and 5 ft of overbank flooding).

In a normal alluvial reach in equilibrium, erosion is typically balanced by deposition. However, significant bank erosion is present throughout the reach, with only transient deposition on beaches, which are often destroyed by floods in the reservoir[109].

The presence of erosion without evidence of deposition may indicate that Project operations are both contributing to erosion and preventing deposition. Rapid erosion on both banks is also shown in cross sections surveyed by FirstLight. In 2007, Field[110] noted that erosion occurred on both sides of the TFI, as opposed to a typical alluvial river in equilibrium, where erosion on one

[109] Field (2007). p. 32 ("However, if river currents still periodically remove sediment at the base of the bank or remove the accumulating beach sediment entirely, then notching and undercutting at the base of the bank can be rejuvenated and the bank will once again be prone to further erosion."); p. 43 ("The presence of higher beach deposits preserved at the base of the bank, particularly in protected areas, suggest prior beaches have been removed by scour").

[110] Field (2007). Table 5.

bank is approximately balanced by deposition on the opposite bank or bars. This does not appear to be the case in the TFI, where erosion predominates (Figure 21).

The prevalence of these erosional sites are ignored or summarily downplayed by Erosion Causation Study text, particularly the Executive Summary[111]. Considerably more slopes are vertical/overhanging than indicated in the study. Extensive erosion is also shown in the 2016 Hydraulic Study addendum[112]. Evidence of deposition is not presented. Downplaying or underreporting erosion in the TFI is consistent with past reports by FirstLight[113].

[111] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume I – Executive Summary and Summary Report

[112] Relicensing Study 3.2.2 Hydraulic Study Of Turners Falls Impoundment, Bypass Reach And Below Cabot Addendum. March 2016.

[113] Field (Field Geology Services), 2012. p. 6 ("However, the dates on the photographs are in some cases inaccurate and the angles and distances from the bank vary between photographs giving rise to a misleading impression of bank stability when either no change has occurred or the purported change can't be confirmed.")

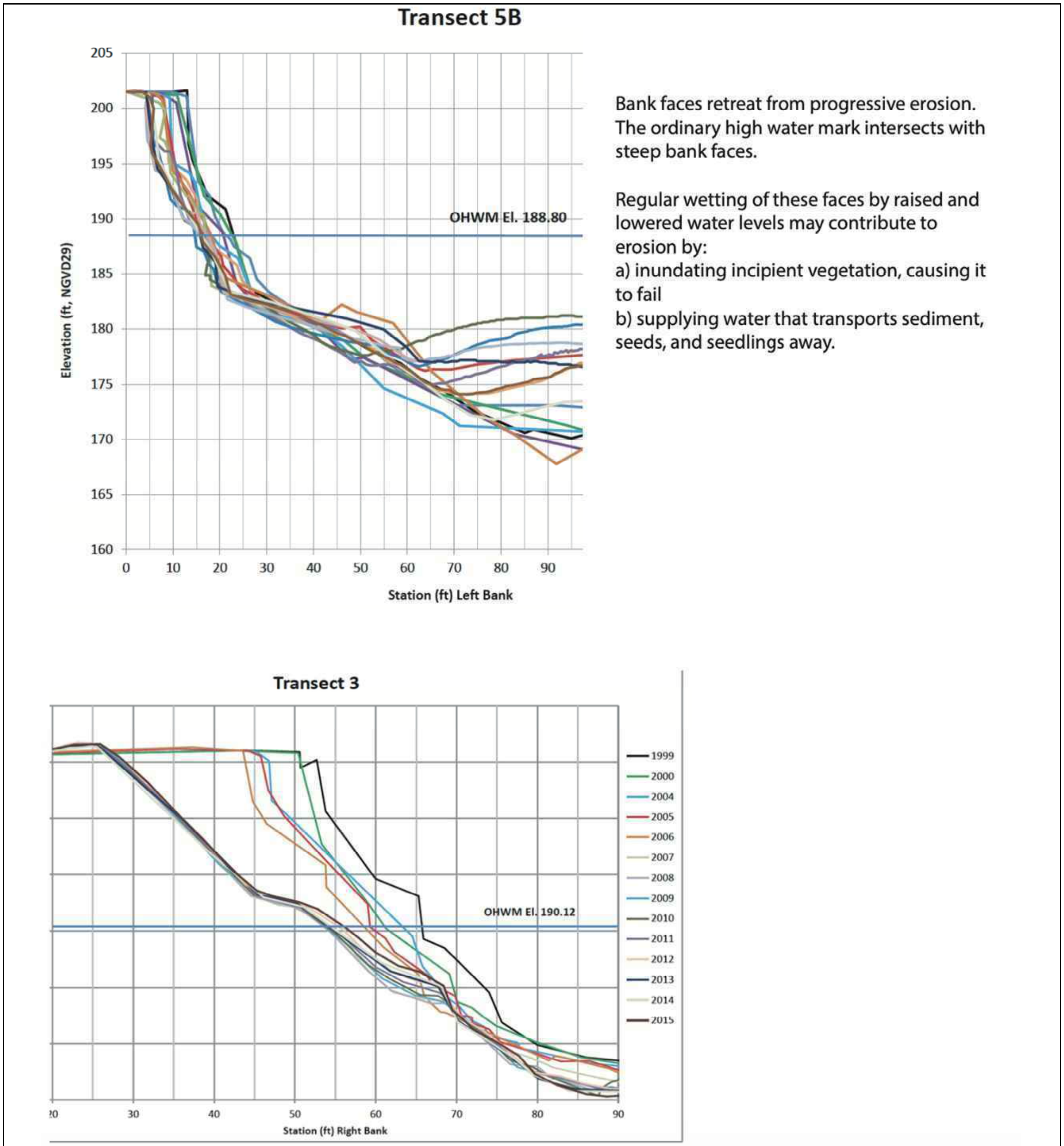

Figure 21. Cross-section profile analysis shows erosion of the shoreline in the Turners Falls Reservoir. These surveys have been conducted approximately annually by FirstLight as a requirement of its current FERC license. High rates of erosion have occurred coincident with large flood events; for instance, historic Tropical Storm Irene caused major flooding and erosion throughout the Connecticut River watershed in 2011. A single at-a-point erosion value per year at these sites does not provide sufficient detail to attribute erosion to certain mechanisms. However, these spatial erosion patterns are consistent both with erosion by flood flows and by water level fluctuations from Project operations, or, more likely, a combination of both.

3. Peer review of FirstLight reports and BSTEM methodology

3.1 Summary

Many of FirstLight's claims rest on a bank erosion model, BSTEM, which was developed by the consultants who prepared the Erosion Causation Study. BSTEM has been used for some peer-reviewed studies, which find it to be a sometimes useful, but inconsistent tool for estimating erosion[114].

Because of the substantial back-and-forth about the Full River Reconnaissance, the Erosion Causation Study, and BSTEM, it seems more valuable to focus on the general failings of the FirstLight studies and BSTEM model (see above), as well as constructive steps to study and reduce erosion in the TFI. However, the following points emphasize specific continuing areas of concern that make the BSTEM model less certain than implied by FirstLight denials of responsibility. ***Any use of BSTEM by FirstLight should be strongly caveated until BSTEM suitability and statistical rigor can be shown.***

The BSTEM Model has substantial uncertainties and lack of transparency in its application to TFI. Although it has been used in several academic studies, a "state-of-the-science" review of BSTEM found it to have uneven success[115]:

> "The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters." (p. 191)

There are several concerns documented below. These are in addition to, and have some overlap with, the many concerns raised by PrincetonHydro in their Peer Review, which were not satisfactorily rebutted by FirstLight in its rebuttal (*Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary*, date: 1/17/2017), as well as those by US Department of Agriculture scientist Eddy Langendoen[116].

3.2 Rough field methods were used despite available of high-quality data

Due to the reduction in cohesive forces (vegetation root systems, sediment grain contacts) and increase in bank slope by undercutting, the slope stability of undercut banks is likely very low. A model evaluating the sources of erosion should incorporate these oversteepened banks, which are often vertical or overhanging. However, despite measuring detailed cross-sections in the TFI for decades as a requirement of its current FERC license, FirstLight does not incorporate the high-

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[114] Klavon, K., Fox, G., Guertault, L., Langendoen, E., Enlow, H., Miller, R., & Khanal, A. (2017). Evaluating a process-based model for use in streambank stabilization: insights on the Bank Stability and Toe Erosion Model (BSTEM). Earth Surface Processes and Landforms, 42(1), 191-213. p. 191 ("The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters.")

[115] Klavon et al. (2017).

[116] Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p.

resolution from these cross-sections in the BSTEM model[117]. Although it is not perfectly clear, given the confusing and sparse descriptions of their methods, it appears that FirstLight used an extremely simple bank geometry parameterization to run BSTEM, generated by "rough surveys of the tested banks"[118]:

> Rough surveys of the tested banks were also carried out at each site with a tape and Brunton compass to provide bank heights, angles, and stratigraphic layering for the tested bank. The data collected in the field were used by Cardno to populate BSTEM-Dynamic 2.3. (p. 4-65)

"Rough surveys" are not sufficient for parameterizing this sensitive model, and no explanation is given for why detailed measurements were not used instead. Such rough surveys would underestimate the effect of locally high slopes. In particular, steep and overhanging slopes that are common in the reservoir are likely not captured in this approach, nor are locally high slopes that may be the nexus of knickpoint erosion (See Section 2.3).

The BSTEM model similarly does not appear to have a way of predicting progressive bank failure by undercutting or rotational failure that may occur when buttressing fails. This is a potentially serious oversight that would shift erosion attribution toward flood flows and away from failure of steep banks during periods of saturation.

Even when field data are incorporated into the model, measurements are often averaged and then applied generally, both at individual sites and by extrapolating to other sites in the TFI (see *Extrapolation,* below). This type of averaging is acceptable in some scientific approaches but must be accompanied by uncertainty and sensitivity analyses to demonstrate that the results do not change dramatically within the range of possible input data.

3.3 BSTEM toe transport is highly uncertain

Sediment transport at bank toes is a complex, highly uncertain process. This uncertainty, and its ramifications for the use of BSTEM, is described in the USACE manual for BSTEM use[119]:

> "Also, it should be noted that most of these transport functions were derived for one-dimensional alluvial transport at the cross section scale. BSTEM applies these transport functions to bank scour at the node scale. This makes transport functions, already uncertain in their intended setting, loose process analogies in toe scour. ***The transport functions often over predict scour substantially*** and results should be interpreted carefully." (Emphasis added)

Although written in technical language, the message from US Army Corps of Engineers is clear: BSTEM tends to overestimate erosion by flooding due to the uncertainty and bias in sediment transport functions in the model. This could directly lead to mis-attribution of erosion to flooding.

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[117] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 4-65. ("Rough surveys of the tested banks were also carried out at each site with a tape and Brunton compass to provide bank heights, angles, and stratigraphic layering for the tested bank. The data collected in the field were used by Cardno to populate BSTEM-Dynamic 2.3.")

[118] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report

[119] https://www.hec.usace.army.mil/confluence/rasdocs/rassed1d/1d-sediment-transport-user-s-manual/bstem-user-s-manual/transport-function-bstem

Despite these cautions from independent reviewers of the BSTEM model, FirstLight in the Erosion Causation Study does not completely document or justify the shear stress and cohesion calculations used to estimate erosion. The erodibility coefficient (k), which is part of an equation with shear stress, t_c, was similarly calculated or established without justification, using just the equation published by Hanson and Simon (2001)[120]:

$$k = 0.2\ t_c^{\ -0.5}$$

They provide no satisfactory explanation for its suitability to the TFI, parameterization, or variability along the diverse reaches along the TFI, never mind vertically on the banks. The shear stress parameterization has been independently assessed as problematic. Klavon et al. (2017) states[121]:

> "BSTEM users should be aware that the τ distribution methods used in BSTEM may be limited in being able to represent actual field conditions." (p. 197)

The uncertainty in toeslope erosion leads to problematic results and discussion throughout the Erosion Causation Study. This uncertainty is essentially unacknowledged by the Erosion Causation Study. However, the approach is clearly highly uncertain. In particular, the jet tests for shear stress have more than an order-of-magnitude variation at individual sites. Yet the median value seems to be applied in each case with no acknowledgement or assessment of the range encapsulated in that median[122].

The models of sediment transport at several sites also indicate the likely error in these analyses, especially during large modeled floods. For example, at Site 3L (and others) there is no shear stress that exceeds sediment transport, even at 100-yr flow event (see below). Yet this site has undergone the 5th most erosion of any site. ***This is not a plausible result in an alluvial reach, particularly one experiencing significant erosion, and suggests the underlying physics used to calculate erosion are incorrect.***

Numerous other sites require a 100-year flood event or greater to cause sediment transport. This is not a physically plausible condition and yet another key failure of the BSTEM model that is not acknowledged. At each site, the critical shear stress, t_c (required for sediment motion), is greater than the shear stress modeled by the Erosion Causation Study during a 100-year flood. The values of t_c and $t_{100\text{-}year}$ for these sites are below[123]:

- Site 5CR (t_c: 1.03; $t_{100\text{-}year}$: 0.98)

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[120] Hanson and Simon (2001)
[121] Klavon et al. (2017).
[122] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Table 4.2.6.6-1: Jet Test Data for Bank Materials of the Turners Falls Impoundment
[123] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Table 5.5.1.1-1: Comparison of Critical Shear Stress and River2D Bed Shear Stress at Detailed Study Sites

- 6AL (t_c: 0.64; $t_{100\text{-}year}$: 0.08)
- 7R (t_c: 7.14; $t_{100\text{-}year}$: 0.22)
- 8BL (t_c: 3.33; $t_{100\text{-}year}$: 0.88)
- 9R (t_c: 10.3; $t_{100\text{-}year}$: 1.34)
- 10L (t_c: 0.585; $t_{100\text{-}year}$: 0.17)
- 10R (t_c: 3.47; $t_{100\text{-}year}$: 1.71)
- 11L (t_c: 2.91; $t_{100\text{-}year}$: 0.03)
- 18L (t_c: 3.27; $t_{100\text{-}year}$: 0.22)
- 29R (t_c: 1.51; $t_{100\text{-}year}$: 1.09)
- 303BL (t_c: 2.49; $t_{100\text{-}year}$: 0.45)

In each case, critical shear stress, t_c, should be lower than the shear stress during an extremely large flood. The shear stress, as parameterized in the model, suggests that sediment is essentially immobile at these 11 sites. Given the clear evidence of sediment transport throughout the reservoir, this is clearly incorrect and undermines model results. Even if some of these sites have been stabilized and thus the critical shear stress is affected by an estimate for rip-rap mobility, evidence of erosion at rip-rap sites documented by Field (2007)[124] shows that modeling a no-erosion scenario there is not reasonable.

Discharge data, as modeled by the new "dynamic" version of BSTEM, is also not sufficiently rigorous to support the confidence with which FirstLight presents its results. A review by a US Department of Agriculture Scientist found[125]:

> "The hourly discharge and erosion records were then used to calculate erosion exceedance probabilities. Unfortunately, the polynomial rating curves do not adequately represent the significant scatter (hysteresis and hydropower operations) in the flow versus depth data, which can be as large as 30,000 cfs (Fig. 5.4.2.2-4). This scatter is especially large for discharges lower than 40,000 cfs, but can still be as large as 10,000 cfs for discharges exceeding the combined hydraulic capacity of Vernon Dam (17,130 cfs) and Northfield Mountain (20,000 cfs) of about 37,000 cfs. The hourly hydraulics used by BSTEM (water surface elevation and energy slope) was provided by HEC-RAS simulations. A matching discharge value should therefore be available for each water surface elevation. Hence, I don't understand why the project team did not use those discharge values directly instead of the developed rating curve. Given the scatter in the discharge, the erosion exceedance probabilities could be different, the significance of which should be determined." (p. 3)

3.4 Cohesion and slope stability provided by vegetation is poorly quantified

Root cohesion, a critical parameter in the BSTEM model, was based on RipRoot outputs for 5 species that have not been tested independently except for in this study. In model parameterization by FirstLight consultants, the percent tree cover was established for the cross-section bank top and bank face, then the percent each tree species contributed was added. Some key deficiencies suggest widespread oversimplification and lack of rigor:

- Only a single, uniform value of cohesion was established for the bank top.

[124] Field (2007) Fig. 29; Fig. 35.
[125] Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p.

- Only 9 cross sections had vegetation-derived cohesion for the bank face. As with the bank top, only a single cohesion value was established, not accounting for the variations in root structure through the face.
- No vegetation-derived cohesion was input for the bank toe, despite vegetation existing at the toe (see above: BSTEM Toe Transport Uncertainty).
- Root cohesion data was only collected for large trees. There is no consideration of grass and smaller vegetation that does much of the work of bank stability and velocity reduction.
- Waves from wind, current, and boat wakes, and flood erosion clearly exists in a feedback process with bank undermining and vegetation, but no consideration of these connected systems is provided, nor are secondary sources of erosion included in the cohesion model.

The additional vegetation-derived cohesion increased erosional resistance by 200% on average. ***The large uncertainties in these vegetation methods thus dramatically increase the uncertainty of the BSTEM model.*** The insufficient field methods and averaging techniques are described below[126]:

> "BSTEM contains a root-reinforcement algorithm, RipRoot that currently contains a database of 25 species, for which root tensile strength and root architecture have previously been collected. The data collection has focused largely on Southeastern, and Western USA riparian species. As part of this study, five species commonly found along the study reach were investigated, to be added to the RipRoot database, and used in BSTEM model simulations of the TFI.
>
> Collection and analysis of root architecture data is time consuming and laborious. To be efficient with this data collection, root architecture data was collected for a range of tree ages for each of the species, and the average distribution of root densities and diameters was calculated for the range of ages. Plant assemblage data (percent cover, species and age) was recorded at each of the BSTEM modeling sites, so that these average root-architecture parameters and species specific root tensile-strength relations could be applied to give a specific root-reinforcement value at each BSTEM modeling site." (p. 4-97)

In addition, it seems as though no time variation of vegetation, or cohesion in general, was included in BSTEM modeling. Cohesion varies with changes in vegetation through the seasons and as vegetation is destroyed or regrows. This is potentially a consequential oversight that could rebalance the attribution of erosion in FirstLight's analysis. No effort was made to address the uncertainty that stems from these omissions.

3.5 "Dynamic" groundwater estimates are based solely on literature values, rather than observations.

In the Princeton Hydro peer review, the scientists raise the issue of pore-water saturation and groundwater, which they identified as being insufficiently characterized in the model. FirstLight's response was that the model was informed by literature values[127]:

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[126] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report

[127] FirstLight Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary. January 17, 2017. p. 2

> "As previously noted, BSTEM includes a near-bank groundwater sub-model which analyzes the impact that groundwater movement has on bank stability. Parameter inputs for the near-bank groundwater model are based on literature values of the important parameters, based on field classification of soil texture and composition. As such, the bank strength was adjusted at each 1 hour time step for the 15-year modeling period according to the magnitude and distribution of both positive and negative pore-water pressures." (p. 9)

Groundwater is strongly dependent on local precipitation, vegetation, and event sequencing, and this rebuttal thus does not answer the Princeton Hydro question. Because no event-by-event observations of erosion have been made to validate the BSTEM model, the FirstLight claim that "No further study modifications are required given that the modeling results already take this dynamic groundwater table into account" is not supported. An independent review by a US Department of Agriculture Scientist similarly found the groundwater modeling to be insufficient[128]. This over-reliance on literature values and absence of calibration to local values is characteristic of the FirstLight approach in applying BSTEM. As has been stated throughout, model success ***must*** be independently validated using independent test sites in the reservoir.

3.6 Extrapolation

The extrapolation from individual sites to the full TFI is summarized in the Erosion Causation Study at 6.1.2.1 Extrapolation Methodology (p. 6-20). The extrapolation presented by FirstLight is a subjective analysis, with no statistical rationale given for choosing the extrapolation method[129]. The geomorphological rationale is not detailed beyond the following:

> "b. Identify the riverbank features, characteristics, and erosion conditions at those sites based on the results of the 2013 FRR;
> c. Identify other segments in hydraulic reach 4 (Vernon) or 2 (Northfield Mountain) that have the same features and characteristics." (p. 6-21)

There was no effort made to test the accuracy of the extrapolation independently (using sites not incorporated in model development), which would be a bare minimum criterium for the wide application carried out here. ***Without rigorous documentation of the statistical robustness of extrapolation, any conclusions should be treated as speculative.***

3.7 Boat wake and wind wave erosion

The processes invoked in wave erosion—by boat wakes and wind/current waves—are accentuated and/or facilitated by water level fluctuations. Erosional benches created by breaking waves become erosional fronts. As water comes back up, then is drawn down again, erosion will be focused on these vertical slopes. Knickpoints thus propagate through the beaches. Beach buffering and buttressing of upper slopes is thus diminished, increasing the likelihood of erosion from those areas.

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[128] Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p. p. 2 ("No quantitative analysis is performed to determine if the seepage force or the increased pore-water pressure could not only weaken the bank material over a height of 1 ft above the water surface, but also reduce the suction forces in the upper part of the bank. This is important as I assume that during these lower flows the groundwater elevation simulated by BSTEM was at the elevation of the TFI water surface, and therefore this reduction in bank-material shear-strength was not simulated.")

[129] Study 3.1.2 Northfield Mountain / Turners Falls Operations Impacts On Existing Erosion And Potential Bank Instability. p. 6-21.

The hydropeaking process in the TFI may lead to higher-than-natural stages, particularly during summer days. Because boats are more common during sunny, warm summer days (when energy demand is highest), peaking is likely the most pronounced, with maximum water stored. As a result, boat waves likely cause more inundation and erosion than would normally occur (Figure 22). This is equivalent to the challenges with sea level rise and storms: with higher starting levels, storm surges are more pronounced.

Figure 5.5.3-3: Notching Due to Boat Waves

Figure 22. Figure 5.5.3–3 from Study 3.1.2 shows notching that FirstLight attributes to boat waves. Erosion has clearly occurred at two different levels, which is consistent with raising and lower of the reservoir level.

3.8 Slope instability due to seepage is ignored/downplayed

According to FirstLight's Erosion Causation Study, seepage was "observed only at a few sites". FirstLight justifies its omission in the following passage and several others like it[130]:

> "Bank undercutting by seepage erosion is similarly not included in the version described herein. This is not considered a problem along the Turners Falls reach as evidence of seepage processes were observed at only a few sites by field crews. Finally, the hydrologic effects of riparian vegetation, including interception, evapotranspiration and the accelerated delivery of water along roots and macro pores cannot be simulated at this time." (p. 4-65)

However, seepage is often difficult to identify in the field, or distinguish from other erosional landforms, particularly after some time has passed. Seepage may lead to other failure modes that would also obscure it as a root cause. Absent more timely, detailed observations, it is difficult to rule out the role of seepage, which thus may be far more relevant than is being implied. For example Field Geology Services in 2007 found that "Springs and seeps were observed repeatedly along banks exposed below higher terraces"[131].

3.9 Floods are identified as important but erosion from floods is not documented

Despite FirstLight's insistence on the importance of floods in causing erosion, no flood erosion is documented except for during Hurricane Irene.

3.10 BSTEM Conclusion

Practitioners using BSTEM have found its results to be uneven and uncertain[132]. They describe how BSTEM requires extensive calibration, often produces to erroneous or spatially inconsistent results, and is generally best suited to the Central United States, where it was developed[133].

This is no surprise. River erosion processes are notoriously difficult to model, with model inputs often having uncertainties that span orders of magnitude[134]. This has been noted in past independent reviews of BSTEM, which urge caution in interpreting its results. A model like BSTEM is useful for helping to untangle processes in complex river systems. However, its results must be treated with caution, given the uncertainty in both its inputs and the processes it models. The certainty with which FirstLight treats its results is not sound scientific practice, particularly since no uncertainty metrics are presented in FirstLight reports. Instead of relying solely on a flawed model, FirstLight should account for the direct observational evidence that its consultants have collected in the impoundment.

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[130] FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report

[131] Field (2007) p. 39

[132] Klavon et al. (2017).

[133] Klavon et al. (2017).

[134] Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p. p. 2 ("Also, for a given critical shear stress value, the erodibility coefficient can vary by several orders of magnitude; the calculated erodibility coefficient value can therefore vary quite a bit from that measured.")

4. Conclusions and recommendations

Erosion in the TFI potentially threatens riparian land, archaeological artifacts, and infrastructure, riverine and riparian ecology, and reservoir functioning production due to sedimentation and turbine damage by eroded sediments. The erosion likely results at least in part from Project operations. As independent scientists have pointed out in several reports, claims by FirstLight that Project operations contribute minimally to erosion are not robustly supported by BSTEM modeling or field observations.

FirstLight should acknowledge and seek to mitigate the likely causes of this erosion in the TFI, regardless of source. This is in the best interest of the community and is also in FirstLight's interest, given the potential threat to dam operations posed by changing reservoir area and volume, the challenges from increased precipitation and flooding by climate change, and the good will that can be built by addressing valid community concerns regarding erosion.

I propose several straightforward recommendations to better address erosion in the Turners Falls Impoundment and mitigate ongoing erosion as much as possible. These recommendations are reasonable and consistent with prior recommendations by Connecticut River Conservancy and Franklin Regional Council of Governments, as well as independent reviewers.

High-resolution, repeatable monitoring of the reservoir has been lacking and is needed. Much of the monitoring technology is much cheaper than in the past and thus improved study need not be prohibitively expensive. At minimum, repeat lidar monitoring of leaf-off banks of the reservoir should be carried out annually during a fall low-water period. For too long, FirstLight has been able to defer responsibility because erosion monitoring has been too poor to resolve the respective importance of natural processes and Project operations. As numerous scientists have detailed in past reports, modeling with BSTEM does not robustly capture the processes at work in the reservoir. The results of BSTEM should not be treated as scientific fact and should not be a substitute for better monitoring, which could much more reliably identify the causes of erosion.

- The current project operational range for reservoir levels likely exacerbates erosion relative to a narrower range by exposing a large swath of the reservoir banks to erosive properties and raising the "base-level" for natural flooding, adding to flood heights and thus erosive power.

- Lack of rigorous, objective study prevents a complete understanding of erosion mechanisms in the TFI. Rather than just once per year, erosion should be monitored multiple times per year at existing cross-section surveys, using lidar (light detecting and ranging), side-scanning sonar, and other detailed survey techniques. In addition, continuous monitoring of riverbank erosion, using a combination of erosion pins and cameras, should be established at representative sites in the reservoir to better understand timing and causes of erosion events. Study design for these monitoring campaigns should target: a) regular fluctuations in water level during normal project operation; b) natural floods; c) freeze-thaw and snowmelt periods.

- Insights from improved study should inform Project operations to limit erosion. If flow modification cannot mitigate erosion, further bank stabilization techniques should be employed in high-erosion areas in the TFI. Better monitoring (see above) is necessary to identify reaches in need of stabilization, as well as stabilization success.

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EDUCATION

August 2020	Ph.D. in Earth Science, Dartmouth College Dissertation title: *Evaluating the impact of natural and anthropogenic disturbances to rivers*
June 2015	M.S. in Earth Science, Dartmouth College Thesis Title: *Landslides modulate transient adjustment to catastrophic flooding*
June 2011	B.A. cum laude; with honors in Geosciences; double major in English, Williams College Thesis title: *Examining knickpoints in the Middle Boulder Creek Catchment, Colorado*

RESEARCH AND PROFESSIONAL EXPERIENCE

2024–	**Assistant Professor,** Colby College Department of Geology. Waterville, ME.
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2022–2023	**Visiting Assistant Professor,** Bowdoin College Department of Earth and Oceanographic Studies. Brunswick, ME.
2020–2022	**Postdoctoral Scholar**, Dartmouth College Department of Environmental Studies. Hanover, NH.
2020–2021	**Postdoctoral Scholar**, Dartmouth College Neukom Institute for Computational Studies and Department of Earth Science. Hanover, NH.
2013–2020	**Dartmouth College Graduate Fellow**. Hanover, NH.
2011–2013	**High School Science Teacher and assistant Nordic skiing coach**, Green Mountain Valley School. Waitsfield, VT.

ACCEPTED PUBLICATIONS

Dethier, E. N., Fields, J. F., Renshaw, C. E., and Magilligan, F. J. (2024, *accepted at GSA Bulletin*), Hillslope destabilization delays fluvial recovery from catastrophic flooding.

Gunther, A. B.*, Camill, P., Jr, C. E. U., Stansfield, A., & **Dethier, E. N.** (2024, *accepted at JGR Bioscience*). Using relationships between vegetation and surface soil biogeochemical properties to assess regional soil carbon inventories for South Baffin Island, Nunavut, Canada

Dethier, E.N., Camalan, S., Silman, M.R., Alqahtani, S., Pauca, P., Díaz Levia, J., Fernandez, L., Renshaw, Tomhave, P*., C. E., and Magilligan, F. J., Lutz, D.A. (2023). A global rise in alluvial mining increases sediment load in tropical rivers. *Nature*, 620(7975), 787-793. doi:10.1038/s41586-023-06309-9

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Lutz, D. A., Steele, B., **Dethier, E.N.**, Brentrup, J. A., Rubin, H. J.*, Herrick, C., Palace, M., Weathers, K. C., Ducey, M. J., Johnson, K. M., Cottingham, K. L. (2023, *submitted*), Estimating lake water clarity using Landsat imagery: a site-specific reflectance and machine learning approach.

Fields, J. F., Renshaw, C. E., **Dethier, E. N.,** Magilligan, F. J. (2024, *in review*). The longer arc of channel recovery post-dam removal.

Fields, J. F., Perotti, J.*, Kriesler, J.*, Renshaw, C. E., **Dethier, E. N.** (2024, *in review*). Temperature Controls Erosion along Arctic Rivers.

Valencius, I.*, Valencius, I., **Dethier, E. N.**, Sheehan, C., Snyder, N. (2024, *in prep*). Estimating River Suspended Sediment Concentration from Sentinel-2: Expansion of Satellite Methods and Applicability to Multi-Dammed Systems.

Erikson, C., Renshaw, C. E., **Dethier, E. N.,** Magilligan, F. J. (2024, *in review*). Watershed-Scale Runoff Efficiency Response to Climate Variability.

Boardman, E.N., Renshaw, C.E., Shriver, R.K., Walters, R., McGurk, B., Painter, T.H., Deems, J.S., Bormann, K.J., Lewis, G.M., Dethier, E.N., Harpold, A.A. (2024, *in review*). Sources of Seasonal Water Supply Forecast Uncertainty During Snow Drought in the Sierra Nevada.

* Denotes undergraduate student advisee

GRANTS AND AWARDS

Aug., 2023 Principal investigator. *Satellite Monitoring of Rivers: A Distributed-Sampling Approach to Improve Satellite Estimates of River Water Quality on a Global Scale.* Funded by the National Aeronautics and Space Administration NSPIRES Program for 2023–2025 ($579,451).

June, 2020 Research Scientist. *Rapid Change from Alluvial Mining and Development in Madre de Dios, Peru: A Multi-Sensor Fusion Approach to Quantify Terrestrial and Aquatic Impacts and Test Policy Effectiveness*. Funded by the National Aeronautics and Space Administration NSPIRES Program for Jan. 2021– Jan. 2024 ($748,224). (P.I. David Lutz)

May, 2020 Guarini School of Graduate and Advanced Studies Award for Best Graduate Teaching. *Annually recognizes the individual in the Guarini Graduate School who best exemplifies the qualities of a college educator.* https://graduate.dartmouth.edu/news/2020/06/2020-guarini-teaching-award recipient-evan-dethier

May, 2020 (also received 2017, 2018, 2019)
Outstanding Graduate Student Teacher, Dartmouth College. *Awarded to graduate students nominated by their undergraduate mentees in recognition of their outstanding teaching.*

May, 2020 Dartmouth Earth Science Best Graduate Student Paper, 2020. *Recognizes the best peer-reviewed publication led by an Earth Science graduate student.*

Jan, 2020 American Meteorological Soc. Annual Meeting Student Presentation Award in Hydrology, runner-up. *Awards presentations were judged on scientific content, presentation quality, and the overall effectiveness of the presentation.*

April, 2017 AAG Gordon "Reds" Wolman Graduate Student Research Proposal Award. *Graduate student research grant awarded to the best written proposal, to help cover the costs of data acquisition, fieldwork, and laboratory analysis required to complete dissertation research.*

April, 2017 AAG Graduate Student Paper Award. *Papers are evaluated on the research contribution to the field of geomorphology and on the effectiveness of the presentation.*

June, 2017 Gary Malone '70 Memorial Award for most engaged graduate student. *Awarded to the graduate student in the Earth Science department who best exemplifies the qualities of Gary Malone '70.*

Mar., 2015 Presidential fellowship in graduate recruitment (Dartmouth College). *Awarded to the top PhD recruit for the Earth Sciences Department.*

Mar., 2014 Student Research Grant (Geological Society of America). *Award to provide partial support of Master's and Doctoral thesis research in the geological sciences for graduate students at universities in the United States, Canada, Mexico and Central America.*

INVITED PRESENTATIONS

February 5, 2024	University of Southern California, Dornsife Department of Earth Sciences.
December 14, 2023	AGU session, *Impacts of Mineral Extraction and Artisanal Mining on Societies and Natural Environments*.
October 18, 2023	AGU Earth and Planetary Surface Processes EPSP-Connects Webinar series
May 11, 2023.	Bowdoin College, Department of Earth and Oceanographic Sciences.
April 21, 2023.	University of Massachusetts, Department of Earth, Geographic, and Climate Sciences.
March 31, 2023.	Colby College, Department of Geology.
October 26, 2022.	Source to Sink Webinar Series.
February 9, 2022.	Temple University, Department of Geology.

TEACHING EXPERIENCE

Primary instructor/mentor

Senior Thesis mentor (11 Honors Thesis students)[1,2]	2017–2022
Geomorphology[1]	2022
GIS and Spatial Analysis[1,3]	2022, 2024
Introduction to Geology, Lab instructor[3]	2024
Introduction to Field Methods in Geology[3]	2023
Advanced Hydrology, instructor[2]	2020
Hydrology, co-instructor[2]	2020
Geology, 11th and 12th grades[4]	2012–2013
Earth Science, 8th and 9th grades[4]	2011–2013
Writing and Journalism[4]	2013
Anatomy, 7th grade[4]	2012

[1]Bowdoin College (undergraduate)
[2]Dartmouth College (undergraduate, graduate)
[3]Occidental College (undergraduate)
[4]Green Mountain Valley School (Grades 7–12)

Teaching assistant at Dartmouth College

Advanced Methods – Environmental Data Analysis, TA and lecturer	2020
The Stretch, off-campus field program, TA	2014, 2015, 2017
River Processes and Watershed Sciences, TA	2015 & 2016
Environmental Applications of GIS, TA	2015
Remote Sensing, TA	2015
Hydrology and Watershed Resources, TA	2014
Hawaii Volcanology, off-campus field program, TA	2013
Intro to Earth Science: How the Earth Works, TA	2013

MENTORING AND VOLUNTEERING

Unlearning Racism in the Geosciences (URGE)
American Geophysical Union Earth and Planetary Surface Processes Executive
Committee Graduate Student Representative to the Faculty, Dartmouth College
Faculty Hiring committee, Graduate Student Coordinator, Dartmouth
College Dartmouth Earth Science Like a Rock mentoring program
Ford Sayre Ski Club, Nordic Ski Coach for six seasons (2013–2018)

Reviewer for *Nature, Science, Nature Geoscience, JGR Earth Surface, Water Resources Research, Nature Communications, JGR Bioscience, Regional Environmental Change,* and *AGU Earth and Space Sciences*.

PROGRAMMING AND ANALYTICS

R Programming language used for statistical analysis and database management of large hydrologic datasets, particularly United States Geological Survey and Water Survey of Canada stream and lake monitoring records, Global Historical Climatology Network, and U.S. Historical Climatology Network precipitation and temperature records, and result of satellite remote sensing analysis in Google Earth Engine.

Python Used for retrieval and analysis of satellite imagery, geovisualization.

Google Earth Engine Used for massively scalable analysis of hydrological data, usually derived from satellite products.

Matlab Used for numerical modeling methods, but have mostly replaced Matlab with R.

JMP Used for rapid data visualization and some preliminary statistical analyses. Also sometimes used to teach statistics.

Cloud Compare Used for processing of high-resolution point cloud data derived from lidar or Structure-from-Motion analysis.

ArcGIS and QGIS Used for GIS analysis and teaching, though have transitioned to primarily using Google Earth Engine and R.

PRESS

Selected press for teaching and advising

Peter Tomhave '23 Contributes to Academic Article on Impact of River Mining. August 25, 2023. Tom Porter, Bowdoin College News. https://www.bowdoin.edu/news/2023/08/peter-tomhave-23-contributes-to-academic-article-on-impact-of-river-mining.html

EOS Professor Warns of Global Mining Crisis in Tropical Rivers. January 26, 2023. Jane Godiner, Bowdoin College News. https://www.bowdoin.edu/news/2023/01/eos-professor-clears-up-murky-water-question-in-science-news-feature.html

2020 Guarini Teaching Award Recipient: Evan Dethier. Jun. 25, 2020. Amy Skinner, Dartmouth Guarini School of Graduate and Advanced Studies, News.
https://graduate.dartmouth.edu/news/2020/06/2020-guarini-teaching-award-recipient-evan
dethier

Women in Science Project Opens Door to Top Journal Publication. Nov. 26, 2019. Bill Platt, Dartmouth News. https://news.dartmouth.edu/news/2019/11/women-science-project-opens-door
top-journal-publication

In Dublin, an Undergraduate Dives Into Big Data. Sep. 27, 2018. Joseph Blumberg, Dartmouth News. https://news.dartmouth.edu/news/2018/09/dublin-undergraduate-dives-big-data

Two Juniors Named Goldwater Scholars. Apr. 29, 2020. Hannah Silverstein, Dartmouth News. https://news.dartmouth.edu/news/2020/04/two-juniors-named-goldwater-scholars

Selected press for mining in rivers

Ríos en riesgo: minería provoca cambios profundos en afluentes de todo el mundo. September 20, 2023. Antonio José Paz Cardona, Mongabay Latin America. https://es.mongabay.com/2023/09/rios-en-riesgo-mineria-provoca-cambios-en-afluentes-de-todo-el-mundo-estudio/

Satellite images show the widespread impact of mining on tropical rivers. August 23, 2023. Bryony Walmsley, Nature Vol 620, 729-730. https://doi.org/10.1038/d41586-023-02349-3

Illegal mining has muddied tropical rivers worldwide. January 11, 2023. Paul Voosen. Science, Vol 379, Issue 6628. https://www.science.org/content/article/illegal-mining-has-muddied-tropical-rivers-worldwide

Mercury-Based Gold Mining Haunts Peruvian Rain Forests. December 15, 2021. Alka Tripathy-Lang. EOS. https://eos.org/articles/mercury-based-gold-mining-haunts-peruvian-rain-forests

Illegal gold mining continues to harm Amazon ecosystem. December 15, 2021. Liza Lester. AGU News. https://news.agu.org/press-release/illegal-gold-mining-continues-to-harm-amazon-ecosystem/

Gold Mining Critically Impairs Water Quality in Rivers Across Peruvian Biodiversity Hotspot. Nov. 11, 2019. Dartmouth College Communications. https://www.dartmouth.edu/press releases/gold_mining_critically_impairs_water_quality_in_rivers_across_peruvian_biodiversity _ hotspot.html

Madre de Dios: imágenes satelitales muestran el impacto de 34 años de minería ilegal en ríos
Translation: Madre de Dios: satellite images show the impact of 34 years of illegal river mining. Feb. 05, 2020. Mongabay Latam, El Comercio. https://elcomercio.pe/tecnologia/ecologia/madre de-dios-imagenes-satelitales-muestran-el-impacto-de-34-anos-de-mineria-ilegal-en-rios-fotos noticia/

Artisanal gold mining polluting Peruvian biodiversity hotspot—study. November 17, 2019. Valentina Ruiz Leotaud, mining.com. https://www.mining.com/artisanal-gold-mining-polluting peruvian-biodiversity-hotspot-study/

Selected press for changing discharge and sediment flux

Satellites Show Magnitude of Human Influence on River Sediment Flux. July 12, 2022. Mohammed El-Said. EOS. https://eos.org/articles/satellites-show-magnitude-of-human-influence-on-river-sediment-flux

New analysis: Extreme flows in US streams are rising: mixed trends become clearer when similar streams are grouped together. December 05, 2020. Scott K. Johnson. Ars Technica. https://arstechnica.com/science/2020/12/new-analysis-extreme-flows-in-us-streams-are-rising/

Study Finds River Flooding on The Rise Across U.S. and Canada. January 31, 2021. The Weather Channel. https://weather.com/news/weather/video/study-finds-river-flooding-on-the rise-across-us-and-canada

Selected press for rapid analysis of Hurricane Ida Flooding in Northeast US

Searches, sorrow in wake of Ida's destructive, deadly floods. September 3, 2021. Mike Catalini, Wayne Parry, and Michael R. Sisak. ABC News. https://abcnews.go.com/US/wireStory/cleanup mourning-continue-ida-soaks-northeast-us-79809550

Ida’s fatal power didn’t shock scientists who study how climate change primed the pump. September 4, 2021. Frank Kummer. https://www.inquirer.com/science/climate/ida-climate change-philadelphia-flooding-tornado-20210904.html

Ida’s impact from the Gulf Coast to Northeast — by the numbers. September 3, 2021. Ian Livingston. https://www.washingtonpost.com/weather/2021/09/03/hurricane-ida-numbers-surge wind-pressure-damage/

CONTRIBUTED PRESENTATIONS

Dethier, E.N., Silman, M., Fernandez, L. E., Leiva, J. D., Alqahtani, S., Pauca, P., ... & Tomhave, P. (2023). A global 21 st century mining boom in tropical river systems: the driver of changes to forest health, riparian geomorphology, and suspended sediment transport. AGU23.

Fields, J., Renshaw, C. E., Magilligan, F. J., & **Dethier, E.N.** (2023). Intrinsic and Extrinsic Controls of Channel Recovery Post-Disturbance and Lessons for River Restoration. AGU23.

Dethier, E.N., Silman, M., Díaz Leiva, J., Alqahtani, S., Fernandez, L. E., Pauca, P., ... & Lutz, D. A. (2022, December). The recent rise of mining in rivers is a global crisis. In AGU Fall Meeting Abstracts (Vol. 2022, pp. H52C-03).

Dethier, E.N., Renshaw, C.E. and Magilligan, F.J., 2021. Satellite analysis reveals global spatial and temporal variation in river suspended sediment transport. In *AGU Fall Meeting*, *2021*.

Dethier, E.N., Silman, M.R., Fernandez, L.E., Caballero Espejo, J., Alqahtani, S. Pauca, P. and Lutz, D.A., 2021. Changing Frequency of Flood and Drought on Rivers in the United States and Canada. In *AGU Fall Meeting*, *2021*.

Dethier, E.N., Sartain, S.L.*, Magilligan, F.J. and Renshaw, C.E., 2020, January. Shifts in the locus of artisanal gold mining and changes in water quality following national-level intervention in the Peruvian Amazon. In *100th American Meteorological Society Annual Meeting*.

Dethier, E.N., Renshaw, C.E. and Magilligan, F.J., 2019. Temporal and spatial variations in watershed connectivity dictate suspended sediment source and fate. *AGUFM*, *2019*, pp.EP51C-2103.

Magilligan, F.J., Renshaw, C.E. and **Dethier, E.N.**, 2019. Bankfull Channel Adjustments to Episodic and Long-Term Changes in Sediment Supply. *AGU Fall Meeting*, *2019*, pp.EP51F-2189.

Dethier, E.N., Magilligan, F.J. and Renshaw, C.E., 2019, March. Timescales of response to a catastrophic flood: Quantifying "event" and "post-event" effects to assess stream recovery following Tropical Storm Irene. In *Northeastern Section-54th Annual Meeting 2019*. GSA.

Dethier, E.N., Magilligan, F.J. and Renshaw, C.E., 2018, December. Elevated post-event sediment yield extends the impact of catastrophic flooding. In *AGU Fall Meeting Abstracts*.

Dethier, E. N., Magilligan, F., and Renshaw, C., 2017b, The Legacy of an Extreme Flood: Landslides Extend Geomorphic Impacts to the Present, *in* Proceedings AAG Annual Meeting, Boston, MA.

Dethier, E. N., Magilligan, F., and Renshaw, C., 2017a, Quantifying Suspended Sediment Concentration from Space: Global Variability and Trends, *in* Proceedings GSA Annual Meeting, Seattle, WA.

Dethier, E. N., Magilligan, F., and Renshaw, C., 2016, Landslides Modulate Transient Adjustment to Catastrophic Flooding, *in* Proceedings GSA Annual Meeting, Denver, CO.

Dethier, E. N., Magilligan, F., Renshaw, C., and Kantack, K., 2015, Response and recovery of streams to an intense regional flooding event, *in* Proceedings AGU Fall Meeting, San Francisco, CA.

Dethier, E. N., Magilligan, F., Renshaw, C. E., and Sinclair, D. *, 2015, Irene-generated hillslope failures in New England: Widespread, persistent sources of sediment to streams, *in* Proceedings GSA Meeting, Northeast Section, Bretton Woods, NH.

Doyle, H. G., Renshaw, C. E., Magilligan, F. J., and **Dethier, E. N.**, 2015, Stream Channel Adjustments to Dam Removal in Headwater Catchments, *in* Proceedings AGU, Fall Meeting, San Francisco, CA.

Kantack, K., Renshaw, C., Magilligan, F., and **Dethier, E. N.**, 2015, Response and Recovery of Streams From an Extreme Flood, *in* Proceedings AGU Fall Meeting, San Francisco, CA.

Dethier, E. N., Magilligan, F., Renshaw, C., and Sinclair, D., 2014, Persistence of Episodic Extreme Events: Sustained Colluvial Contributions of Fine Sediment to Vermont Rivers Post-Irene, *in* Proceedings AGU Fall Meeting, San Francisco, CA.

Gartner, J., Renshaw, C., Magilligan, F., Buraas, E., **Dethier, E. N.**, and Dade, W., 2014, Spatial gradients in stream power and the implications for lateral and downstream transport of material during the 2013 Floods in Colorado and 2011 Irene Floods in Vermont, USA, *in* Proceedings AGU Fall Meeting, San Francisco, CA.

Dethier, E. N., 2013, Knickpoint-Controlled Landscape Evolution In the Middle Boulder Creek Watershed, CO, *in* Proceedings GSA Meeting, Northeast Section, Bretton Woods, NH.

Attachment 2. FRCOG Motion to Intervene

May 22, 2024

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

In re:
FirstLight MA Hydro LLC) Turners Falls Hydroelectric Project No. 1889-085
Northfield Mountain LLC) Northfield Mountain Project No. 2485-071

MOTION TO INTERVENE
OF
THE FRANKLIN REGIONAL COUNCIL OF GOVERNMENTS

Pursuant to Rules 210, 212, and 214 of the Federal Energy Regulatory Commission's ("Commission") Rules of Practice and Procedure, 18 C.F.R. § 385.210, 385.212, and 385.214, the Franklin Regional Council of Governments (FRCOG) ("Movant") hereby moves to intervene and request party status in this proceeding.

On April 29, 2016, FirstLight Hydro Generating Company filed a Final License Application for the Turners Falls Project and Northfield Mountain Pumped Storage Project while several relicensing studies were still underway. On December 4, 2020, FirstLight MA Hydro LLC, owner of the Turners Falls Hydroelectric Project and Northfield Mountain LLC, owner of the Northfield Mountain Pumped Storage Project, collectively "FirstLight," filed an Amended Final License Application ("AFLA"). FERC issued a letter of deficiency and additional information request on January 14, 2021 and an additional information request on April 19, 2021.

FirstLight then re-engaged interested parties in separate settlement negotiations starting in late 2021. On March 31, 2023, FirstLight filed a Flows and Fish Passage Settlement Agreement, which also included whitewater releases for recreation. On June 12, 2023, FirstLight filed a Recreation Settlement Agreement.

On February 22, 2024, the Commission issued a Notice of Application Accepted for Filing, Soliciting Motions to Intervene and Protests, Ready for Environmental Analysis, and Soliciting Comments, Recommendations, Preliminary Terms and Conditions, and Fishway Prescriptions, requiring motions to intervene to be filed on or before April 22, 2024.

I. Communications and Service of Process

All communications, pleadings and orders with respect to this proceeding should be sent to the following individuals. In the event of personnel changes, the person in the positions listed below will serve the same role.

Name: Address: Phone: Email:	Linda Dunlavy, Executive Director FRCOG, 12 Olive St., Suite 2, Greenfield MA 01301 413-774-3167 x. 103 lindad@frcog.org
Name: Address: Phone: Email:	Kimberly Noake MacPhee, Land Use & Natural Resources Program Manager FRCOG, 12 Olive St., Suite 2, Greenfield MA 01301 413-774-3167 x. 130 KMacPhee@frcog.org

II. Position of the FRCOG

Pursuant to the Commission's rules, 18 C.F.R. § 385.214(b)(1), requiring a statement of the FRCOG's position, the FRCOG seeks to have any license issued by FERC conditioned to assure that the Northfield Mountain Pumped Storage Project does not cause erosion. The FRCOG is interested in project impacts on erosion upstream of the Turners Falls Dam. Erosion caused by the Pumped Storage Project degrades water quality in violation of state and federal clean water laws, harms fish and wildlife habitat, causes the loss of land along the river including prime agricultural land, threatens important transportation and municipal water and wastewater infrastructure, increases flood risks, impedes boat access for recreation and emergency rescues, and damages important historical and cultural resources. The FERC license for this facility should include conditions that will prevent these harms by erosion from occurring.

As a party to the recreation settlement agreement filed with FERC on June 12, 2023, the FRCOG fully supports the recreation provisions in the settlement agreement and requests FERC to accept the Recreation Management Plan (RMP). The RMP and recreation settlement agreement satisfy the FRCOG's recreational interests with regard to both projects, and if kept intact in the final license, its provisions will be a great asset to the region.

In accordance with Section 2.2 of the Recreation Settlement Agreement, although we were not a party to the flows and fish passage settlement agreement, the FRCOG has agreed not to oppose any of the terms of the flows and fish passage settlement agreement. The FRCOG has an interest in the Connecticut River being a healthy river ecosystem.

III. Interests of Movant

The FRCOG has ample interest in participating in this matter to justify intervention as required by the Commission's rules, 18 C.F.R. § 385.214(b)2).

A. Direct Interests

The FRCOG is a political subdivision of the Commonwealth of Massachusetts and serves as the Regional Planning Agency (RPA) for the 26 municipalities in Franklin County, Massachusetts. The FRCOG was formed by statute in 1996, after Massachusetts abolished its county government system. The FRCOG is the replacement governmental entity to what was formerly the Franklin County Commission. The FRCOG Council is the governing body of the FRCOG. FRCOG Council membership is comprised of one Select Board member or assigned representative from each of the 25 towns and one city of Franklin County, two regionally elected members, and one representative of the Franklin Regional Planning Board, which acts in an advisory capacity on planning issues to the FRCOG.

As the RPA for Franklin County, we provide land use, natural resource, climate resiliency, recreation, economic development and transportation planning services to our communities and the region. In addition, we provide extensive GIS database development, mapping, and analysis services and are an affiliate of the Massachusetts State Data Center. As of the 2020 decennial Census, Franklin County has a population of 71,029, and is the most rural and one of the poorest counties in the Commonwealth of Massachusetts. Most of our member municipal governments have a very limited number of paid professional staff and many roles are served by volunteer boards.

For almost three decades, FRCOG (and its predecessor organization, the Franklin County Commission) and its Connecticut River Streambank Erosion Committee (CRSEC) have been actively involved with landowners and organizations concerned about the ongoing and extensive erosion in the Turners Falls Power Pool. FERC recognized FRCOG's CRSEC in 1999 as an Ad Hoc Committee that would work with the power company to develop and implement bioengineering bank stabilization projects pursuant to an Erosion Control Plan ordered and approved by the FERC.

The Connecticut River bisects Franklin County and is a central part of the regional economy, environment, and quality of life for residents of our member towns. FirstLight owns land in the Towns of Northfield, Erving, Gill, and Montague, and the City of Greenfield, and project operations impact each of these communities. The FRCOG's interests include agricultural soils classified as "prime farmland," recreational amenities, local and regional economies, the improvement of water quality; enhancing aquatic and related terrestrial habitat; protecting and restoring the threatened and endangered plant and animal species of the valley; preserving wetlands, undeveloped shore lands, and the many significant archaeological, cultural, and historical sites within the Massachusetts portion of the Projects' boundaries.

Erosion interests

Soon after Northfield Mountain Project operation began in 1972, landowners along the Connecticut River in the Turners Falls impoundment (TFI) began complaining about increased erosion along the river banks. In an attempt to reduce erosion, the project owner engaged in helicopter logging along the banks in 1976 and 1977. In 1979, the Army Corps published a report examining the causes of erosion along the Connecticut River.[1] This report identified shear stress (velocity), pool fluctuations, boat waves, gravitational forces, seepage forces, natural stage variations, wind waves, ice, flood variations, and freeze-thaw as causative factors to erosion, in that order from most important to least important.

The 1979 Army Corps report prompted demonstration bank protection projects installed by the Army Corps in 1981. In 1991, the Army Corps published an investigation study of the Connecticut River in the TFI, and reported that approximately one-third of the 148,000 linear feet of shoreline was undergoing some form of active erosion, concluding that since 1979, riverbank erosion had increased almost threefold.[2]

Also in 1991, Northeast Utilities Service Co., Inc. hired consultants Northrop, Devine, and Tarbell, Inc. to prepare a Connecticut River Riverbank Management Master Plan. This study also documented that 30% of the riverbanks were eroding. The Master Plan recommended stabilization projects to be implemented by 1996. The Plan led to a series of meetings organized by the Franklin County Commission, with a recognition by FERC that the company needed to do more to address concerns and comply with License Article 19.[3] In September of

[1] Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire, and Vermont. Prepared by D. B. Simons et al. for the U.S. Army Corps of Engineers, 1979. Contract No. DACW 33-78-C-0297.

[2] General Investigation Study Connecticut River Streambank Erosion: Connecticut River, Turners Falls Dam to State Line, MA. July 1991. U.S. Army Corps of Engineers

[3] In a letter from FERC to Northeast Utility's vice president, dated July 28, 1994, FERC cited Article 19 in the Turners Falls license, which states, "In the construction, maintenance, or operation of the project, the Licensee shall be

1994, Northeast Utilities submitted a riverbank action plan, and in August 1995, Western Massachusetts Electric Company (WMECO) submitted a Long-term Riverbank Plan for the Connecticut River. In September 1998, Northeast Utilities submitted an Erosion Control Plan that also included a riverbank erosion survey. A revised Erosion Control Plan was submitted in June of 1999 and accepted by FERC on July 8, 1999. This Erosion Control Plan was still in effect as of the beginning of relicensing. Through this entire process, the Franklin County Commission, and later when it became FRCOG, was involved in meetings and filing motions to intervene and comment to FERC.

As part of the requirements of the 1999 Erosion Control Plan, FirstLight and its predecessor owners conducted Full River Reconnaissance (FRR) efforts during 2001, 2004, and 2008. The 2004 FRR showed the erosion control efforts were not keeping pace with the rate of erosion. FERC issued a letter on June 28, 2005, requiring Northeast Generating Company (NGC) to submit a plan of action by which it would be able to show a reduction in the rate of erosion by the next FRR. In response to the FERC letter, NGC retained a fluvial geomorphologist to study the Turners Falls pool and make recommendations. On December 12, 2007, NGC filed the geomorphologic study report prepared by Field Geology Services. FERC again required a plan unless the 2008 FRR was able to demonstrate a reduction in the rate of erosion. NGC hired a new consultant, changed some of their methods, and this time, the 2008 FRR did demonstrate this reduction. FERC accepted the 2008 FRR without a plan in a letter dated November 17, 2009. The 2013 FRR was included as Relicensing Study 3.1.1, submitted to FERC in September 2014. The Erosion Control Plan committed the licensee to conduct FRRs every 4-5 years until the end of the license term, which was originally 2018 but has since been administratively continued. No FRR has been completed since 2013, and it has now been almost 11 years since the last survey of the status of the riverbanks in the impoundment.

FRCOG has been working to ensure that government agencies and project owners respond to landowner and community concerns about riverbank erosion since the Northfield Mountain project first began operating, and throughout the process described above.

Water quality and habitat interests

FRCOG recognizes that water quality is essential to sustainable use and enjoyment of the Connecticut River and its tributaries. FRCOG planning staff regularly provide towns assistance

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responsible for, and shall take reasonable measures to prevent, soil erosion on lands adjacent to streams or other waters, stream sedimentation, and any form of water or air pollution. The Commission, upon request or upon its own motion, may order the Licensee to take such measures as the Commission finds to be necessary for these purposes, after notice and opportunity for hearing."

by preparing Watershed Based Plans (WBPs) for impaired water bodies in Franklin County. The WBPs recommend ways to reduce nonpoint source pollution in Franklin County waterways that are tributaries to the Connecticut River, and ultimately drain into Long Island Sound. Long Island Sound is impaired (low dissolved oxygen from nutrient loading) and has a multi-state Total Maximum Daily Load for nitrogen. FRCOG has been the recipient of Clean Water Act s.319 nonpoint source pollution funding and other grants to reduce the amount of sediment, and nutrients, being discharged into Long Island Sound.

FRCOG assists towns with zoning bylaw changes and has been working with several communities on making amendments to floodplain bylaws and river corridor overlay districts. FRCOG has initiated grant-funded work to conduct fluvial geomorphic assessments of tributaries of the Connecticut River, which has led to several restoration projects and other work related to municipal resiliency planning.

As such, FRCOG is invested and involved in efforts that make Franklin County's rivers healthy and clean. These efforts are impacted by the operations of the Turners Falls Hydroelectric and Northfield Mountain Pumped Storage projects.

Recreation interests

As the Regional Planning Agency for Franklin County, our planning staff regularly assist towns with preparing Open Space and Recreation Plans (OSRPs). OSRPs contain a 7-year action plan to implement the open space and recreation needs in each community. As such, FRCOG is familiar with the recreation and open space needs of our communities. In addition, our Economic Development staff prepare 5-year Comprehensive Economic Development Strategy (CEDS) Plans for Franklin County. FRCOG's most recent CEDS plan covers the years 2020 to 2025. The 2020-2025 CEDS Plan identifies "Outdoor/Adventure Recreation and Cultural Tourism" and "Renewable energy and energy efficiency" as two of Franklin County's key industry clusters. Outdoor/adventure recreation and cultural tourism are economic drivers in Franklin County that the local communities would like to encourage.[4]

Access to recreation and nature are a cultural and economic benefit to the region, and they enrich the quality of life for Franklin County residents. This can be a reason why people choose to move to or continue to live in Franklin County. There is also growing evidence that access to

[4] FRCOG. 2020. *2020-2025 Comprehensive Economic Development Strategy (CEDS) Five-Year Plan for Franklin County, MA.* Adopted June 11, 2020.

"blue" and "green" space, or water and vegetated areas, positively impact mental health and well-being.[5]

Outdoor recreation has always been important to Franklin County but has increased in prominence as a potential source of economic development for the county. Over the last several years, many State, regional, and local planning projects were initiated to promote outdoor recreation for economic development. These efforts were summarized in FRCOG's Outdoor Recreation Plan published in 2022.[6]

According to FRCOG's 2022 Outdoor Recreation Plan, the top 10 preferred outdoor recreation activities in Franklin County are listed below. These activities were ranked according to community surveys that are taken as part of the OSRP process. Many of these activities are offered at FirstLight's recreation facilities.

1. Hiking
2. Walking
3. Swimming
4. Nature Observation
5. Boating
6. Biking
7. Cross-country Skiing and Snowshoeing
8. Gardening
9. Running
10. Fishing

The Franklin County Outdoor Recreation Plan listed the following outdoor recreation activities as projected to have increased, stable, or decreasing demand in the near future.

Outdoor Recreation Activities Projected for Increased Demand (+)	
ACTIVITY	**NOTES**
Biking	E-bikes, mountain biking, and gravel biking technology is improving and price points have decreased to facilitate entry
Visiting a dog park	Interest in dog parks has increased
Boating (non-motorized)	Cheaper entry price points for the purchase of canoes and kayaks have increased participation

[5] National Library of Medicine: "Green-blue space exposure changes and impact on individual-level well-being and mental health: a population-wide dynamic longitudinal panel study with linked survey data." Available online at https://www.ncbi.nlm.nih.gov/books/NBK597114/ .
[6] Franklin County Outdoor Recreation Plan, 2022. Online at https://frcog.org/wp-content/uploads/2023/05/FC-Outdoor-Recreation-Plan-Final-5.30.23.pdf

Outdoor Recreation Activities Projected for Increased Demand (+)	
ACTIVITY	**NOTES**
Swimming	The popularity of swimming is increasing as more people seek out cooling activities during hot weather, though the accessibility of swimming is slow to improve
Paddle boarding	The popularity of paddle boarding continues to increase as a low-intensity, low-risk way to be on the water
Rock climbing	The proliferation of indoor rock gyms has made outdoor rock climbing more popular
Nature observation (birding, wildlife photography)	Birdwatching and wildlife photography has dramatically increased in popularity among baby boomers, assisted by internet-based information sharing
Pickleball	Baby boomers and others are increasingly interested in this alternative version of tennis

Outdoor Recreation Activities Projected for Stable Demand (=)	
ACTIVITY	**NOTES**
Hiking	Consistently high interest
Walking	Consistently high interest
Running	Consistently high interest
Fishing	Consistently moderate interest
Gardening	Consistently moderate interest
Picnicking	Consistently moderate interest
Camping	Demand for camping may have increased slightly, but supply has not increased in a few decades
Field sports (football, soccer, lacrosse, field hockey)	Fueled by school programming, participation is likely stable; although a decline in Franklin County school enrollments has led to decreased options for school-based teams in some cases
Horseback riding	Consistent, though may have seen a small jump during the Covid-19 pandemic
Skateboarding	Interest in the development and use of skate parks in Franklin County has remained consistent for a decade
Motorboating	Demand for motor boating may be increasing but barriers to access have not changed
Racing	The popularity of road races, triathlons, and adventure races stabilized after years of growth

Outdoor Recreation Activities Projected for Decreased Demand (-)	
ACTIVITY	**NOTES**
Downhill skiing/snowboarding	Becoming more difficult with less consistent snow and more frequent freeze/thaw cycles, although snowmaking technology has improved
Ice skating	Becoming more difficult when outdoors, with more frequent freeze/thaw cycles

Outdoor Recreation Activities Projected for Decreased Demand (-)	
ACTIVITY	**NOTES**
Snowmobiling	Becoming more difficult with less consistent snow and more frequent freeze/thaw cycles
Cross-country skiing/snowshoeing	Becoming more difficult with less consistent snow and more frequent freeze/thaw cycles
Baseball/softball	The popularity of baseball and softball is decreasing among both youth and adults
Hunting	Likely that this sport struggles with generational loss and increasingly restricted land access to private property in the region

With these priorities in mind, FRCOG engaged with FirstLight and other interested parties to negotiate a recreation settlement agreement that was filed with FERC on June 12, 2023. FRCOG believes that the resulting agreement, together with the Recreation Management Plan filed with the settlement agreement, is a strong package that addresses our priorities and will be beneficial to the entire region.

Land uses along the Connecticut River

FRCOG is interested in preserving agricultural use of lands along the Connecticut River. FRCOG advocated for project lands to be put into conservation restrictions, which is now part of the RMP Sections 4.2.1 and 4.3.1. Agricultural lands adjacent to the River are impacted by the operations of the Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project.

Infrastructure interests

Franklin County communities that host the Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project and lands, and those downstream, are all vulnerable to dam failure from the facilities.

Bridges and wastewater treatment facilities and outfalls are other pieces of infrastructure potentially impacted by the projects and project operations.

Indigenous, archaeological, and historical interests

FRCOG recognizes that indigenous peoples lived along the Connecticut River for thousands of years. The River is and was a source of sustenance, transportation, and spiritual connection with all living beings. In more recent centuries, much of the region’s industrial history also had a connection to the Connecticut River. FRCOG supports the interests of the Towns and indigenous groups who wish to preserve the history and the living connection with the river.

For these reasons, the FRCOG has a direct and substantial interest in the outcome of the relicensing process for the Northfield Pumped Storage Project and the Turners Falls Project.

B. Public Interest

The operations of the Turners Falls Dam and Northfield Pumped Storage Project affect the public interest by causing erosion and contributing to the loss of prime farmland soils, diminishing aquatic and riparian habitat for rare and endangered species, and impacting water quality. FirstLight's recreation facilities along the Connecticut River also affect the public interest. These impacts affect the quality of life, economic well-being, and access to a clean environment for the region's residents.

FRCOG has long advocated for the protection of water quality and habitat on the river, as well as the environmentally-responsible use of the river. As such, FRCOG has been an active stakeholder in the ongoing Integrated Licensing Process for the referenced Projects, and was involved for many decades prior to relicensing out of concern for project operations on bank erosion.

During the 1990's, the FRCOG formed the Connecticut River Streambank Erosion Committee (CRSEC) in response to public concern over erosion occurring in the TFI and Article 19 of the Northfield Pumped Storage Project license. CRSEC consists of representatives from local, regional and State government, nonprofit conservation organizations, and affected landowners who are concerned with erosion around the Turners Falls Impoundment. The mission of the CRSEC has been to address the erosion problems existing around the TFI. Many of the landowners and organizations that make up CRSEC have participated in the Integrated Licensing Process to date.

During the late 1990's, 2000's, and 2010's until relicensing, CRSEC worked with the Applicant and state agencies to prioritize stabilization efforts, secure funding for, and to implement effective shoreline stabilization projects. Many stabilization projects were funded by the power company, but the FRCOG/CRSEC secured over $900,000 in Federal funds to help pay for innovative bank stabilization projects and active stakeholder involvement.[7] Grant funding

[7] Funding sources include three s.319 Nonpoint Source Pollution competitive grants using federal funds through MassDEP, and one EPA Targeted Watershed Grant.

secured by FRCOG helped to stabilize over 3,000-feet of shoreline in the impoundment, and led to an evolution of new riverbank restoration techniques to satisfy landowner concerns and be more protective of state-listed dragonflies. Over these years, FRCOG and the CRSEC filed dozens of letters to FERC regarding riverbank erosion.

The FRCOG and its Connecticut River Streambank Erosion Committee (CRSEC) intervened and commented on temporary amendments to use expanded capacity of the upper reservoir in May of 2001, November of 2005, June of 2006, October of 2014, and October of 2017 (denied).[8] CRSEC intervened and commented on permanent license amendments in May of 2007 (FirstLight withdrew) and October 2015 (resulted in a temporary amendment for the winter of 2015-2016). In each of these filings, CRSEC expressed concerns about the impacts of expanding the range of the upper reservoir on riverbank erosion.

FRCOG and its CRSEC have submitted numerous comments to FERC since the relicensing process began, including comments on the Pre-Application Document (PAD) and study requests in 2013, versions of the Study Plan in 2013, the Quality Assurance Project Plan for Full River Reconnaissance in 2013, and study reports between 2014 and 2016.

In 2019, FRCOG filed a Protest and Request for Intervenor Status regarding the transfer of both licenses to separate limited liability companies (LLCs). FERC accepted FRCOG's intervention (and all interventions filed by the deadline) on July 1, 2019, saying, "The intervenors have an interest in the fitness of the transferee and the potential impact on the Connecticut River. Therefore, the intervenors' motions to intervene are granted."

Most recently, in June of 2023, the FRCOG signed on as a party to a recreation settlement agreement to both licenses.

For all these reasons, the FRCOG has a strong interest in project operations and stewardship of lands within the Connecticut River watershed affected by the referenced projects. The communities of Franklin County depend upon the FRCOG to facilitate and assist with the coordination of their input into federal and state government processes like this one and to provide a level of capacity and expertise in support of their interests that the Towns could not achieve through acting individually.

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[8] CRSEC did not intervene during the temporary amendment request for the winter of 2016-2017. CRSEC member Connecticut River Watershed Council (CRWC) did file timely comments.

IV. Conclusion

Granting intervenor status to the FRCOG will allow the FRCOG to present an important regional perspective and relevant information for the Commission's consideration. The FRCOG is coordinating with other municipalities in Franklin County and will, except where interests diverge, endeavor to coordinate and minimize duplication to ensure the efficient presentation of relevant information to the Commission.

For these reasons, the FRCOG respectfully requests that the Commission grant this Motion to Intervene as a party with full rights to participate in all further proceedings.

Kevin P. Fox
Kevin Fox
Chair, FRCOG Council Executive Committee

4-16-24
Date

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

In re:	) Turners Falls Hydroelectric Project No. 1889-085
FirstLight Hydro Generating Company	) Northfield Mountain Project No. 2485-071

DECLARATION OF LINDA DUNLAVY

I, Linda Dunlavy, pursuant to 28 U.S.C. § 1746, hereby state that I am over the age of 18 and am in all respects competent and qualified to make this Declaration.

1. I am the Executive Director of the Franklin Regional Council of Governments ("FRCOG") and in that role supervise a staff of 50 people across 12 programs, and we actively collaborate with each of our 26 municipalities in Franklin County, Massachusetts. FRCOG is a regional planning agency and in that role, we work with communities to plan open space and recreation, housing, transportation, climate change resilience, hazard mitigation, and economic development. Our other programs can generally be described as being involved with the health, safety, and wellbeing of residents in our rural region, as well as the economic vibrancy.

2. In fulfilling my responsibilities, I have become familiar with the Franklin County's history, culture, natural resources, infrastructure, and economic status through personal observation and also through information obtained from Town staff, expert consultants, other public officials at the local, regional, state, tribal and federal levels, and reviewing public documents or reports and publications prepared by experts.

3. As stated in more detail in the FRCOG's Motion to Intervene in the above-referenced matter relating to the Federal Energy Regulatory Commission ("FERC") licensing of the Turners Fall Hydroelectric Project and the Northfield Mountain Pumped Storage Project ("Projects"), the FRCOG has a direct interest in and acts on behalf of the region for the following:
    a. The economic well-being of the region.
    b. The region's recreation facilities, which are important to the economic vitality and the quality of life for Franklin County residents.
    c. Land uses along the Connecticut River, including agriculture, forestry, industrial and commercial buildings, recreation access, and residential use along the River.
    d. Continued use and upkeep of infrastructure, including wastewater and bridges over the Turners Falls canal and Connecticut River.

d. Continued use and upkeep of infrastructure, including wastewater and bridges over the Turners Falls canal and Connecticut River.

e. Hazard mitigation and emergency preparedness in the event of operational or infrastructure failure of high hazard dams.

f. Preserving the environment, including water quality, fish habitat, and riparian habitat and health.

g. Improving the climate resiliency of our municipalities and our region.

h. Preserving and honoring the region's indigenous and recent history.

4. As stated in more detail in the FRCOG's Motion to Intervene in the above-referenced matter, the FRCOG acts on behalf of its Council and Executive Committee and member towns in furtherance of the public interest in access to a clean and healthy environment, access to recreation facilities, economic well-being, continued use of farmland and soils classified as prime farmland soils, and protection of a clean and healthy Connecticut River for people and aquatic life. The FRCOG has long demonstrated its interest in protecting the public interest through decades of active participation in proceedings before FERC and negotiations with the applicant involving both Projects.

5. Depending on the situation, I or my staff represent the FRCOG in negotiations, including that which led to the recreation settlement agreement with FirstLight. My staff and I actively consult with the FRCOG Council, who serve as the Chief Executive Officers of the FRCOG relative to the settlement agreement and the FRCOG Council Executive Committee consider and sign such documents and agreements on behalf of the FRCOG.

6. My staff and I participated in the development of the FRCOG's Motion to Intervene in the above-referenced matter. I have reviewed the facts stated in Section III titled "Interests of the Movant" and, based on my personal knowledge as Executive Director, attest that these facts are true and correct.

I state, under penalty of perjury under the laws of the United States of America, that the foregoing is true and correct.

4/16/24
Date

Linda Dunlavy
Executive Director, Franklin Regional Council of Governments

Attachment 3. Connecticut River Watershed Council (CRWC) Comments on Final Study Report for Study 3.1.2 Causation Study

December 15, 2016

Contains Princeton Hydro peer review

Comments on other studies deleted.

Connecticut River Watershed Council is now doing business as the Connecticut River Conservancy.

CONNECTICUT RIVER WATERSHED COUNCIL
The River Connects Us
15 Bank Row, Greenfield, MA 01301 crwc@ctriver.org www.ctriver.org

December 15, 2016

Honorable Kimberly D. Bose Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project No. 2485-063
Turners Falls Project No. 1889-081
Connecticut River Watershed Council Comments on FirstLight Study Reports filed October 14, 2016; Request for Study Modification to Require Compliance with the RSP.

Dear Secretary Bose,

The Connecticut River Watershed Council, Inc. (CRWC) is a nonprofit citizen group established in 1952 to advocate for the protection, restoration, and sustainable use of the Connecticut River and its four-state watershed. We have been participating in the relicensing of the five hydropower facilities on the Connecticut River since the beginning of the process in late 2012. We have reviewed the set of Study Reports that were posted by FirstLight on October 14, 2016. CRWC attended the study report meetings held on October 31 and November 1, 2016. Included as part of these comments, is the *Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report (October 2016), Princeton Hydro Bullet List of Major Points* prepared by Princeton Hydro (attached) ("Peer Review"). Don Pugh assisted us on our comments on the fisheries studies. Below are our comments.

I. Study Dispute and Request for Study Modifications

These comments and the attached Peer Review demonstrate that numerous, significant aspects of Study 3.1.2 and others were conducted: (1) in violation of the Revised Study Report (RSP) dated August 14, 2013 and approved with modifications from FERC on September 13, 2013 or February 20, 2014; (2) failed to rely on generally accepted scientific methods; and/or (3) otherwise reached conclusions that the science, data or evidence do not support. Accordingly, some conclusions are invalid. CRWC requests that these studies be modified pursuant to 18 C.F.R. § 5.15(a) and (d) (1) to fully address these comments and the Peer Review. Portions of reports, as detailed in the comments below and the attached Peer Review, should be revised or redone. Where appropriate, FirstLight should modify the study conclusions based on the revisions.

Individually or together, violations of the RSP, the failure to adhere to generally accepted science, failing to ground properly conclusions in the data and evidence, providing invalid conclusions, all provide good cause to modify studies. The Peer Review details how each of the several faults in Study 3.1.2 provides good cause for modification. The following comments do the same. Indeed, these faults and failures are significant and skewed Study 3.1.2's outcomes and conclusions, providing further good cause for modification. As detailed in the Peer Review and comments, study modification is required to assess properly the Projects' actual impacts on water quality, habitat, and the environment.

II. Comments

3.1.2 Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability

CRWC hired consulting engineering firm Princeton Hydro (http://www.princetonhydro.com/) and Dr. Melinda Daniels of the Stroud Water Research Center to conduct a peer review of this study report. Their attached memo identified several areas where the study was not done according to generally accepted scientific practice or did not follow methodology described in the RSP.

The study concludes that banks erode during high flow events, and that project operations have a minimal impact. Unfortunately, the study was set up in several ways that would preclude a determination of project effects – the instigating effect of erosion of the bank at the water level was apparently not taken into consideration, no model scenario considered erosion without operational fluctuations, the river was segmented into four sections and project operations were not considered in all segments during the extrapolation phase, erosion impacts caused during flows that occur in the river over 90% of the time (and when the river is under the influence of hydropower peaking operations at three facilities) were mostly not evaluated, and study results were completely ignored and erroneous conclusions written. In addition, we are not clear what river velocities were used at the bank, and these are very important inputs to the study. The extrapolation methodology is fatally flawed and either should be modified or eliminated altogether.

In short, the study has significant flaws that preclude FirstLight's conclusions. FirstLight asserts that natural high flows, boat waves, land use, and ice have impacts on shore erosion. But clearly, Project operations have an important impact on bank erosion. The questions remain: how much, and what to do about it? FirstLight is obligated to answer that question before proceeding, and to do so, FirstLight must redo this study.

CRWC adopts and puts forth Princeton Hydro's 24 recommendations. In summary, CRWC requests that FirstLight modify study 3.1.2 as follows (numbers indicate comment # in Peer Review memo):

- More data should be provided to reviewers, including
    - the BSTEM simulation results in higher resolution (#1),
    - clarification of the use and inputs to the River2D model, as well as figures or data tables giving velocities modeled at the banks used or converted for use in BSTEM (#7),
    - cross-section surveys with the water surface elevation range (#8),
    - data to support reasoning that decreased water surface fluctuation increases the impact of waves and ice on the bank (#21)
- The entire report seems to ignore that erosion at the water line (the toe of the bank) can instigate erosion and contribute to larger failures that are washed away during high flow events. Given

this could be an important effect of project operations, several changes to the study are necessary to gain a better understanding of project operations (#2, #5, #12, #20).

- The BSTEM analysis should be re-run to:
  - determine if preclusion of vegetative growth due to operational-induced river level fluctuations contributes to erosion (#3),
  - create new scenarios that would isolate project effects from the operation of Turners Falls and Vernon, and no project effect (#5, #15),
  - assess primary causes of erosion in all reaches of the river (#6),
  - use stage and discharge data from the HEC-RAS modeling near the Turners Falls dam (#11),
- Revise the extrapolation portion of the study in the following ways.
  - Assess impacts of project operations throughout the entire impoundment rather than using the 4 river reaches (#11),
  - incorporate 2D modeling into near-bank analysis (#11),
  - thresholds for dominant and primary causes of erosion should be re-examined and agreed upon (#12),
  - eliminate bias by conducting a random review by a third-party reviewer (#13, #14),
  - avoid direct comparison of BSTEM analysis results with land use analysis (#16),
- Revise conclusions to reflect observations or results (#17, 19, #20, #22, #23)
- Improve groundwater analysis to better understand how movement of groundwater may weaken the bank materials (#9)
- Improve investigation of ice impacts due to operational water surface fluctuations (#24);
- Revise definition of lower and upper bank to be consistent with general scientific practice (#4, #15).
- Use historical past aerial photos to compare against current aerial photos as required by FERC in the Study Plan Determination (#18)
- Potentially extrapolate erosion analysis downstream of Vernon to downstream of Turners Falls operations to provide consistency (#10).

These modifications are required to comply with the RSP, and to assure scientific integrity and valid conclusions. These are important departures from standards and requirements mandated by the RSP, and therefore provide good cause for these modifications.

CRWC has the following additional comments based on our review:

Historic bank analysis

The Peer Review memo points out that the FERC Study Plan Determination required a historic geomorphic assessment. Section 2.3.1 of Volume II of the Study 3.1.2 Report explains many limitations to comparing aerial photography over time, and in the end concludes that it can't be done in a meaningful way. Inexplicably, the end of the first paragraph on page 2-16 says, "The results of georeferencing efforts conducted by FirstLight as part of this study typically yielded root-mean-squared (RMS) values less than ±15 ft." What this analysis is based on is never explained.

We note that the Field, 2007 Report[1] in section 9.3b recommendation #10 was, "Portions of the 1971 ground surveys by Ainsworth and Associates, Inc. of Greenfield, MA should be resurveyed to identify changes in bank position since the opening of the Northfield Mountain Pumped Storage Project."

CRWC Recommendation: There are several possible ways FirstLight could have analyzed bank movement over time. What they have produced in this report is inadequate and should be re-done.

River segments

The Peer Review memo points out several flaws with FirstLight's use of the Energy Grade Line to parse the river into 4 segments and then use those sections in the extrapolation process. We have also found two instances, described below, in which other relicensing reports describe river fluctuations that influence the river outside of the river segment that FirstLight created:

- Section 2.4 and Figure 2-5 of the October 2016 Alden Report included in Appendix C of Study 3.1.3, notes a Northfield tailwater surface elevation fluctuation range of 5 feet at lower flows. The Report indicates that the RFP stated that, "the fluctuation is not an artifact of operations at Northfield but results from downstream control of the river."

- Study Report 3.6.6 goes into much detail about the conditions under which the Governor Hunt Boat Launch located just downstream of the Vernon Dam are affected by operation of Turners Falls Dam and Northfield Mountain Pumped Storage. Though Study 3.6.6 concludes that the operation of Vernon Dam has the most control, the operation of the downstream facilities do affect river levels in this area below the Dam.

CRWC recommendation: We re-iterate the Peer Review recommendation to look at operational effects in the entire reach, and we do not concur with page iii of Volume I of Study 3.1.2 Report which states that, "The results of the hydraulic and BSTEM models indicated that hydropower operations can only potentially impact erosion processes within the hydraulic reach where the project is located due to the varying hydraulic characteristics of the TFI."

River bank Transects

On November 23, 2016, FirstLight filed an Answer to CRWC's November 21, 2016 motion to intervene and comments on FirstLight's application for a temporary license amendment. In the Answer (page 4), FirstLight stated, "CRWC's crude analysis reflects a gross misunderstanding of how field surveying is actually performed. Even when using the same techniques, protocol, and equipment, differing results can occur—particularly when measurements are taken from opposite banks of the river when many locations cannot have permanent ground markers. When plotted, a difference of one foot—or even a few inches—in location from one year to the next can erroneously show dramatic movement in banks. Nonetheless, FirstLight's survey techniques have improved significantly with advances in technology and the results not only show remarkable consistency, but also verify bank stability."

[1] "Fluvial Geomorphology Study of the Turners Falls Pool on the Connecticut River Between Turners Falls, MA and Vernon, VT. Prepared for Northfield Mountain Pumped Storage Project. Prepared by Field Geology Services, Farmington, ME. November, 2007.

In this statement, FirstLight now reveals that there are some transects that do not have permanent ground markers, and are surveyed from the bank across the river. They say that the survey techniques have improved, but that sometimes a difference of a few inches can show dramatic movement in banks. CRWC and members of the Connecticut River Streambank Erosion Committee (CRSEC) have long requested that methods to assess banks be written down in a Quality Assurance Project Plan (QAPP). The QAPP submitted as part of the RSP to Study 3.1.1 did not have a protocol for bank transect surveys. Section 4.2.4 included two sentences on methods: “Transect surveys typically entailed surveying the complete cross-section starting at one riverbank, across the channel bed, and up the other riverbank. Permanent markers are typically placed on both banks denoting the start/end points of the cross-section survey to allow for direct comparison of past and future surveys.” We note that the Full River Reconnaissance (FRR) conducted in 2004 by New England Environmental showed diagrams of cross-sections with the location of bank pins indicated in each profile.

FirstLight’s November 23, 2016 Answer on page 4-5 indicates that some of the transect profiles in Appendix E to Study 3.1.2 were inadvertently flipped, but that the data are correct and FirstLight will file an errata report, as needed. To date, no errata report has been filed for this study.

The Field 2007 report Section 7.3a describes rates of erosion at long term cross-sections. It states that the highest peak discharge since 1990 at the Montague gauge was 1998, a year in which the greatest one-year change in bank position did not occur at any of the cross sections. It also said that the most significant period of bank recession for several cross sections occurred in the early 1990’s with average rates of recession ranging between 1.7 and 4.5 ft/year, but that no flood discharges were recorded during this period. These observations seem to be at odds with the results of Study 3.1.2 that reveal erosion only happens during high flow events.

<u>CRWC recommendations</u>:

- FirstLight submit SOPs for review to state and federal agencies for bank transect survey work.
- FirstLight submit an addendum that explains which transects have permanent markers and which do not.
- FirstLight explain what transect data was input into the BSTEM model – if FirstLight has determined that some transect data can erroneously show dramatic movement in banks, yet this was used to “calibrate” the BSTEM model, did FirstLight smooth out or modify the transect data to fix these errors?
- FirstLight should clarify if the flipped profiles were input into BSTEM on the wrong bank side, or if the presentation in Appendix E doesn’t reflect how the profiles were input into BSTEM.
- Appendix E transect profiles should be corrected and should be re-drawn showing no vertical exaggeration, and the typical operating range of the river elevations should be shown on each profile.

Hydraulic Modeling and Sheer Stresses

The Field 2007 report used two-dimensional numerical hydraulic modeling using bathymetric data. That report stated in Section 6.0 that, "While erosion does occur where high flow velocities and sheer stresses approach near the bank (Figure 17), significant amounts of erosion also occur where flow velocities near the bank are low (Figure 18 and Appendix 4)." Study 3.1.2 comes to the opposite conclusion, that erosion occurs only during high flow events. However, we aren't sure what velocities were used in Study 3.1.2.

Section 4.2.3 of the Study 3.1.2 Report states that two hydraulic models were utilized for this effort – HEC-RAS model developed as part of the Study No. 3.2.2 Hydraulic Study and a River2D model created specifically for the Causation Study. Although we have reviewed Study 3.2.2, the Hydraulic Study, we have not seen any of the background data that would tell us what kind of river velocities are experienced at the banks during any flow range or operational parameter.

As for the River2D model, it appears from the description that the River2D model for this study may be different than the 2-D model developed for Study 3.3.9. This should be clarified, particularly with regard to comments that USFWS submitted regarding the roughness co-efficient in this study and other technical comments.

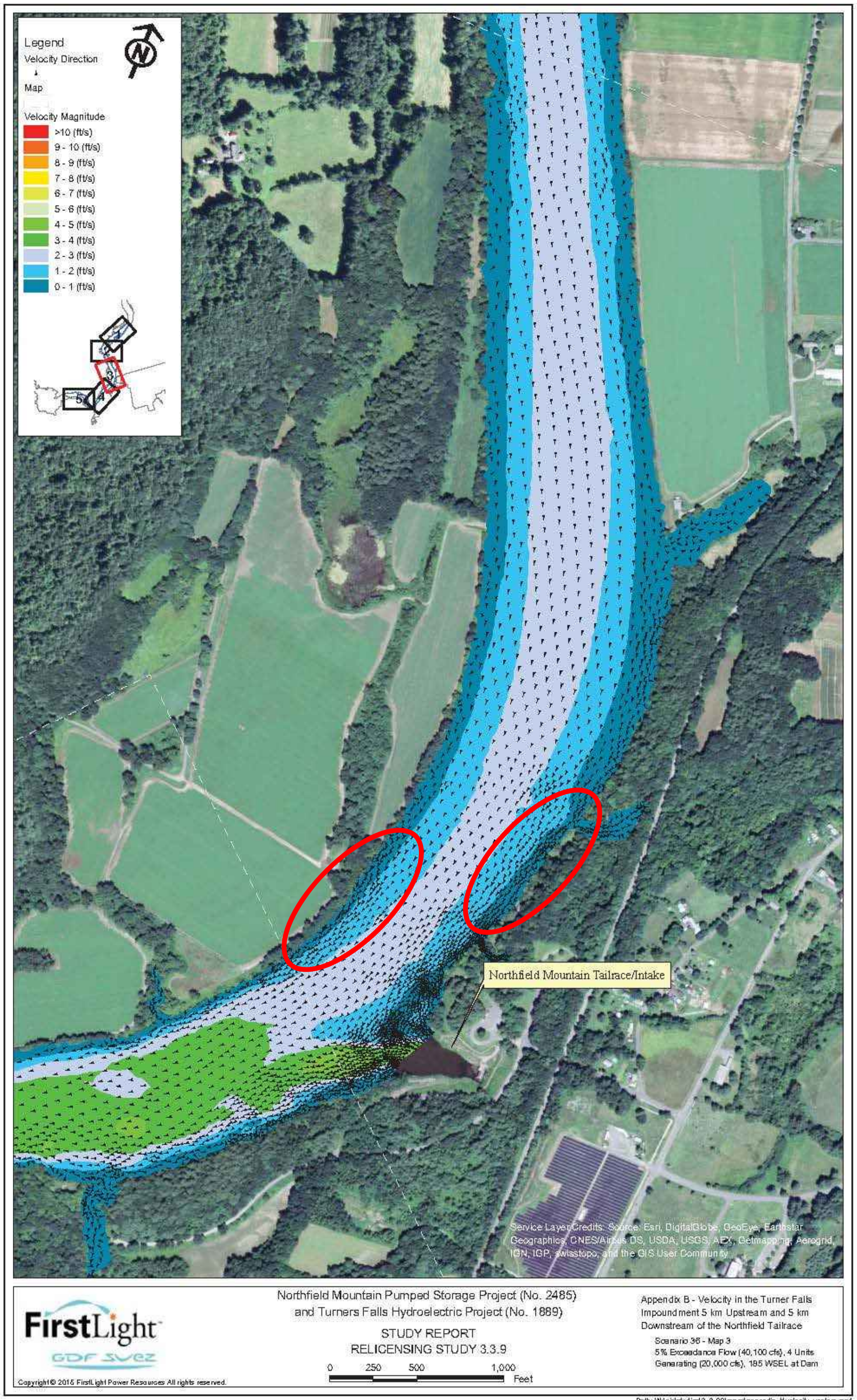
Sheer stresses at flows below 30,000 cfs apparently were not assessed under the RIVER2D model constructed for Study 3.1.2. Pumping and generating with 3 or 4 units apparently was not assessed either, see page 5-29. It is unclear what sheer stress numbers were used in BSTEM for lower flows. If no modeling was done for flows under 30,000 cfs, then it seems like a foregone conclusion that no impacts would be seen if they weren't even assessed.

The pumping data in Study Report 3.1.2 Volume II Table 5.1.3.1-2 for inflow >30,000 cfs does not quite match what was listed in the September 2016 Alden Report for Study 3.1.3. Also, the pumping velocity for 1 and 2 pumps does not match what was listed in the Alden Report. Please see Table 7 in the September 2016 Alden Report and accompanying text for flow and pump use scenarios.

Study 3.1.2 Volume II Section 5.5.1 shows a few velocity maps, but it appears some areas with velocity vectors were overlain upland areas, so it is not clear what velocities are estimated for the river in contact with the bank.

See also the maps on the next two pages copied from Appendix B of Study Report 3.3.9 – Scenario 36 Map 3 (river flow 40,100 cfs with 4 units generating) compared to Scenario 12 Map 3 (river flow 4,900 cfs, 4 units generating). Though one would need to zoom in, a look at these maps hint that there may be areas where <u>bank velocities are higher at the bank under the lower flow scenario</u> (4,900 cfs) than the higher flow scenario. We could find no evidence in Study 3.1.2 of that dynamic being considered.

Red circles in the next two pages highlight areas that should be compared to look at the higher flow (40,000 cfs) vs. a lower flow (4,900 cfs) under maximum generation of 20,000 cfs. Note the higher velocities near the banks under the lower flow scenario. Velocities of water in contact with the bank are not known.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Northfield Mountain Tailrace/Intake
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
FirstLight
GDF SUEZ
Copyright © 2015 FirstLight Power Resources All rights reserved.
Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
STUDY REPORT
RELICENSING STUDY 3.3.9
0 250 500 1,000 Feet
Appendix B - Velocity in the Turner Falls Impoundment 5 km Upstream and 5 km Downstream of the Northfield Tailrace
Scenario 36 - Map 3
5% Exceedance Flow (40,100 cfs), 4 Units Generating (20,000 cfs), 185 WSEL at Dam
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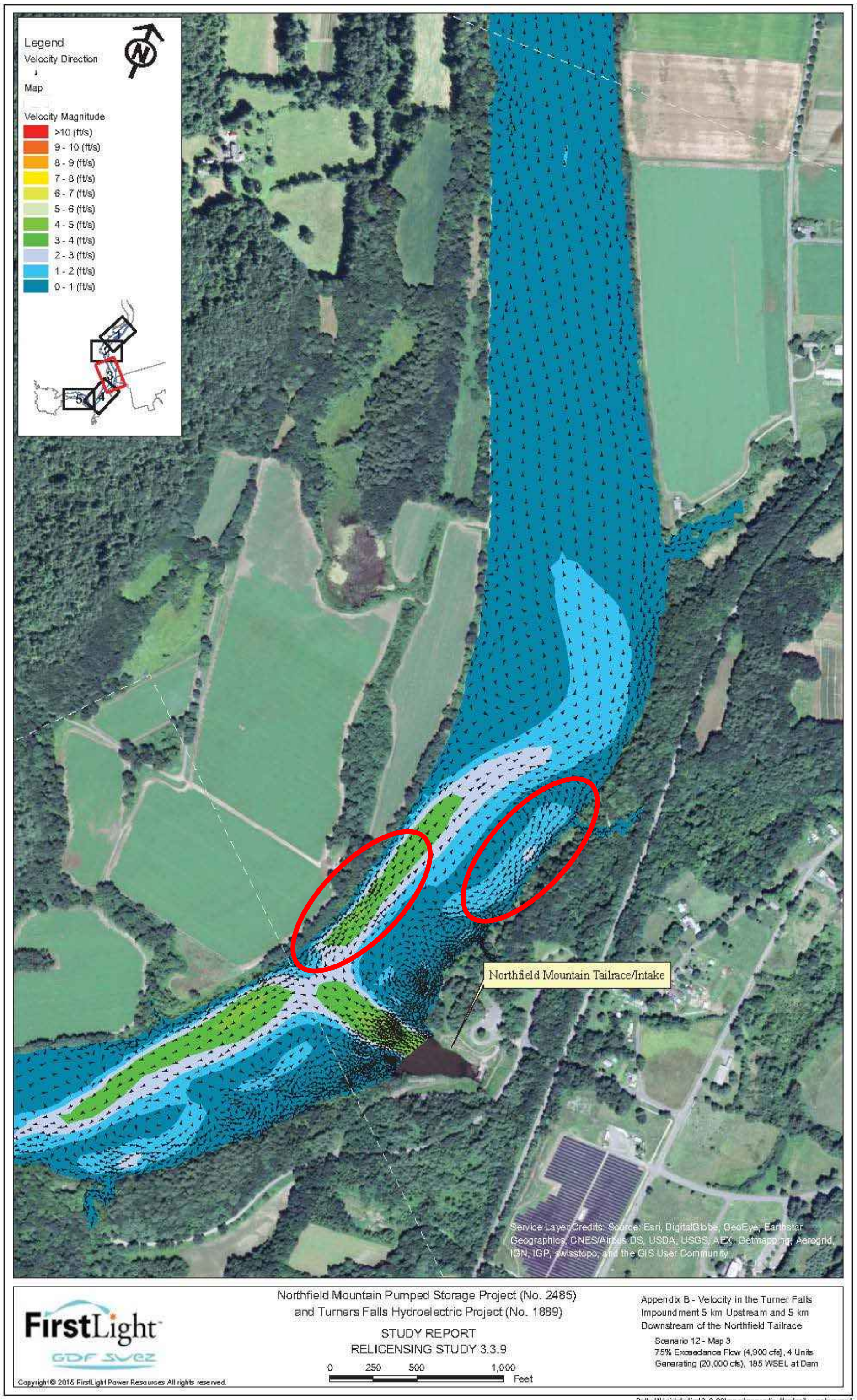
Connecticut River Watershed Council comments on FirstLight Study Reports dated October 14, 2016
December 15, 2016



See also our comments on page 15 later in this letter on Study 3.1.3. Table 7 in the September 2016 Alden report indicates significant uptake of sediments to the upper reservoir during low flows over a given year. This seems to undermine the hypothesis in Study 3.1.2 that erosion only occurs during naturally high flows.

CRWC recommendation:

FirstLight should explain in detail how the RIVER2D model was used. If flows less than 30,000 cfs were indeed not modeled, this appears to be inconsistent with the RSP and FirstLight should explain the rationale.

FirstLight should provide detailed data on hydraulic modeling results and sheer stresses at each of the transects to allow for a complete review.

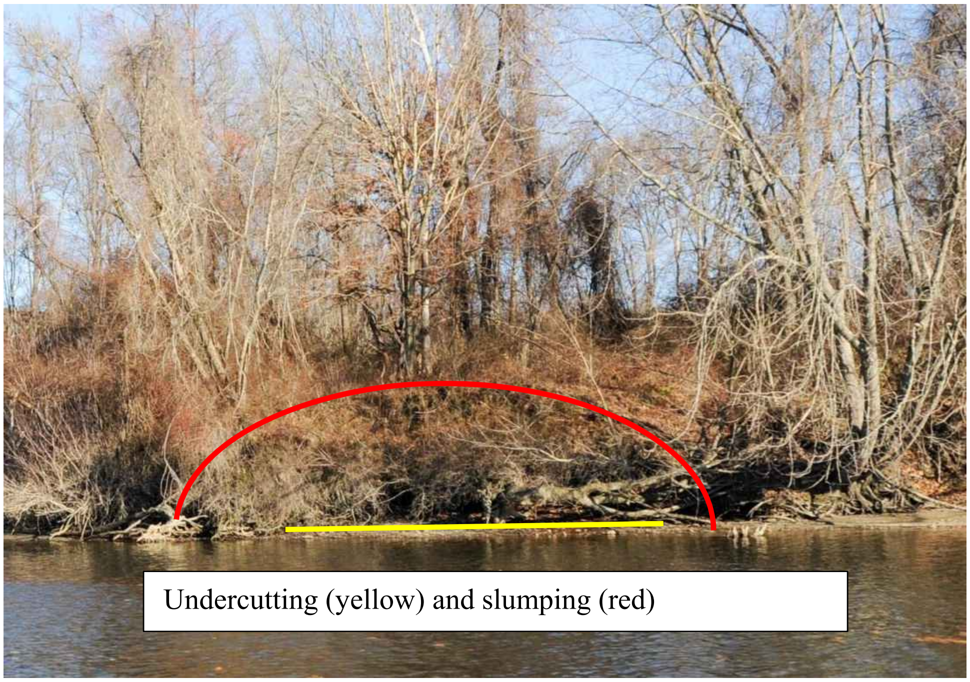
Cyclical process of erosion

Section 7.4 of the Field 2007 report described a cyclic process of erosion, started by the creation of a notch or undercut at the base of the bank by the individual removal of particles. The notch grows taller and steeper, and eventually there will be a topple or slide, and the mass of sediment can be washes away from the bank by water currents. When the report came out in 2007, this description made sense to CRWC and the members of CRSEC, because it described a condition we saw happening out on the river.

This process appears to have been lost in the complexity of Study 3.1.2.

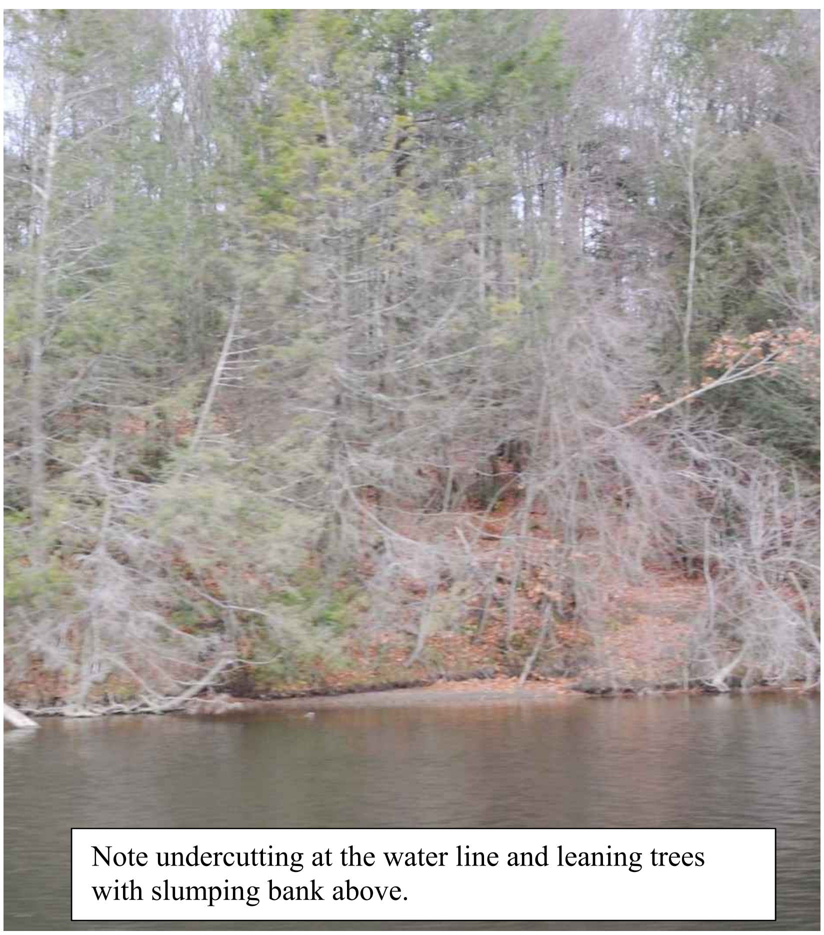
Study 3.1.1 Appendix K November 2013 photos were published online, and during a quick look through those photos, we immediately found two examples in which erosion at the toe of the slope appears to be creating other erosion above it.

The photo below is a cropped version of DSC_0764.jpg from Study 3.1.1 Appendix K photos from November 2013. The location of this photo is river left across from Bennett Brook.



Undercutting (yellow) and slumping (red)

The photo below is a cropped version of DSC_0997.jpg from Study 3.1.1 Appendix K photos from November 2013. The location of this photo is river right downstream of Kidds Island.



Note undercutting at the water line and leaning trees with slumping bank above.

CRWC recommendation:

Study 3.1.2 has ignored a key process of erosion. See the Peer Review memo for specific ways to remedy this so that the study can meet the goals stated in the RSP.

Boat Wave Analysis

Section 4.2.8 provides many pages of detail on the input and results of the boat wave analysis. CRWC did not have enough time to review this section in any detail.

However, for the purposes of *Study 3.6.4, Assessment of Day Use and Overnight Facilities Associated with Non-Motorized Boats*, as well as *Study 3.6.1 Recreation Use/User Contact Survey*, we would like to make note of Table 4.2.8.5-1, which gives results for total numbers of boats (power boats only, or all types?) counted in a season. The data have been copied below. Also Tables 4.2.8.5-3 and -4 give average numbers each day of the week for all weather and for sunny days only.

Table 4.2.8.5-1: Total Measured Number of Boats

Wave Logger	Location	Dates	Number of Boats
WLOG-1	Schell Bridge	May 21 – Aug 28	2,133
WLOG-2	Rt. 10 Bridge	May 21 – Sep 14	2,650
WLOG-3	French King Bridge	May 21 – Sep 14	7,365
WLOG-4	French King Bridge	May 21 – Sep 14	7,263

Progress Reports Lacking

We note that the FERC Determination on the Initial Study Report (ISR) dated January 22, 2015 required FirstLight to provide stakeholders updates after each study task was completed. Since that time, stakeholders received one or two updates in 2015 in addition to the Updated Study Report (USR) filed in September 2015. No progress reports have been provided to stakeholders since the September 2015 USR.

3.1.3 Northfield Mountain Project Sediment Management Plan

In May of 2010, the upper reservoir of Northfield Mountain was drained for routine dredging. Draining the reservoir caused sediments to become entrained in the project's works, and the pumped storage project ended up being off line for five months while the company cleaned out the sediment. During the summer of 2010, the company began dumping excavated sediment into the Connecticut River until the EPA issued a cease and desist order. EPA Clean Water Act Administrative Order Docket No. 10-016 required that FirstLight, "shall submit a report identifying the measures that it will adopt to prevent discharges of sediments associated with draining the pumped-storage reservoir in the future and a schedule for their implementation." FERC letters dated August 10, 2010 and January 20, 2011 requested, "a plan and/or procedures to avoid or minimize the entrainment of sediment into the project's works during similar drawdowns in the future."

Fulfilling the EPA and FERC requirements were essentially the purpose of this study, but the study was incorporated as a relicensing study and the RSP stated that the study purpose "is to better understand sediment transport and dynamics between the Connecituc River and Upper Reservoir. After a few years of monitoring SSC and conducting annual bathymetric surveys in the Upper Reservior, FirstLight will evaluate management meausures to avoid or minimize the entrainment of silt into the Project works and Connecticut River during future Upper Reservoir drawdowns."

The study involved the following elements described below.

Upper reservoir bathymetry surveys and sediment accumulation

FirstLight has chosen to conduct annual bathymetry studies to understand the accumulation rate of sediment in the upper reservoir. The study concludes on page 4-1 that the accumulation rate of sediment in the upper reservoir, based on two different methods, is ~4,000 to ~8,000 cubic yards/year.

In Appendix C, Alden Research Laboratory used the bathymetric studies performed in 2010, 2011, 2012, and 2013 to estimate an average of 17,600 cubic yards of "sediment uptake to the Deposition Zone" (page 36 of September, 2016 Alden Report).

Alden used the higher accumulation rate to calibrate a FLOW-3D model. If FirstLight thought the accumulation rate was too high, it is not apparent from the study.

FirstLight should explain the order of magnitude discrepancy between its sediment accumulation rate and Alden's.

Suspended Sediment Monitoring

Seasonal patterns and trends observed in relation to flow

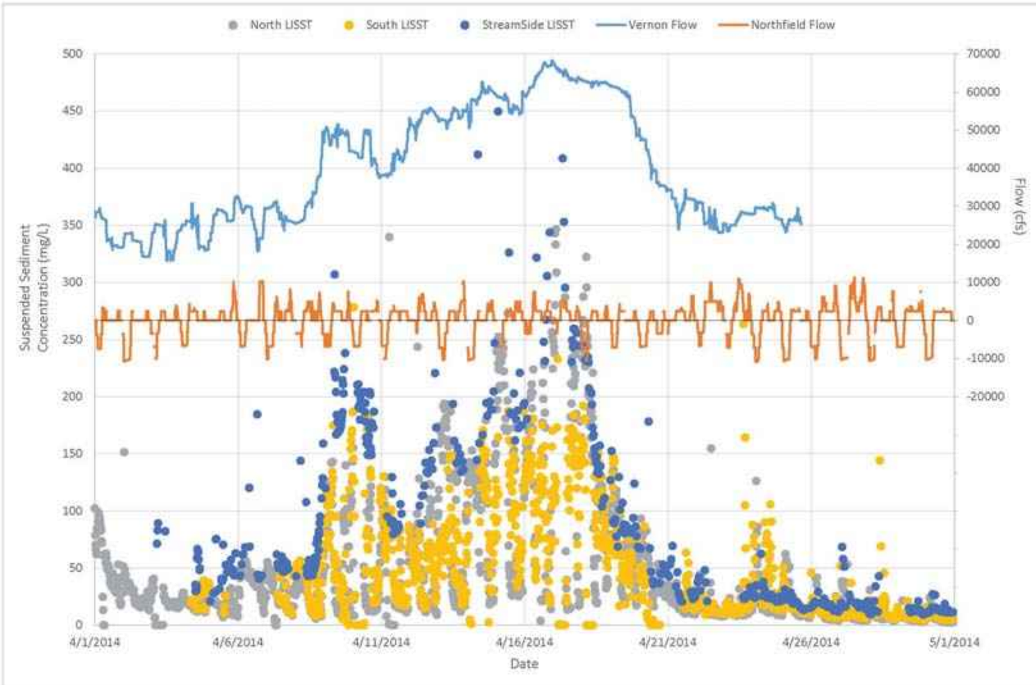
The study concludes that suspended sediment concentrations (SSC) in the Connecticut River were relatively low and without an apparent trend when flows from Vernon Dam were below 12,000 cfs; increase between 12,000-35,000 cfs, and were significantly higher when flows exceeded 35,000 cfs.

CRWC has examined the Figures and graphs in the appendices. What we have observed is that during spring high flows (above 35,000 cfs), SSC levels increase above 40 mg/L. In the spring, flows between 20,000-35,000 cfs experience low SSC levels (generally below 20 mg/L). However, in the summer and fall, SSC levels above 20 mg/L can be triggered by moderate high flow events in the range of 12,000-30,000 cfs.

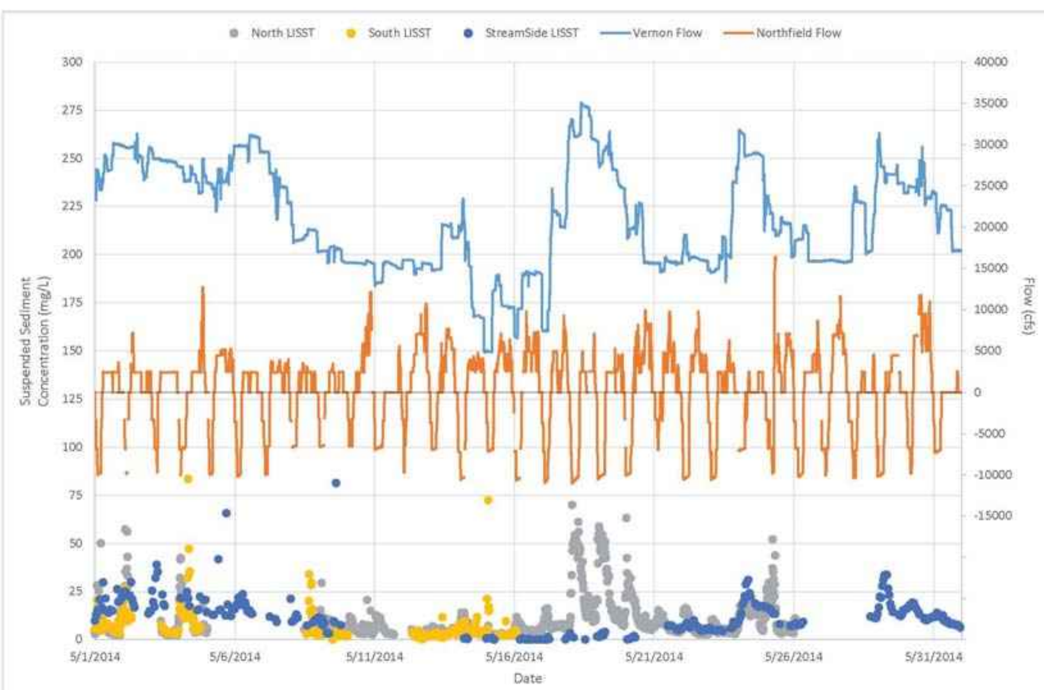
We do not concur with the three flow thresholds identified in the report, therefore, and think the report should note the possibility of seasonal thresholds.

Patterns and trends observed in relation to flow, Vernon operations, and Project operating conditions.

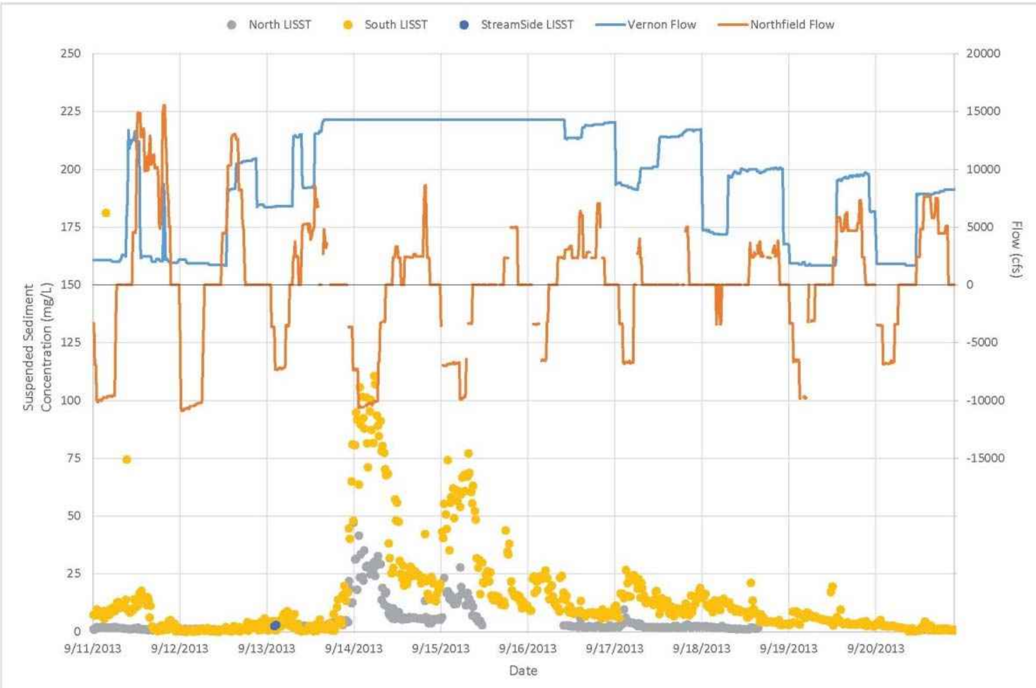
Figure 4.2.1-15 shows box plots indicating that Northfield Mountain tailrace samples analyzed during pumping had higher SSC than during generating. This fits with the hypothesis that sediment in the river is deposited in the Northfield Mountain upper reservoir. What wasn't investigated in detail is whether pumping concentrations exceeded river concentrations. Are there situations where pump concentrations are higher than ambient river sediment? During April 2014, during high flows (40-70,000 cfs) – no. See graph copied below from Appendix D (p. 437 in pdf file).



When high spring flows stabilized and declined, there were hints that SSC levels when pumping (yellow and gray) were higher than the ambient river SSC levels (blue dots). See above and below (copied from Appendix D (pdf page 438). CRWC doesn't have an explanation for a mechanism that would cause higher SSC levels when pumping than is in ambient river levels, other than erosion caused during pumping, but it may be worth additional thought.



Below shows a scenario (graph copied from Appendix D, pdf page 430) in September 2013 when flows from Vernon were stable and elevated (~14,000 cfs) for about three days, and the SSC levels at the Northfield tailrace rose and fell with the Northfield pumping and generating cycles.



Other than Table 4.2.2-3, there is no analysis of SSC levels compared to the number of units pumping and generating. Better analysis is needed, showing 1-4 units pumping (only 2 units pumping is shown for a single date), and 1-4 units generating (1-3 units are shown, each on a single date) and concentrations when idle (only a single date is shown). The analysis should include multiple dates, separated by season.

Sediment Management Techniques Explored

Physical change to upper reservoir intake channel and operational changes

Alden Research Laboratory was contracted by FirstLight to create a 2-D sedimentation model for the upper reservoir and to evaluate sediment management alternatives. Their work was summarized in a report called "Engineering Studies of Sedimentation at the Northfield Mountain Project" and dated May, 2014 ("2014 Alden Report"). It was included as an appendix the December 2014 Sediment Management Plan report.

The 2014 Alden Report compared an existing conditions model to three sediment management strategies. One management strategy was to narrow the intake channel of the upper reservoir, which would increase the velocity of water exiting the upper reservoir. The two other strategies involved lowering the minimum upper reservoir level to 928 or 920 ft, to flush out some of the sediment build-up. All of these options led to a 4-5% reduction in sediment accumulation in the reservoir and intake area compared to current operating procedures.

A sensitivity analysis was performed to model drawdowns to 901 feet to mobilize small annual amounts of sediment. The 2014 Alden Report concluded that an adaptive management plan could be developed to draw down the reservoir level for controlled release of sediment on a periodic basis.

Sediment exclusion structure in Connecticut River intake/tailwater

Alden Research Laboratory was contracted by FirstLight to create a 3-dimensional (3-D) Computational Fluid Dynamic (CFD) model of the Connecticut River Intake/Tailwater to better understand the mobilization of Connecticut River sediment determine if physical modifications to the intake/tailwater could help to reduce future sediment accumulation in the Upper Reservoir t. Their work was summarized in a report called "Engineering Studies of Sediment Uptake at the Northfield Mountain Connecticut River Intake/Tailwater" and dated September 12, 2016 ("September 2016 Alden Report"). It was included in Appendix C to Study 3.1.3.

Table 7 in the September 2016 Alden Report summarizes the model runs, looking at sediment transported during five different representative river flow levels (5,000; 15,000; 25,000; 35,000; and 50,000 cfs), representative sediment concentrations for each flow, scenarios for 1-4 pumps, and weighted against actual operational patterns with these flows. It shows an uptake of 24,155 tons of sediment material transported into the upper reservoir over the course of a year. If you add up the sediment transported under all pumping scenarios for the three lowest flows (approximately 85% of the year, according to the flow duration curve), 13,719 tons of sediment is transported to the upper reservoir during these times of year, or 56.8% of all the sediment in the year.

The September 2016 Alden Report concluded that plant operations and pumping rates have an influence on the amount of sediment uptake to the Upper Reservoir. The model runs showed consistently higher amounts of sediment uptake when 3 and 4 pumps were running. For example, when the river flow was 5,000 cfs and 4 pumps were running, this transported 2,878 tons of material, which was 12% of the annual sediment transport to the upper reservoir. In fact, this scenario estimated more sediment transport than any flow scenario using fewer pumps, except for 3 pumps at 50,000 cfs,

The September 2016 Alden Report concluded that a sediment exclusion structure could be expected to decrease sediment mobilization to the Upper Reservoir by 10-20%.

Physical model testing of exclusion structure

Alden Research Laboratory was contracted by FirstLight, based on a request for proposals in 2015, to conduct field data collection and create a scaled physical model of the Connecticut River Intake/Tailwater with the "main objective" to design and test proposed new civil works to be constructed at the existing Connecticut River intake structure in order to reduce the intake of sediment during the pumping cycle of the plant. The model upstream end is 3.2 km upstream of the Northfield Mountain intake. The downstream model boundary is 0.8 km from the intake, for a total length of 4.0 km. Their work was summarized in a report called "Connecticut River Physical Modeling Project" and dated October 12, 2016 ("October 2016 Alden Report"). It was included in Appendix C to Study 3.1.3.

In Section 2.5.3 of the October 2016 Alden Report, it states, "Based on discussions with GDF Suez the target model sediment concentrations shown in Figure 2-12 were identified. At a river flow of 70,000 cfs, a suspended sediment concentration of about 400 mg/L was targeted." As the report points out, a flow of 70,000 cfs has a recurrence interval of 5-10 years (page 7) and the target suspended sediment concentration of 400 mg/L is significantly higher than observed values in the river (page 12). CRWC is unclear why so much effort was put into modeling a high flow event that occurs relatively rarely, and at a concentration not representative of typical conditions. The motive was not stated. Most of the physical model test runs were based on 70,000 cfs. When they ran the test at 40,000 cfs, they used an SSC concentration much lower than observed results. One wonders what the other objectives of the project were.

Section 6.3 of the October 2016 report indicates that the contribution of sediment to the reservoir during periods of low flow relative to periods of high river flow remains unknown. Based on the physical model results, Alden recommended further analysis to estimate the amount of sediment transported to the reservoir during periods of low river flow. It also recommended exploring the constructability of a moving weir and to conduct the physical model tests during generation.

The Background section in the October 2016 Alden Report states, "The upper reservoir has experienced chronic sediment accumulation; however, the rate of accumulation appears to have increased in part due to an operational change in the reservoir management… Historically, the reservoir level varied between a high of about 1,000 feet and a low of about 920 feet. More recently the reservoir low water level was increased to 938 feet." CRWC is curious about this statement, since the original license mentioned a low of 938 and this, to our knowledge, has been the license limit of lower reservoir level for the history of the project, other than during temporary amendments.

Pilot Dredging of Upper Reservoir

FirstLight conducted a pilot dredging project between April and November of 2015, during which approximately 45,000 cubic yards of sediment were successfully removed by deep water dredging. The study indicates that hydraulic dredging was found to be a viable sediment management measure.

Proposed Sediment Management Measures

After six years of study, FirstLight's plan is the following:

- Conduct bathymetric surveys of the Upper Reservoir and intake channel at least every two years.
- Excavation of the intake channel and/or other target areas will be planned and initiated "as needed to minimize entrainment of sediment into the Project works during dewatering.
- FirstLight will develop protocols to be followed during 1) an emergency dewatering and 2) during a maintenance or other type of dewatering.
- No operational or physical modifications are proposed.

Absence of protocols

CRWC was surprised that protocols were not included in the final report. This is what EPA and FERC requested in 2010.

<u>CRWC recommendation:</u>

CRWC recommends FirstLight prepare an addendum to Study 3.1.3 that contains the following details:

- protocol to follow during future dewatering events.
- levels (or approximate levels) of sediment accumulation in the upper reservoir that would trigger either targeted hydraulic dredging or dewatering and maintenance. If this is not possible, state a maximum number of years between maintenance activities. *Note*: CRWC asked about this at the study report meeting, and we were told that the information was in the Alden 2014 report. After close read of this report, we believe sediment accumulation trigger levels were not discussed in this report.
- FirstLight should specify which technology will be consistently used for future bathymetry surveys (i.e., multi-beam echosounder surveying) so that years can be compared.
- FirstLight should identify how much storage capacity it has in the upper reservoir area for dredged sediments, and what the plan is for future disposal/storage options.
- Schedule for implementation of plan.
- FL should clarify what operational change in upper reservoir management has increased the rate of sediment accumulation, as mentioned in the October 2015 Alden Report.

3.3.1 Instream Flow Study in Bypass Reach and below Cabot

CRWC has been participating in meetings related to this study, and we will be reviewing subsequent filings. At a meeting held on December 2, 2016, FirstLight and stakeholders agreed on additional runs and mapping of currently completed runs.

3.3.2 Evaluate Upstream and Downstream Passage of Adult American Shad

Study 3.3.2 is an important study, with the goal of the study, "to identify the effects of the Turners Falls and Northfield Mountain Projects on adult shad migration." There are 9 study objectives listed in the RSP, aimed at understanding upstream and downstream migration delays, route selection and behavior, passage rates, and effectiveness of the existing fish ladders. Don Pugh wrote a letter to FirstLight dated March 25, 2016 that summarized all the telemetry information he and other stakeholders wished to see in the report. Don's letter is attached at the end of this letter. Much of that information was not in the report. In addition, clarification and additional data are necessary to understand whether or not FirstLight followed the RSP and whether or not the study objectives were met. Moreover, stakeholders want to have a good understanding of the results so as to enter into future upcoming license discussions. CRWC is recommending that FirstLight revise and re-submit the study report for Study 3.3.2, so that stakeholders can adequately review the methods, results, and conclusions of this important study. We prefer a revised report to an addendum to avoid confusion as to what information is in what report.

Connecticut River Watershed Council comments on FirstLight Study Reports dated October 14, 2016
December 15, 2016

General comments:

- The report identifies the Montague receiver as part of the lower river spoke. Discussions with all stakeholders, prior to the release of the report, noted, with agreement of all, that Montague was within the project. That fish detected at Montague had arrived at the project.
- Tabular data should be presented for the numbers of fish at important locations (Montague, tailrace, entering Cabot ladder, exiting ladders, at base of dam, at upper end of the canal, in the Cabot forebay, etc.) and associated passage statistics including total project passage efficiency.
- Additional tabular data should include but not be limited to: number of hours fish are in the tailrace and number of entries by hour, time spent by fish at the base of the dam, time spent in the canal prior to Gatehouse passage, time spent in the impoundment prior to downstream passage (both routes), time spent in the canal during downstream passage.
- The terms survival, transition, recapture, attraction are at times confusing (e.g. Cabot attraction, Spillway attraction are unclear as to whether that means entry of close proximity). These should be clarified.
- For all state tables and charts, the number of fish represented should be included.
- Adjust numbers of fish detected by eliminating ‘fish’ that were spurious detections (e.g. Holyoke released fish only detected in the canal or with few detections at a single location that has a high proportion of spurious detections).
- Heat maps that include bypass flows should be limited to 7,500 cfs to understand in better detail the potential effects of manageable flows as opposed to flows beyond control by the project

Specific comments:

3.2 Study Design and Methods

- The report states that the fishways were operated in the normal method with one foot differentials at the entrance. Does this apply to the old entrance to the Gatehouse ladder?

Table 4.2-3

- The number of detections at T1, T2, and T3 should be included. T3 is considered as the arrival at project location.

4.4 Mobile Tracking and Evaluation of Mortality

- Mortality determined from receiver detections for a prolonged period of time with no subsequent location up- or downstream should be included.
- Route specific mortality should be reported (e.g. x number of fish pass through the units and y number died).

4.5 Data Reduction

- How were single detections evaluated for validity? Fig 4.5-2 would seem to indicate that all single detections were false.

4.6.1 Holyoke to Montague

- It is not clear how hours in the state table relate to individual fish movement as it appears to group all fish. For example, there were 514 hours when fish remained at the Canoe Club, but was this one fish or 25 fish, and if it was many fish, what was the distribution of hours?
- The report needs to define the "project". Previous discussions, with all stakeholders, defined arrival at the project as detection at Montague. It should not be included with T1 or T2 as lower river.

4.6.2 Montague Spoke

- Tabular numbers of fish at Montague, moving to Smead Island, the tailrace and the bypass will enhance the understanding of fish behavior at this location.
- Fish likely made multiple attempts moving upriver from Montague and this should also be noted. Time spent at Montague should be evaluated including the effect of flow and diel period.
- Some fish moved from Montague to the bypass (Conte discharge) without being detected at Smead Island or the tailrace but are not discussed in the text. Others were detected at the tailrace far field antenna for a brief period indicating movement through that area, but not a "stop" at the tailrace. It is not clear which category these fish fell in: tailrace or bypass. They should be included in the Montague to bypass category. For these fish, the time of detection at the tailrace that is determinative of route/location and the justification for that time should be provided.

4.6.3 Cabot Ladder Attraction

- Tabular data for numbers of fish in the tailrace, entries into the ladder, range/distribution of entries by fish, time from first detection in the tailrace to entry, number of hours fish were in the tailrace would provide context to movement probabilities.
- "The state table counts 137 forays into Cabot ladder, with 120 from the tailrace, 8 from downstream receivers and 9 from the bypass reach. This number of forays differed from the sum of the number of forays per fish according to the raw recapture data." (Quote from pg. 4-55) How and why they are different should be explained.

4.6.5 Bypass Reach

- Again, tabular data would assist understanding movement in the bypass reach: how many fish moved to either side of Rawson Island, how many fish passed each side and how many failed, what were the times fish spent in the east side, how many fish passed Rawson Island undetected and what were the flows associated with success or failure in passing.

4.6.6 *Spillway ladder attraction*

- Figure 4.6.6-2 describes fish approaching the spillway ladder by time of day. It is unclear if approach means 'in the proximity of' or 'enters the ladder.' For the limited number of fish in the pool below the dam, 144 'approaches' seem high.
- Paragraph 5 says 11 dual tagged fish made at least one attempt on Spillway ladder (entered?) and in the next paragraph it says, "In total, 34 dual tagged fish made at least 17 successful attempts into the spillway ladder from the spillway,…". This seems contradictory or confusing.
- A more complete analysis of the time from the first Montague detection to the first detection at the dam T-19 & T20 should be done to assess delay associated with finding and entering the spillway ladder.

- During different periods of the study Station #1 operated or did not. Bypass flow is earlier described as spill plus Station #1. For the Spillway ladder attraction model it is not clear what flow is used in Tables D-1.6-1, D-1.6-2 and the histogram of bypass flow. For analysis of entry into the bypass or passage at Rawson Island including flow from Station No. 1 is appropriate. For entry into the Spillway ladder it is not.

4.6.7 Spillway Ladder Efficiency

- Spillway ladder entrance efficiency for both dual and PIT only tagged fish is stated as 91.5%. It is unclear how this is derived. Ladder entrance efficiency is generally the number of fish that enter divided by the number available/in close proximity (detected in this case by T19 or T20). Since PIT tagged fish cannot be detected in the pool, they cannot be used in calculating a measure of entrance efficiency. A table of fish in the pool below the dam the fish that entered, and the number of attempts would be appropriate.
- Overall ladder efficiency is the number of fish that pass, divided by the number of fish available. Again, as PIT tagged fish are not 'available', overall ladder efficiency can only be calculated with dual tagged fish as opposed to internal efficiency which can use PIT tagged fish. Tabular data of PIT and dual tagged fish would better describe the performance of the ladder.

4.6.8 Upstream Migration through the Canal

- An analysis of the telemetry database shows only 6 dual tagged fish passed the Cabot ladder making a total of 56 dual tagged fish for canal upstream movement.
- Of those 22 were detected at T22 (downstream of gatehouse). Four fish that came up the Spillway ladder were also detected on T22. It is unclear if the detections at T22 were if the fish dropped into the canal or when they were in the Spillway ladder not, but they cannot be considered as fish that moved from the lower canal to the head of the canal

4.6.9 Gatehouse Ladder

- Gatehouse ladder efficiency should be calculated as the number of fish passed / number of fish available (detected at T22).

4.6.10 Upstream Migration through the TFI Impoundment

- Movement and delay times at Northfield Mountain Pumped Storage Facility("Northfield") for all operating conditions should be more fully detailed. The report states for upstream movement past Northfiel,d there was some delay and milling at the intake. The numbers of fish, project operation status, and their respective delays should be provided along with analysis.

4.6.11 *Downstream Migration through the TFI Impoundment*

- Impoundment-released fish that were detected at Shearer or Stebbins Island and then moved downstream should be included in the analysis.
- A more complete analysis of delay at the Northfield intake, including specifics as to delay and the effect of operations on that delay, is needed.

31 *4.6.12 Downstream Migratory Route Choice at Turners Falls Dam*

- In addition to impoundment-released fish and TransCanada fish, FirstLight fish that passed into the impoundment should be included in the evaluation of downstream route.

- Downstream route choice and delay by route should be analyzed in relation to flow to the canal, to spill and the number of fish available under different conditions.
- Delay at the dam should not include impoundment released fish that move downstream within 24 hours of release.

4.6.13 Downstream Migration through the Canal

- Multi-state Markov has 86 fish "moving through the telemetry subnetwork" and Time to Event uses 98 fish. An explanation as to why different numbers were used would be helpful.
- The second paragraph states that 28 fish transitioned from the Cabot forebay to the tailrace but the fifth paragraph says 37 passed from the forebay through the turbines (pg. 4-88). This is confusing.
- The sixth paragraph on page 4-88 states, "Fish at the Downstream Bypass were most likely to be detected next at the Cabot Forebay, though the probability of next detection decreased with increases in flow (93% at 25th percentile flow decreasing to 97% at 100th percentile flow; …" It seem like the probability is <u>increasing</u> when it goes from 93 to 97%.
- Last paragraph on page 4-88 says that fish passed quickly through the downstream bypass while the text on page 4-89 (2nd paragraph) says that there was a large delay for fish using the downstream bypass. How are these reconciled?

<u>Discussion and Conclusions</u>

Upstream migration

- The 2nd paragraph says, "Fish preferred to move into the Cabot Tailrace during times of low flow," while the 3rd paragraph says, "Attraction to the Cabot ladder increased as Cabot discharge increased, suggesting the discharge from the powerhouse provides attraction flow." These statements appear to be contradictory.

Summary

- Though just over half of the fish released at Holyoke were detected, a better metric for fish reaching the project is the number of dual tagged fish detected at the project (94) divided by the number detected (154) or detected at Rt. 116 or above (116) to account for post tagging effects. In that case, movement to the project would be 61.0% or 81.0%, respectively.

3.3.3 Evaluate Downstream Passage of Juvenile American Shad (Interim Report)

<u>General comments</u>:

Problems associated with milling at the hydroacoustic installations other than Cabot, and the erratic swimming and poor survival of radio tagged fish, negate the results of this study. As such, no information on entrainment at Northfield or route choice of juvenile shad at the Turners Falls dam or in the canal is available. FirstLight made a good faith effort to re-do the telemetry portion of this study in the fall of 2016, but river conditions (low flow due to a serious drought all summer) would have made any results of little value, and the study was not done. CRWC recommends that the study be repeated in 2017.

Our additional comments on specific parts of the Study Report follow.

4.1 Run Timing, Duration, and Magnitude (Hydroacoustics)

- For the Northfield Mountain and Power Canal locations that had significant milling, a review of the data to evaluate the amount of milling may provide a general picture of the timing of shad movement.
- Section 4.1.3 in the report fails to note that the study was conducted during a season in which only three of the possible four turbine pumps/generators were in operation.

4.2.2 Routes of Passage

- The report says 129 fish were released above Shearer. Of the 129, 77 were detected at Shearer and 24 detected in the Northfield forebay and 3 in the upper reservoir. This does not provide sufficient information as to whether fish different fish were detected down river from Shearer. A table with individual fish ID's at each location would be very helpful to better understand movement.
- The description of the fate and routes of fish released above the Turners Falls dam is inadequate.
- A calculation of a 3.9% entrainment requires that the 77 fish detected at Shearer all pass Northfield.
- Based on the fish loss from upstream station to downstream station, it seems overly optimistic to assume that no fish were lost between Shearer and the project. As such any calculation of entrainment would be bias.
- Three fish were entrained and 21 last detected at the intake of the Northfield station. It is likely that some of the 21 fish were entrained, and that they lost their tag during the pumping cycle (highly likely as tags were lost in the control tank) or that they were not detected in the upper reservoir. If all 21 were entrained and 77 did pass, the entrainment rate would be 31.2% (24/77). And if only the fish last detected during pumping were entrained, the entrainment rate would be 22.1%. Again, this assumes that all 77 Shearer fish passed the project. While this is somewhat speculative, the potentially high entrainment rate reinforces the need to repeat the study.

Discussion

- CRWC agrees that the problems with the study call into question the telemetry results. A similar study done at the Vernon project (FERC # 1904) was successful in assessing routes of passage. While monitoring juvenile shad is difficult, it is not impossible, and not a justification to not repeat the study. The potential entrainment of more than 30% of juvenile shad passing the project and the high mortality of shad spilling over the dam would severely impact restoration efforts in the Connecticut River.

3.3.6 Addendum: Impact of Project Operations on Shad Spawning, Spawning Habitat and Egg Deposition in the Area of the Northfield Mountain and Turners Falls Projects

We spent some time comparing Table 1 of the Addendum (2005-2009) with Table 4.1-1 of the Study Report (2010-2014) side by side. Each shows the discharge changes/generation changes over 5 years for the hours of 8 PM to 2 AM for May and June. For 2010-2014, the total number of decreases = 130 and total number of increases = 216. During this 5-year period, there were more <u>increases</u> in generation than decreases. For 2005-2009, the total number of decreases = 483 and total number of increases = 242. For this earlier 5-year period, there were many more decreases in generation than increases.

For 2010-2014, 33% of changes were increases of 0-10 MW, followed by 22% decreases of 0-10 MW and 20% increases of 10-20 MW. For 2005-2009, 46.3% of changes were decreases of 0-10 MW, followed by 19% increases of 0-10MW and 15.7% decreases of 10-20 MW. Generation change decreases in the highest category went from happening almost never (only 1 time total from 2005-2008) to something happening at least 1 time per "season" up to 5 times/season.

It seems that operations in one 5-year period, 2005-2009, was quite different than the following 5-year period, 2010-2014. What that means for spawning, or any other study, we don't know. We also are not sure what this means for future operations or for using 2002 as a "typical" year in other studies, since it we don't have information for 2002 and it appears that operations have not stayed similar over the past 10 or so years.

3.3.7 Fish Entrainment and Turbine Passage Mortality Study

The last paragraph of the Executive Summary states that, "Operation of the Northfield Mountain Project may impact fishes due to entrainment. However, pumping operations generally only occur over a few hours between midnight and 6:00 a.m., thereby limiting impacts to a 6 hour period each night." No further information is included in the body of the report regarding this statement. CRWC does not have access to operational data, other than the data filed with FERC during temporary amendment periods during the winter. That data show that pumping often lasts until 7 AM, 8 AM, or 9 AM in the morning during the winter months. Also, in March of 2016, the data show a few afternoons when pumping occurred. We have no way of verifying whether or not that is true during the later spring and summer; however, we question the validity of FirstLight's statement until more information is provided. Moreover, there are no restrictions on times of day that the facility can pump or generate.

CRWC offers the following additional comments on the study report:

- The adult shad telemetry study (Study Report 3.3.2) notes that six fish detected were detected at the Station No. 1 forebay with 7 successful escapes (pg. 4-72). The Kleinschmidt Associates (contractor to FirstLight) database has 7 fish including 2 released in the impoundment including one which did not escape. Clarification is needed.
- The estimate of 3.9% entrainment at the Northfield project of juvenile shad represents the absolute minimum, as not all 77 fish detected at Shearer likely passed the Northfield project and more than 3 fish were likely entrained.

3.3.13 Impacts of the Turners Falls Project and Northfield Mountain Project on Littoral Zone Fish Habitat and Spawning Habitat

The RSP to this study listed one of the specific objectives as, "delineate, qualitatively describe…, and map shallow water habitat types." The report shows a map with dots for nesting spots identified, but no delineation of habitat types.

The RSP had many maps showing the study area for this study (Figures 3.3.14-1, Pages 1 through 23[we think the numbering should have been 3.3.15-1]). It appears that the entire study area could not have been covered in the two field days devoted to this effort in May and then June.

Task 2 of the RSP indicates that FirstLight was supposed to observe tributariess identified in Study 3.3.17 as accessible during spawning seasons. The report says they looked at "major" tributaries and list a few by example, but it is unclear if Study 3.3.17 was consulted in any way.

The second paragraph of Section 3.1 in the Study Report said the littoral zone was considered to be the area extending from the edge of the water line at the shore of the time of survey to 6 ft in depth. Relying on 6 ft of water during the field visit is a little odd, since water level fluctuated by 2 ft or so during a field day. Also, the RSP maps show some potential littoral areas in the middle of the river. Did the field crew confirm that those areas were not good candidates?

The raw data sheets in Appendix A only contain sites 001-006 for the early spring surveys. Sites 8-17 were not included.

The literature review section 4.1 is very paltry. Did the Fish Assemblage Study 3.3.11 results have any bearing?

All the figures showing the sites and the unsteady and steady state flows (Figures 4.3.2-1 through 15) indicates that many sites are very susceptible flow fluctuations. This seems to be glossed over in the text.

We believe that the flow duration curves for the Turners Falls dam from the PAD dated October 30, 2012 (Figure 4.3.1.2-19 from the PAD copied below) are essential to the analysis of the "steady state" graphs provided in this report. In this study, steady state is a simulated condition under a Turners Falls elevation of 176, 181.3, and 185 ft. For example, in Figure 4.3.2-3, Site 10, if you brought the Turners Falls pool level down to 176 ft, you would need a flow of 25,000 cfs just to have the water level match that of the spawning habitat. Looking at the flow duration curve, that only happens 30% of the time in May. That seems like a high impact, if the facility operated under its licensed conditions.

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)
PRE-APPLICATION DOCUMENT

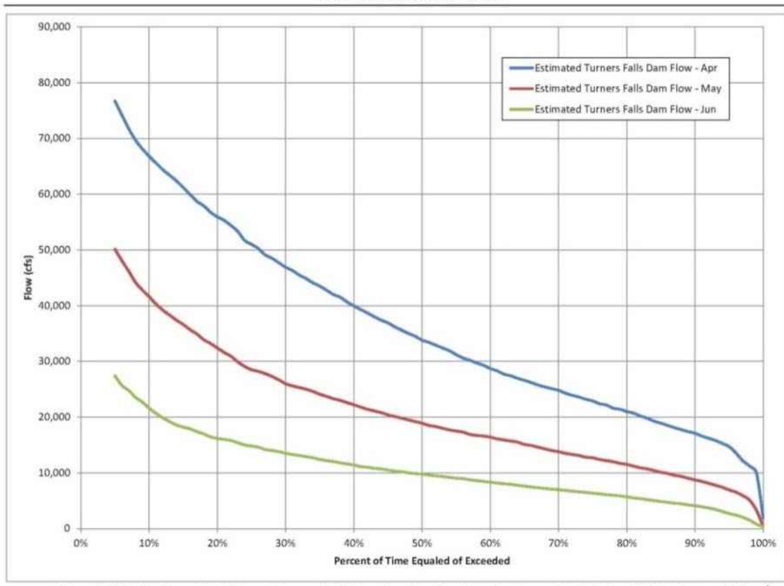


Figure 4.3.1.2-19: Connecticut River at Turners Falls Dam, Apr-Jun Flow Duration Curve, Jan 1941-Sep 2010, Drainage= 7,163 mi^2

October 2012 *4-71*

3.3.15 Assessment of Adult Sea Lamprey Spawning within the Turners Falls Project and Northfield Mountain Project

CRWC offers the following comments on the study report:

- The FERC Study Plan Determination dated February 21, 2014, stated on page B-71, …"we recommend FirstLight not limit its detailed monitoring to only 25 redds, but utilize all survey data, including the location and depth of suitable habitat and redds, for comparison with results of the hydraulic model in study 3.2.2. FirstLight should then determine if spawning areas/redds are subject to dewatering and describe the degree of project-related water level fluctuation at each spawning site." The hydraulic model was used only to confirm that during the period from June 19 to July 10 that the observed redds were not dewatered. This is a single year of data when flows during this period were generally high. Redd locations observed during the study and all suitable habitat should be evaluated using a low flow year.
- Because FirstLight did not adequately use the hydraulic data, we do not concur wioth the conclusion that there is no project effect at all spawning sites in the study. For comparison, Table 5.3-3 in TransCanada's Study 16 showed that some of the sea lamprey nests near Stebbins Island were exposed 5% of the time. There was nothing like that in the FirstLight observations.
- Depths and velocities from field notes when sea lamprey were observed on redds should be used to revise the Habitat Suitability Index (HSI) curves.
- Revised HSI curves should then be used to revise habitat mapping.

3.3.16 Habitat Assessment, Surveys and Modeling of Suitable Habitat for State-Listed Mussel Species in the Connecticut River below Cabot Station

CRWC did not review this study report in detail, but we would like to point out that having the consultant who was hired to prepare the mussel report (Ethan Nedeau of Biodrawversity) also sit on the Delphi panel compromises the objectivity of the results.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

This study used results from multiple other relicensing studies to analyze the effects of project operation on project recreation facilities and land use. The study did not assess the effects of project operation on the ability to recreate in certain areas. For example, the current minimum flows in the bypass reach prevent the use of boats in that stretch, but that kind of effect was not assessed in this study.

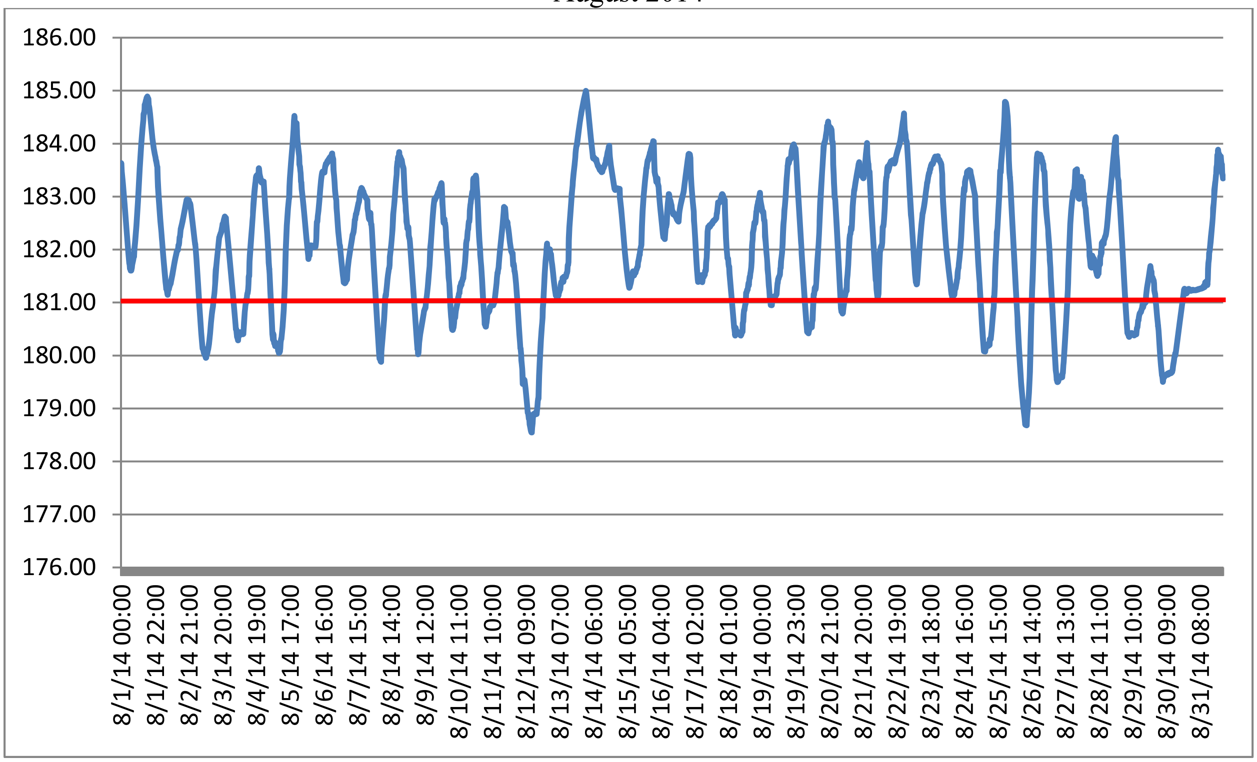
Overall, the study preparers expended little effort to produce this report and the data involves little meaningful analysis. Below are our comments.

4.2.2 Pauchaug Boat Launch. As we discussed at the Study Report meeting held on November 1, 2016, the presentation of water level data in this report leaves much to be desired. The analysis involves median monthly water elevations and water surface elevation curves for each summer month. What is most important is the daily fluctuation below a minimum level. What happens in the middle of the night when people aren't boating is irrelevant.

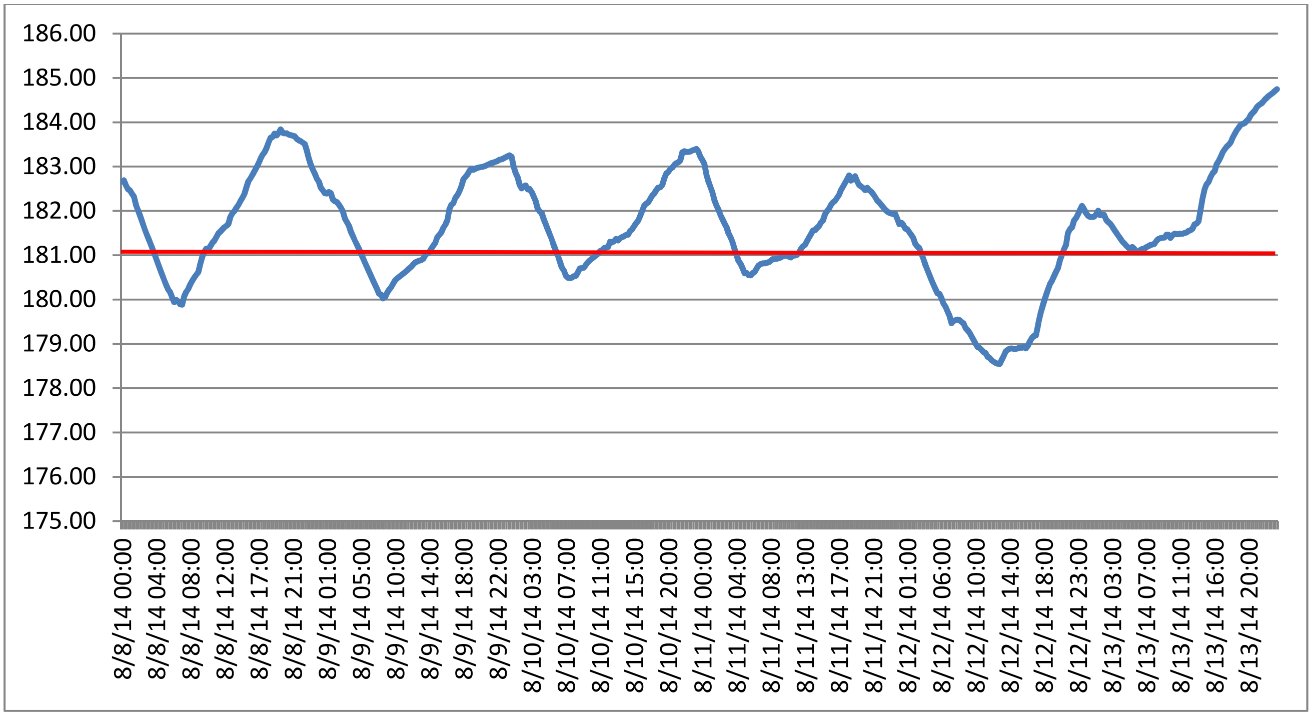
CRWC looked at the actual logger data provided as part of Relicensing Study 3.2.2 in Excel format. The report states that 3 feet of water at the end of the boat ramp is necessary for launching and/or retrieving boats on trailers, so a water surface elevation (WSEL) of 181 ft is necessary for the boat ramp to be usable for power boats. From this, we see that it's not unusual at all for river levels to drop below the 181 ft level during the night-time early morning hours, making it difficult to launch boats until mid morning or noon, or even later. In Sept. of 2014, there were even a couple of stretches where the river level was too low for the better part of two entire days. This happened twice. September of 2014 was more typical of dry summer conditions than the rest of the summer, which was on the wet side.

See graphs below.

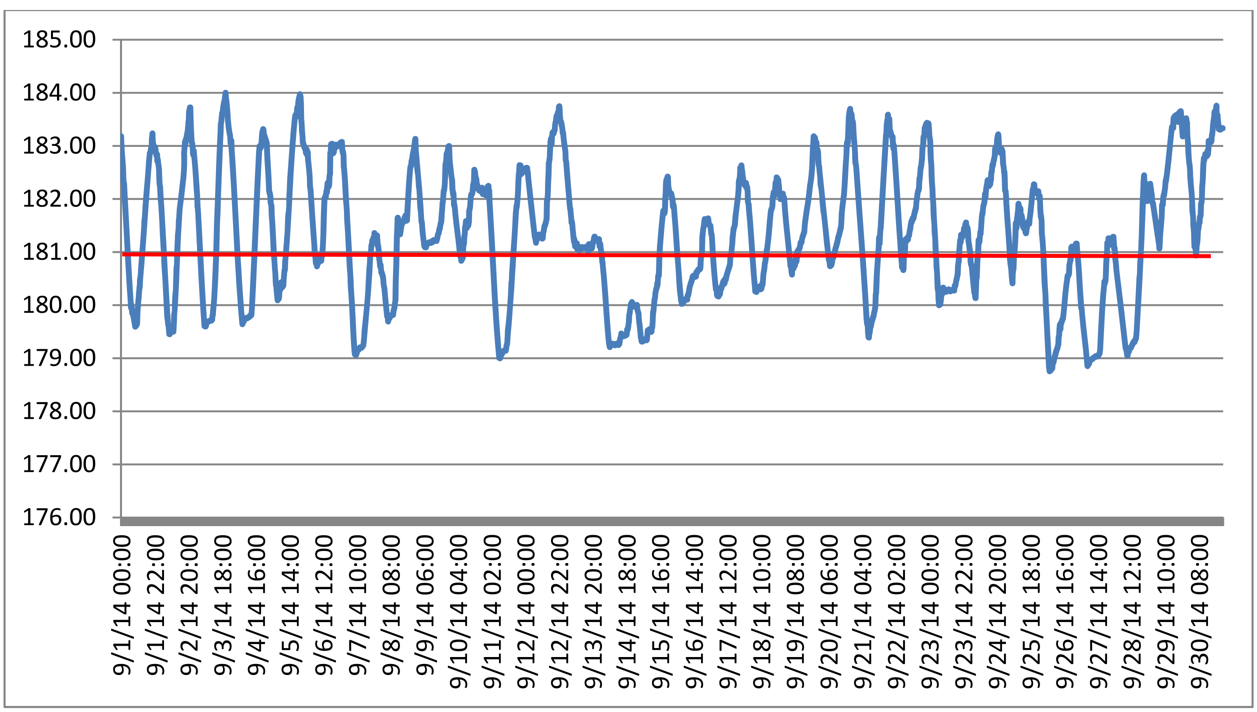
River elevations from FirstLight logger located downstream Pauchaug
August 2014



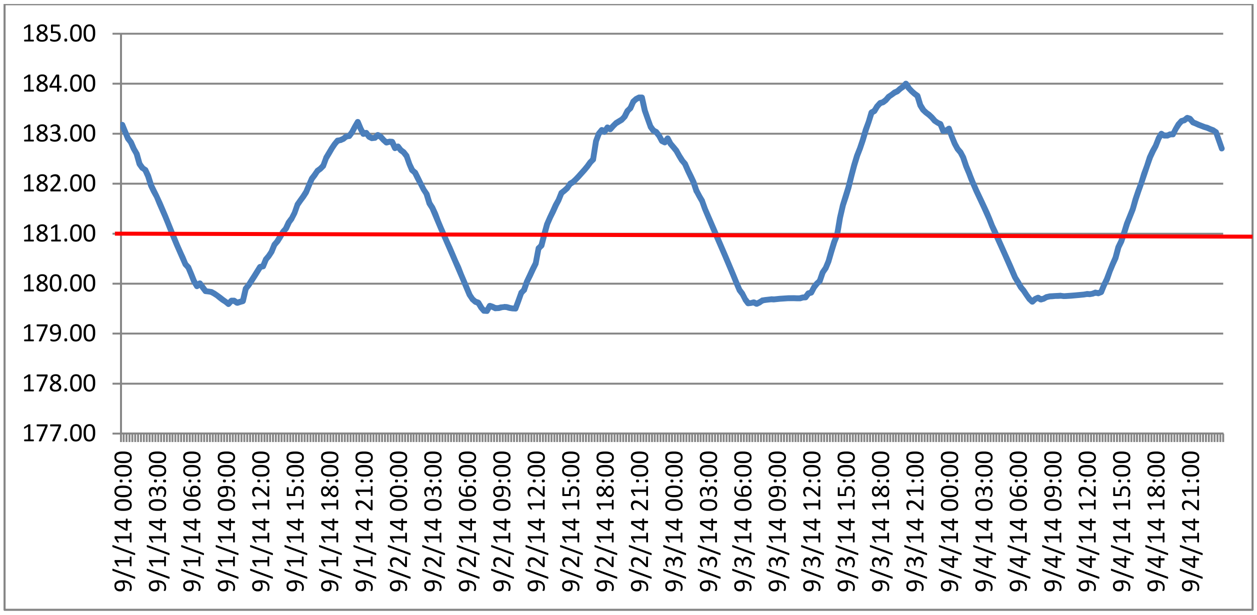
Same data, but shorter time span showing 8/8 to 8/13 in 2014.



River elevations from FirstLight logger located downstream Pauchaug
September 2014



Same data, shorter time span showing 9/1 to 9/4 in 2014, showing typical dry weather summer flow conditions. Note that river elevations tend to dip below 181 ft around 3:00 AM and then rise above 181 between noon and 3:00 PM. This would tend to make the river unusable to motor boats all morning into the early afternoon on a typical summer day.



4.2.3 Munn's Ferry Boat Camping. The results from Study 3.3.9, showing conditions when the river flows upstream and strange eddies, do not seem to have been considered.

4.2.4 Boat Tour and Riverview Picnic Area. This section evaluated the use of power boats at this location only. Study Report 3.6.4 listed the Riverview Picnic Area as a formal river access site. If that is what FirstLight considers this site to be, and dismisses the need for additional water trail access points, then Study 3.6.6 needs to assess project effects for paddlers in this location, including operational impacts that cause the river to flow upstream as shown in Study 3.3.9.

4.2.5 Cabot Camp Access Area. Study Report 3.6.4 listed the Cabot Camp Access Area as a formal river access site. If that is what FirstLight considers this site to be, and dismisses the need for additional water trail access points, then Study 3.6.6 needs to assess project effects for paddlers in this location, including operational impacts that cause the river to flow upstream, or create eddies, as shown in Study 3.3.9.

4.2.10 Poplar Street Access Site and 4.2.11 Sunderland Bridge Boat Launch. Our comment from Study 3.3.2 was that based on the August 11-16, 2012 graph downstream of the Turners Falls dam (Appendix C of Study 3.3.2), peaking flows out of the Cabot units can result in 5-ft sub-daily fluctuations in Montague and 4-foot subdaily fluctuations at the Sunderland Bridge in the middle of the summer. Flows rapidly decrease at midnight until mid morning or mid day, then steadily increase during the latter half of the day. At Poplar Street, our experience and anecdotal stories indicate that higher water levels can make launching a boat more dangerous and difficult. As for the Sunderland Boat launch, the graphs provided do not tell us the full story, and no user surveys were conducted in that area, despite CRWC's request during the review of the RSP (see RSP page 3-352).

The whole point of conducting these expensive studies is to better inform all involved in the relicensing effort so that we understand the project effects. When we are given flow duration curves, that obscure the true issue of the subdaily fluctuations of the river, we are little better off than we were at the beginning of this process. We knew then that river users complain about low river levels in the morning at Pauchaug and at the Barton Cove state boat ramps, for example. This study has done little more to add to the understanding.

We appreciate the opportunity to provide comments on the studies submitted on October, 2016.

Sincerely,

Andrea F. Donlon

Andrea Donlon
River Steward

ATTACHMENTS

Princeton Hydro peer review memorandum
Letter from Don Pugh to James Donahue of FirstLight dated March 25, 2016, regarding shad telemetry data presentation for Study 3.3.2

Princeton Hydro

Scientists, Engineers & Environmental Planners Designing Innovative Solutions for Water, Wetland and Soil Resource Management

December 7, 2016

MEMORANDUM

To: Andrea Donlon, CRWC
David Deen, CRWC

From: Laura Wildman, P.E., Princeton Hydro, LLC
Paul Woodworth, Fluvial Geomorphologist, Princeton Hydro, LLC
Melinda Daniels, PhD, Fluvial Geomorphologist, Stroud Water Research Center

Re: FERC Re-Licensing Process for FirstLight Power Resources Inc.
Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report (October 2016)
Princeton Hydro Bullet List of Major Points

The Connecticut River Watershed Council (CRWC) is a stakeholder and participant in the re-licensing process of the Federal Energy Regulatory Commission (FERC) for two hydropower facilities owned by FirstLight Power Resources Inc. on the Connecticut River, Northfield Mountain and Turners Falls Operations. Princeton Hydro, with the Stroud Water Research Center, was retained by CRWC to complete a peer-review of Relicensing Study 3.1.2, Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report, Volume I – Executive Summary and Summary Report, Volume II – Main Report, and Volume III – Appendices, dated October 2016. As part of this work, we reviewed the Revised Study Plan (RSP), dated August 14, 2013, and the FERC Study Plan Determination dated September 13, 2013. Revisions to the approved RSP were made by FirstLight to incorporate an analysis of the effects of icing (see Initial Study Report dated September 15, 2014). In addition, the Updated Study Report dated September 14, 2015 indicated that the study methods for the boat wave analysis deviated from the RSP, and that boat wave sensors were installed along the river[1].

FRAMEWORK FOR THIS PEER REVIEW

Our comments have been structured to address the questions outlined within the Integrated Licensing Process (ILP) regulations 18 CFR § 5.15(d)(1) regarding Conduct of Studies, specifically:

Were the studies completed as per the Revised Study Plan?

1. Were the objectives set in the Revised Study Plan (RSP) met?
2. Was the analysis described in the RSP conducted? And if not, what was omitted.
3. Were the methods described in the RSP utilized?

[1] Our review was limited to the RSP and Relicensing Study 3.1.2, Volumes I through III. No field work was conducted as part of our review, so we cannot comment if the observations stated in the study accurately reflect field conditions within the project reach, and if the observations were applied in an impartial manner. In addition, we did not review the numerous other studies submitted to FERC as part of FirstLight's recent submittal.

4. Was the Study conducted in a manner consistent with generally accepted scientific practice?
5. Were the conclusions of the study consistent with the scientific evidence presented?
6. Were the deliverables promised in the RSP included in the final study report submittal?

As stated in the RSP, the goal of Study 3.1.2 is to "evaluate and identify the causes of erosion in the Turners Falls Impoundment and to determine to what extent they are related to Project operations." Due to the complexity of the study and the length of the report volumes, our review primarily focused on three of the objectives to meet the study goal:

- "Identify the causes of erosion present in the Turners Falls Impoundment, the forces associated with them, and their relative importance at a particular location. Conduct various data analyses to gain a better understanding of these causes and forces"
- "Conduct detailed studies and analyses of erosion processes at the fixed riverbank transects"
- "Evaluate the causes of erosion using the field collected data and the results of the proposed data analyses This evaluation will include quantifying and ranking all causes present at each fixed riverbank transect as well as in the Turners Falls Impoundment in general."

We have focused this memorandum summarizing our peer review into four primary categories. These categories are:

1. **Problems with the Analysis** – This section reviews specific problem areas regarding how the analysis proposed in the RSP was conducted.
2. **Omissions in the Analysis** – This section relates to omissions in the analysis.
3. **Problems with the Extrapolation Methodology** – This section reviews the methodology proposed and then how it was applied and expanded from the RSP.
4. **Validity of the Study Conclusions** – This section reviews the validity and impartiality of the conclusions resulting from the field data collection, analysis and methodology applied to synthesize and summarize the data.

For ease of review of this memorandum we have italicized, placed in quotes, and referenced page numbers for any text taken directly from the Revised Study Plan (RSP) and the Relicensing Study 3.1.2.

PROBLEMS WITH THE ANALYSIS

The Bank-Stability and Toe-Erosion Model (BSTEM) was used in the Relicensing Study 3.1.2 to understand the effects of hydraulic shear stress due to flowing water and the impact of water level fluctuations as related to the constant wetting and drying of the banks, and to quantify the relative percentages due to different causes of erosion, and to compare the results for the different causes analyzed. The use of BSTEM is consistent with the analysis proposed in the RSP. We agree that a BSTEM analysis is a generally accepted scientific practice appropriate for the proposed analysis.

However, we did find several problem areas with the BSTEM analysis. These either prevent us from being able to evaluate whether or not the work is consistent with generally accepted scientific practice, or indicate to us that the study goals were not met. We offer the following comments regarding the application of the BSTEM model by FirstLight and their consultants to assess the causes of erosion for the Turners Falls Impoundment (TFI).

1. **Difficult to review:** It was difficult to review the results of the BSTEM model without actually being given the input and output files, as well as the version of the program used for this assessment. There were multiple output graphs missing that might have helped in a more detailed review of this modeling effort, as discussed throughout this review.

In addition, the low resolution of multiple figures, particularly in Section 5 of Volume II, made them nearly impossible to read. Specifically, bank cross-section figures presented in Section 5.4.3 BSTEM Simulation Results were too pixelated and of low resolution to discern where the lines were overlapping or not, for the different model runs/simulations. The figure on page 364 of Volume II is an important figure to demonstrate impacts of water surface elevation (WSE) fluctuation but again was hard to read and does not seem to be repeated for all the cross-sections (also on page 410). This makes understanding and interpreting these results extremely difficult.

Recommendation: In order to facilitate stakeholder and FERC review of the study, many of the BSTEM figures should be regenerated at a higher resolution and submitted again. Where model results overlap so significantly that it is hard to differentiate each scenario run, the hidden and overlapping runs should be called out with leader lines and an explanation, to clarify what the figure is presenting.

2. **The Comparison of Erosion Rates by Volume of Material Eroded, Disregards Cyclical Erosion Process:** BSTEM analysis distinguishes 'hydraulic erosion' from 'geotechnical erosion' and calculates the volume eroded by each separately (Volume 1, page 43 and PDF page 51). The Relicensing Study 3.1.2 then takes these volumetric results and assesses each as a percent contribution to erosion (i.e. the larger the volume of sediment eroded from the bank for a given cause, the larger the percentage it is granted as a contributing cause). However, this approach seems to overlook the cyclical nature of this process, and disregards the causal relationship between the two modes of erosion. Specifically, hydraulic erosion at the toe of a bank can lead to geotechnical failure, which in turn can re-set the erosion process whereby hydraulic erosion then becomes dominant again, as noted on Figure 5.1.3-7, Volume II, page 5-22 [PDF page 305]). The importance of one mode of erosion (i.e. causes that initiate erosion at the toe of the bank) should not be dismissed based solely on the volume of material eroded, especially when it may instigate or perpetuate the cycle of erosion that later leads to a bank failure, for which this assessment would attribute only to a high flow event. Figure 5.1.3-7 in the Relicensing Study 3.1.2 also depicts how lower bank hydraulic erosion leads to upper bank geotechnical failure; therefore without lower bank erosion, the upper bank would remain stable. The volumetric approach transferred to percentages does not seem to allow for an assessment of the connectivity of causes.

   Recommendation: Because of the interconnected nature of various types of streambank erosion, toe erosion, which results in a small quantity of sediment eroded, can instigate a more significant bank failure during periods of high flow, resulting in larger quantity of sediment eroded. Specifically minor toe erosion caused by daily operational water surface fluctuations can instigate more significant erosion volumetrically during high flows. We recommend that the analysis be revised to include the causal nature of each contributing factor. Otherwise, the study goals and objectives from the approved RSP cannot be met, and a critical element of the cycle of erosion has been overlooked in this study.

3. **WSE Fluctuation Precludes Riverbank Vegetation:** Daily water surface fluctuations can preclude the establishment of stabilizing vegetation. The BSTEM analysis conducted did not include the likely change in geotechnical conditions of the bank if permanent vegetation were allowed to become established. This lack of vegetation likely occurs at the toe of the bank or the lower bank, where hydraulic erosion is likely greatest even at higher flows.

   Recommendation: We recommend that the BSTEM analysis be rerun to determine if the preclusion of vegetative growth due to operational induced WSE fluctuation is a contributing factor to streambank erosion.

4. **Upper and Lower Bank Terms are Used Inconsistently:** The report states that WSE fluctuation only acts on lower bank, or what the Study refers to as the beach area on page 5-208 and 5-217 in Volume II, but multiple graphs show it acting at toe of bank, "the intersection of upper and lower bank" according to their definitions.

   In addition, the lower bank definition used throughout the report is problematic. The beach-like lower bank identified, is not a bank feature but instead is a wave-cut terrace platform resulting from long-term erosion at the water surface. Water stage fluctuations correspond to this "lower bank" surface as indicated by plots of stage versus bank profiles. Photographs of these features clearly show ripples parallel to the upper, true, bank indicating wave motion and sediment transport perpendicular to the upper bank. The water contact point at the junction between upper and "lower" banks will continue to be a focus for wave/ice erosion.

   Recommendation: We recommend that this inconsistency between the analysis and report discussion be corrected. In addition, we recommend that the lower and upper bank definition be revised to correspond with the definitions consistent with general scientific practice, which typically include the toe of the bank within the lower bank.

OMISSIONS IN THE ANALYSIS

We offer the following comments regarding omissions in the analysis as prepared for the Relicensing Study 3.1.2., as per what was proposed for analysis in the Revised Study Plan (RSP).

5. **No Model Run Isolates the Effects of the Turners Falls Operations:** While the primary objective of this study was to "evaluate and identify the causes of erosion in the Turners Falls Impoundment (Connecticut River) and to determine to what extent they are related to Northfield Mountain and Turners Falls Project Operations" (Volume 1, page *i* [PDF page 2]), there was no analysis of data or a numerical modeling run that specifically targeted (e.g. by isolation or exclusion) the impacts of Turners Falls operations (Volume 1, page 26 [(DF page 34]). Hydraulic modeling and the Bank Stability Toe Erosion Model (BSTEM) was utilized to analyze existing conditions, along with the impacts of waves, and the Northfield Mountain Project operations, which were isolated in "Scenario 1". Northfield Mountain operations account for only 2 feet of WSE fluctuation during low flow (Volume 1, page 19). While the label "Scenario 1" implies that subsequent scenarios should follow, no comparable model run was performed that specifically targeted Turners Falls operations that would have provided a basis for comparison. Nor was there a run with all operation related WSE fluctuation "turned off", such that the impacts of the combined operational WSE fluctuations could be assessed. Without analyzing this additional modeling scenario (e.g. a "Scenario 2" or "Scenario 3"), the overall conclusions of this study are incomplete. Analysis of the effects of Turners Falls throughout the impoundment is simply dismissed by interpretation of the Energy Grade Line. The Energy Grade Line is not an absolute determination of the limit of influence of dam operations; wherever water levels fluctuate from dam operations, there is a potential for an impact.

   In addition we propose that a scenario be run that assesses the "instigating" role of toe erosion on proceeding streambank erosion under high flow scenarios (i.e. how toe erosion, relating to operational WSE fluctuation and associated ground water differentials, instigates additional bank failure during high flows). This additional scenario could be assessed by isolating erosion caused by high flows from its co-dependence on destabilizing toe erosion. For example, a scenario should be run where the toe of bank is stabilized for each site, compared to Baseline Conditions for all sites (excluding the restored versions of the sites) such that erosion rates can be assessed where relatively minor erosion at the toe is instigating future erosion at high flows. In absence of creating a scenario where all the toes of the streambank have been artificially stabilized, this could perhaps be assessed by comparing the sites that have both pre-stabilization and post-stabilization data, and determine if the toe stabilization implemented at these sites did, in fact, reduce the sites potential for erosion during both low and high flows.

Recommendation: We recommend that the entire Turners Falls Impoundment (TFI) be analyzed for impacts due to Turners Falls Dam, and at a minimum, this modeling scenario must be incorporated into the study prior to completion. Further, additional scenarios should also be completed that isolate (i) both Northfield Mountain Project Operations and Turners Falls Operations combined, (ii) the operations of Vernon Dam (e.g. a "Scenarios 3 and 4")., and (iii) the "instigating" role of toe erosion on proceeding streambank erosion.

6. **Large Portions of the Turners Falls Impoundment Remain Unassessed**:
   Multiple additional runs and analysis seem to still be needed in BSTEM in order to complete the assessment proposed in the Revised Study Plan, see gaps shown in the table below. Many of these gaps were justified in the Study 3.1.2 Report under the rationale that operations only impacted the reach in which they were designated because of the use of the Energy Grade Line and the report's focus on the impacts of high flow. As previously stated, we do not agree with the application of the EGL assessment to justify the exclusion of reaches from analysis and we do not agree that operational WSE impacts are limited to the reaches where the facilities exist, since the analysis shows these impacts extending throughout the TFI. See table below that highlights the reaches not assessed in the Study 3.1.2 Report.

Primary Cause of Erosion	***Reach 1*** ***(Near Turners Falls Dam)***	***Reach 2*** ***(Vicinity of NFM tailrace)***	***Reach 3***	***Reach 4*** ***(Downstream of Vernon Dam)***
Moderate or High Flows	Assessed	Assessed	Assessed	Assessed
Boat (Waves)	Assessed	Assessed	Assessed	Assessed
Vernon Operations	Not Assessed	Not Assessed	Not Assessed	Assessed (but discounted for lower half of reach)
Northfield Mountain Operations	Not Assessed	Assessed (but discounted, even though model output showed significant impact)	Not Assessed	Not Assessed
Turners Falls Operations	Assessed, qualitatively, without BSTEM	Not Assessed	Not Assessed	Not Assessed
Land Use	Assessed qualitatively only			
Ice	Assessed qualitatively by visual observation only			

Recommendation: The analysis should be extended to include assessment of all the reaches for all of the primary causes of erosion. Segmenting the river into the four reaches and only looking at particular influences in that reach is not acceptable and does not meet the study goals laid out in the RSP.

7. **2D Modeling Not Used:** Previous comments were submitted by USFWS dated 1/12/16 regarding channel roughness and the use of the 2D modeling prepared for Study 3.3.9. It is unclear in reading

the Relicensing Study 3.1.2. if these corrections relating to the calibration of the roughness coefficients were implemented for the River2D model proposed for use in the RSP for this study. These corrections are critical, especially as they related to composite friction coefficients and the near bank velocity and shear stress computations. In addition, the USDA also conducted a peer review, comments dated 11/28/16, that explain how the River2D modeling results were not utilized to verify the hydraulic shear stresses estimated by BSTEM. Our review as well has noted the lack of integration of the 2D modeling results within the analysis.

The RSP in Task 5a stated on page 3-41 that, *"Both HEC-RAS and RIVER2D modeling will be used to analyze near-bank velocity to determine shear stress along the bed and riverbanks. RIVER2D computes velocity vectors showing the magnitude and direction of velocity across the channel at each node representing the channel geometry. Of particular interest are the velocity vectors in the near-bank region where the flow of water directly affects the bank. At the fixed riverbank transects, the velocity vectors will be determined over a range of flow conditions…. Results of RIVER2D will allow the analysis to focus on the region of the flow next to the banks where flowing water exerts hydraulic forces that directly affect the riverbanks."* However based on our peer review of the Study 3.1.2 Report, we cannot determine how or whether RIVER2D was used to revise near bank velocities and shear stresses, and if so, what values were used. In addition, RIVER2D appears to have been developed only for high flows, which is inconsistent with the RSP.

Recommendation: We recommend that FirstLight provide more information that would aid in stakeholder review, and we suggest that the USFWS and USDA recommendations be included in a revised analysis which incorporates the results of the 2D modeling to more accurately assess roughness and near bank velocities and shear stress.

8. **Key Figures are Not Provided:** Figures for each cross-section do not overlay the range of WSE fluctuation, which is a key component in interpreting bank erosion. In addition, no figure is provided comparing the WSE fluctuation for the Baseline Conditions versus Scenario 1. This figure would be important since it would highlight the fact that there was no scenario run that excluded daily WSE fluctuations associated with hydro-electric operations.

   Recommendation: We recommend that these additional figures be included in a revised Relicensing Study 3.1.2 so as to be in compliance with Task 4c of the RSP.

9. **Groundwater Analysis:** Based on the limited groundwater investigation described in the Study 3.1.2 Report, the observed groundwater level was approximately 1 foot above the river's water surface elevation. The USDA (11/28/16) review comments pointed out that this groundwater differential indicates "persistent movement of groundwater towards the TFI during lower flows, which may weaken the bank materials" and potentially "reduce the suction forces in the upper part of the bank". The USDA reviewer, who was one of the developers of BSTEM, states that based on his peer review it appears that "this reduction in bank-material shear-strength was not simulated" in BSTEM. We agree with the concerns stated in the USDA review and feel that this potentially critical reduction in bank material strength and suction forces needs to be integrated into the analysis in order to appropriately assess the impacts of daily operational WSE fluctuations. It is also noted that these field observation were conducted at one location only, approximately 50 feet away from the Connecticut River.

   Recommendation: We recommend a quantitative analysis be conducted to determine if the seepage force or increased pore-water pressure could not only weaken the bank material over a height of 1 foot above the water surface elevation of the river, but also reduce the suction forces in the upper part of the bank, as per the USDA observations, over the full length of the TFI.

10. **No Assessment of Downstream Impacts:** Given that the Study 3.1.2 Report includes an analysis and determination of impacts due to the upstream Vernon Dam operations on the TFI, it would follow that WSE fluctuations caused by the releases at Turners Falls are potentially impacting reaches downstream. While the study added an assessment of the Vernon operation, the study does not assess the impacts on bank erosion that the Turners Falls Dam/Cabot Station operations have on the reach downstream, and we recognize that assessment of the downstream reach was not included in the RSP. However because the Study 3.1.2 results do demonstrate that the Vernon operations impact streambank erosion within the TFI, it would follow that in a complete assessment of operational impacts due to TF and NFM on streambank erosion would include the reach downstream of Turners Falls operations.

    Recommendation: Any discussions of impacts downstream of Vernon Dam operations could be expanded to include potential impacts downstream of Turners Falls Dam and the power canal.

PROBLEMS WITH THE EXTRAPOLATION METHODOLOGY

In the Study 3.1.2 Report, the BSTEM analysis at each of the transects was extrapolated out into the entire reach of the streambanks between the Turners Falls Dam and the Vernon Dam. The RSP in Task 6 stated simply that, "This evaluation will include quantifying and ranking the primary causes of erosion present at each fixed riverbank transect as well as in the Turners Falls Impoundment in general." Therefore, the RSP provided no detail as to the methodology of the extrapolation process. Our review focuses on this methodology and identifies several flaws.

The following section regarding our review of the extrapolation methodology is divided into 7 sections, based on the 8 steps included in the extrapolation methodology utilized in the Relicensing Study 3.1.2, (summarized on pages 45-51 of Volume I); the final two steps have been grouped into one section. We start each section by briefly describing the methodology included for the step we are reviewing (shown in italics under the bolded name of the step), followed by our peer review comments regarding the implementation of the methodology for that step and our recommendations.

11. **Step 1: Analyze the variability of hydraulic forces throughout the TFI**
    This step defines the hydraulic reaches and limits the analysis based on them

    We do not agree with the determination that operations only impact the reach in which they have been allotted to in the Relicensing Study 3.1.2 (i.e. TF to Reach 1, NFM to Reach 2, and Vernon to Reach 4). The Energy Grade Line (EGL) approach described appears to only apply when looking at impacts associated with high flow (>37,000) where the 1-dimensional velocity and sheer stresses determined through HEC-RAS play a dominant role in erosion. The report is clear that for flows below 37,000 cfs (moderate and low flows as per their definition), which occur over 90% of the time according to Figure 4.3.1.2-17 from the October 30, 2012, PRE-APPLICATION DOCUMENT (see figure that follows), the hydroelectric operations of Turners Falls and Northfield Mountain are both controlling factors for the WSE elevation fluctuation throughout the entire TFI, and that for flows below 17,130 cfs, Turners Falls, Northfield Mountain, and Vernon operations are the dominant influence controlling WSE fluctuation throughout the entire TFI. The analysis should not be limited based on hydraulic reaches that only seem applicable for high flows when over 90% of the time the flows in the TFI are lower than the defined high flow, and almost all of the WSE fluctuation caused by the combined hydropower operations is happening below the defined high flow, which is only equaled or exceeded less than 10% of the time.

Figure 4.3.1.2-17 from the October 2012 Pre-Application Document: Shows the Annual Flow Duration Curve for the Connecticut River at Turners Falls Dam. We have overlain the high moderate and low flow thresholds, as described by the Relicencing Study 3.1.2 and their associated percentage of time equaled or exceeded.

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)
PRE-APPLICATION DOCUMENT

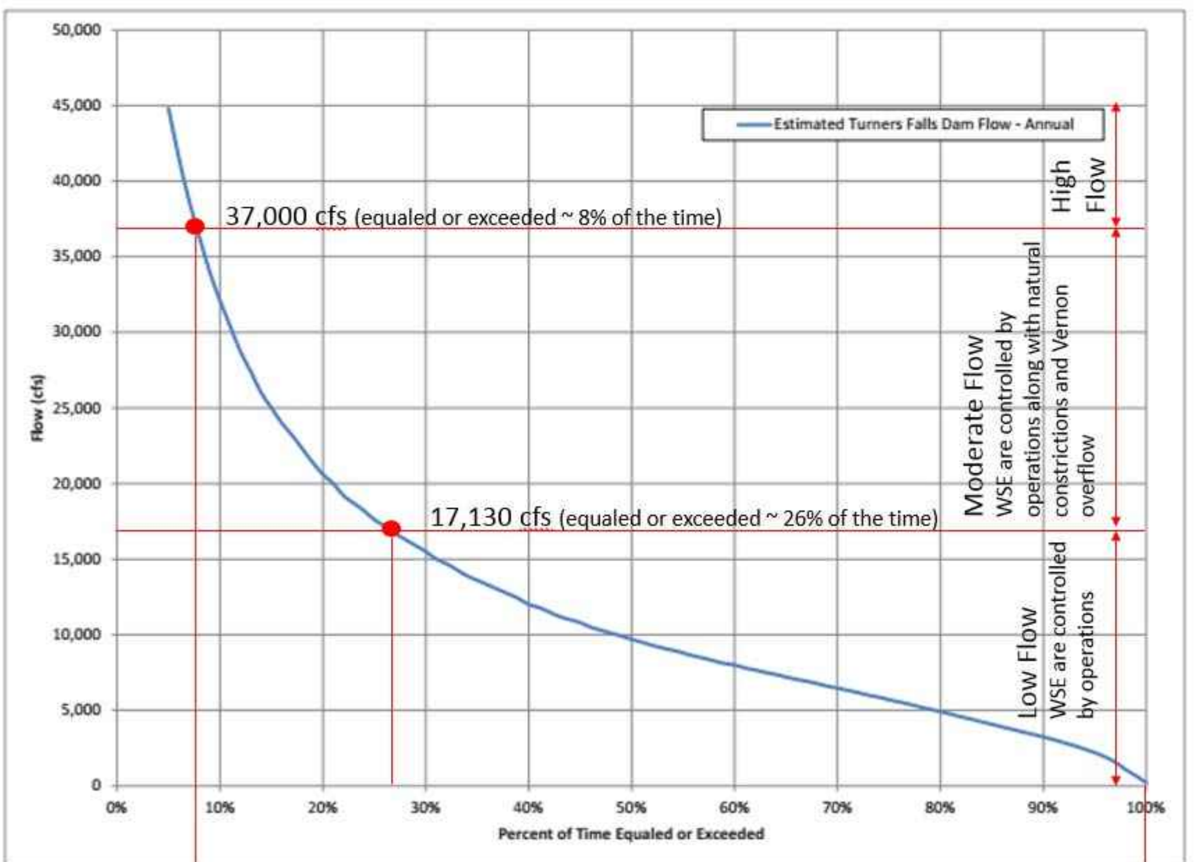


Figure 4.3.1.2-17: Connecticut River at Turners Falls Dam, Annual Flow Duration Curve, Jan 1941-Sep 2010, Drainage= 7,163 mi²

The assessment of the hydraulics and determination of hydraulic reaches using an energy grade line assessment, also did not incorporate the near-bank data that was supposed to have been developed from the 2D hydraulic modeling once the friction coefficients were corrected as per USFWS recommendations (1/12/16). Once corrected the 2D analysis would have provided more accurate near-bank hydraulic forces.

In addition, since stage-discharge relationships could not be determined for the Turners Falls Dam operations and limited study site data was available in the lower reach, the Turners Falls Dam operations were not assessed in a similar manner to Northfield Mountain operations, where operations were turned “off” or “on” and scenarios were then directly compared. Instead the TF operations were completely ruled out based on a series of assumptions and observations that were not quantifiable. This has been discussed in our comments #6 and #7 as well. Furthermore the USDA (11/28/16) review letter, written by one of the principal designers and developers of BSTEM, states that the development of stage-discharge rating curves to convert hourly stage values to discharge values, is not an appropriate method and cannot adequately represent the significant scatter in the flow versus depth data. It is noted that this inappropriate rating curve method was also used to set the threshold flows based on 10,000 cfs intervals (see page 30 Volume I). USDA also recommends that the accuracy of the BSTEM results would be improved if the flows and stage output from the HEC-RAS analysis had been used and that this would allow for the Turner Falls operations to be analyzed in a similar manner as was the Northfield Mountain operations.

The use of the energy grade line approach to segment reaches and assess only the reaches where the operations were located, was not included as part of the methodology described in the Revised Study Plan (page 3-40 to 3-41). Nor was the conversion of stage values to discharge values, to calculate erosion exceedance probabilities, included in the RSP. Therefore these two approaches within the methodology were not previously reviewed or agreed upon by the stakeholders.

Recommendation: For Step 1 in the methodology, we recommend that the impacts of operation be assessed throughout the entire impoundment reach and not be limited to the single reach the facilities are in, especially when assessing impacts during moderate and low flows. We therefore recommend that the delineation of 4 reaches, based on the EGL assessment under high flows, be disregarded, and not used to limit the analysis of impacts throughout the TFI. Our recommendation is supported by the fact that Study 3.1.2 makes it clear that the hydroelectric operations of Turners Falls and Northfield Mountain are both controlling factors for the WSE elevation fluctuation throughout the entire TFI for flows that occur over 90% of the time.

We recommend that the results from the 2D modeling be incorporated into the analysis to better calibrate the near-bank data utilized.

We recommend that the method of converting hourly stage into discharge, and then using the resulting hourly discharge erosion records to calculate erosion exceedance probabilities, be discarded. The BSTEM model should then be run with the stage and discharge data from the HEC-RAS modeling, thereby eliminating the error associated with this approach (as described in the USDA 11/28/16 review memo) and allowing for a BSTEM analysis of the impacts of the TF operations to be conducted.

12. **Step 2: Analyze and review the site specific BSTEM results**

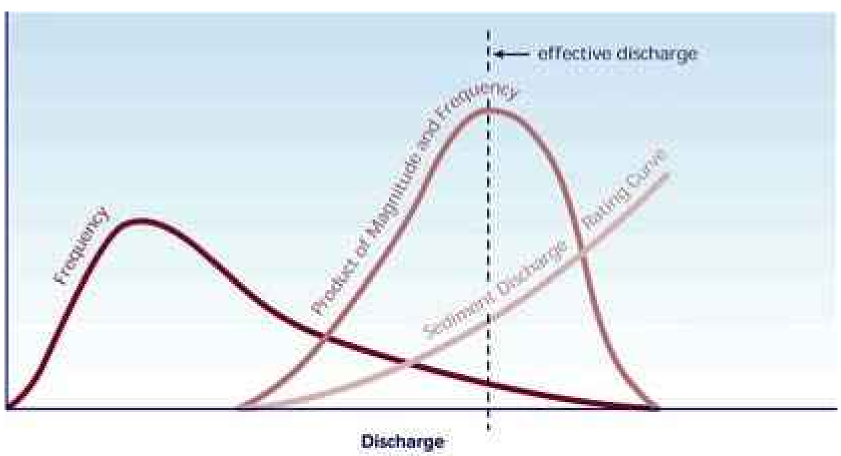
This step defines which study sites are dominant or contributing

While the RSP stated that both primary and secondary causes of erosion would be assessed, it did not give a definition of those terms. The Relicensing Study 3.1.2 now renames these causes to dominant primary, contributing primary and secondary causes (page 621-622 of Vol II). It then arbitrarily defines the dominant primary as “one that is responsible for 50% (or >50%) of the erosion at a cross-section” and the contributing primary as being responsible for between 50% and 5% of the erosion at a cross-section. This was not described in the Revised Study Plan, nor was it agreed to by the stakeholders. These definitions are arbitrary in nature, lead to dismissing lesser but still important causes, and disregard multiple site specific impact results that come very close to the 5% limit that are associated with operational WSE fluctuations. Once a cause has been dismissed as not being a “dominant primary cause” it is then interpreted as 0% in the subsequent steps of the assessment. This is just one example where the Relicensing Study 3.1.2 uses arbitrarily assigned thresholds, not included in the Revised Study Plan, that potentially introduce bias to the results and limit what is truly being assessed (other examples include the flow thresholds, and the delineation of hydraulic reaches). Later in the Relicensing Study 3.1.2 (as shown on page 38 Vol 1) the document classifies the sites having “measurable/significant rates of bank erosion” by stating “[I]in order to be classified as having measurable/significant rates of bank erosion, the rate of erosion at a given site must be greater than the erosion rate that represents the lowest 5% of all rates or 0.163 ft3/ft/yr." Again the threshold applied seems arbitrary and in this case includes restored sites with little erosion post stabilization of the toe of bank.

It is noted that the use of these arbitrary thresholds to define dominant primary and contributing causes, as well as to define what are measurable/significant rates of bank erosion, was not included as part of the methodology described in the Revised Study Plan, and therefore the use of these thresholds was never agreed upon by the stakeholders or FERC.

In addition, step 2 of the methodology weighs anthropogenic factors against the significant river-forming natural processes, which significantly biases the results because the volumetric values associated with erosion of a particular type (i.e. WSE fluctuation) are converted to relative percentages and compared against the contributing percentages that are associated with natural river-forming processes. This approach ends up dismissing anthropogenic impacts such as WSE fluctuation merely because volumetrically they do not compare to the natural forming processes of a river. This approach also does not seem to adequately account for key causes that initiate larger bank stability issues as described in our review comment #2 and #6.

By lumping natural sediment transport/erosion processes (i.e. the effects of high flow events) with anthropogenic causes of erosion (i.e. WSE fluctuation due to operations) when determining the final percentages, and basing these percentages on a comparison of volumetric estimates of erosion, critical anthropogenic causes are discounted just because they do not compare in magnitude to the natural forming processes of a river. While the RSP does says they will assess the impacts of high flow, the final result is that they have proved that rivers are primarily formed by flow, and that the highest percentage of channel formation (i.e. sediment transport and erosion) is accounted for during higher flow events. These are all things we already know about rivers based on simplified theories of effective discharge (see graph below).



From Wolman and Miller, 1960. Fig. 7.5 – Effective discharge determination from sediment rating and flow duration curves. In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98. Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

However, studies conducted under the Integrated Licensing Process (ILP) are geared towards evaluating impacts of project operations on streambank erosion and if these impacts instigate additional long-term erosion. For example we know that the sun heats the earth, we also know that climate change due to anthropogenic impacts is a reality. However, if we were to compare the percent increase in warming due to climate change to the percent of daily warming that the sun provides, and then state that the causes only matter if the account for more than 50% of the solar warming, we would basically end up concluding that the anthropogenic effects of climate change are negligible and therefore, should not be addressed.

Recommendation: We recommend that Step 2 of the study methodology (and any other steps where arbitrary thresholds not listed in the RSP were utilized) be reanalyzed after agreed upon thresholds have been vetted and approved by the stakeholders and FERC. We also suggest that an additional "cause of erosion" be defined and included in the analysis that looks at potential "instigating" causes of erosion, not solely based on volumetric comparisons of the percent of erosion to value contributing significance. This may allow for a better distinction between natural erosion and channel forming processes and how anthropogenic impacts (such as operational WSE fluctuations) might be inducing additional long-term stream bank erosion.

13. **Step 3: Analyze the Riverbank Features, Characteristics, and Erosion Conditions**

This step identifies which segments are "similar" to the studied sites

It is difficult for us to review this step in any detail, since no field verification was included in our peer-review budget and tight timeline and data referenced from 1998 were not shown in the Study 3.1.2 Report. However the analysis for this step seems to show significant bias, relating to how the analysis was limited to comparisons to specific hydraulic reaches, (even when the Qe_{95} was low), and how the results to other segments were subjectively compared (only within given reaches and seemingly only considered similar when they were near exact matches) to extrapolate river lengths impacted by varying causes. An example of this potential bias has been extracted below:

> *"A similar analysis was then conducted for Site 8BR-Pre. Due to the fact that 8BR is a restoration site, the riverbank features and characteristics as observed during the 1998 FRR were compared against the features and characteristics identified during the 2013 FRR for all riverbank segments found in reach 2 to <u>determine if similarities exist</u> at other locations within the reach. <u>No riverbank segments were found</u> in reach 2 with the <u>same</u> characteristics as were observed at Site 8BR in 1998. Although <u>no</u> riverbank segments were <u>found to be an exact match</u>, three FRR segments were identified as having <u>very similar characteristics</u> – 75, 87, and 109."* (Page 47 Vol I; emphasis added)

This paragraph from the report above shows how the results of this step of the extrapolation methodology can be easily subjectively biased toward a specific outcome. The report stated that they would determine if "similar" reaches existed, they then state none were found based on their conclusion that the segments were not the "same" (meaning an exact match), and then they report there were however three that were "very similar". This type of summary and assessment make us, as peer reviewers, question if this report was prepared in an impartial manner when they were identifying segments with similar characteristics. This comparison and assessment is a critical part of their extrapolation to determine the "% of river reach" impacted, and if not conducted in an impartial manner, could significantly skew the report's final conclusions. The RSP also did not state that the 1998 erosion data would be compared against 2013 data. We have no knowledge as to whether the data are actually comparable.

Recommendation: We recommend that a random detailed review of a portion of the studied sites and the segments described in the FRR, conducted by a third-party reviewer (perhaps a state or federal scientist), to provide a second opinion on what seems to be a potentially subjective process. A period of time and funding may need to be provided for this third party review such that stakeholders are not burdened with the cost of this verification of impartiality. Rationale for comparison of years, and methodology for the earlier data set along with that data set needs to be provided to stakeholders.

14. **Step 4: Assign each riverbank segment dominant and contributing causes of erosion**

    This step applies the dominant and contributing causes to river segments

    This analysis only looked only at Reach 4 and 2, limiting potential impacts associated with Vernon operations to Reach 4, and potential impacts associated with Northfield Mountain to Reach 2. We do not agree with the limitations the report is applying to its assessment, as previously stated in our review comments #6, #7, #11. Application of results relating to segments seems arbitrary and biased against demonstrating any operational impacts. The determination of dominant and contributing causes by river segment are not always based on similar characteristics, and defaults to splitting a segment halfway between downstream and upstream apparently whenever adequate information was unavailable.

    It is also unclear how data from study sites that have undergone riverbank stabilization and restoration were or were not incorporated into the final determinations and contributing percentages of erosion. It would seem to make intuitive sense to base this analysis on only pre-stabilized sites and not the sites that have since been modified with engineered stabilization, since the results are primarily being extrapolated to non-stabilized river segments. By including the stabilized sites in the data, the results could demonstrate a bias towards less impact associated with operational WSE fluctuations, since typically the restoration work focused on stabilizing the toe of the riverbank.

    This potential bias in the extrapolation methodology and report results is perhaps best characterized by comparing the results of the BSTEM analysis listed in Table 5.4.2.2-2 on page 5-73 of Volume II and Table 13 on page 40 of Volume I, to the summary table of project results, Tables 15 and 16 on pages 51 and 52 in Volume I. While Table 5.4.2.2-2 shows multiple sites relating to NFM operations that would qualify as a dominant primary cause (i.e. demonstrate percentages of contributing erosion greater than 50%) and Table 13 actually lists NFM as a dominant primary cause, NFM operations are not listed in Table 15 as a dominant primary cause of erosion, and NFM operations are only listed as a contributing cause in Table 16 responsible for 4% of total riverbank length. The summary tables therefore do not accurately reflect the analysis results, due to the bias incorporated into the extrapolation methodology In fact it appears that Figure 5.4.3-1 on page 5-88 of Volume II, which summarized the erosion rates at all study sites for both baseline and Scenario 1 (NFM turned off), demonstrates that site 8BR-pre has the highest and most significant change in erosion rates based on a comparison of the two scenarios, and this erosion is associated solely to NFM operational impacts, but later disregarded in the summary tables.

    Recommendation: A random detailed review of step 4 must be included in the recommended review of step 3 in our comment #13, to ensure that the study has been conducted in an impartial manner. We also recommend that the analysis be conducted on all reaches of all operational impacts under all flows conditions, as previously stated, and that previously stabilized sites not be included in summaries of contributing percentages of erosion.

15. **Step 5: Conduct supplemental hydraulic and geomorphic analyses in Reach 1 to determine the impact, if any, of Turners Falls Project operations**

    This step assesses the potential impacts of the Turners Falls Operation only in Reach 1

    According to the Study 3.1.2 Report the analysis for TF operations can't be assessed the same way NFM operations were assessed, because FirstLight's consultants were unable to develop stage-discharge relationships and did not have enough studied sites in the reach. They conclude that TF operations have no impact on Reach 1 (or any other reach) and that WSE management during high flows may even aid in the prevention of erosion of Reach 1 (page 49 Volume I), based on little data and multiple subjective assumptions. We do not agree with this conclusion based on the data they provided. Please refer to our review comment #11 relating to why the stage discharge relationships developed in the study are not appropriate for use in analysis and how the TF operations can be assessed with BSTEM if the original HEC-RAS stage and discharge data is utilized.

It is noted that the exclusion of the TF operational impact assessment from the BSTEM analysis, was not discussed in the Revised Study Plan. The RSP stated that all operational impacts would be assessed using a similar analysis and methodology.

In addition, the study's comments relating to bedrock seem justified at first (although we have not conducted a field investigation to confirm these observations), but the only WSE fluctuation graph of Reach 1 included in the Relicensing Study 3.1.2, Figure 5.4.1.1-4, does not seem to support the conclusion that the WSE fluctuation is almost always on the lower bank, which they have stated is bedrock dominated. If in fact, the WSE fluctuation is not all limited to the lower bank, as seems to be demonstrated in Figure 5.4.1.1-4, then the study's concluding assumptions may not be valid.

Recommendation: Please confirm with the results of the hydraulic modeling and gaging that the operational WSE fluctuation is limited only to what is defined as the lower bank and does not reach the toe of the bank or any portion of the upper bank. If this cannot be confirmed, then the conclusion of step 5 needs to be reassessed. In addition, it is clear after reading the USDA (11/28/16) review, prepared by a principal designer and developer of BSTEM, that the HEC-RAS stage and discharge data should be utilized and that a BSTEM analysis of the TF operations, similar to what was completed for the NFM operations, can be conducted. It therefore also follows that a scenario could be run with both the TF and NFM operations turned "off". We recommend that this additional scenario be included in the BSTEM analysis, along with a scenario that looks at just TF operations turned "off", as per our review comment #5.

16. **Step 6: Analyze land-use and width of riparian buffers**

This step assesses impacts associated with land use

The analysis of land use utilizes a completely different methodology and yet still results in "percentage of total riverbank length" that is then directly compared and included with the total percentages calculated with volumetric results from BSTEM. This direct comparison seems misleading.

Recommendation: We recommend that the analysis prepared for step 6 of the extrapolation methodology not be compared directly in this manner with the results determined through the BSTEM analysis.

17. **Steps 7 and 8: Create a map identifying the causes of erosion and calculate summary statistics**

This step maps the results by river segment and provides the summary statistics in table format

As previously discussed in our review comment #14, NFM operations are shown to be a dominant cause of erosion and are even listed as such in Table 13 on page 40 of Volume I. However the concluding statements from the study, as included below, completely contradicts the analysis results and reflects a potential bias in the extrapolation of the results and the study's conclusions. The study also states that since high flows were such a dominant cause that most of the sites have no contributing cause, which also seems contradicted by Table 13 on page 40 of Volume I. This study conclusion also relates back to our concern that by comparing natural river-forming processes to anthropogenic impacts in a volumetric only manner, the report disregards the additional long term impacts that can be initiated by facility operations.

> *"Once the extrapolations steps were complete, the dominant and contributing primary causes of erosion were quantified based on the total number of FRR segments, the total length of those segments (in both feet and miles), and the % of total TFI riverbank length for each primary cause (excluding ice)."* page 51 Vol I
>
> *"the dominant and contributing primary causes of erosion were quantified using relative percentages for every TFI riverbank segment identified during the 2013 FRR"* page 52
>
> *"Northfield Mountain operations were not found to be a dominant cause of erosion at any riverbank segment in the TFI."* page 52 Vol I

Recommendation: We recommend that the summary tables be revised to reflect the changes in methodology and analysis that we have recommended in our review comments #1 through #17, and that the final tables and figures reflect a consistent summary of the results.

VALIDITY OF THE STUDY CONCLUSIONS

18. **Historic Geomorphic Conclusion is Incomplete:** The FERC Study Plan determination stated, "To provide more detailed methodology (section 5.9(b)(6)), we recommend that FirstLight's perform its historic geomorphic assessment using available mapping such as the 1970 vintage ground survey of the impoundment as a base map, comparing it against more recent aerial imagery and available survey data to analyze trends in bank position within the Turners Falls impoundment. We estimate the costs of the recommended study modification to be $20,000." However, the geomorphic assessment within Relicensing Study 3.2.1 is based heavily on former reports that were not part of the FERC process and therefore not reviewed and edited. The assessment looked at 20 cross-sections where erosion was already present and that were likely selected for that reason. This assessment of historic erosion appears to be limited and does not seem to analyze the before and after operation data in a meaningful way. The Relicensing Study 3.1.2 therefore does not appear to comply with FERC's determination.

    Recommendation: We recommend that an analysis be prepared that compares past aerial photos with current aerials as requested by FERC, fully understanding that there are some limitation to this approach but agreeing with the utility of this comparison. See, for example, Appendix C to TransCanada's Study 1.

19. **Operational Water Surface Elevation Fluctuation Characterized Incorrectly**: Page 24 Vol 1 of the Relicensing Study inaccurately states that "operations can result in water level fluctuations up to 4 feet at a given location over the course of a day", when the daily fluctuation appears, based on the data, to range from 4 to 6 feet with regular peaks in fluctuation closer to 9 feet. In fact, 9 feet of WSE fluctuation is currently allowed based on the FERC license, and yet there was no analysis to show potential erosion on riverbanks if FirstLight exercised the full 9 feet of WSE fluctuation allowed by their existing license on a regular basis in the future.

    The study also states that "during low to moderate flow periods the water surface in the TFI typically rests on the lower bank" however Figures 5.4.1.1-4 to 6 of the cross sections included in the study on pages 5-58 to 5-60 in Volume II demonstrate otherwise. These figures show that the WSE fluctuations straddle the toe of the upper bank and extend into both the lower and upper bank.

Recommendation: We recommend that the study conclusions regarding WSE fluctuations be revised to match the data provided. In addition it would be important to model the full 9 feet of WSE fluctuation allowed based on the FERC license, in the event that FirstLight chooses to exercise the full 9 feet of WSE fluctuation on a regular basis during the course of their new license period.

20. **Inaccurate Conclusion on Erosion Commencement:** Page 24 Vol 1 of the Relicensing Study states that "it is not until the water surface reaches the upper bank that erosion processes can potentially commence". This statement only makes sense if you consider the toe of bank as being part of the upper bank, since WSE fluctuations clearly impact the toe of the bank. The Relicensing Study then continues by stating that "even then the flow threshold to initiate erosion process was found to be greater than 37,000 cfs at the majority of detailed study sites". We question how this statement can be accurate since that would mean that there was basically no undercut bank formation (i.e. toe erosion) and even if there was that this toe erosion was not considered the initiation of the erosion process. This is counter-intuitive based on the cycle of erosion and the visual observations of multiple cross sections where undercut bank is evident, as well as on other cross sections where the toe of the bank was stabilized due to historic observations of undercut banks. In addition, the written descriptions of the individual cross-sections specifically note erosion observed at the toe of the bank.

    Recommendation: The conclusions stated in the Relicensing Study should be revised to reflect the cross-sectional observations of toe erosion as well as the understanding that the cyclical process of fluvial erosion and mass failure, whereby erosion at the toe of a bank can initiate additional bank failure.

21. **Counter-intuitive Conclusion Regarding WSE Fluctuation Impacts:** An increase in the WSE fluctuation range due to operations increases the vertical range on the streambank where both boat waves and ice can now impact the streambank, however the study concludes the opposite (in the lower reach at least), claiming that a decreased WSE fluctuation increases the impact of waves on the bank, by stating “the impact of waves in reach 1 can be attributed to the general lake-like conditions found in the lower TFI where water surface elevations vary across a narrow range. The narrow band of water surface elevation fluctuations focuses wave impacts in the zone where the beach/toe intersect the lower-most part of the upper bank.” (Volume 1, page 28). This conclusion is counter-intuitive.

    Recommendation: We recommend that the Relicensing Study provide further support for their reasoning behind this statement, due to the fact that it seems counter-intuitive and the study does not include enough data to prove otherwise.

22. **Inaccurate Conclusion:** Page 28 Vol 1 of the Relicensing Study states “The operational difference between the two scenarios was determined to identify the change in erosion rates resulting from operations at Northfield Mountain. The results of this analysis showed very small effects at every detailed study site indicating that Northfield Mountain operations are not a dominant cause of erosion at any location.” But the study then states: “except at 8BR-Pre”, which they dismiss as significant because it has been stabilized, even though it contributed to 74% of erosion at that site. However recent stabilization of a site does not mean that WSE fluctuations were not impacting the site. Their dismissal of the significance of this impact was then applied across the entire TFI to similar sites that have not been stabilized. They also then state that sites 7L and 119BL also have minor impact due to NFM operations but fail to mention that Table 7 shows that 19 of the sites show some sort of impact due to NFM operations, 7 of them contributing to over 3.7% of the total erosion and 3 of those contributing over 5% of the total erosion. And yet the final concluding Tables show 0% (for dominant) and 4% (for contributing) for NFM operational impacts.

Recommendation: We recommend that the results that show operation impacts not be dismissed as insignificant for subjective reasons, and therefore not be applied along reaches that were not included as study sites.

23. **Conclusion Misleading:** The Relicensing Study's conclusions that most of erosion occurs during high discharges oversimplifies/ignores the bank weakening processes active at lower flow stages (ice, freeze/thaw, wave, etc.). Large flows are likely simply removing material that has been weakened at lower flows.

    Recommendation: We recommend the study incorporate discussion of the cyclical processes of erosion and, as previously stated, modify their extrapolation methodology and conclusions to reflect that understanding.

24. **Conclusion Regarding Ice Potential:** The Relicensing Study largely cast aside ice as a major erosion factor despite clear photographic evidence of cracked ice sheets/blocks active along the channel margins within the stage-fluctuation ("toe" and "lower bank") zones. These ice blocks will jostle and move with stage changes, abrading the bank surface in the process. They may also detach/reattach to sediments as they move with operationally influenced stage fluctuations.

    Recommendation: We recommend that the study investigate the potential for increased ice impacts due to operational WSE fluctuations.

SUMMARY OF OUR PEER REVIEW

Based on our review of the Relicensing Study 3.1.2 Volumes I, II, and III, our review team has made 24 recommendations as discussed earlier in this memorandum.

In general, we have identified several areas where the study was not done according to generally accepted scientific practice, or did not follow a methodology described in the RSP. We also believe that a number of erroneous assumptions have been made that may severely skew the results. Without recommended revisions, the Study 3.1.2 Report does not accomplish the overall study goal to "evaluate and identify the causes of erosion in the Turners Falls Impoundment and to determine to what extent they are related to Project operations."

Most critically, we find that the Relicensing Study 3.1.2 did not include an analysis of any scenarios without operational WSE fluctuations. Both the Baseline Conditions and Scenario 1 include significant WSE fluctuation due to operations impacts. The Baseline Conditions include the daily WSE fluctuation from Vernon, NFM and TF, and Scenario 1 includes the daily WSE fluctuation from Vernon and TF. A non-fluctuating WSE run was not developed or analyzed to compare what the baseline conditions prior to the current operational impacts might have been. See review comment #6.

There are significant gaps in the analysis for the Relicensing Study 3.1.2 including entire reaches where no analyses was completed, as well as no BSTEM analysis completed to assess the operational impacts of Turners Falls, even though we believe this analysis is possible to conduct, contrary to what the study suggests, by utilizing the HEC-RAS data for stage and discharge. See review comment #7 & #11.

The extrapolation methodology utilized in the Relicensing Study 3.1.2 includes multiple arbitrary definitions and thresholds, not included in the RSP and therefore not agreed upon in advance, that potentially bias the study results. The extrapolation methodology also includes subjective observations that appear to not maintain impartiality, and may also be biasing the study results. See review comments #11 through #17.

The Relicensing Study's comparison of percentages of erosion based solely on a volumetric interpretation of the erosion rates, ignores the cyclical processes of erosion, whereby a small amount of toe erosion due to anthropogenic causes (i.e. WSE fluctuation along with its resulting groundwater and vegetation impacts, and boat waves) can instigate more significant erosion and accelerate bank failure due to natural causes (i.e. high flow).

FirstLight should revise the Relicensing Study 3.1.2 or issue an Addendum to the study that includes the revisions as per the recommendations set forth in this peer review, as well as the USDA (11/28/16) recommendations.

Laura A.S Wildman, PE

Director, New England Regional Office, Princeton Hydro, LLC
Fisheries Engineering and Aquatic Resource Management

Education:

- PhD Candidate, current, Engineering and the Environment, University of Southampton, United Kingdom (part time enrolment) – Focus Dam Removal
- Masters of Environmental Management, 2004. Yale University, New Haven, CT. Relevant course work in Biology of Fishes, Fish Biomechanics, Organic Pollutants, and River Processes (TA in River Processes & Restoration)
- B.S. Civil Engineering, 1989, University of Vermont, Burlington.

Professional Certifications and Awards:

- Registered Professional Engineer in the State of Connecticut
- NOAA Restoration Center Award for Leadership in Restoration for Service in Fish Passage Engineering; Coastal Am. Spirit Award for Anadromous Fish Restoration

Professional Training/Courses Instructed:

- Succeeding with a Dam Removal Project – Univ. of WI Madison, 2000 - 2014
- River Processes & Restoration – Assist with instruction of Yale University FES graduate course, New Haven, Connecticut, 2000-2009.
- Dam Removal Demystified – American Rivers' Workshop, NC 2011
- Dam Removal Short Course – Fish Passage 2015 Conference in Groningen, Netherlands; and ASDSO National Conference, DC, 2011
- Removing Small Dams & Stream Barriers Short Course – ASCE/EWRI, 2010
- Sustainable Floodplain Management Through Stream Restoration Short Course - ASCE/EWRI Conference, Providence, RI, 2010
- EWRI Short Course on Dam Removal and Sustainable Flood Management, 2010
- Sustainable Flood Management – Organized course and instructed, NJ, 2008
- Engineering Innovative Fish Passage: Dam Removal and Nature-like Fishways – Univ. of Wisconsin/ Madison, NH 2002 & CA 2003
- Applied Hydrology - Assist w/ instruction of Yale FES Masters course, New Haven, Connecticut 2003.
- Dam Removal: The Restoration of a River – USFWS training course, MA, 1999 and WV, 2000.
- Hydrology and Hydraulics for Restoration Projects –ACOE HEC in-house training course, CA, 2000.
- Advanced Training for River Geeks Series – Organized/Instructed courses on Sediment Mobility & HEC-RAS, 2008
- Academic Guest Lecturer: Tufts University; Bucknell University; Connecticut College; Wesleyan; UCONN, Yale, Mt. Holyoke, UMASS, University of WI-Madison, Western NE College School of Law, SUNY, Univ. of Montana's River Center, Cornell

Areas of Expertise:

- Involved in hundreds of fish passage, barrier removal, and river restoration projects
- Extensive experience in fish passage, fish behavior, fish biology, and fish biomechanics relating to migratory fish passage in the NE
- Design, implementation and management of fish passage, fish habitat, ecological restoration, sustainable flood & watershed management, and dam repair projects
- National and international expert in barrier removal and alternative fish passage technologies
- Governmental grant, policy and advocacy experience relating to fish passage and river science/restoration
- Instructor/lecturer for courses on fish passage, barrier removal, river processes/ restoration, sustainable flood management, risk communication & hydraulic modeling
- Expertise in fluvial geomorphology, water resource management, and instream flow management
- Construction oversight & administration on numerous river restoration projects
- Has provided guidance and input for multiple fish passage prioritization/optimization approaches

Professional Affiliations:

- President of the American Fisheries Society's Bioengineering Section – 2012 – 2015; current Past President
- Board of Governors for the American Fisheries Society 2012- 2015; and Management Committee 2014-2015
- Board of Governors for the Environmental and Water Resources Institute of ASCE (EWRI) 2010 - 2013
- University of CA-Berkley's Dam Removal Clearinghouse Steering Committee – established in 2002 - 2013
- Established and Manages the Dam Removal & Fish Passage LinkedIn Network, 2010 – Current; Co-manager of World Fish Migration Platform, 2012-Current
- Federal Interagency Advisory Subcommittee on Sedimentation - Dam Removal, 2008 - Current
- Aspen Institute's National Policy Dialogue on Rivers & Dams, 2000-2002;
- Chairman EWRI/ASCE Task Committee on Sediment Dynamics Post Dam Removal 2004 - 2011
- Co-chairman EWRI/ASCE River Restoration Manual of Practice Task Committee 2007-2008
- Established & Chairman of the Northeast Stream Barrier Task Force, 2001-2008
- AFS, Bioengineering Section, Fluvial Ecological Engineering Curriculum Working Group 2002-2003
- Member: ASCE, EWRI, ASDSO, ASFPM, AFS, Diadromous Species Restoration Research Network

Laura A.S. Wildman, PE
Director, New England Regional Office

Summary of Qualifications:

Ms. Wildman is a practicing fisheries engineer and aquatic resource manager that established and runs the New England Regional Office for Princeton Hydro focusing on ecological restoration consulting for aquatic systems. Her expertise and passion, centers on the restoration of rivers through the reestablishment of natural functions and aquatic connectivity. She is considered one of the foremost experts on barrier removal and alternative fish passage techniques, regularly lecturing, instructing, and publishing on these topics; including assisting with the instruction of courses for the University of Wisconsin and Yale University, and a recent publication for a special edition of the Journal of Engineering Geology regarding the history and human dimensions of barrier removal projects. Her work has also focused on reconnecting communities to rivers, and the socio-economic complexities relating to the balance between natural resource management and healthy river systems. She has been involved in hundreds of river restoration, barrier removal, and fish passage projects throughout the U.S.; working on all aspects of the projects from inception, project identification, cooperative agreement development, and funding, through design, project tracking/scheduling, identification of cost effective solutions, and construction, both as a licensed professional engineer designing and managing the projects and as a non-profit project partner during her 8 years with American Rivers (AR) managing their fish passage and barrier removal efforts and NOAA grants in the NE. Ms. Wildman received her bachelor's in Civil Engineering from University of Vermont and her Master of Environmental Management from Yale University, and integrates both engineering and a deep understanding of fisheries biology and river science into her restoration work. In 2009 she received a Leadership in Restoration award from NOAA's Restoration Center for her many years of dedicated service in fish passage engineering and a Coastal America Spirit Award for anadromous fish restoration in 2001.

Prior to returning to consulting, Ms. Wildman worked on fish passage and dam removal as American Rivers' Director of River Science and Chief Engineer, where she established and managed AR's Northeast Filed office, and served as their fish passage coordinator throughout the northeast and oversaw, managed and implemented multiple large scale fish passage, barrier removal and watershed restoration/management efforts. She initiated and led the Northeast Stream Barrier Task Force for 8 years, which established a network for NGO's state, and federal agencies working on aquatic connectivity issues (fish passage and barrier removal) throughout the greater northeast. She developed numerous guidance documents and standardized procedures for the removal of barriers to promote fish passage. In addition during her AR tenure, Ms. Wildman lead the AR-NOAA Open River Initiative Grant Program in the northeast, worked on policy and advocacy issues relating to rivers, and was an active member in the VT Dams Task Force, the NH River Restoration Task Force, Hudson River Stream Barrier Task Force, the CT Migratory Corridor Group, and the Gulf of ME Barrier Removal Monitoring Coordinating Committee. In 2010 she developed and now leads the Dam Removal and Fish Passage Network on LinkedIn with almost 2,000 members internationally, as well as co-manages the World Fish Migration Network.

Ms. Wildman was an invited participant in the Aspen Institute's two year National Policy Group regarding dam removal and played a key role in establishing the online University of CA-Berkley's Clearinghouse for Dam Removal Information. Ms. Wildman was also a member of the American Fisheries Society Bioengineering Section (AFS-BES) Working Group that developed curriculum guidance for a master's level program in Fluvial Ecological Engineering, which was recently incorporated into the UMASS Fish Passage Engineering Program. Ms. Wildman has developed and lead multiple successful symposia, one of which lead to the creation of a recently published American Society of Civil Engineers Environmental and Water Resource Institute's (ASCE-EWRI) manual on Sediment Dynamics Post Dam Removal, for which Ms. Wildman chaired the Task Committee. She is currently a member of the Federal Interagency Advisory Subcommittee on Sedimentation developing guidelines for sediment management and dam removal. In 2008 she headed the Environmental Impacts subgroup for Association of State Floodplain Managers' (ASFPM) Working Group on Dams.

Ms. Wildman the current Past-President for the Bioengineering Section (BES) of the American Fisheries Society (AFS) and served on the AFS Governing Board. She is a former member of the Governing Board of American Society of Civil Engineers' (ASCE) Environmental and Water Resource Institute (EWRI), where she continues to lead and participates in multiple committees relating to fish passage, barrier removal and river restoration. In 2011, Ms. Wildman initiated an Ad Hoc Committee under both AFS-BES and ASCE-EWRI leadership to further the strategic goals of both organizations with the objective of developing a partnering relationship between the two organizations on the topic of fish passage, by establishing the joint reoccurring national fish passage conference and developing a large scale online database/repository for fish passage information.

In addition to her work in river restoration, fish passage and barrier removal, Ms. Wildman also has significant experience in fluvial geomorphology, fisheries habitat, instream flow analysis, dam modification/repair, open channel hydraulics, grant coordination, public outreach and communication, and advanced hydraulic and sediment transport modeling.

Laura A.S. Wildman, PE
Director, New England Regional Office

Employment History:

- 2009-Current, Director of the New England Regional Office for Princeton Hydro; Fisheries Engineer; S. Glastonbury, CT
- 2001-2009, Chief Engineer and Director of River Science at American Rivers, Glastonbury, CT
- 1991-2001, Project Manager and Water Resource Engineer at Milone & MacBroom, Cheshire, CT
- 1989-1991, Water Resource Engineer at Urban Design, Inc. Kirkland, WA

Select Project Experience

Farmington River Restoration, Farmington/Bloomfield, CT (2009-2012) – Dam Removal & Nature-like Fishway

Ms. Wildman was the Project Manager for the engineering assessment, final design, and construction management/oversight for this fast paced fish passage improvement project on the famed Wild & Scenic Farmington River in Connecticut. The restoration project included both the removal of the Spoonville Dam and the design of a nature-like fishway (inverted partial rock ramp fishway) at the Winchell-Smith Dam. The design for both sites was completed in less than one year and the construction was accelerated years ahead of schedule for the Spoonville Dam Removal through the Project Manager's suggestion and leadership regarding the implementation of a design-build approach, which saved the client approximately $700,000.00 on the final project construction cost. The project included multiple public meetings to gain the support of the local whitewater community who actively use the site and the renowned whitewater run directly upstream for recreational kayaking.

Mitchell Brook Restoration, Whatley, MA (2009-2013) – Replaced Perched Culvert with Arch Culvert

Ms. Wildman was the Project Manager for the replacement of the existing perched, undersized 36" CMP culvert at Conway Road on Mitchell Brook, just upstream of the confluence with West Brook, in Whately, MA. Specifically, the services for the project included engineering design, geotechnical investigation, geomorphic assessment, permitting, bid preparation, construction management, and construction oversight. The project goals and objectives included: the design of a crossing meeting the MA River and Stream Crossing Standards; restoration of a stable, natural channel upstream and downstream, for a range of flow events; restoration of open aquatic and terrestrial passage for a variety of species; the creation of a successful project that could be used as a "model" demonstration site. The site already had extensive data collected relating to the distribution of native brook trout populations and this monitoring will be continued post-project to verify the success of the effort.

Guilford Lakes Nature-Like Fishway, Guilford, CT (2002) – Nature-like & Alaskan Steeppass Fishway

While Chief Engineer at American Rivers, Ms. Wildman was asked to investigate alternative fish passage options for the Guilford Lakes Dam that would reduce the cost of fish passage, previously estimated at $70-100K. Ms. Wildman enrolled the help of Yale graduate students and completed a design for a nature-like fishway that modified an existing bypass route along with two sections of Alaskan Steeppass fishway, and reduced the project cost down to $31K, for which she helped obtain two grants through the American Rivers-NOAA Community-Based Restoration Program Partnership and USFWS. Ms. Wildman later conducted an in-field hydraulic analysis of the completed fishway to assess velocities and potential passage routes. Additionally a more detailed telemetry study, completed by others, demonstrated passage through the fishway while identifying areas where the fishway would need adaptive management to further increase efficiency. The project had been designed with adaptive management in mind and additional stones had been stockpiled on-site to accommodate future modification.

Naugatuck River Restoration, Naugatuck Valley, CT (1998-2001) – Four Dam Removals & One Bypass Channel

The Naugatuck River Restoration Project was part of a large scale multi-million dollar watershed management and restoration effort that included the investigation of dam removal and fish passage around eight obsolete industrial dams on the Naugatuck and Mad Rivers. The project sought to improve water quality, increase public access to the river and restore the historic diadromous fish runs. The project dams included the Anaconda Dam, Union City Dam, Platts Mill Dam, Freight Street Dam, Tingue Dam, Chase Brass Dam, Plume & Atwood Dam, and Bray's Buckle Dam, ranging in size from 100-300 ft long and 4-20 ft high. Five of the eight dams investigated were removed and an innovative bypass channel was designed to circumvent another. Ms. Wildman was the engineering Project Manager for the project and led the fish passage feasibility assessments, the hydrologic/hydraulic analyses, the dam removal designs, and the preliminary bypass design, as well as providing full-time construction oversight for four of the dams removed. This multimillion dollar restoration effort was one of the first of its kind in the country and targeted the restoration of American shad, blueback herring, alewife, American eel, and sea-run brown trout to the watershed.

Laura A.S. Wildman, PE
Director, New England Regional Office

Barrier Removal & Fish Passage/Habitat Project Experience While at Princeton Hydro (2009-Current):

- Clarks Brothers Dam Removal (CT) – Project Manager
- Carpenter Dam Removal (CT) – Project Manager
- Papermill Dam Removal (CT) – Project Manger
- Hyde Dam Removal (CT) – Project Manager
- Spoonville Dam Removal & Winchell-Smith Dam Fishway – 2 dams (CT) - Project Manager
- Middle Street Dam Removal (CT) - Project Manager
- Heminway Pond Dam Removal (CT) - Project Manager
- West Branch Saugatuck Ford Removal (CT) - Project Manager
- Noroton Fish Passage (CT) - Project Manager
- Furnace Brook Fish Passage (CT) - Project Manager
- Pond Lily Dam Removal Sediment Assessment (CT) - Project Manager
- Mill Street Dam Assessment & Wiley-Russell Dam Removal – 2 dams (MA) - Project Manager
- Tannery Dam Removal (NH) – Project Manager
- Tel-Electric Dam Removal (MA) – Project Manager
- Mitchell Brook Culvert Replacement (MA) - Project Manager
- Century Brook Bog Restoration and Barrier Removal (MA)
- Hunters Mill Pond Dam Removal (MA) - Project Manager
- Horseshoe Pond Dam Fish Passage Alternatives Assessment (MA) – Project Manger
- Cumberland Fish Passage Assessment Technical Review Team (ME)
- Saccarappa Fish Passage Assessment (ME) - Project Manager
- Marshfield-8 Dam Removal (VT) - Project Manager
- Dunkard Creek Dam Removals – 2 dams (PA)
- Little Lehigh Dam Removals – 4 dams (PA)
- Home Depot Dam Removals – 3 dams (PA)
- Jordon Creek Dam removals – 5 dams(PA)
- Rakes Pond & Marshell's Pond Dam Removals – 2 dams (PA)
- Plymouth Crossing Dam Removal (PA)
- Finesville Dam Removal Feasibility Study (NJ)
- Lawrence Brook Fish Passage – 2 dams (NJ) - Project Manager
- Cumberland Dam Removal Assessment (MD) - Project Manager
- Klamath Dam Removal Report Peer Review – 4 dams (CA)
- SanClemente Dam Removal Technical Advisory Team – 2 dams (CA)
- Otsego Dam Removal Expert Assistance – 2 dams (MI)
- Goldsboro Dam Removal Assessment (NC) - Project Manager
- Lassiter Dam Removal (NC) - Project Manager
- Neuss River Restoration & Fish Passage Assessment (NC) - Project Manager

Selected Barrier Removal & Fish Passage/Habitat Project Experience Prior to Joining Princeton Hydro (1998-2009)**:**

- Pizzini Dam Removal (CT) – Design & Construction Oversight
- Raymond Brook Dam Removal (CT) – Design & Construction Oversight
- Penobscot Dam Removals – Great Works & Veazie (ME) – Technical Oversight
- Cumberland Dam Removal on the Presumpscot (ME) – Technical Oversight
- Zemko Dam Removal (CT) – Technical & Construction Oversight
- Springborn Dam Removal (CT) – Technical Oversight
- Willimantic Dam Removals (CT) – Technical Oversight
- Milbury Dam Removal Assessment (MA) – Technical Assistance
- Cobbesecontee Dam Removal (ME) – Technical Assistance
- Winnicut Dam Removal (NH) – Technical Assistance
- Merrimack Village Dam (NH) – Technical Assistance
- Cuddebackville Dam Removal (NY) -– Technical Assistance
- Pawtuxet Dam Removal Assessment (RI) – Technical Assistance

- East Burke Dam Removal (VT) – Technical Assistance
- Matilija Dam Removal (CA) – Technical Review
- Klamath Dam Removals (CA) – Technical Review of Reports
- Presumpscot Dam Removals (ME) – Technical Assistance
- Naugatuck River Dam Removals: Anaconda, Freight St., Union City, Platts Mill Dams (CT) - Project Manager
- Naugatuck River Dam Removal Assessments: Brays Buckle, Chase Brass, Tingue, & Plume & Attwood Dams (CT)
- Coginchaug River – Dam Removal Assessments for Starr Mill Pond and Savage Mill Dams (CT) – Project Manager
- Billington Street Dam Removal (MA) – Project Manager for Preliminary Design
- Edwards Dam Removal (ME) – Technical Oversight

Publications

- **Dam Removal: A History of Decision Points** – Sole author, **Reviews in Engineering Geology**, 2013
- **From Sea to Source** – Section of Dam Removal Monitoring in the USA, coauthor Peter Philipsen, edited by Peter Gough, 2012
- **ASCE/EWRI Manual on Sediment Dynamics Post Dam Removal** – Chairman of task committee, heading publication, & co-author on and supervisor of summary paper. 2011
- Avoiding Dam Breach Through Preemptive Dam Removal & Public Awareness - ASDSO Conference Proceedings, September 2006
- Community Guide to Dam Removal – Contributor. Written by Connecticut River Watershed Council. 2006.
- **Gravel Streambed Dynamics Post Dam Removal: Case Study of the Anaconda and Union City Dam Removals** -Primary author. **Journal of Geomorphology** October 2005. Presented at the 2002 Binghamton International Geomorphology Symposium.
- 10 Dam Removals, 10 Years Later – Primary author. ASDSO National Conference Proceedings 2008
- An Illustrative Handbook on Nature-like Fishways - Primary author. Summary version presented at the American Fisheries Society's Annual Conference, Baltimore, 2002. Final publication scheduled for completion 2008.
- Dam Removal: A New Option For a New Century - Contributor and dialogue participant. The Aspen Institute Program on Energy, The Environment, and the Economy, Dialogue on Dams and Rivers, 2002.
- Stream Barrier Removal Monitoring Guidelines – Coordinating Committee & Workshop Participant
- A Cross-section of Swimming Performance and Biomechanics of Five Fish Species in a New England Stream – Author. Prepared for Yale Biology of Fishes Master's course. 2003
- Hydraulics of Nature-Like Fishways: Velocity Cross-Section Analyses of Sennebec and Guilford Lakes Nature-Like Fishways - Author. Prepared for Yale Independent Study on River Processes & Restoration for Masters degree program. 2004
- Sediment Transport & Management Relating to Dam Removal - Author. Prepared for Yale Independent Study on River Processes & Restoration for Masters degree program. 2003
- Dam Removal – A Tool for River Restoration on the Naugatuck River – Primary author. American Society of Engineers' Joint Conference on Water Resources Engineering and Water Resource Planning and Management Proceedings, Minneapolis, Minnesota, 2000
- Dam Removal: One Size Does Not Fit All! - Primary author, 2003. ASCE-EWRI Conference in Philadelphia, 2003
- Why Are The River Rocks Round – Author. Children's book on fluvial geomorphology and aquatic ecology. Written for Master's course at Yale University. Completed 2004, currently looking into publication.
- Fluvial Ecological (River) Engineering Curriculum - Co-author. AFS Bioengineering Section Working Group, to be presented at the Annual American Fisheries Society Conference in Canada, 2003.
- Cursed on Both Ends and Dammed in the Middle – Author. Editorial article on the controversy surrounding the removal of the Billerica Dam in MA, prepared for Yale Environmental Writing masters course. 2003
- Exploring the Human Dimensions in the Efforts to Remove Dams and Restore Rivers- The Billerica Dam Case Study – Author. Prepared for Yale Human Dimensions masters course. 2003
- Dam Removal Success Stories – Contributor. Trout Unlimited and American Rivers' publication, 1999.
- Sediment Transport Relating to Dam Removal - A Literature Search of Current Methods Used for Analyzing Sediment Transport - Sole author. University of Connecticut graduate studies paper, Storrs, Connecticut, 1997
- Engineering: Exploring the Human Dimension - Sole author. University of Vermont undergraduate studies paper. First Place Northeast American Society of Civil Engineers Paper Competition, 1989

Invited Lecturer & Presentations (2000 – Current)

Dam Removal

- *The Evolution of the Pro-Active Dam Removal Movement in the US over the Last Quarter Century* – Plenary, International Fish Passage Conference, June 2015, Groningen, Netherlands
- *The Dam Removal Movement In The US - Key Elements Of The Evolution and What We Can Learn For The Situation In Europe* – Atlantic Salmon Summit, Huningue, France, September 2015
- *Dam Removal Key Lessons Learned* – Instructor, World Fish Migration Foundation Webinar, 2015
- *Dam Removal Short Course* – Instructor, International Fish Passage Conference, June 2015, Groningen, Netherlands
- *Effects of Dams on Floodplain* Function – Annual AFS Conference, 2014
- *Biggest Barriers to Barrier Removal* – International Fish Passage Conference, June 2014, Madison, Wisconsin
- *Dam Removal Case Studies* – Plenary, Poland, 2014
- Highlights *of Historic Battles over Dams & Fish* – Plenary, National Conference on Engineering & Ecohydrology for Fish Passage, MA, 2011; Farmington River Watershed Assoc., plenary, 2011; & Wesleyan University, 2012; EWRI, NM, 2012
- *Dam Removal Techniques & Sediment Management* – ASDSO, 2011 & Dam Removal Workshop, NC, 2011
- *Dam Removal Classification System* – National Conference on Engineering & Ecohydrology for Fish Passage, Amherst, MA, 2011; Joint Federal Interagency Conference on Hydrologic and Sediment Transport Modeling Las Vegas, NV, 2010; & ASCE/EWRI National Conference, Providence, RI, 2010
- *Dam Removal Lessons Learned*– ASCE/EWRI National Conference, Providence, RI, 2010
- *Willimantic River Dam Removal* – UCONN Environmental Journalism Course, 2009
- *Categorization of Dam Removals* – Diadromous Species Restoration Research Network, Bangor, ME 2009
- *Restoring the Naugatuck River* – Ansonia Nature & Recreation Center, CT 2009
- *Dam Removal Case Studies* – Invited presenter for Yale's Water Resources case Study Masters Course, 2008-2011
- *Dam Removal: A History of Decision Points* – Chauncey Loomis Lecture Series by HVA, CT, 2010 & Mount Holyoke's Environmental Leadership Series, 2007
- *Avoiding Dam Breaches Through Preemptive Dam Removal and Public Awareness –Association of State Dam Safety Officials Annual Conference, Boston, MA, September 2006*
- *Do It Yourself Dam Removal Investigation* – Session talk. National River Rally, NH, 2006
- *Dam Removal Overview: Issues to Consider, Regulatory Approaches and Lessons Learned* – Massachusetts Permit Streamlining Committee Meeting, 2006
- *Sediment Dynamics Post Dam Removal: State of the Science & Practice* - Joint Federal Interagency Sedimentation & Hydrologic Modeling Conference, 2006
- *Restoring Rivers Through Selective Dam Removal* – CT Department of Environmental Protection In-house Training, June 2006
- *Dam Removal: A History of Decision Points* – ASWM & UMASS Integrated River Restoration Workshop, 2005
- *Dam Removal: One Size Does Not Fit All* - ASCE/EWRI Watersheds 2005 Conference – Organized and Lead seven sessions (25 papers) on sediment dynamics post dam removal and presented individual paper
- *How Do You Remove a Dam? Technical Challenges* - Univ. of Montana Dam Removal Workshop, 2005
- *Dam Removal: One Size Does Not Fit All* - Association of State Dam Safety Officials annual meeting, AZ, 2004
- *Dam Removal Lessons Learned* – UMASS Workshop 2004
- *A History of Decision Points* - Boston Environmental Exposition, 2004
- *Dam Removal A New Option for a New Century* - Association of State Dam Safety Officials annual meeting, PA, 2003
- *Un-Designing Dams* - Bucknell University, 2003
- *Dam Removal A New Option for a New Century* - Vermont Dam Task Force, 2003
- *Restoring Our River Through Selective Dam Removal* - Plenary talk. *Anadromous Fish Restoration in the Naugatuck River Basin* - Session talk. New York Regional American Fisheries Society annual meeting, 2003.
- *An Overview to Dam Removal, Dam Removal: Sediment and Site Restoration* - Dam Removal and Alternatives Workshop, Mid-Atlantic/Northeast Training Workshop, Stream, Floodplain And Wetland Restoration: Improving Effectiveness through Watershed and Source Water Programs, Bear Mountain, NY, 2002.

- *Gravel Streambed Dynamics Post Dam Removal: Case Study of the Anaconda and Union City Dam Removals* - Binghamton International Geomorphology Symposium , 2002
- *Dam Removal Project Overview, and Hydrology and Sediment Management for Small Dams* - New Jersey Dam Safety, one-day course put on by Princeton Hydro, 2002.
- *Dam Removal: River Sediment Processes* - NOAA National Marine Fisheries Retreat, Plymouth, 2002
- *Restoring Rivers Through Dam Removal and Fish Passage* - CT Association of Wetland Scientists, 2001
- *Creating A Northeast Action Agenda: Dam Removal and The Restoration of Biological Integrity* - Organizer and presenter, Plymouth, Massachusetts, May 2001.
- *Restoring Rivers through Dam Removal and Non-Traditional Passage Alternatives* – California-Nevada Chapter of American Fisheries Society's 34th Annual Symposium and Conference, Ventura, California, 2000
- *Dam Removal - Anadromous Fish Restoration the Naugatuck River Basin* – Norwalk River Watershed Association, Inc., Connecticut, 2000.

Fish Passage – Fishways

- *Opening Rivers to Fish Migration in the US* – Plenary, Poland, 2014
- *Applied Fish Passage Strategies: Getting Fish Up Rivers* - NY Regional Herring Workshop, NYC, 2012
- *Categorization of Nature-like Fishways Worldwide* – AFS National Conference, Seattle, WA, 2011
- *Removing Barriers at Road Crossings using Stream Simulation Techniques in the Northeast US* **-** ASCE/EWRI National Conference, Providence, RI, 2010
- *Fish Passage Options For Connecticut's Rivers: Thinking Outside of the Box* -Connecticut Watershed Conservation Network, 2005
- *Thinking Outside The Box: An Introduction to Nature-Like Fishways* - River Management Interagency Workshop, WV, 2003
- *Thinking Outside of the Box - An Introduction to Nature-Like Fishways* - Dam Removal and Alternatives Workshop, Mid-Atlantic/Northeast Training Workshop, Stream, Floodplain and Wetland Restoration: Improving Effectiveness through Watershed and Source Water Programs, Bear Mountain, NY, 2002.
- *Restoring New England's Historic Herring Runs* - North and South River Watershed Association and Massachusetts's Audubon, 2003.
- *An Engineers Perspective on Research Needs In Dam Removal and Fish Passage* - Academy of Natural Sciences, 2002
- *Illustrated Handbook on Nature-Like Fishways* – National American Fisheries Conference 2002
- *Natural Approach to Dam Removal and Fish Passage* - Association of State Dam Safety Officials annual meeting in Florida, 2002.
- *Thinking Outside of The Box - An Introduction to Nature-Like Fishways* - New Jersey Dam Safety, one-day course put on by Princeton Hydro, 2002.
- *Restoring Rivers through Dam Removal and Non-Traditional Passage Alternatives* – Western District American Fisheries Society's Annual Conference, Telluride, Colorado, 2000.

Monitoring

- *10 Dam Removals, 10 Years Later* – ASDSO National Conference, CA, 2008
- *Stream Barrier Removal Monitoring Guide* – EWRI/ASCE National Conference, HI, 2008

Dams and Risk Communication

- *Manmade Flood Zones* – Wesleyan University lecture series, Middletown, CT, 2012
- *Dam Safety Experience from Neighboring States* – New York Federation of Lake Associations, NY, 2009
- *Risk Communications* – invited presenter to the National Dam safety review Board, 2008; NJASFM, 2009
- *Inundation Zones* - ASDSO National Conference , TX, 2007
- *An Introduction to Dam Impacts & Dam Removal Efforts*- Thames River Watershed Partners, CT, 2007
- *Easily Accessible Inundation Zone Mapping: Linking GIS Databases to Google Maps* - NE ASDSO, NH 2007
- *Dam Nation: Legal Aspects* – Western NE College, School of Law, 2007

- *Dam Nation* – Plenary presentation for Yale's Conference on Large Dams. Keynote speaker: Bruce Babbitt, 2006
- *Dam Ownership By Default: Buyer Beware* - Convocation of Connecticut Land Trusts, 2006
- *Our Dam: Should It Stay or Should it Go!* - Stanford Land Trust, 2002.

River Restoration & Fish Habitat

- MC, Overview, and Panel Discussion - Naugatuck River Forum, 2011
- *Restoring Rivers for a Living* – presentation to East Hartford 7th Graders, 2007
- *Restoring Our Rivers* - Plenary speaker and *River Morphology - The Shaping Processes of a River* - Co-presenter, New Hampshire River and Wetlands Conference, 2001.
- *River Restoration through Fish Habitat Enhan*cements - New England Association of Environmental Biologists Annual Conference, Connecticut, 2001.

Hydraulic & Sediment Transport Modeling

- *HEC-RAS for Non-Modelers* – Initiated the Advanced Training for River Geeks Series and am currently developing this course under series to be offered in 2008.
- *One Size Does Not Fit All* - EWRI/ASCE Conference for the Sediment Dynamics Task Committee, 2003
- *Applied Hydrodynamic Modeling: Case Studies* – Coastal America Modeling Workshop for Salt marsh Restoration, Massachusetts, 1999.
- *Applied Hydrodynamic Modeling* – 7th Annual Long Island Sound Research Fund Symposium at Connecticut College, Connecticut, 1999.

Management/Outreach

- *Lessons Learned & Next Steps: Creating National & Regional Support for Clean Water Infrastructure* – Panelist, Long Island Sound Citizens Summit, CT 2009
- *It Takes A Village To Pass A Fish*: Linking Fish Passage Efforts & Experts - AFS Nat. Conference, CA, 2007
- *Community Resilience & Sustainability within Riverine Systems* – to FEMA Management in DC, July 2008
- *Model State Dam Removal Programs* – lead panel discussion for the ASDSO National Conference, CA, 2008
- *American Rivers & The USFWS Sustainable Ecosystem Restoration in New England* – presented to USFWS Management, MA, 2007
- American Rivers Board Meeting Presentations - 2003 & 2005

Flood Management

- *Dam & Levee Impacts on Community Resilience & Sustainability* – Wesleyan University lecture series, Middletown, CT, 2012
- *Implementation of Sustainable Flood Management Practices: Examples & Methods* - ASFPM, FL 2009
- *Community Resilience & Sustainability within Riverine Systems* – FEMA Mitigation Seminar, DC, January 2008
- *Healthy Rivers Promoting Healthy Communities* – FEMA Community rating System Task Force, MA, 2008
- *Economic Benefits of Sustainable Flood Management*- Organized & presented at the NJ Sustainable Flood Management Course, NJ, 2008

MELINDA D. DANIELS

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EDUCATION:

2003: Ph.D. in Physical Geography, University of Illinois, Urbana-Champaign, Illinois.

1997: Master of Research in Environmental Science, University College London, London, United Kingdom.

1996: B.S. (Honors) in Natural Resources and Environmental Science, Cornell University, Ithaca, New York.

PROFESSIONAL EXPERIENCE:

2013 –	Associate Research Scientist, Director of Fluvial Geomorphology Section, Stroud Water Research Center, Avondale, PA.
2013 –	Adjunct Associate Professor, Graduate Faculty Member, Kansas State University, Department of Geography,
2014 –	Ancillary Associate Professor, University of Delaware, Department of Geography
2015 –	Ancillary Associate Professor, University of Delaware, Department of Geology
2010-2013	Associate Professor and Graduate Program Director, Kansas State University, Department of Geography, Physical and Environmental Geography
2008-2010:	Assistant Professor, Kansas State University, Department of Geography, Physical and Environmental Geography (Accepted position in 2007, deferred start date to 2008 to have my first child in 9/2007 in Connecticut. First tenure application 2009, approved effective 2010)
2002-2008:	Assistant Professor, University of Connecticut, Department of Geography, Physical and Environmental Geography (no tenure application)
2001-2002:	Instructor, University of Illinois, Introduction to Physical Geography
1998-2001:	Research Assistant and Fellow, University of Illinois, Stream Confluence Dynamics, River Restoration Science

PUBLICATIONS: *(*denotes students)*

Albertson, L. K., and **M. D. Daniels**. *In press.* Invasive crayfish influence fine sediment accumulation, gravel movement, and macroinvertebrate communities in streams. *Freshwater Science.*

Rüegg, J., W. K. Dodds, **M. D. Daniels**, K. R. Sheehan, C. L. Baker, W. B. Bowden, K. J. Farrell, M. B. Flinn, T. K. Harms, J. B. Jones, L. E. Koenig, J. S. Kominoski, W. H. McDowell, S. P. Parker, A. D. Rosemond, M. T. Trentman, M. Whiles, W. M. Wollheim. 2016. Baseflow physical characteristics differ at multiple spatial scales in stream networks across diverse biomes. *Landscape Ecology* 31(1)1: 119-136. doi:10.1007/s10980-015-0289-y

Caldas M.M., M.R. Sanderson, M. Mather, **M. D. Daniels,** J. S. Bergtold, J. Aistrup, J. L. Heier Stamm, D. Haukos, K. Douglas-Mankinh, A. Y. Sheshukov, and D. Lopez-Carr. 2015. Opinion: Endogenizing culture in sustainability science research and policy. *Proceedings of the National Academy of Science of the United States of America* 112(27): 8157–8159.

Fencl J. S., M.E. Mather, K. H. Costigan, **M. D. Daniels.** 2015. How Big of an Effect Do Small Dams Have? Using Geomorphological Footprints to Quantify Spatial Impact of Low-Head Dams and Identify Patterns of Across-Dam Variation. *PLoS ONE* 10(11): e0141210.

Ruffing, C. M., K. A. Dwire, and **M. D. Daniels**. 2015. Carbon pools in stream-riparian corridors: legacy of disturbance along mountain streams of southeastern Wyoming. *Earth Surface Processes and Landforms*. DOI: 10.1002/esp.3830

Grudzinski, B. P., Daniels, M. D., Anibas, K., & Spencer, D. (2015). Bison and cattle grazing management, bare ground coverage, and links to suspended sediment concentrations in grassland streams. *JAWRA Journal of the American Water Resources Association*, n/a-n/a. doi: 10.1111/1752-1688.12364

Dodds, W.K., Gido, K., While, M.R., **Daniels, M.D.**, Grudzinski*, B.P. 2015. The stream biome gradient concept: controlling factors of streams across broad biogeographic scales. *Freshwater Science,* 34(1):1–19.

Ruffing*, C., **M. Daniels,** and K. A. Dwire. 2015. Disturbance legacies of historic tie-drives persistently alter geomorphology and large wood characteristics in headwater streams, southeast Wyoming. *Geomorphology,* 231:1-14.

Costigan, K.H., **M.D. Daniels,** W.K. Dodds. 2015. Fundamental spatial and temporal disconnections in the hydrology of an intermittent prairie headwater network. *Journal of Hydrology*, 522: 305-316.

Costigan* K. H., Ruffing* C. M., **Daniels M. D.** and Perkin* J. S. 2014. Rapid response of a sand-dominated river to installation and removal of a temporary run-of-the-river dam. *River Research and Applications*, DOI: 10.1002/rra.2843

Burchsted*, D., & **Daniels, M. D.** 2014. Classification of the alterations of beaver dams to headwater streams in northeastern Connecticut, USA. *Geomorphology, 205*, 36-50. doi: 10.1016/j.geomorph.2012.12.029

Costigan*, K. H., **Daniels, M.D.**, Perkin, J. S., & Gido, K. B. 2014. Longitudinal variability in hydraulic geometry and substrate characteristics of a Great Plains sand-bed river. *Geomorphology, 210*, 48-58. doi: 10.1016/j.geomorph.2013.12.017

Perkin*, J. S., Gido, K. B., Costigan*, K. H., **Daniels, M.D.**, & Johnson, E. R. 2014. Fragmentation and drying ratchet down Great Plains stream fish diversity. *Aquatic Conservation: Marine and Freshwater Ecosystems*, n/a-n/a. doi: 10.1002/aqc.2501

Fischer*, J., Paukert, C., & **Daniels, M.D.** 2014. Influence of riparian and watershed alterations on sandbars in a Great Plains river. *River Research and Applications*, doi: 10.1002/rra.2811

Larson* DM, Grudzinski* BP, Dodds WK, **Daniels M**, Skibbe A, Joern A. 2013. Blazing and grazing: influences of fire and bison on tallgrass prairie stream water quality. *Freshwater Science* 32(3):779–791.

Plater, A.J., **Daniels, M.D.** and Oguchi, T. 2012 Present Research Frontiers in Geomorphology, Chapter in Treatise in Geomorphology, Elsevier.

Chin, A., Laurencio, L., Wohl, E., **Daniels, M.D.**, Urban, M., Boyer, K., Butt, A., Piegay, H., and Greory, K. 2012. The significance of perceptions and feedbacks for effectively managing wood in rivers, *River Research and Applications*, DOI: 10.1002/rra.2617

Fischer*, J., Paukert, C. and **Daniels, M.D.** 2012. Fish community response to habitat alteration: impacts of sand dredging in the Kansas River, *Transactions of the American Fisheries Society*, 141:6, 1532-1544

Costigan*, K.H. and **Daniels, M.D.**, 2012. Damming the prairie: Human alteration of Great Plains river regimes. *Journal of Hydrology*, 444-445, 90-99.

Costigan*, K.H. and **Daniels, M.D.**, 2012. Spatial pattern, density, and characteristics of large wood in Connecticut streams: Implications for stream restoration priorities in southern New England. *River Research and Applications*, In Press, available online, DOI: 10.1002/rra.158.

Daniels, M.D. and McCusker*, M.H. 2011. Reply to Bunte et al. (2011) "Discussion of Daniels and McCusker (2010): Operator bias characterizing stream substrates using Wolman pebble counts with a standard measurement template." Geomorphology 115, 194–198. *Geomorphology*, 134, 501-502.3

Burchsted*, D., **Daniels, M.D.**, Thorson, R.M., and Vokoun, J.C. 2010. The river discontinuum: beavers (*castor canadensis*) and baseline conditions for restoration of forested headwaters. *Bioscience*, 60(11): 908-921.

Daniels, M.D. and McCusker*, M.H. 2010. Operator bias characterizing stream substrates using Wolman pebble counts with a standard measurement template. *Geomorphology,* 115: 194–198**.**

Daniels, M.D., D. Burchsted*, J. MacBroom, L. Wildman, S. Harold, M. Carabetta, P. Woodworth, and G. Boardman **2010**. Redefining the Dam Removal Paradigm in Formerly Glaciated Forested Headwater Systems, *Proceedings of the EWRI/ASCE Congress, 2010*

Burchsted*, D., **Daniels**, **M. D.**, and R. M. Thorson. 2010. Restoring the River Discontinuum: Looking at the Example of Beaver Dams, *Proceedings of the EWRI/ASCE Congress, 2010*

McCusker*, M.H., and **Daniels, M.D.** 2009. The potential influence of small dams on basin sediment dynamics and coastal erosion in Connecticut. *Middle States Geographer*, 41:82-90.

Daniels, M.D., Boardman*, G.C., and Woodworth*, P.M. 2008. Assessing dam removal impacts on downstream geomorphic stability using hydrodynamic modeling. *Papers of the Applied Geography Conference*, 31: 133-141.

Chin, A., **Daniels, M.D.,** Urban, M., Piegay, H., Gregory, K.J., Gregory, S.V., Wohl, E., Laurencio, L., Bigler, W., Boyer, K., Grable, J., LaFrenz, M. 2008. Perceptions of Wood in Rivers and Challenges for Stream Restoration in the United States. *Environmental Management*, 41(6): 893-903.

Rhoads, B.L., Garcia, M.H., Rodriguez, J., Bombardelli, F., Abad, J., and **Daniels, M.** 2008. Methods for evaluating the geomorphological performance of naturalized rivers: examples from the Chicago metropolitan area. *Uncertainty in River Restoration*, Sears, D. and Darby, S. (editors). Wiley, Chichester, pp. 209-228.

Daniels, M.D. and Rhoads, B.L. 2007. Influence of experimental removal of large woody debris on spatial patterns of three-dimensional flow in a low-energy meander bend: A LWD removal experiment. *Earth Surface Processes and Landforms*, 32: 460-474.

Daniels, M.D. 2006. Grain size sorting in meander bends containing large woody debris. *Physical Geography*, 24(7): 348-362.

Daniels, M.D. 2006. Distribution and dynamics of large woody debris and organic matter in a low-energy meandering stream. *Geomorphology*, 77(3-4): 286-298.

Urban, M.A. and **Daniels, M.D.**, 2006. Exploring the links between geomorphology and ecology. *Geomorphology*, 77(3-4): 203-206.

Daniels, M.D. and Rhoads, B.L. 2004. Effect of LWD Configuration on Spatial Patterns of Three-Dimensional Flow in Two Low-Energy Meander Bends at Varying Stages. *Water Resources Research*, 40 (11) W11302 10.1029/2004WR003181 25 November 2004

Daniels, M.D. and Rhoads, B.L. 2004. Spatial patterns of turbulence kinetic energy and shear stress in a meander bend with large woody debris. Chapter in the American Geophysical Union Monograph volume entitled “Riparian Vegetation and Fluvial Geomorphology: Hydraulic, Hydrologic and Geotechnical Interactions”, S. Bennett and A. Simon (eds.).

Daniels, M.D. and Rhoads, B.L. 2003. Influence of a large woody debris obstruction on three-dimensional flow structure in a meander bend. *Geomorphology*, 51, 159-173.

Wade, R.J., Rhoads, B.L., Rodriguez, J., **Daniels, M.D.**, Wilson, D., Herricks, E.E., Bombardelli, F., Garcia, M., and Schwartz, J. 2002. Integrating Science and Technology to Support Stream Naturalization near Chicago, Illinois. *Journal of the American Water Resources Association*, 38, 931-944.

GRANTS AND CONTRACTS AWARDED

C. Staudt, S. Christy, T. Ganesh, **M. Daniels (Co-PI)**, N. Dietrich. Strategies: Water SCIENCE: Supporting Collaborative Inquiry, Engineering, and Career Exploration with Water. NSF ITEST, $1,199,608

L. Kaplan, J. Khan, B. Sweeney, A. Aufdenkampe, **M. Daniels (Co-PI)**. Long-Term Research in Environmental Biology (LTREB): Trajectory for the Recovery of Stream Ecosystem Structure and Function during Reforestation, NSF DEB, 2/1/16 – 1/31/21, $450,000

Melinda Daniels (PI), with L. Kaplan, M. Erhart, and A. Aufdenkampe. Transforming Water Quality in the Sharitz Run Headwaters of Brandywine Creek, PA DEP Growing Greener, 2015-2020, $1,789,571

Melinda Daniels (PI), with B. Sweeney, D. Arscott, M. Erhart, W. Eldridge, J. Jackson, S. Gill, Restoring Flood Attenuation and Ecological Resiliency in the Mid-Atlantic Piedmont, 2014-2016, National Fish and Wildlife Foundation, $3,030,000

Melinda Daniels (PI), with A. Aufdenkampe, N. Dietrich, C. Staudt. Collaborative Research: Teaching Environmental Sustainability - Model My Watershed, 2014-2016, NSF DRK-12, $1,588,886

J. Blair, J. Nippert, S. Baer, W. Dodds and T. Joern (**M. Daniels: Senior Personnel**). KNZ LTER VII: Long-Term Research on Grassland Dynamics – Assessing Mechanisms of Sensitivity and Resilience to Global Change, 2014-2019, NSF, $6,100,000

Melinda Daniels (PI), with J. Aistrup, J. Bergtold, M. Caldas, K. Douglas-Mankin, D. Haukos, J. Hierr-Stamm, M. Mather, and A. Sheshukov, CNH: Coupled Climate, Cultivation, and Culture in the Great Plains: Understanding Water Supply and Water Quality in a Fragile Landscape, 2013-2016, NSF CNH, $1,450,000

Melinda Daniels (PI) and Bartosz Grudzinski*, Doctoral Dissertation Research: Influence of Grazing Differences on Stream Geomorphology in Tallgrass Prairie Headwater Streams, 2013, National Science Foundation GSS $15,759

Melinda Daniels (PI) and Claire Ruffing*, Doctoral Dissertation Research: The Impact of Historical Logging Activities on the Ecology and Geomorphology of Mountain Streams, 2013, National Science Foundation GSS $15,972

Melinda Daniels (PI), Impacts of In-Channel Sand Mining on the Geomorphology of the Kansas River, 2012-2014, Kansas Water Resources Institute (USGS), $53,390.

Melinda Daniels (PI) and Katie H. Costigan*, Doctoral Dissertation Research: Thermal, Hydraulic and Geomorphological Dynamics at Stream Confluences, 2012, National Science Foundation GSS $11,695

Melinda Daniels (PI), Watershed Assessment of the Wakarusa River, KS, Blue Earth LLC/Kansas Department of Health and the Environment, 9/19/2011-12/15/2012, $14,000.

Melinda Daniels (PI), Impacts of Large-Scale Forest Loss on Stream Channel Form, Process and Sedimentation, US Forest Service (USDA), 8/19/11-8/20/15, $49,667

Keith B. Gido, Joshuah S. Perkin, **Melinda Daniels (co-PI)** and Katie H. Costigan*, Reproductive Life History Of Great Plains Pelagic-Spawning Fishes In The Ninnescah River, Kansas, FY 2011 State Wildlife Subgrant Program, Kansas Department of Wildlife and Parks, 5/1/2011 to 4/30/2013, $192,675

Melinda Daniels (PI) Assessing the Impact of Channel and Riparian Zone Modifications on Aquatic Biodiversity in the Kansas River Basin, Kingsbury Family Foundation, 12/25/2011-12/25/2012, $24,951

Melinda Daniels (PI) American Rivers Patapsco River Restoration Project, McCormick Taylor, INC, 12/18/2010-12/18/2012, $11,299

Melinda Daniels (PI) KSU ORSP Faculty Development Award for travel to the 12th International Symposium on the Interactions between Sediments and Water, UK, (June, 2011) $1,200

Melinda Daniels (PI) Wildcat Creek Watershed Assessment, US Department of Agriculture/Blue Earth, LLC, 10/10-1/11, $7,400

Melinda Daniels (PI) Subcontract to Konza NSF LTER for geomorphology research support, 8/2010-8/2011, $26,000

Craig Paukert and **Melinda Daniels (co-PI)** Sand Dredging Effects on Fishes and Fish Habitat in the Kansas River, FY 2009 State Wildlife Subgrant Program, Kansas Department of Wildlife and Parks, 1/2010-1/2012, $181,983

Keith Gido, **Melinda Daniels (co-PI)** and Joe Gerken Seasonal Fish Assemblages and Habitat Effects near Bowersock Dam: Implications for Fish Passage, FY 2009 State Wildlife Subgrant Program, Kansas Department of Wildlife and Parks,1/2010-1/2012, $195,249

Melinda Daniels (PI) Hydraulic, Geomorphologic and Thermal Dynamics at Small Tributary Confluences, University Small Research Grant, Kansas State University, 2009, $1,500

Eric Schultz, Jason Vokoun and **Melinda Daniels** (Co-PI) Integrating Fluvial Geomorphology and Stream Ecology: Processes Shaping the Distribution of Freshwater Mussels in Connecticut, Connecticut Department of Environmental Protection, 2007-2009, $16,185

Melinda Daniels (PI) Post-Ice Control Structure Geomorphological Assessment of the Salmon River, NOAA/The Nature Conservancy, 2007 $3,500

Melinda Daniels (PI) Fluvial Dynamics of Large River Secondary Channels: Channel Morphology, Hydraulic Habitat, and Potential for Restoration, National Science Foundation Geography and Spatial Sciences, 7/11/2006-3/11/2009, $56,793

Melinda Daniels (PI) The Nature Conservancy: Dam Removal Alternatives Assessment for Umpawaug Pond Brook, 6/2006-12/2007, $19,800

Melinda Daniels (PI) National Park Service/Farmington River Alliance: Habitat and Flushing Flow Evaluation of the Farmington River Wild and Scenic Reach, CT, 1/2007-8/2007, $12,000

Melinda Daniels (PI) UCONN Research Foundation Large Faculty Grant: Thermal Dynamics At Tributary Confluences: Geomorphological And Hydraulic Research To Support Restoration Design And Management, 2006, $10,573

Melinda Daniels (PI) Monitoring the Effects of Dam Removal, NOAA/The Nature Conservancy, 1/2006-12/2006, $9,300

Jason Vokoun and **Melinda Daniels (co-PI)** CT Institute for Water Resources: Development and evaluation of a multi-dimensional spatially and temporally dynamic mesohabitat classification model for stream management and water flow allocation planning in southern New England streams, 2005-2007, $24,996

Melinda Daniels (PI) Pre-Ice Control Structure Geomorphological Assessment of the Salmon River, The Nature Conservancy, 6/2005-6/2006, $7,500

Melinda Daniels (PI) A preliminary study of the sediment dynamics of the Pomperaug River, Connecticut, Pomperaug River Watershed Coalition, 6/1/2004-9/1/2004 $2,000

Melinda Daniels (PI) Fluvial Dynamics of Large River Secondary Channels: Process, Form and Potential for Restoration, UCONN Research Foundation Faculty Grant Program, 6/2003-5/2004, $20,000

Bruce Rhoads and **Melinda Daniels (Co-PI)** Doctoral Dissertation Research: The Role of Large Woody Debris in the dynamics of a Low-Energy Meandering Stream in The Midwest, National Science Foundation Geography and Spatial Sciences, August 2000-August 2001, $9,274

AWARDS AND FELLOWSHIPS

Provosts Award: Development of new undergraduate curriculum: Global Change and Natural Hazards, University of Connecticut, 2006

Environmental Leadership Certificate of Appreciation (Finalist for Faculty Environmental Leadership Award) University of Connecticut Environmental Policy Advisory Council, 2005

University of Illinois Graduate Fellowship August 2001 - May 2002, $10,000

University of Illinois Joseph Russell Graduate Fellowship August 2000 - May 2001, $10,000

University of Illinois Charles S. Alexander Graduate Fellowship August 1999 - May 2000, $10,000

University of Illinois Graduate Program Enhancement Fellowship, August 1997 - May 1998, $10,000

GRANTS, FELLOWSHIPS AND SCHOLARSHIPS AWARDED TO STUDENTS UNDER MY SUPERVISION ($520,760)

Melinda Daniels (PI) and **Bartosz Grudzinski**, Doctoral Dissertation Research: Influence of Grazing Differences on Stream Geomorphology in Tallgrass Prairie Headwater Streams, 2013, National Science Foundation $15,759

Melinda Daniels (PI) and **Claire Ruffing**, Doctoral Dissertation Research: The Impact of Historical Logging Activities on the Ecology and Geomorphology of Mountain Streams, 2013, National Science Foundation $15,972

Melinda Daniels (PI) and **Katie H. Costigan**, Doctoral Dissertation Research: Thermal, Hydraulic and Geomorphological Dynamics at Stream Confluences, Submitted to Geography and Spatial Sciences, 2012, National Science Foundation $11,695

Katie H. Costigan, 2011 Yellow Springs Instruments (YSI) Graduate student grant and equipment loan (M9, CastAway CTD, IQ), $10,000 grant; $1,000 travel grant; estimated equipment value of $80,000

Katie H. Costigan, Reds Wolman Graduate Student Research Award, Association of American Geographers Geomorphology Specialty Group, “Critical Corridors in the Fluvial Ecosystem Landscape; Hydraulic, Geomorphologic and Thermal Habitat Dynamics at Confluences”, 2011, $600

Heidi Mehl and Melinda Daniels (Faculty Sponsor) EPA-F2011-STAR-B1. Tribes and American Indian/Alaska Native/Pacific Islander Communities (B1). A cultural ecology of riparian systems on the Prairie Band Potawatomi Nation: understanding stream incision, riparian function, and Indigenous Knowledge to increase best management plan adoption, 9/2011-9/2014, $97,920

Keith B. Gido, Joshuah S. Perkin, Melinda Daniels, and **Katie H. Costigan* (co-PI)**, Reproductive Life History Of Great Plains Pelagic-Spawning Fishes In The Ninnescah River, Kansas, FY 2011 State Wildlife Subgrant Program, Kansas Department of Wildlife and Parks, 5/1/2011 to 4/30/2013, $192,675

Denise Burchsted, Beaver Meadow Hydrology, Sigma Xi Grant in Aid of Research, 2010, $1000

Denise Burchsted, Pre-Colonial River Conditions in Connecticut: Baseline Hydrology and Morphology for River Restoration, Geological Society of America Graduate Student Research Grant, $2,600

Denise Burchsted, Turner Designs Instrument Donation Program. June 2010. Aquafluor Handheld Fluorometer. Instrument and materials resale value $2,500.

Denise Burchsted, UConn Center for Environmental Science and Engineering, Multidisciplinary Environmental Research Award, 2007 and 2010 (two awards). $11,400

Denise Burchsted and **Melinda Daniels (Faculty Sponsor)** EPA-F2007-STAR-E1. Aquatic Systems Ecology - freshwater systems only) Pre-Colonial River Conditions in Connecticut: Baseline Hydrology and Morphology for River Restoration, 9/2007-9/2011, $110,000

PROFESSIONAL PRESENTATIONS AND WORKSHOPS
*(last 6 years) *denotes student*

Geological Society of America Annual Meeting, Baltimore, MD, 1-4 November 2015: *Longitudinal variation in thickness and composition of legacy sediments and buried organic soils in headwaters of the Christina river basin, USA*, <u>Daniels,</u> M.D., Marshall, A. and Chatterjee, S.

American Association of Geographers Annual Meeting, Chicago, IL April 21-25 2015: *Reconstructing River and Watershed Restoration: Physical Geography and a New Restoration Design Science*, INVITED as part of the Symposium on Physical Geography: Environmental Reconstruction I, Daniels, M., Ruffing, C. and Marston, B.

American Association of Geographers Annual Meeting, Chicago, IL April 21-25 2015: *Climatic influences and temporal variability in suspended sediment dynamics in actively grazed grassland streams,* Grudzinski, B., Ruffing, C., Barnes, P. and Daniels, M.D.

American Association of Geographers Annual Meeting, Chicago, IL April 21-25 2015: *Barriers to Fluvial Connectivity and Aquatic Biodiversity in the Central Great Plains: Fragmentation of Stream Networks in Semi-Arid Kansas,* Chatterjee, S. and Daniels, M.D.

National Science Teachers Association Area Conference in Philadelphia: November 12–14, 2015: *Sim City in the Real World: Modeling YOUR Neighborhood Environment*, Marcum-Dietrich, N., Daniels, M.D. and Staudt, C.

National Science Teachers Association Area Conference in Philadelphia: November 12–14, 2015: *NARST Session: Teaching Environmental Sustainability Using a Place-Based Watershed Modeling Application*, Marcum-Dietrich, N., Daniels, M.D. and Staudt, C.

National Science Teachers Association Area Conference in Philadelphia: November 12–14, 2015: *Teaching Environmental Sustainability Using Model My Watershed*, Marcum-Dietrich, N., Daniels, M.D. and Staudt, C.

Society for Freshwater Science Annual Meeting: Milwaukee, WI, May 17-21, 2015: *Are engineering effects of crayfish on gravel bed morphology mediated by species identity, behavior, and body size?* Albertson, L.K. and Daniels, M.D.

Society for Ecological Restoration, Newark, DE, March 28, 2015: *What's wrong with our streams and how can we fix them?* Daniels, M.D. (presentation to field trip group at SWRC)

River & Regolith Erosion and Deposition Summit, Newark, DE, May 2015: *Legacy Impacts of Tie Driving on Rocky Mountain Streams*, Daniels, M.D., Ruffing, C., Marston, B. and Dwire, K.

BP Grudzinski, **MD Daniels**, K Anibas, D, Spencer, *"Influence of watershed grazing management on bare ground production and sediment dynamics in grassland headwater streams"* Association of American Geographers, 2014 (Tampa, FL)

MD Daniels, L Kaplan*,"Riverscape Forcing Of Hot Spots, Hot Moments And Carbon Sequestration In A Topographically Complex Watershed"* Association of American Geographers, 2014 (Tampa, FL)

S. Chatterjee and **MD Daniels,** "Stream Network Fragmentation and Drought Combine to Drive Native Fishes from the Great Plains" Association of American Geographers, 2014 (Tampa, FL)

H Mehl and **MD Daniels**, "Land Tenure and Watershed Restoration on a Fractionated Indian Reservation" Association of American Geographers, 2014 (Tampa, FL)

S Chatterjee and **MD Daniels**, *"Coupled mechanism of unsystematic Damming and Climate Change effect on the rivers of the Great Plains of Kansas"* American Geophysical Union Fall Meeting, 2014 (San Francisco, CA)

J Schoenstein, **MD Daniels**, S Chatterjee, J Matkov, "Thermal Dynamics and Transient Storage in a Spring-fed Forested Headwater Stream, Southeastern PA, USA" CUAHSI 2014 Biennial Colloquium, 2014 (Sheperdstown, WV)

Ruffing, C.M., **M. D. Daniels**, W. K. Dodds, K. A. Dwire. 2013. "Fluvial Geomorphic Legacies of Tie Driving Regulate Carbon Cycling in Rocky Mountain Headwater Streams, WY" American Geophysical Union Fall Meeting, San Francisco, CA, December 9-13.

Ruffing, C.M., **M. D. Daniels**, W. K. Dodds, K. A. Dwire. 2013. "Carbon Cycle Legacies of Tie Driving in Rocky Mountain Headwater Streams, WY." Geological Society of America Annual Meeting, Denver, CO, Oct. 27-30.

Ruffing, C.M., **M.D. Daniels**, K. A. Dwire. 2013. "Influence of disturbance legacies on geomorphic and riparian dynamics in mountain streams" Association of American Geographers Annual Meeting, Los Angeles, CA, April 9-13.

BP Grudzinski*, **MD Daniels** "*Influence of grazing treatments and riparian protection on stream geomorphology and sediment concentrations in the Flint Hills and Osage Plains"* American Geophysical Union, 2013 (San Francisco, CA)

BP Grudzinski*, **MD Daniels** (University of Wisconsin, Eau Claire, WI) "*Influence of grazing treatments and riparian protection on stream geomorphology and sediment concentrations in the Flint Hills and Osage Plains"* West Lakes Association of American Geographers, 2013

BP Grudzinski*, **MD Daniels** "*Influence of grazing treatments and riparian protection on stream geomorphology and sediment concentrations in the Flint Hills and Osage Plains"* Geological Society of America, 2013 (Denver, CO)

BP Grudzinski*, **MD Daniels** "*Influence of grazing treatments and riparian protection on stream geomorphology and sediment concentrations in the Flint Hills and Osage Plains"* Grasslands Symposium, 2013 (Manhattan, KS)

BP Grudzinski*, **MD Daniels** *"Influence of grazing treatments and riparian protection on stream geomorphology and sediment concentrations in the Flint Hills and Osage Plains"* Association of American Geographers Annual Meeting, 2013 (Los Angeles, CA)

Marston*, B., **MD Daniels**, SE Ryan, "*Influence of The Mountain Pine Beetle Infestation on Wood Loads in Headwater Streams of The Medicine Bow National Forest, Rocky Mountains USA",* Geological Society of America Annual Meeting, Denver, CO, Oct. 27-30.

Mehl*, H.E., **M. Daniels**, B. Swenson*, and L. Calwell. 2012. Commercial sand dredging in the Kansas River. Presented at the Governor's Conference on Water and the Future of Kansas; Manhattan, KS, Oct. 31, 2012.

Daniels, M.D. Workshop: Integrating Hydro-geomorphology into LTER Research Programs, NSF LTER All Scientists Meeting, Estes Park, Sept. 10-13, 2012.

Grudzinski*, B. Larson, D., **Daniels, M.D.** Influence of Grazing Treatments on Nutrient, Bacteria, and Suspended Sediment Concentrations and Channel Geometry in the Flint Hills, Kansas, NSF LTER All Scientists Meeting, Estes Park, Sept. 10-13, 2012.

Perkin, J.S., K.B. Gido, K.H. Costigan*, **M.D. Daniels**, and E. Johnson. 2012. Distribution of Cyprinid Fish Reproductive Guilds in a Fragmented Great Plains Riverscape. American Fisheries Society, St. Paul, MN, August 2012.

Perkin, J.S., K.B. Gido, K.H. Costigan*, **M.D. Daniels**, and E. Johnson. 2012. Distribution of Cyprinid Fish Reproductive Guilds in a Fragmented Great Plains Riverscape. American Fisheries Society, St. Paul, MN, August 2012.

Dodds, W. K**.,** Gido, K.; Whiles, M. R., **Daniels, M. D**., Grimm, N. B., The unique qualities and global significance of grassland streams, Society of Freshwater Sciences Annual Meeting, Louisville, KY, May 20-24, 2012

Russell, D. M., Grudzinski*, B. P., **Daniels, M.D.**, Dodds, W. K., Joern, A., Skibbe, A., Blazing and grazing: fire and bison in tallgrass prairie streams, Society of Freshwater Sciences Annual Meeting, Louisville, KY, May 20-24, 2012

Russell, D. M., Grudzinski*, B. P., **Daniels, M. D.**, Dodds, W. K., Joern, A., Skibbe, A., Blazing and grazing: Influences of fire and bison (*Bos bison*) on the suspended sediment and nutrient dynamics of tallgrass prairie streams, The 22nd Konza Prairie LTER Annual Workshop, KPBS, June 7, 2012.

Grudzinski*, B., D. Russell, W.K. Dodds, and **M.D. Daniels**. Influence of Grazing Treatments on Nutrient and Bacteria Concentrations in the Flint Hills, Kansas, The 22nd Konza Prairie LTER Annual Workshop, KPBS, June 7, 2012.

Daniels, M.D. and Costigan*, K.H. Human Alteration of Great Plains River Regimes and Implications for Aquatic Species Management, Annual Meeting of the Association of American Geographers, New York, NY, Feb 24-28, 2012

Daniels, M.D., The local hydraulic and geomorphic effects of natural large wood structures, Technical Workshop on Large Wood Applications and Research Needs in River Restoration, sponsored by the US Bureau of Reclamation and the US Army Corps of Engineers, Seattle, WA, Feb 14-15, 2012 (INVITED)

Daniels, M.D. and Costigan*, K.H. Human Alteration of Great Plains River Regimes and Implications for Aquatic Species Management, Kansas Natural Resources Conference, Wichita, KS, Jan 26-27, 2012

Fischer*, J., Paukert, C. and **Daniels, M.D.** Human Alteration of Great Plains River Regimes and Implications for Aquatic Species Management, Kansas Natural Resources Conference, Wichita, KS, Jan 26-27, 2012

Mehl*, H.E., Pockrandt*, B., **Daniels, M.D.**, Annett, C.A., Calwell, L. and Daniels, R. Developing a public database of geospatial information for the Kansas River Watershed, Kansas Natural Resources Conference, Wichita, KS, Jan 26-27, 2012

Daniels, M.D. and Grudzinski*, B. *Hydrology and Geomorphology of Tallgrass Prairie Intermittent Headwater Streams*, American Geophysical Union Fall Meeting, San Francisco, CA, December 4-9, 2011

Costigan*, K.H. and **Daniels, M.D.** *Hydrologic Alteration of Great Plains Rivers*, American Geophysical Union Fall Meeting, San Francisco, CA, December 4-9, 2011

Grudzinski*, B. and **Daniels, M.D.** *Impact of Cattle and Bison Grazing on Stream Morphology in a Tallgrass Prairie*, GPRM AAG Regional Division Meeting, Denver, CO, October 6-8, 2011

Ruffing*, C. and **Daniels, M.D.** *Using Lidar to Assess Local Water Resource Concerns at a Watershed Scale,* GPRM AAG Regional Division Meeting, Denver, CO, October 6-8, 2011

Mehl*, H. and **Daniels, M.D.** *Water Quality and Channel Stability on the Prairie Band Potawatomi Reservation,* GPRM AAG Regional Division Meeting, Denver, CO, October 6-8, 2011

Costigan*, K.H. and **Daniels, M.D.** *Damming the Prairie: Human Alteration of Great Plains River Regimes*, GPRM AAG Regional Division Meeting, Denver, CO, October 6-8, 2011

Terry*, E. Bartlett*, S., Ruffing*, C. **Daniels, M.D.**, and Marston*, B. *Effects of Water Diversions on Drainage Basins in the Medicine Bow National Forest.* GPRM AAG Regional Division Meeting, Denver, CO, October 6-8, 2011

Mehl*, H.E., Pockrandt*, B., Calwell, L., Annett, C. and **Daniels, M.D.** *An Inventory of the Kansas River.* Water and the Future of Kansas Conference, Topeka, KS, September 30, 2011

Dodds, W.K., Gido, K., Whiles, M.R., and **Daniels, M.D.** *Grassland Streams.* Grasslands in a Global Context, Manhattan, KS, September 12-14, 2011

Grudzinski*, B. and **Daniels, M.D.** *Influence of Grazing Treatments on Stream Substrate and Channel Geometry in the Flint Hills, Kansas.* Grasslands in a Global Context, Manhattan, KS, September 12-14, 2011

Fischer*, J., Gerken*, J., Paukert, C. and **Daniels, M.D.** *Habitat and Fish Community Response to Sand Dredging In a Large Great Plains River.* The American Fisheries Society 141st Annual Meeting, Seattle, WA Sept. 4-8, 2011

Daniels, M.D. and Grudzinski*, B. *Impacts of Grazing and Riparian Management on Geomorphology of Prairie Streams.* The 21st Annual Konza Prairie LTER Workshop, Manhattan, KS, April 16th, 2011.

Daniels, M.D. *The Great Failures Of River Conservation And Restoration – Can Redemption Be Found In An Emerging Fluvial Landscape Ecology?* Invited Seminar, University of Missouri Department of Geography, Columbia, MO, March 11, 2011

Daniels, M.D., Fischer*, J., Gerken*, J., Costigan*, K.H. and Paukert, C. *Using Hydroacoustic Technology to Assess the Impacts of In-Channel Dredging on Hydraulic Habitat Conditions in the Kansas river.* 2011 USGS National Surface Water Conference, Tampa, FL, March 28-April 1, 2011

Grudzinski* B.,and **Daniels, M.D.** *Influence of Grazing Treatments on Stream Geomorphology in the Flint Hills*, Kansas Natural Resources Conference, January 20-21, 2011, Wichita, KS.

Fischer*, J., Gerken*, J., Paukert, C., and **Daniels, M.D.** *Fish Community Response to Habitat Alteration: Impacts of Sand Dredging in the Kansas River*, 71st Midwest Fisheries and Wildlife Conference, Minneapolis, MN, December 12-15, 2010

Fischer*, J., Gerken*, J., Paukert, C., and **Daniels, M.D.** *Influence of Sand Dredging on Fish Communities in the Kansas River*, Kansas Natural Resources Conference, Wichita, KS, January 20-21, 2011

Russell*, D.M., Dodds, W.K., Grudzinski*, B. and **Daniels, M.D.** *Effects of Bison and Prescribed Fire on Prairie Stream Sediments*, Kansas Natural Resources Conference, January 20-21, 2011, Wichita, KS.

Fischer*, J., Gerken*, J., Paukert, C. and **Daniels, M.D.** *Fish community response to habitat alteration: Impacts of sand dredging in the Kansas River*, Midwest Fish and Wildlife Conference, Minneapolis, MN, December 2010

Daniels, M.D. Hook*, L.M., Sheeley, J. Brown, T. *Spatial and temporal lateral discontinuity on the pre-engineered Missouri River*, GSA Annual Meeting, , Denver, CO, November 2010

Burchsted*, D. **Daniels, M. D.** *Beaver dam impacts on sediment and water regime*, GSA Annual Meeting, Denver, CO, November 2010

Daniels, M. D., Burchsted*, D. *Incorporating pre-disturbance discontinuity into dam removal and river restoration paradigms*, GPRM Regional AAG, Lawrence, KS, October 2010

Costigan*, K.M., **Daniels, M.D.**, Gritzmacher*, G.G. *Evaluating local bed shear stress estimates in meander bends using acoustic Doppler velocimeter data*, GPRM Regional AAG, Lawrence, KS, October 2010

Daniels, M.D., Burchsted*, D. , MacBroom, J., Wildman, L., Harold, S., Carabetta, M., Woodworth, P., and Boardman, G. *Redefining the Dam Removal Paradigm in Formerly Glaciated Forested Headwater Systems*, EWRI/ASCE World Environmental and Water Resources Congress, 2010, Providence, Rhode Island, May 16-20, 2010

Burchsted*, D., **Daniels, M.D.**, and Thorson R.M. *Restoring the River Discontinuum: Looking at the Example of Beaver Dams*, EWRI/ASCE World Environmental and Water Resources Congress, 2010, Providence, Rhode Island, May 16-20, 2010

Banner, E. and **M. D. Daniels** *Documenting the historical spatial extent and character of riparian forests in Kansas using General Land Office Survey Records*, Kansas Natural Resources Conference, Wichita, KS, February 4-5, 2010

BOOK REVIEWS, REPORTS AND OTHER PUBLICATIONS

Flat Creek Restoration Assessment, National Elk Refuge, Jackson, Wyoming. 2013. Report to the Wyoming Department of Fish and Game.

Sand Dredging Effects on Fishes and Fish Habitat in the Kansas River. 2012. Report to the Kansas Department of Wildlife, Parks, Recreation and Tourism.

Seasonal Fish Assemblages and Habitat Effects near Bowersock Dam: Implications for Fish Passage. 2012. Report to the Kansas Department of Wildlife, Parks, Recreation and Tourism.

Assessing the Impact of Channel and Riparian Zone Modifications on Aquatic Biodiversity in the Kansas River Basin. Report to the Kingsbury Family Foundation.

Book Review: Urban Watersheds: Geology, Contamination and Sustainable Development**.** Martin M. Kaufman, Daniels T. Rogers and Kent. S. Murray. Boca Raton: CRC Press, 2011. 547 pp., *The Professional Geographer*, in press.

Watershed Assessment of the Wakarusa River, KS. 2012. Report to the Kansas Department of Health and the Environment.

Wildcat Creek (KS) Watershed Assessment. 2011. Report to the USDA Natural Resources Conservation Service and US Army (Fort Riley).

Processes Shaping the Distribution of Freshwater Mussels in Connecticut. 2010. Report to the Connecticut Department of Environmental Protection.

Habitat and Flushing Flow Evaluation of the Farmington River Wild and Scenic Reach, CT. 2009. Report to The National Park Service.

Post-Ice Control Structure Geomorphological Assessment of the Salmon River. 2008. Report to The Nature Conservancy (CT office).

Book Review: Hydrological Applications of GIS. A.M. Gurnell and D.R. Montgomery (Editors). John Wiley and Sons, 2000. 173 pages. *Geomorphology*, 54, 347-351.

SERVICE

Board Memberships
United States Army Corps of Engineers Environmental Advisory Board, Appointed by the Secretary of Defense, reporting directly to the Chief Engineer

Journal Editing
Editorial Board, *Geomorphology*
Special issue co-editor: "Linking Geomorphology and Ecology" *Geomorphology* Volume 77, Issues 3-4, Pages A1-A2, 203-334 (30 July 2006), edited by M.A. Urban, M.D. Daniels and M. Doyle

Special issue co-editor: “Discontinuity in Fluvial Systems” *Geomorphology*, in progress, edited by M.D. Daniels, D. Burchsted, and E. Wohl

Peer Reviews: Agencies

USGS: external publication reviews, personnel performance and promotion reviews
NSF Panelist, Water Sustainability and Climate; Hydrological Sciences; Geography and Spatial Sciences
NSF External Reviewer: Geography and Spatial Sciences, Hydrologic Science, CAREER, Water Sustainability and Climate

Peer Reviews: Journal and Monograph Manuscripts

PLOS ONE, Water Resources Research, *Freshwater Science, Ecosystems, Environmental Management, Middle States Geographer, Geomorphology, The Professional Geographer, GeoForum, Earth Surface Processes and Landforms, The Northeastern Geographer, River Research and Applications, JGR Earth Surface, Journal of the North American Benthological Society,* American Geophysical Union Monograph: “*Riparian Vegetation and Fluvial Geomorphology: Hydraulic, Hydrologic and Geotechnical Interactions*”, *Journal of Women and Minorities in Science and Engineering, Area*

Leadership in Scholarly Organizations

Organizer and Chair: Science, Policy, and Politics for Restoration of the Florida Everglades: The Taylor-Francis/Rutledge Distinguished Lecture in Geomorphology, AAG Geomorphology Specialty Group, 2014 Annual Meeting
President, AAG Geomorphology Specialty Group, 2013-2014; Secretary, 2012-2013 (elected positions)
Chair, AAG Geomorphology Specialty Group Awards Committee, 2011-2012
Interim Chair, AAG Geomorphology Specialty Group Awards Committee, 2010-2011
Session co-organizer, “Migration and Economic Restructuring in Rural America: Papers in Memory of Alex Vias”, Association of American Geographers Annual Meeting, February 2012, New York, NY.
Session co-organizer, “Linking Geomorphology and Ecology”, Association of American Geographers Annual Meeting, April 2005, Denver, CO.
Session co-organizer, “Linking Geomorphology and Ecology I”, Association of American Geographers Annual Meeting, March 2004, Philadelphia, PA.
Session co-organizer, “Linking Geomorphology and Ecology II”, Association of American Geographers Annual Meeting, March 2004, Philadelphia, PA.
Session co-organizer, “New Perspectives on River Processes: Fluid Dynamics, Wood Dynamics, and Morphologic Change”, American Geophysical Union meeting, December 2001, San Francisco, CA.

Graduate Students Supervised

Sarmistha Chatterjee (Univ. Delaware, PhD, active)
Heidi Mehl (KSU, PhD, Geography, active)
Bryce Marston (KSU, PhD, Geography, active)
Barrett Swenson(KSU, MA, Geography, active)
Bartosz Grudzinski (KSU, PhD, Geography, 2014)
Claire Ruffing (KSU, PhD, Geography, 2014)
David Spencer (KSU, MA, Geography, 2014)
Brianna Roberts (KSU, MA, Geography, 2014)
Katie Costigan (KSU, PhD, Geography, 2013)
Denise Burchsted (UCONN, PhD, Geological Science, 2013)
Lisa Hook (KSU, MA, Geography, 2010)
Piyumi Obesekara (UCONN, MS, Geosciences, 2009)
Natalie Vibert (UCONN, MA, Geography, 2008)
Paul M. Woodworth (UCONN, MA, Geography, 2008)
Graham Boardman (UCONN, MA, Geography, 2008)
Megan MCusker (UCONN, MS, Geosciences, 2008)
Jason Miller (UCONN, MA, Geography, 2007)
Heather Pierce (UCONN, MA, Geography, 2006)
Elizabeth Spender (UCONN, MA, Geography, 2006)
Grant Gritzmacher (UCONN, MA, Geography, 2006)

Megan McCusker (UCONN, MA, Geography, 2005)

Center, Departmental, College and University Service

Strategic Planning Committee Member, SWRC, 2013-2014
Graduate Program Director, 2010-2013, Kansas State University Department of Geography
Faculty Steering Committee, Urban Water Institute, KSU-Olathe campus, 2011-2013
University Graduate Council Member, 2010-present, Kansas State University
Sub-committee for Academic Affairs Member, University Graduate Council, 2010-2013, Kansas State University,
Geography Interim Head of Department Search Committee Member, Kansas State University, 2010-2011
Graduate Committee Member, 2009-2010, Kansas State University Department of Geography
Gamma Theta Upsilon Faculty Advisor, 2008-2009, Kansas State University
Graduate Program Committee, 2005-2008, University of Connecticut Department of Geography
Center for Integrative Geosciences Advisory Committee, 2005-2008, University of Connecticut College of Liberal Arts and Sciences
Undergraduate Program Committee Member, 2005-2008, University of Connecticut Department of Geography
Visiting Assistant Professor in Residence Search Committee Member, 2005, University of Connecticut Department of Geography
Department Head Search Committee Member, 2004-2006, University of Connecticut Department of Geography
Visiting Assistant Professor in Residence Search Committee Member, 2004-2005, University of Connecticut Department of Geography
Geosciences Advisory Review Board, 2004-2005, University of Connecticut College of Liberal Arts and Sciences,
UCONN Environmental Policy Advisory Council, 2004-2007
UCONN Environmental Policy Advisory Council Subcommittee on Land Use and Sustainable Development, Office of the Chancellor, University of Connecticut, 2003-2007
UCONN Undergraduate Coordinator, Department of Geography, University of Connecticut, 2003-2004
UCONN Environmental Science Major Program Advisory Committee, University of Connecticut, 2003 - 2007
UCONN College of Liberal Arts and Sciences Undergraduate Education Council, University of Connecticut, 2002 – 2004
UCONN Teale Nature and the Environment Lecture Series Organizing Committee, University of Connecticut, 2002 - 2007
Faculty Search Committee, Department of Geography, University of Illinois, 2000-2001

Outreach/Community Service

I have actively collaborated/consulted with several environmental non-profit and government agencies on a pro-bono basis, including the Northeast Salmon Commission, the Gulf of Maine Council on Stream Barrier Removal Monitoring, the Southbury Land Trust, the Pomperaug River Watershed Coalition, the Houston Valley Association, The Nature Conservancy, The Trustees of Reservations, The KS office of the Natural Resource Conservation Service, The Connecticut Department of Environmental Protection, the Kansas Water Office, the USACE Kansas City office, the Kansas Department of Wildlife, Parks and Recreation, Friends of the KAW, and the Kansas River Keeper.

TEACHING EXPERIENCE

UNIVERSITY OF PENNSYLVANIA: 2013-
- Freshwater Biology

KANSAS STATE UNIVERSITY: 2008-2013
- Environmental Geography
- World Regional Geography
- Fluvial Geomorphology
- Methods Theories and Models in Geography

Geographic Information Systems I
River Regimes

UNIVERSITY OF CONNECTICUT: 2002-2008

Introduction to Physical Geography
Fluvial Geomorphology
Advanced Seminar in Fluvial Geomorphology
Advanced Seminar in Coastal Geomorphology
Environmental Evaluation and Assessment
Environmental Planning and Management
Environmental Restoration
Advanced Seminar in Environmental Restoration

UNIVERSITY OF ILLINOIS: 2002

Introduction to Physical Geography

MEMBERSHIP IN PROFESSIONAL ORGANIZATIONS

Society for Freshwater Science
Association of American Geographers
American Geophysical Union
Geological Society of America

Paul M. Woodworth
Fluvial Geomorphologist

Princeton Hydro

Education
- Master of Arts, Geography (Fluvial Geomorphology), University of Connecticut, 2008
- Bachelor of Arts, Biology and Environmental Studies, Middlebury College, 1999

Technical Training
- United States Forest Service, Designing Road-Stream Crossings for Aquatic Organism Passage (Stream Simulation), 2015
- Connecticut Dam Safety Program Update, Environmental Business Council of New England, 2014
- Ecological Risk Assessment: Practice and Protocols Rutgers, Office of Continuing Professional Education, 2014
- River 2D Workshop, Amherst, Massachusetts, 2012
- River & Stream Restoration: Geomorphic & Ecological Processes, NJ-AWRA, 2009
- Certificate in Geographic Information Systems, University of Connecticut, 2008
- Master Wildlife Conservationist, Connecticut Department of Environmental Protection, 2005

Areas of Expertise:

Fluvial Geomorphology
- Geomorphic Assessment
- Channel Forming Processes
- Hydrodynamic 2-D Modeling

Stream Restoration
- Process-Based Restoration
- Sediment Stability / Mobility
- Habitat Creation / Enhancement
- Aquatic Organism Passage
- Stream Simulation / Continuity

Dam Removal
- Feasibility Assessment
- Sediment Sampling, Analysis and Management
- Ecological Risk Assessment
- Geomorphic / Engineering Design & Restoration

Project Support
- Total Station Survey
- CAD / GIS
- Regulatory Compliance
- Construction Oversight

Summary of Qualifications
Focused on removing obsolete dams and restoring rivers, Mr. Woodworth has advanced over 50 barrier removal projects, which have resulted in over 25 barriers removed, in his 6 years at Princeton Hydro. He is the primary staff member responsible for integrating fluvial geomorphology into the assessment and restoration of stream channels, wetlands, and floodplains.

Mr. Woodworth supports all phases of project development, from initial project conceptualization through data collection, design, permitting and construction. During planning phases, Mr. Woodworth routinely conducts geomorphic assessments, sediment sampling, topographic surveys of channels, bathymetric surveys of impoundments, and the collection of flow data.

For project design, Mr. Woodworth analyzes and interprets sediment analysis results, geomorphic metrics, flow data, and sediment stability and mobility. His dam removal designs incorporate responsible management of sediments, restoration of channel-forming processes, enhancement of in-stream habitat, and restoration of riparian plant communities. He analyzes laboratory data and ecological screening criteria to assess ecological risk associated with sediment exposure, disturbance and release. He designs stream channels to restore lateral connectivity, fluvial processes, dynamically stable channel morphology, pool-riffle sequences, and woody material habitat features.

In addition, Mr. Woodworth has experience with complex modifications of active dams, designing creative solutions that balance aquatic organism passage with existing dam services including the design of fish by-pass channels, fish-passable rock ramps, and fish ladders. Mr. Woodworth is experienced in the interpretation of applicable regulations, completion of permit applications for county, state, and federal regulatory agencies, as well as coordination and negotiation with regulators. He has developed unique stream assessment protocols by synthesizing existing diverse approaches that incorporate geomorphology with aquatic ecology and riparian floristic quality. He has conducted long-term, repeat geomorphic surveys to monitor project success and coordinated a watershed-scale study to assess 100 culvert crossings and identify priority sites for fish-passage restoration projects. He synthesizes his work into high-quality, detailed deliverables including feasibility studies, alternative analyses, engineering design plans, and technical engineering reports. Finally, Mr. Woodworth has worked first-hand with contractors to guide the removal of approximately 10 individual dams; work that involved adapting designs to dynamic river conditions while still satisfying project goals.

Selected Project Experience:
Cross Fork Creek AOP Culvert Replacement, Potter County, PA (2014) – Completed site assessment, USFS Stream Simulation Design, engineering design plans, and permitting for the replacement of culverts with open-bottom spans on two tributaries of Cross Fork Creek: Gravel Lick Run and Little Lyman Run.

Tannery Brook Dam Removal, Boscawen, NH (2014) – Completed due diligence assessment, site survey, geomorphic design, engineering design plans, and permitting for the removal of a large dam in central New Hampshire.

Pleasant Grove Dam Removal and Wetland Restoration, Jackson, NJ (2012) – Completed permitting and restoration design for the removal of an earthen dam on unnamed tributary to Toms River. Project included the creation and restoration of wetland habitat within the former impoundment, marking the first use of dam removal for direct wetland mitigation in the State of New Jersey.

Pomperaug Large Woody Debris Design, Southbury, CT (2012) – Completed site assessment and survey of a reach of the Pomperaug River at the Audubon Center at Bent-of-the-River for habitat restoration through the installation of large-woody debris. Developed cost-effective design, for minimal regulatory involvement, and swift progression to construction.

Little Lehigh Creek Dam Removals, Allentown, PA (2012) – Completed geomorphic assessments, topographic survey, sediment sampling, permitting and restoration design for three low-head dams for Allentown-based environmental nonprofit, Wildlands Conservancy.

Cooks Creek Culvert Assessment, Bucks County, PA (2012) – Developed culvert assessment protocol, trained volunteers, analyzed and prioritized 100 stream-road crossings for retrofits, developed conceptual designs for Bucks County Chapter of Trout Unlimited.

Nevius Street Dam Fish Passage Feasibility and Design, Raritan River, Raritan, NJ (2012) – Completed survey and site assessment; supported hydrologic and hydraulic modeling, and design of a dam notch that restores upstream migration of American shad while still supplying an existing water supply intake.

Mitchell Brook Culvert Replacement, Whately, MA (2012) – Completed a geomorphic assessment, topographic survey, and applied USFS Stream Simulation guidelines and Massachusetts Stream Crossing Standards to complete final design of an open-bottom culvert crossing that enables passage of resident cold-water fish.

Quakertown Preserve Dam Removal and Wetland Restoration, Franklin Township, Hunterdon County, NJ (2011) – Secured funding on behalf of Hunterdon Land Trust; led site assessment, design, permitting and construction oversight. Project set an important precedent, demonstrating that dam removal, which results in floodplain and wetland restoration is suitable for wetland mitigation. Project marks first dam removal financed by the NJ Wetland Mitigation Council.

Publications / Presentations:
Michael Jastremski, CFM and Ryan Williams, Housatonic Valley Association; Paul Woodworth, Princeton Hydro LLC; Xinyi Shen, Ph.D., Lanxin Hu, and Emmanouil N. Anagnostou, Ph.D., Department of Civil & Environmental Engineering, University of Connecticut. *Integrating Stream Habitat Connectivity Restoration into Local Flood Hazard Mitigation Planning in Connecticut's Northwest Hills.* April 4, 2016. Northeast Annual Fish and Wildlife Agency Conference, Annapolis, MD.

Woodworth, P.M. *River and Streams*; *Human Impacts on Rivers, Part 1: Dams*; and *Human Impacts on Rivers, Part 2: Road Crossings*. November 20, 2014. Connecticut Audubon Society, Master Naturalist Course.

Woodworth, P.M. 2011. *Redesigning Road Crossings with Stream Simulation Techniques and MA Stream Crossing Standards.* Presentation at Fish Passage 2011 – National Conference on Engineering & Ecohydrology for Fish Passage.

Woodworth, P.M., Helminiak, J.E. *Connectivity and Clutter: Ecological Uplift in Watson Creek*. February 19, 2010. Poster presentation at the Society for Ecological Restoration 2010 Mid-Atlantic Conference, New Brunswick, New Jersey.

Geoffrey M. Goll, P.E.
Vice President

Princeton Hydro

Education:
- M. Eng. Engineering Management, University of Wisconsin, Madison
- B.S. Civil Engineering, Rutgers University

Professional Certifications:
- Professional Engineer:
  Maryland, Massachusetts, New Jersey, New York,
  Pennsylvania, Vermont, Virginia
- Nuclear Regulatory Commission, Certified Radiation Safety Officer and Soil Density and Moisture Content Gauge Operator

Professional Training:
- Rosgen Level I

Professional Affiliations:
- Continuing Education Instructor Rutgers Office of Continuing Education
- American Society of Civil Engineers
- Association of State Dam Safety Officials

Areas of Experience:
- Geotechnical engineering and subsurface investigation
- Stream and river restoration
- Stormwater management
- Dredging
- Flood hazard area and floodplain modeling
- Dam restoration and removal
- Wetland mitigation design and implementation
- Regulatory permitting
- Construction administration
- Expert witness/forensic investigation for water resource-related litigation
- Assembling project partners for water resource restoration projects

Summary of Qualifications:
Mr. Goll is a founding Partner of Princeton Hydro and has extensive experience in geotechnical engineering, stormwater management, hydrology, floodplain hydraulics, environmental assessments, and environmental permitting; his professional background is specific to water resource and geotechnical engineering. The breadth of his experience ranges from stream restoration and modeling to the design of large retaining structures and building foundations; he has provided expert consultation, engineering design and support on a variety of projects including residential developments, solid waste transfer stations, correctional facilities, and wastewater treatment plants.

Mr. Goll has extensive experience in subsurface investigations, geotechnical design, and soils classification and engineering. He has designed and implemented over 100 subsurface investigation programs ranging from foundation investigations to septic system design, includes test borings in soil, bedrock and in-lake and harbor sediment. He has designed engineered steep slopes (greater than 2:1) and retaining walls, performed slope stability analysis and has provided on-site earthwork and compaction monitoring services. With regard to subsurface sewage disposal, Mr. Goll has progressed subsurface investigations for residential developments of up to 100 units. Mr. Goll has provided extensive subsurface investigations within the New Jersey coastline, the Coastal Plain, Piedmont, Highlands and Ridge and Valley geologic provinces. Mr. Goll has also provided forensic subsurface investigations to determine the origins of historic fills and determine original ground surface elevations to determine appropriate bearing locations for structure footings.

Mr. Goll has provided engineering design services, testimony, and review of stormwater management facilities for public and private clients, and has provided guidance in the development of watershed management plans and stormwater ordinance development in both New Jersey and Pennsylvania. He is well versed in stormwater runoff theory and modeling, as well as extensive knowledge of soil infiltration testing and design methods, as is required by the Phase II Stormwater Management Regulations.

Mr. Goll has extensive experience in the quantification and analysis of accumulated sediment within freshwater lakes and rivers. He is also well versed in the processes of sediment transport and accumulation and has been in responsible charge for the design of over 500,000 cubic yards of dredging projects and over 1,000,000 cubic yards of sediment quantification in lakes and rivers throughout the Mid-Atlantic region. His experience also extends to harbor dredged materials where he was in responsible charge of the stabilization of dioxin-, PCB- and heavy metal-contaminated dredged materials for a Brownfield redevelopment. Mr. Goll's most important value to dredging projects is through his understanding of the spatial distribution of sediment types throughout a waterbody's environment and his ability to create technical and bidding specifications that ensures cost control of projects and eliminates the open interpretation of vertical and horizontal project excavation limits via strict survey control.

Mr. Goll has pioneered dam removals for the purposes of fish passage in the State of New Jersey. He was in responsible charge of the first dam removal in New Jersey funded by American Rivers, NOAA, NRCS and the US Fish and Wildlife Service. Mr. Goll regularly coordinates multiple grant sources to fund such removals as well brings different parties together to create momentum for projects. Mr. Goll has prepared public presentations to educate local communities regarding the benefits of dam removal and providing conceptual photographic images of post-removals. His understanding of sedimentation mechanisms and management of sediment behind impoundments has been instrumental in managing the mitigation of environmental impacts during and after demolition of river and streams obstructions.

Mr. Goll has also been in responsible charge of the restoration of Low to High Hazard Potential dams. He has provided design and construction management services for a number of clients in the States of New Jersey and Pennsylvania. He has run hydrologic and hydraulic modeling, and inundation mapping; prepared Emergency Action Plans and Operation and Maintenance Manuals; progressed geotechnical investigations and stability analysis; and prepared technical and bidding specifications.

During the construction phase of projects, Mr. Goll has the practical knowledge of implementation of designs through his past experience as a field inspector for civil works projects, such as residential developments and dam construction. His past field experience, combined with his design knowledge and current oversight of many construction projects, allows him to make informed and practical decisions in the field when confronted with physical site challenges.

Mr. Goll has been accepted as an expert witness by the Superior Court of New Jersey (Morris and Gloucester Counties) in the areas of stormwater management and soils. Mr. Goll provided live testimony on stormwater impacts to high elevation headwaters to the Vermont State Legislature. Mr. Goll has also provided expert testimony on behalf of applicants in front of Planning Board and Zoning Board of Adjustments and governing committees and council; projects included mining applications, residential developments, and golf courses.

Selected Project Experience:

Westtown Dam Analysis and Emergency Action Plan, Westtown Township, Chester County, PA (2012) – Mr. Goll was in responsible charge of the assessment, stability analysis, and hydrologic and hydraulic modeling of the Westtown Lake Dam, a Significant Hazard dam owned and operated by the Westtown School. Princeton Hydro completed a hydrologic and hydraulic analysis of the watershed to Westtown Lake, including developing spillway design storm flows, dam breach analysis, and the preparation of inundation mapping. Following the completion of the inundation analysis, an Emergency Action Plan (EAP) was prepared to allow for a coordinated emergency response effort to notify the public and to address varying breach scenarios during an overtopping or breach event.

NJM Regional Operations Facility Stormwater Management System, Hammonton, NJ (2010) **–** Mr. Goll was the engineer-of-record for the stormwater management design and geotechnical investigations for a 250,000 square foot corporate campus on a 55-acre site. Due to a number of site physical constraints, the site was designed to contain nearly all stormwater runoff on site, up to and including the 100-year frequency, 24-hour duration storm event. Site geotechnical investigations included investigations for building foundations, parking lot and drive subgrades and stormwater infiltration with all laboratory testing completed in-house.

Medford Lakes and Birchwood Lakes Dredging, Burlington County, NJ (2007) – Mr. Goll was in direct charge of the investigation, design, permitting and construction management of these projects Princeton Hydro progressed sediment surveys, analyzed the sediment for geotechnical properties and contamination, designed the dredging, prepared permit application and managed the construction phase of the dredging. The quantity of sediment removed from both dredging projects totaled 143,000 cubic yards. Both projects were completed on time and on budget. The Medford Lakes Colony dredging was completed for a construction cost of $2.2 million and the Birchwood Lakes dredging was completed for a construction cost of $1.3 million.

Earthwork Monitoring and Materials Testing for Multi-family Residential Development, Lambertville, NJ (2008) – Princeton Hydro was contracted to provide earthwork monitoring and materials testing for a 129-unit, multi-family residential development. The site required fills in excess of 20 feet and cuts through bedrock of 10 feet. Princeton Hydro's role was to complete laboratory testing of soils, in-field compaction rate testing, and observation of placement and excavation of fills.

Subsurface Investigation – 37 Foot High Stream Crossing, West Amwell, NJ (2003) – Provided subsurface investigation for a 9-foot high by 35-foot span concrete arch culvert with associated 20-foot high retaining walls and reinforced earth slopes. The span was to be overlain with 26 feet of controlled compacted fill. The investigation focused on the determination of bearing capacities of the underlying bedrock and to prepare specifications for the placement of controlled compacted fill.

Select Presentations and Publications:

Goll, Geoffrey M. (Presenter), *Green Infrastructure Stormwater Management Techniques (September 18, 2015)*, Montclair State University Continuing Education Program for Environmental Professionals, Montclair, NJ

Goll, Geoffrey M. (Presenter), *Advanced Stormwater Management (2014 to present)*. Rutgers University, Office of Continuing Education, New Brunswick, NJ

Goll, Geoffrey M. (Presenter), *Lake Management Course; Dredging and Dam Safety Compliance sessions (1996 to present)*. Rutgers University, Office of Continuing Education, New Brunswick, NJ.

Goll, Geoffrey M. (Presenter), *Pond Management, Construction and Restoration; Dredging and Dam Safety Compliance sessions (2000 to present)*. Rutgers University, Office of Continuing Education, New Brunswick, NJ.

Goll, Geoffrey M. (Presenter and Panel Discussion), March 9, 2012, *NJ Future Redevelopment Forum 2012, Treating Flooding as the "New Normal",* New Brunswick, NJ.

Goll, Geoffrey M. (Instructor and Course Coordinator), September 29, 2011, *Dam Removal Technical Track Half Day Program*, Association of State Dam Safety Officials, National Conference, Washington, DC.

Goll, Geoffrey M. (Instructor), September 20-22, 2010, *Dam Removal Case Studies*, The University of Wisconsin, Madison, Succeeding with a Dam Removal Project, Philadelphia, PA.

Woodworth, Paul, Galster, Josh, Wyrick, Josh (Presenter), Goll, Geoffrey M. (Presenter), May 18, 2010. *Dam Removal: Adaptive Management & Bed Sediment Monitoring Before and After,* ASCE, Environment and Water Resource World Congress 2010, Providence, RI.

Goll, Geoffrey M. (Presenter), Paist-Goldman, Mary, May 18, 2010. *Case Study: Preparing for Dam and Barrier Removals along the Darby Creek,* ASCE, Environment and Water Resource World Congress 2010, Providence, RI.

Goll, Geoffrey M. (Author and Presenter), May 18, 2010. *Sediment Management and Dredging for Dam Removal,* ASCE, Environment and Water Resource World Congress 2010, Providence, RI.

Helminiak, Jacob, Wildman, Laura, Goll, Geoffrey M. (Presenter), May 18, 2010. *Removing Barriers at Road Crossings Using Stream Simulation Techniques in the Northeast United States,* ASCE, Environment and Water Resource World Congress 2010, Providence, RI.

Goll, Geoffrey M., *Sustainable Approach to Stormwater Management Design: NJM Hammonton Regional Operations Facility*, April 8, 2010. Presentation at the University of New Hampshire Stormwater Center Workshop, Jacque Cousteau National Estuarine Research Reserve, Tuckerton, NJ.

10 Old Stage Road
Wendell, MA 01379

March 25, 2016

Mr. James Donohue
FirstLight Hydro Generating Company
North Field Mountain Station
99 Millers Falls Road
Northfield, MA 01360

Dear Mr. Donohue

Following are comments regarding telemetry analysis for study 3.3.2

In addition to the MARK and time to event analysis the report should include a more 'traditional' evaluation of the telemetry data. This would include but not be limited to:

<u>Upstream Turners Falls</u>

Efficiency of ladders

- # entering
- # leaving at exit
- Time of day entering
- Time to ascend
- Failed attempts
    - Spillway PIT antenna detections
    - Time in ladder
- Discharge at time of entry
    - Cabot
    - Spillway
    - Gatehouse

Ladder entry and passage efficiency

- Number within area of entrance
    - Cabot tailrace (#'s 5 & 6)
    - Spillway – pool at base of the dam (#'s 19 & 20)
    - Canal/Gatehouse (#21)
- Number entering
- Time from entering area until entry into the fishway
- Number exiting the ladder
- Bypass and generation flow

Delay

- Overall project delay
    - Time from first detection at Montague (#3) to passage
- Delay at fishway entrances
    - Time from first detection at Cabot station to Cabot entry

   - Time from first detection at base of dam (#'s 19 & 20) to Spillway entry
- Delay at Station #1 while passing in the bypass

Forays – multiple forays mean delay and loss of energetics

The number of times a fish attempts to enter a ladder – two ways to assess forays

   - Montague (#3) to Cabot tailrace (#'s 5 or 6)
   - Detection at #'s 5 or 6 separated by time interval (30 m, 1h)
   - Station #1 (#16) to base of dam (#'s 19 & 20)
   - Detection at #'s 19 or 20 separated by time interval
   - Upper canal (#21) to Gatehouse (#22)
   - Detection a t #21 separated by time interval

Influence of bypass flows on attraction to bypass and dam

- Percent of fish in Cabot tailrace that hold or that move upriver at different bypass and generations flows

<u>Upstream Northfield</u>

Numbers of fish:

- Exiting Gatehouse
- Impoundment (#23)
- Gill bank (#24)
- NMPS intake (#25)
- NMPS upper reservoir (#31)
- Shearer (#'s 26 & 27)
- Vernon tailrace

Times of passage from location to location

Delay at NMPS

Entrainment at NMPS

Changes in movement – upstream movement, downstream movement, upstream movement

<u>Downstream Turners</u>

Numbers of fish:

- Gill bank (#24)
- Impoundment (#23)
- Over dam (#'s 19 & 20)
- Enter Gatehouse (#'s 22 & 21)
- Canal downstream of Station #1 (#18)
- Station #1 forebay (#17)
- Station #1 river (#16)
- Lower canal (#13)
- Conte lab (#14)
- Cabot forebay (#8)
- Cabot tailrace (#'s 5 & 6)
- Bypass (#9 & P13)

Delay at Turners Falls dam

Delay in canal
Delay at Cabot station

Route selection
Survival at Station #1, Cabot and in spill
Mortality in canal
Mortality below project – mobile tracking

<u>Downstream Northfield</u>
Numbers of fish:

- Shearer farm (#'s 26 & 27)
- NMPS intake (#25)
- NMPS upper reservoir (#31)
- Gill bank (#24)
- Impoundment (#23)

Entrainment at NMPS
Mortality in impoundment

<u>Consider in up- and downstream analysis</u>
Sex differences in behavior/passage
Time of year/river temperature differences in behavior/passage
Mobile tracking information on mortality tags

<u>Information needs</u>
Hourly generation from Station #1 during May and June
Hourly spill during May, June and July until later of fishway s closed or telemetry ended
Detection probabilities at PIT readers and telemetry stations [#detected / #known to pass]
Down times or no reading periods for PIT and telemetry antennas

Thank you for the opportunity to comment. I can be reached at the above address, 978 544 7438, or don.pugh@yahoo.com.

Sincerely,

Donald Pugh

cc: John Warner, USFWS
Ken Sprankle, USFWS
Melissa Grader, USFWS
Caleb Slater, MADFW
Bill McDavitt, NOAA
Andrea Donlan, CRWC
Karl Meyer
Chris Tomichek, Kleinschmidt
Mark Wamser, Gomez and Sullivan

Attachment 4. FRCOG Comments on Final Study Report for Study 3.1.2 Causation Study

December 15, 2016

Franklin Regional Council of Governments

December 15, 2016

Honorable Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Project No. 1889
Comments on Study Report 3.1.2. Northfield Mountain/Turners Falls Operations Impacts on Existing Erosion and Potential Bank Stability Volumes 1-III.

Dear Secretary Bose:

The Franklin Regional Council of Governments (FRCOG) is the regional planning agency for Franklin County, Massachusetts. Two committees of the FRCOG, the Connecticut River Streambank Erosion Committee (CRSEC) and the Franklin Regional Planning Board (FRPB), have worked closely with the owner/operator of the Northfield Mountain and Turners Falls Projects for over 20 years to develop and implement bank stabilization projects that address problems of significant streambank erosion occurring in the Turners Falls Impoundment on the Connecticut River. During this time, FRCOG secured over $900,000 in Federal funding to help pay for innovative bank stabilization projects and active stakeholder involvement.[1] This cooperative effort set aside differences over erosion causes and focused instead on working together to identify and achieve solutions that protect prime farmland, structures, and other natural resources.

Since the new licenses for these projects will be valid for 30 to 50 years, stakeholders have a “once in a lifetime” opportunity to participate in the process to identify, evaluate and mitigate the environmental impacts of these projects. We believe that it is vital for the residents and municipalities of Franklin County to be actively represented and engaged in the relicensing effort to ensure that the health and vitality of the river is sustained; to protect the region’s treasured prime farmland, riparian and aquatic habitat for rare and endangered species; and to make sure that recreational areas and facilities are

[1] Funding sources include three MassDEP s.319 Nonpoint Source Pollution Competitive Grants and an EPA Targeted Watershed Grant. For more information about this work, see www.restoreconnriver.org

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maintained. We hope that FERC will hold the owner of the hydroelectric projects to high standards and expectations.

We have been and continue to be concerned with the frequent and significant water level fluctuations associated with the operation of the Northfield Mountain Pumped Storage and Turners Falls projects, which result in streambank erosion and impacts to water quality, threatened and endangered species, fisheries, wetlands, and riparian and littoral habitat. In particular, we believe that because the Northfield Mountain Pumped Storage project was built over 40 years ago, when environmental permitting and our knowledge of river ecosystems was less robust, the project's operational use of the Connecticut River has been a long-term "experiment" that has resulted in significant adverse environmental impacts.

We understand from these proceedings that it is FERC's intention to collectively review and consider the cumulative impacts of the five hydroelectric projects on the Connecticut River as part of the current Integrated Licensing Process.[2] The FRCOG endorses this holistic and cumulative approach because we strongly believe the river and these projects should be evaluated as a single, hydrologically-interconnected system. It is imperative that FERC and the mandatory conditioning agencies have the information they need to better understand the individual and cumulative environmental impacts of all these projects and to balance power generation with environmental protection of the river.

Throughout each step of the Integrated Licensing Process, we have filed detailed comments with FERC that describe our concerns with the Study Plans and Study Reports for the two studies specifically related to river bank erosion: Study 3.1.2 Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability and Study 3.1.1, the 2103 Full River Reconnaissance. We appreciate this current opportunity to submit our comments on the Final Study Report 3.1.2 Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability filed by FirstLight on October 15, 2016.

Study 3.1.2 Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability.

Background

The stated goal of Study 3.1.2 is "…to evaluate and identify the causes of erosion in the Turners Falls Impoundment and to determine to what extent they are related to Project operations."[3] According to the Revised Study Plan (RSP), Study 3.1.2 "calls for collectively looking at all available data and applying various analyses methods to make a determination as to whether the erosion and/or bank instability is caused, in whole or combined with other factors, by hydropower operations." As stated in the Methodology (18 CFR § 5.11(b)(1), (d)(5)-(6)) section of the Revised Study Plan, Study 3.1.2 was

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[2] The three upstream projects are Vernon Dam (FERC No. 1904), Bellows Falls Project (FERC No. 1855) and Wilder Dam (FERC No. 1892), operated by TransCanada. http://www.transcanada-relicensing.com/

[3] Revised Study Plan, p. 3-25.

"designed to provide a thorough investigation of the causes of erosion in the Turners Falls Impoundment in a manner consistent with generally accepted scientific practice." (emphasis added). Seven (7) tasks were included "in order to provide a clearly organized methodology that will accomplish the goals and objectives". These tasks are listed below

- Task 1: Data Gathering and Literature Review;
- Task 2: Geomorphic Understanding of the Connecticut River;
- Task 3: Causes of Erosion;
- Task 4: Field Studies and Data Collection;
- Task 5: Data Analyses;
- Task 6: Evaluation of the Causes of Erosion; and
- Task 7: Report and Deliverables

With the completion of Study 3.1.2, FirstLight concluded that "[h]ydropower operations have limited to no impact on bank erosion in the TFI."[4] (TFI is the Turners Falls Impoundment, emphasis added). This statement is contrary to decades of stakeholder and landowner observations and filings with FERC as well as the findings of both the 1979 Army Corps of Engineers' study and the 2007 Field Geology Services report.[5] Incredibly, FirstLight was able to calculate that: 1) Northfield Mountain Project operations are not a dominant cause of erosion at any riverbank segment in the TFI. They are a contributing cause of erosion at 4% of the total riverbank segments (8,600 ft.); 2) Turners Falls Project operations are not a dominant or contributing cause of erosion at any riverbank segment in the TFI; and 3) Vernon Project operations are a dominant cause of erosion at 9% of all riverbank segments in the TFI (20,200 ft.). They are not a contributing cause of erosion at any riverbank segment.

We are concerned that much of the foundation work (Tasks 1-3) for Study 3.1.2 is so biased and incomplete that the work conducted under the remaining four tasks is rendered unreliable and the conclusions of the study are fatally flawed. The basis of our concern is the simple fact that the Turners Falls Impoundment is a highly manipulated river with three hydroelectric projects, including two dams and the Northfield Mountain Pumped Storage project, that exert a huge influence on the geomorphology

[4] Page 67 of Volume 1 – Study Report 3.1.2.
[5] Simons, D.B., Andrew, J.W., Li, R.M., & Alawady, M.A. (1979). Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire, and Vermont. Waltham, MA: US Army Corps of Engineers (USACE). Field Geology Services. (2007). Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT. Prepared for Northfield Mountain Pumped Storage Project. Farmington, ME: Field Geology Services. Field, John. 2011. Detailed Analysis of the 2008 Full River Reconnaissance of the Turners Falls Pool on the Connecticut River: Unpublished report prepared for The Landowners and Concerned Citizens for License Compliance.

of the river system. Amazingly, FirstLight chose to completely ignore this in the work undertaken for Section 2 – Geomorphic Understanding of the Connecticut River of Study Report 3.1.2.

Almost 60 pages of Section 2 focused instead on developing an erroneous narrative that claims that the Connecticut River behaves as a natural, alluvial river. Examples of this unsupported, undocumented and completely incorrect bias pose serious questions about the validity of the work done for the remaining tasks of Study 3.1.2. These statements are not supported in any meaningful way by FirstLight's own "analysis" or the available scientific literature for regulated alluvial rivers.

FirstLight states that: "The modern geomorphology of the Connecticut River <u>is typical of an alluvial river</u> and is consistent with that described in Section 2.1. Alluvial rivers by definition continue to adjust over time through processes of aggradation, degradation, scour, deposition, lateral migration, and bank erosion. Given this, although <u>the river has reached a state of dynamic equilibrium</u> over time, some degree of erosion is expected to continue."[6] (emphasis added).

Contrast FirstLight's characterization of the river with that provided by the Army Corps of Engineers in their comprehensive 1979 report "Connecticut River Streambank Erosion Study":

- On page 21: "Turners Falls Dam was raised by 5.5 feet in 1971 as part of the Northfield Mountain Project. Prior to that time it operated similarly to the three upstream dams. Conditions have dramatically changed since completion of this project. Soils that were rarely wet are subject to frequent inundation. Pool fluctuations and variations in discharges and velocities have increased. In fact, the entire hydraulics of the system has changed."

- On page 17: Variations in flow from the Vernon and Turners Falls Dam, Northfield Mountain Project and two major tributaries (Millers and Ashuelot Rivers) "cause a very dynamic situation to exist in Turners Falls Fool that significantly affects bank erosion."

- In the Executive Summary – "Note that forces exerted on the bank of a channel by the flowing water can be increased as much as 60 percent by such factors as flood stage variations, pool fluctuations, boat and wind waves, etc. Evaluation of forces causing bank erosion verifies the relative importance of causative factors. In descending order of importance they are: shear stress (velocity), pool fluctuations, boat waves, gravitational forces, seepage forces, natural stage variations, wind waves, ice, flood variations, and freeze-thaw."

- On pages 118-120 – "The impacts of hydropower development on bank stability in Turners Falls Pool have been and continue to be more severe than for the other pools. The increase in pool level, the larger pool fluctuations and flow reversals caused by the present hydropower operation all contribute to the documented bank instabilities in this part of the study reach. The increase in

[6] Study Report, P. 2-57.

pool fluctuations on bank stability in Turners Falls Pool is a very significant factor. Pool fluctuations on the order of 5 feet are at least twice as destructive to banks or pool fluctuations of about 1-3 feet as experienced in the other hydropower pools."

Many of the river conditions and observations described in the 1979 Army Corps report were reinforced and expanded upon by the findings of the 2007 Fluvial Geomorphology Study of the Turners Falls Pool prepared by Field Geology Services.[7] Despite the availability of these two well conducted studies and the opportunity to build upon the studies' findings, Section 2 of FirstLight's Study 3.1.2 is filled with unhelpful information. For example, descriptions of the geomorphology of natural alluvial river systems and river systems in National Parks, listing the reasons why FirstLight couldn't use historic datasets in their analyses (which we find very curious and not convincing because scientists involved with many other investigations regarding regulated rivers and dams use historic aerial photographs, maps, survey data, transects, etc.), and ending with the unsupported and incorrect conclusion that "[t]he Connecticut River, with the exception of rare bedrock lined sections such as the French King Gorge, is an alluvial river."

We are frustrated and disappointed that much of the work completed for Study 3.1.2 brings us no closer to understanding the complex hydraulic and geomorphologic processes at work in the Turners Falls Impoundment. FirstLight did not provide an accurate or scientifically defensible geomorphic assessment of the Connecticut River and Turners Falls Impoundment. The lack of discussion about the impacts of the dams on the river is particularly egregious and must be remedied. FRCOG filed extensive comments with FERC regarding our concerns about the lack of a clear methodology for Study 3.1.2 and the lack of scientific rigor in FirstLight's approach to the study.

Our specific comments are organized by the tasks listed in Study 3.1.2.

Task 1: Data Gathering and Literature Review

FirstLight states that they conducted "an in-depth literature review and data gathering effort which provided the foundation" for Study 3.1.2 and "allowed for the identification of potential data gaps."

Page 3-29 of the Revised Study Plan states that the "full list of available data that will be utilized for this study is summarized in the "Existing Information (18 CFR §5.11(d)(3))section." FirstLight's literature review was not "in-depth" and consisted primarily of unpublished studies and reports about the Connecticut River authored by the members of FirstLight's consultant team.[8] These reports were not peer-reviewed and are characterized by a lack of scientific rigor, a strong bias towards "proving" that little or no erosion is happening in the Turners Falls Impoundment, and a remarkable lack of quality assurance/quality control for the data collected and the analyses performed.

[7] Field Geology Services. (2007). Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT. Prepared for Northfield Mountain Pumped Storage Project. Farmington, ME: Field Geology Services.

[8] One exception to this are the peer-reviewed papers related to the Bank Stability Toe Erosion Model (BSTEM).

The FRCOG and other stakeholders have previously filed detailed comments with FERC regarding our concerns with the 2013 Full River Reconnaissance (Study Report 3.1.1) and the 2012 Riverbank Erosion Comparison along the Connecticut River prepared for FirstLight by Simons & Associates (S&A). The 2012 S&A report does not include a documented methodology, the analysis lacks a robust data set, and the analysis itself is qualitative and subjective.

We object to the fact that whole sections of the 2012 S&A report were repeated in Section 2 of Study 3.1.2, including the unsupported and biased conclusion that the Turners Falls Impoundment is in better condition than all other reaches of the river studied. This conclusion is based on a subjective analysis of a few erosion sites in the Holyoke, Turners Falls, Vernon and Bellows Falls impoundments, documented photographically in 1998 and again in 2008. Additionally, the 2012 S&A report's conclusions are tied to the results of the 2008 Full River Reconnaissance (which FRCOG and others disputed, with our detailed comments filed with FERC), and the misinterpreted findings of a detailed fluvial geomorphic study that focused on the 85-mile long "free-flowing" reach of the Connecticut River between Pittsburg, NH and Dalton NH (Field Geology Services, 2004).

The 2012 S&A report repeatedly pointed back to this "free-flowing" reach of the Connecticut River as an example of how "natural" alluvial rivers erode their banks. Although there is one small extant dam in this reach, the river is not a natural, alluvial system. Field (2004) identified five (5) human activities, as well as the river's response to deglaciation, that are contributing to channel instabilities and erosion in the 85-mile long reach, including:

1) channelization;
2) land clearance and other human land use in tributary watersheds;
3) continuing adjustments to deglaciation;
4) agricultural practices in the riparian zone;
5) dams; and
6) reforestation of hill slopes cleared in the 18th and 19th Century.

The important and basic point to remember with respect to the geomorphology of the entire Connecticut River and its watershed is this: human activities on the land and manipulation of the river itself (dams, channelization, etc.) have a huge and long-lasting effect on how the river behaves (flow, bank erosion, etc.).

<u>Impacts of Dams on Rivers</u>

There is a robust body of scientific literature, spanning decades, that describes the impacts that dams have on river systems. FirstLight included only one peer-reviewed scientific paper on this topic in Section 8-Literature Cited of Study Report 3.1.2. This paper was authored by Dr. Andrew Simon, et.al, and describes a project that evaluated the channel stability of a section of the Missouri River downstream of the Fort Peck Dam.[9] Actually, this well documented investigation describes conditions that are applicable to the geomorphic conditions of the Turners Falls Pool but none of the information appears to have been used to inform Study 3.1.2. For example, the results of the Missouri River study indicate:[10]

- Dam closure caused significant bed degradation in the study reach and, in particular, an increase in the occurrence of long-duration, medium- and high-stage flow events. Both have had deleterious effects on bank stability.

- Analyses confirm that banks with low cohesion and erodible toes are particularly unstable and that those with high cohesion, few cracks, and unerodible toes are most stable.

- In addition, maintenance of high flows can cause bank saturation, eliminating matric suction and creating positive pore-water pressures significant enough to promote instability.

- Planar failures due to toe scour and over steepening by fluvial undercutting were the most common mechanisms of bank failure.

Interestingly, the discussion regarding Implications for Bank Stability for the Missouri River study (excerpted below) could have been written for the Turners Falls Impoundment.

<u>Implications for Bank Stability</u>[11]

"<u>It is common along regulated rivers such as the Missouri for moderate and high stages to be maintained for a longer period of time than under predam conditions</u> (emphasis added). If moderate to high stages are maintained for sufficient time, the near-bank region may become saturated by lateral infiltration at levels above low water. If stage is then decreased rapidly, a drawdown condition occurs, resulting in unfavorable pore-water pressure conditions. Additionally, the shifting of peak flows into the winter when parts of the river are frozen can have significant effects on channel morphology by generating positive pore-water pressures higher up the banks and by altering flow distributions, thereby providing a given discharge with a greater erosive power. However, if stage is reduced slowly, permitting positive pore-water pressures to dissipate, streambanks can sometimes maintain their strength and stability. The effects of pore-water pressures and confining pressures on bank stability have been explored by many other authors including Casagli et al. (1997), Simon and Curini (1998), Rinaldi and Casagli (1999), and Simon et al. (2000)."

[9] Simon, Andrew, Robert E. Thomas, Andrea Curini, and F. Douglas Shields Jr. Case Study: Channel Stability of the Missouri River, Eastern Montana, in the Journal of Hydraulic Engineering, Vol. 128, No. 10, October 1, 2002. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.203.4833&rep=rep1&type=pdf
[10] Ibid.
[11] Ibid.

If FirstLight had performed a reasonable literature search, they would have found many articles with information that could have informed their work for Task 2: Geomorphic Understanding of the Connecticut River, as well as the remaining tasks for Study 3.1.2.

Task 2: Geomorphic Understanding of the Connecticut River

FirstLight states that based on "the literature and datasets gathered" they were "able to conduct a qualitative historic geomorphic assessment of the Connecticut River and the Turners Falls Impoundment." FirstLight claims that the results of the historic assessment provided " important context to the study as well as a better understanding of the various hydrologic, hydraulic, geotechnical, and geomorphic dynamics at play in the study reach." We disagree. In fact, most of the information in the Geomorphic Understanding of the Connecticut River section is contrary to the body of scientific literature and understanding of large, regulated, alluvial rivers.

As stated in the Revised Study Plan, the stated goal of Study 3.1.2 is "…to evaluate and identify the causes of erosion in the Turners Falls Impoundment and to determine to what extent they are related to Project operations."[12] The Connecticut River in the Turners Falls Impoundment is manipulated by the operation of three hydroelectric projects which discharge or draw water from the river for hydropower generation. FirstLight should have evaluated the impact of these projects on the historic and modern geomorphology of the river. The 1979 Army Corps study did, as did the 2007 Field Geology Services report.

From the start of Study 3.1.2, FirstLight's bias towards claiming that the erosion is due to typical alluvial processes is made quite clear. The entire foundation of Study 3.1.2 is flawed because of FirstLight's basic misunderstanding and misrepresentation of the riverine system. Throughout Study 3.1.2, shaky conclusions are drawn and questionable parallels made between the Connecticut River and other alluvial rivers, including rivers in Yellowstone and Glacier National Parks, which FirstLight claims are examples of "natural river dynamics" where "no significant development or regulation of the rivers for hydropower, agriculture, water supply, navigation, or recreational powerboat use is typically found."[13] The Connecticut River has been subject to all of the activities listed in the previous sentence so it would have been more useful to investigate how these human activities, specifically the hydropower projects, affect river dynamics.

It is an undisputed fact, supported by decades of scientific investigations, that dams have a dramatic and often deleterious effect on river morphology and fluvial processes, including flow regimes, channel morphology, sediment transport and the ecological processes, such as the quality of riparian and aquatic

[12] Revised Study Plan, p. 3-25.
[13] Revised Study Plan, p. 2-5.

habitats.[14] The U.S. Geological Survey studied the downstream effects of dams on alluvial rivers and concluded that:

- "[h]undreds of kilometers of river distance downstream from a dam may be required before a river regains, by boundary erosion and tributary sediment contributions, the same annual suspended load or sediment concentration that it transported at any given site prior to dam construction."[15]

- Further, in several of the rivers studied, "bank erosion appears to account for more than 50 percent of the sediment eroded from a given reach."[16]

As stated in a professional paper contributed by Luna B. Leopold on August 15, 2000 to the Proceedings of the National Academy of Sciences, "[o]nce altered by dam construction, an alluvial river will never function as before."[17] The 10 alluvial river attributes that are impacted by dams are described in detail by the authors. This information can be used to recommend flow releases and other management activities below an existing dam to help restore degraded alluvial functions. The paper concludes by stating that to obtain the societal benefits of water diversion, flood control, and hydropower generation, rivers will continue to receive less flow and sediment than under unimpaired conditions. But if important attributes are provided to the greatest extent possible, alluvial river integrity can be substantially recovered. The compromise will be a smaller alluvial river; it may not recover its predam dimensions, but it would exhibit the dynamic alternate bar and floodplain morphology of the predam channel. Although a restoration strategy guided by the alluvial attributes is an experiment, it may be the most practical direction toward recovering regulated alluvial river ecosystems and the species that inhabit them.[18]

Given the history of dam building on the Connecticut River and its tributaries, the river is the furthest thing from a natural, alluvial river as one could imagine, despite what Section 2 of Study Report 3.1.2 claims. Click on the link to see a time progression of dam building on the river, courtesy of the Connecticut River Watershed Council (CRWC) or refer to the image on this page, also courtesy of the CRWC web site. http://www.ctriver.org/images/maps/dams%201850%20to%20now.gif

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[14] Katherine J. Skalaka, Adam J. Benthem, Edward R. Schenk, Cliff R. Huppa, Joel M. Galloway, Rochelle A. Nustad, Gregg J. Wiche. Large dams and alluvial rivers in the Anthropocene: The impacts of the Garrison and Oahe Dams on the Upper Missouri River. In Anthropocene Volume 2, Pages 1-102 (October 2013), Geomorphology of the Anthropocene: Understanding The Surficial Legacy of Past and Present Human Activities. Edited by Anne J. Jefferson and Karl W. Wegmann. http://www.swc.nd.gov/pdfs/oct_2013_impacts_garrison_oahe_upper_missouri.pdf

[15] Williams, Garnett P. and M. Gordon Wolman, Downstream Effects of Dams on Alluvial Rivers, U.S. Geological Survey Professional Paper, 1286. Second Printing 1985.

[16] Ibid.

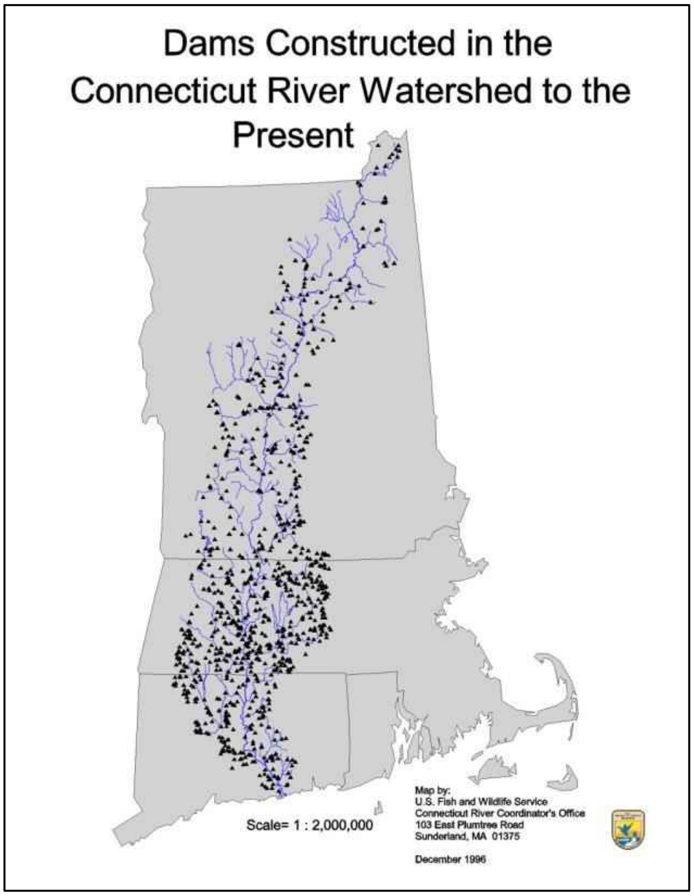
[17] William J. Trush*, Scott M. McBain‡, and Luna B. Leopold§. Attributes of an alluvial river and their relation to water policy and management. *Institute for River Ecosystems, Fisheries Department, Humboldt State University, Arcata, CA 95521; ‡McBain and Trush, P.O. Box 663, Arcata, CA 95518; and §Department of Geology and Geophysics, University of California Berkeley, 400 Vermont Avenue, Berkeley, CA 94707. Contributed to the Proceedings of the National Academy of Sciences by Luna B. Leopold, August 15, 2000.

[18] Ibid.

The cursory geomorphological investigation conducted by FirstLight ignored decades of scientific literature and methodologies available to them. Once again, regulators and stakeholders were provided with little to no useful information to inform the FERC relicensing process or MassDEP's 401 Water Quality Certification process, including the development of project operation requirements and other mitigation and enhancement measures. The lack of relevant, scientifically grounded information also stymies the participation of state regulatory agencies, NGOs and other stakeholders.

Recommendation for Tasks 1 and 2:

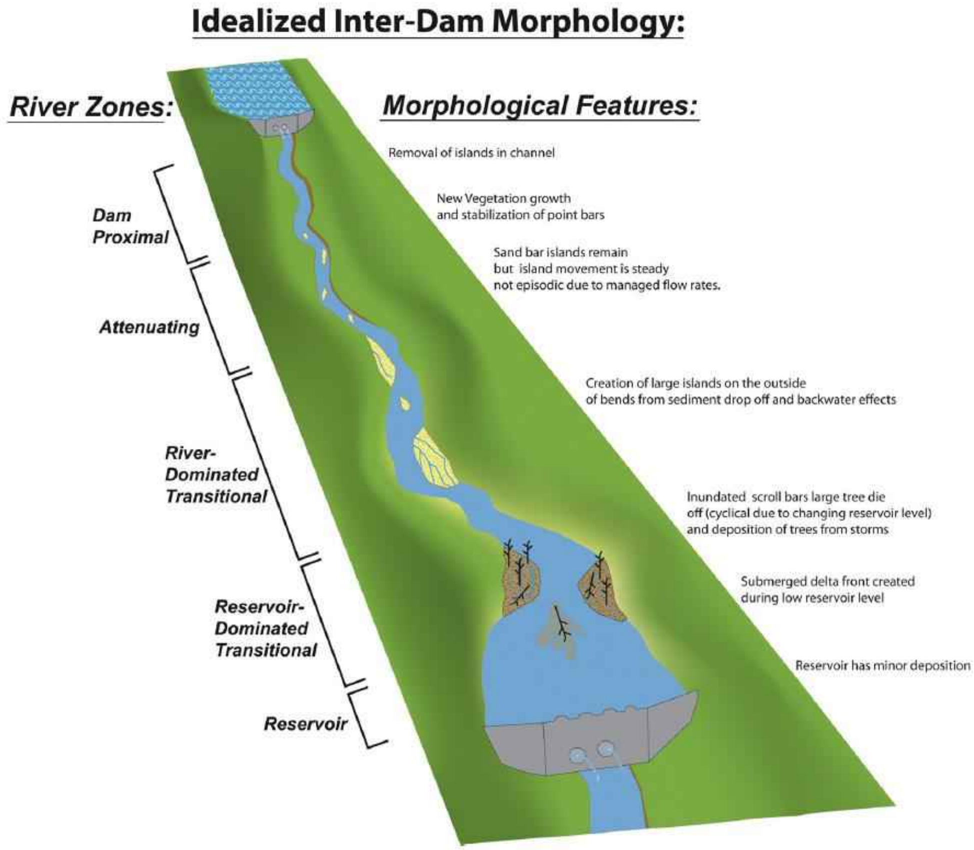
We recommend that FERC require FirstLight to review the available scientific literature regarding the impacts of dams on rivers and revise Section 2 – Geomorphic Understanding of the Connecticut River to reflect the current understanding of the geomorphology of large, regulated rivers and to meet the Study Goals and Objectives (18 CFR § 5.11(d)(1)) " to evaluate and identify the causes of erosion in the Turners Falls Impoundment and to determine to what extent they are related to Project operations."



We ask that FERC require FirstLight to use an available conceptual geomorphic model, such as the Inter-Dam Sequence Conceptual Model, to evaluate the geomorphology of the Turners Falls Impoundment.[19] This model addresses both the downstream and upstream impacts of dams on large rivers and uses data that is available to FirstLight, including historical aerial photographs, stream gage data, and cross sectional surveys. Application of this Inter-Dam Sequence conceptual model, along with a qualitative evaluation of the 10 alluvial functions of the river system that are affected by the operation of the hydropower projects would have been a more useful discussion for FERC, MassDEP and stakeholders (for more information on the 10 alluvial functions see the professional paper submitted to the National Academy of Sciences by Luna B.

[19] Much of the information in this section is adapted from the following article: Katherine J. Skalaka, Adam J. Benthem, Edward R. Schenk, Cliff R. Huppa, Joel M. Galloway, Rochelle A. Nustad, Gregg J. Wiche. Large dams and alluvial rivers in the Anthropocene: The impacts of the Garrison and Oahe Dams on the Upper Missouri River. In Anthropocene Volume 2, Pages 1-102 (October 2013), Geomorphology of the Anthropocene: Understanding The Surficial Legacy of Past and Present Human Activities. Edited by Anne J. Jefferson and Karl W. Wegmann.
http://www.swc.nd.gov/pdfs/oct_2013_impacts_garrison_oahe_upper_missouri.pdf

Leopold (2000); footnote 17 on page 9 for complete citation). Unlike FirstLight's work for Section 2 of Study 3.1.2, the approach described in FRCOG's recommendation is consistent with generally accepted scientific practices.



Inter-Dam Sequence Conceptual Model[20]

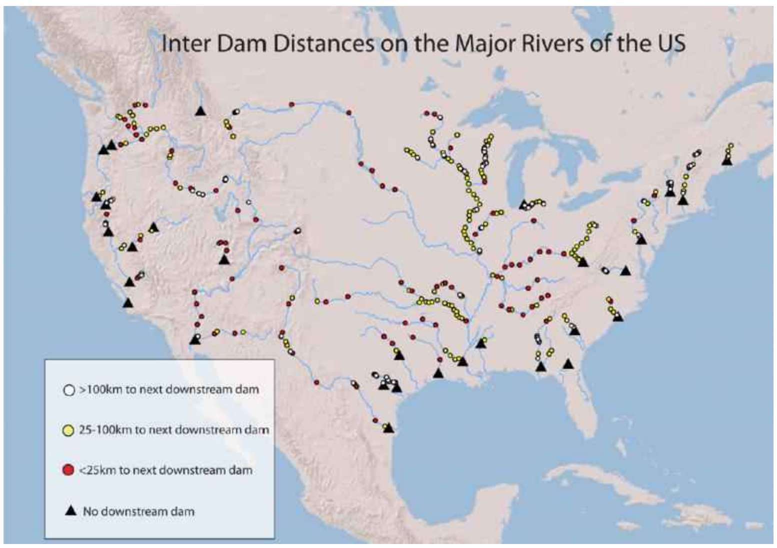
Over the past five decades, scientists have studied the upstream and downstream impacts to rivers of different types of dams, including hydroelectric and flood control dams, and there is a readily available and robust bibliography for this body of work. The downstream impacts of dams are well documented and several generalized conceptual models are available.

Downstream impacts include an imbalance in sediment supply and stream flow, which can result in a downstream sediment deficit or surplus and channel changes that can persist for hundreds of kilometers downstream of a dam. Much information is also available regarding the upstream impacts of dams, particularly the sedimentation of the impoundments, landslides and shoreline erosion.

[20] Ibid. Figures on pp. 11-12 adapted from:http://www.swc.nd.gov/pdfs/oct_2013_impacts_garrison_oahe_upper_missouri.pdf

These investigations typically focused on the impacts to a river from a single dam, with the hypothesis being that the upstream and downstream impacts of the single dam attenuate both in space and time until a new equilibrium is reached in the system. Recently, a growing body of evidence describes and quantifies the overlapping upstream and downstream impacts that multiple dams have on a river. In other words, scientists are finding that it can take hundreds of kilometers for this attenuation of impacts and equilibrium conditions to establish. On large rivers with multiple dams, like the Connecticut River, where the impacts of five of the 15 dams on the river (and the Northfield Mountain Pumped Storage project) are currently being evaluated via the Integrated Relicensing Process, the interaction of multiple dams results in unique and complex geomorphological changes and sequences.

For a recent investigation of a section of the Missouri River, which has 15 dams on the mainstem and hundreds more on the tributary rivers (similar to the entire Connecticut River watershed), scientists from the U.S. Geological Survey examined the river's geomorphology using historical aerial photographs, stream gage data and cross-sectional surveys to demonstrate that the influence of the upstream dam is still a major control of river dynamics even as the backwater effects of the downstream reservoir begin. The study describes a model of morphologic progression between dams called the Inter-Dam Sequence that illustrates the simultaneous upstream and downstream impacts between multiple dams on a river and state that this condition is "likely prevalent on most large rivers in the U.S. and potentially common across the world".[21]



The study identified five geomorphic reaches between the two dams on the Missouri River that are based on observed changes in cross-sectional area, channel planform and morphology. Within each reach, the river is adjusting and responding to the influences of the dams, either by erosion of the river bed, banks and islands, or deposition. Dams disrupt natural flow regimes by reducing peak floods and enhancing baseflow discharges, which can result in a stable channel thalweg over time. If the deepest part of the channel does not migrate, the river will increase its capacity by eroding its bed and banks.

[21] http://www.swc.nd.gov/pdfs/oct_2013_impacts_garrison_oahe_upper_missouri.pdf

<u>Comments on the Remaining Sections of Study 3.1.2 (Tasks 3-7)</u>

We agree with and support the analysis, conclusions and recommendations of Princeton Hydro, which was hired by the Connecticut River Watershed Council to conduct a peer review of Study 3.1.2, focusing on the application of the Bank Stability Toe Erosion Model (BSTEM) dynamic v.2.3 and the conclusions of Study 3.1.2. We also agree with and support the findings and recommendations of the peer review provided by the U.S. Department of Agriculture, Agricultural Research Service National Sedimentation Laboratory, one of the developers of the BSTEM model. This peer review was performed at the request of NOAA's National Marine Fisheries Service.

Recommendations:

As FERC considers the comments provided by the two peer reviews prepared by Princeton Hydro and USDA, we request that you consider the following additional information in support of their recommendations.

- We note for the record that FirstLight provides only a short paragraph discussing the limitations of the application of the BSTEM model in the Turners Falls Impoundment. BSTEM runs were only done on 22 of the 25 transect locations identified in the Revised Study Plan. FRCOG and other stakeholders previously filed comments with FERC that described our concerns with the transect locations chosen by FirstLight for the BSTEM runs.

- We question the use of BSTEM at previously stabilized sites and do not believe the data to be relevant to a discussion of bank erosion. Almost 50% of the BSTEM runs (10 of the 22 transect locations) were performed on stabilized sites. This raises the important question of how was the input data for the pre-stabilization sites determined? We note that the input data for the BSTEM runs for 2L Pre-Restoration and 2L Post-Restoration are <u>exactly the same</u>; the input data for 3R Pre-Restoration and 3R Post-Restoration <u>are almost identical except for the riprap changing a few input parameters</u> for 3R Post-Restoration; and that trend continues for the remaining 3 sets of BSTEM input data for the pre- and post-restoration sites.[22]

- FirstLight does not acknowledge what are clear data deficiencies in the data input used for the model, particularly the glaring and inexcusable lack of groundwater elevation data (used less than 1 year of groundwater elevation data (July 97-Feb 98) for 3 wells near the Rt. 10 bridge rather than installing piezometers at each transect); using what appear to be reference values for hydraulic conductivity; and the questionable similarity among transects for the data input for certain parameters, despite the field data collection efforts described in Volume II of the Study Report.

[22] Study Plan 3.1.2, Volume III, Appendix L – BSTEM Input Data.

- FirstLight did not do a detailed stratigraphic analysis at the transect sites and used deficient data and analyses from the flawed 2013 Full River Reconnaissance.

- FirstLight dismisses the importance of the role that pool fluctuations and seepage play in bank instability despite the findings of the 1979 Army Corps study that indicated that "[a]lthough these forces (pool fluctuations and seepage) are not large in magnitude compared to forces acting on the banks at flood stage, the erosion caused by this combination of factors is significant because the forces have acted continuously and are confined within a fixed zone imposed by the dams and adopted operation techniques."[23]

- FirstLight spent a lot of money and time trying to parse out "responsibility" for erosion and, in our opinion, <u>mis-applied</u> a potentially useful tool – the BSTEM model. BSTEM is *typically used to predict streambank erosion, sediment load estimates and test the effectiveness of mitigation and restoration measures*.

- FRCOG could not find any peer-reviewed, published articles that describe the application of BSTEM to "tease out" different causes of erosion. The Turners Falls Impoundment should not be a "guinea pig" for applying the model in an inappropriate and unsupported way.

- BSTEM has been applied in a range river of environments. Has BSTEM ever been applied to an impoundment and one that is likely to be one of the more dynamic hydropower pools in the country? If not, then the model might overstate the impact of river flow over project water fluctuations as the model was developed in alluvial environments where shear stress caused by river flow is more important than daily fluctuations.

- The "methodology" used to extrapolate the BSTEM results is highly suspect and not based on any cited scientific methodology.

- A 2010 investigation used BSTEM to evaluate the impact on bank stability of 6 release scenarios downstream of the Bagnell Dam on the Osage River.[24] This information could inform additional BSTEM runs for the Turners Falls Impoundment.

- Two recent (2016 and 2015) peer-reviewed papers regarding the application and limitations of BSTEM are summarized below. We are intrigued by the paper that describes the coupling of two models – BSTEM and a 2-dimensional mobile bed model that accomplishes three things: 1) it predicts the complex flow field and sediment transport within the near-bank zone; 2) it simulates fluvial erosion of the bank face and bank toe in a relatively independent fashion; and 3)

[23] P.165.

[24] Heinley, Kathryn Nicole, "Stability of streambanks subjected to highly variable streamflows: the Osage River Downstream of Bagnell Dam" (2010).*Masters Theses.* Paper 5022. http://scholarsmine.mst.edu/cgi/viewcontent.cgi?article=6021&context=masters_theses

it more accurately characterizes how the failed bank materials are removed by flowing water. This enhanced version of BSTEM may be a more appropriate model for the Turners Falls Impoundment and may address some of the short-comings described in the Princeton Hydro and USDA peer review reports.

- Modeling of Multilayer Cohesive Bank Erosion with a Coupled Bank Stability and Mobile-bed Model. Lai, YG, Thomas, RE, Ozeren, Y, Simon, A., Greimann, BP and Wu, K. (2015). Geomorphology, 243. 116-129. ISSN 0169-555x. http://www.sciencedirect.com/science/article/pii/S0169555X1400381X

  Abstract (with emphasis added): *Streambank erosion can be an important form of channel change in unstable alluvial environments. It should be accounted for in geomorphic studies, river restoration, dam removal, and channel maintenance projects.* Recently, one-dimensional and two-dimensional flows and mobile-bed numerical models have become useful tools for predicting morphological responses to stream modifications. Most, however, either ignore bank failure mechanisms or implement only simple ad hoc methods. In this study, a coupled model is developed that incorporates a process-based bank stability model within a recently developed two-dimensional mobile-bed model to predict bank retreat. A coupling procedure that emphasizes solution robustness, as well as ease-of-use, is developed and described. The coupled model is then verified and validated by applying it to multilayer cohesive bank retreat at a bend of Goodwin Creek, Mississippi. Comparisons are made between the predicted and measured data, as well as results of a previous modeling study. On one hand, the study demonstrates that the use of two-dimensional mobile-bed models leads to promising improvements over that of one-dimensional models. It therefore encourages the use of multidimensional models in bank erosion predictions. On the other hand, the study also identifies future research needs in order to improve numerical modeling of complex streams. The developed model is shown to be robust and easy to apply; it may be used as a practical tool to predict bank erosion caused by fluvial and geotechnical processes.

- Evaluating a Process-Based Model for Use in Streambank Stabilization: Insights on the Bank Stability and Toe Erosion Model (BSTEM). Submitted to Earth Surface Processes and Landforms. Authors: Kate Klavon,[1] Garey Fox, [1] Lucie Guertault,[1] Eddy Langendoen,[2] Holly Enlow, [2] Ron Miller[2] and Anish Khanal.[2] 2016.
  [1]Oklahoma State University Biosystems and Agricultural Engineering, Oklahoma, United States; [2]USDA-ARS National Sedimentation Laboratory Oxford, MS, Oxford, United States. http://onlinelibrary.wiley.com/wol1/doi/10.1002/esp.4073/abstract

  Abstract (with emphasis added): Streambank retreat is a complex cyclical process involving subaerial processes, fluvial erosion, seepage erosion, and geotechnical failures and is driven by several soil properties that themselves are temporally and spatially variable. <u>Therefore, it</u>

can be extremely challenging to predict and model the erosion and consequent retreat of streambanks. However, modeling streambank retreat has many important applications, including the design and assessment of mitigation strategies for stream revitalization and stabilization. In order to highlight the current complexities of modeling streambank retreat and to suggest future research areas, this paper reviewed one of the most comprehensive streambank retreat models available, the Bank Stability and Toe Erosion Model (BSTEM), which has recently been integrated with several popular hydrodynamic and sediment transport models including HEC-RAS. The objectives of this paper were to: (i) comprehensively review studies that have utilized BSTEM and report their findings, (ii) address the limitations of the model so that it can be applied appropriately in its current form, and (iii) suggest directions of research that will help make the model a more useful tool in future applications. The paper includes an extensive overview of peer reviewed studies to guide future users of BSTEM. The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters.

Conclusions

One of the greatest influences that humans have had on rivers is the construction of dams. The impacts to the important alluvial attributes of a river, including damages to riparian and aquatic habitats, changes to flow regime and sediment transport capacity, and bank and channel bed erosion, are well documented. Available scientific literature describes how these impacts extend tens to hundreds of kilometers upstream and downstream of a dam. On a river with multiple dams, the river may not be able to “adjust” (e.g., by eroding their banks and channel beds) to the impacts from an upstream dam before the river hits the next downstream dam. Then, add the Northfield Mountain Pumped Storage Facility into the mix to further complicate the river’s geomorphic adjustment processes (bank erosion, channel erosion, flow regime and sediment load changes) and riverbank instability is the result.

Despite this extensive scientific literature, FirstLight claims that most of the erosion in the Turners Falls Impoundment (TFI) is due to the “natural” erosion that happens during high flows in an undammed, unregulated river. FirstLight goes so far as to draw comparisons between the erosion in the TFI and erosion seen in “natural alluvial” rivers in Yellowstone and Glacier National Parks.

We have documented FirstLight’s bias and lack of scientific rigor in their geomorphic analysis of the TFI and how this unsound work influenced FirstLight’s use of the BSTEM model. FirstLight’s conclusion that "[h]ydropower operations have limited to no impact on bank erosion in the TFI"[25] is fatally flawed. We urge FERC to require that FirstLight conduct the additional, scientifically rigorous investigations to supplement Study 3.1.2., as described in the recommendations of FRCOG's comment letter and the recommendations of the Princeton Hydro and USDA peer review reports.

We are very concerned that our opportunity to collect good data and apply sound scientific methods to analyze how the hydropower facilities are impacting the river – water quality, geomorphic function, bank erosion, etc. – is slipping away and may be lost for the next 30-50 year period of the new license. We have learned little about how the pumped storage project and the dams impact the hydrology, riparian and aquatic habitat and geomorphology of the Connecticut River. This huge ongoing experiment, which began over 40 years ago, will essentially continue unmonitored for another 30 to 50 years if FERC doesn't require FirstLight to rigorously examine the impacts of the hydropower projects on the river and provide FERC, MassDEP, NGOs and stakeholders with sufficient information to craft FERC license articles and a 401 Water Quality Certificate that adequately protects the local, regional and national treasure that is the Connecticut River.

Sincerely,

Linda Dunlavy, Executive Director
Franklin Regional Council of Governments

Jerry Lund, Chair
Franklin Regional Planning Board

Tom Miner, Chair
Connecticut River Streambank Erosion Committee

cc: Congressman James McGovern
Franklin County Legislative Delegation

[25] Page 67 of Volume 1 – Study Report 3.1.2.

FirstLight Hydro Generating Company
NOAA – National Marine Fisheries
U.S. Fish and Wildlife Service
U.S. Army Corps of Engineers
Massachusetts Department of Environmental Protection
Massachusetts Division of Fisheries and Wildlife
Connecticut River Watershed Council
Franklin Conservation District
Windham Regional Commission
Landowners and Concerned Citizens for License Compliance
Town of Gill, MA Conservation Commission
Town of Northfield, MA Selectboard and Conservation Commission

Attachment 5. CRSEC Comments on Updated Study Report for Study 3.1.2 Causation Study

November 10, 2015

Franklin Regional
Council of Governments

CONNECTICUT RIVER STREAMBANK EROSION COMMITTEE

November 10, 2015

VIA ELECTRONIC FILING

Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project No. 2485-063
Turners Falls Project No. 1889-081
Comments on the 2015 Updated Study Report
Study 3.1.2 Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability

Dear Secretary Bose:

Study 3.1.2, Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability, the so-called "Causation Study," is a critical relicensing document of great importance to the Connecticut River Streambank Erosion Committee (CRSEC) and the Franklin Regional Council of Governments (FRCOG). The Approved Study Plan calls for evaluating the causes of erosion in the Turners Falls Impoundment, determining if they are related to project operations, and identifying measures to stabilize the sites. To accomplish this, FirstLight is collecting data on the susceptibility of riverbanks in the Turners Falls Impoundment to erosion and will seek to allocate responsibility, i.e., causes, for the erosion. Below are our comments on the progress of this study as described in FirstLight's Updated Study Report (USR) dated September 14, 2015.

When we commented on the Initial Study Report for Study 3.1.2, we expressed our concerns with FirstLight's request to withhold details and data for the causation study from stakeholder review until March 2016 (see letter dated November 14, 2014). The Initial Study Report issued on September 15, 2014 provided little or no information to stakeholders and one year later, the 2015 Updated Study Report contains little or no information, even for tasks reported as complete. There is an inherent public interest in the timely issuance of substantive progress reports so that stakeholders and the Commission can review and comment on data that will be the underpinning of findings and recommendations affecting the new project license.

We appreciate that in January 2015, FERC recommended that FirstLight file a progress report after the completion of each of the seven tasks included in Approved Study Plan for Study 3.1.2.[1] Unfortunately, FirstLight filed their first progress report on August 18, 2015, one month before the release of the Updated Study Report Summary so both documents contained the same information (or lack of).

We note for the record that the 2015 August Progress Report filed by FirstLight did not meet the requirements of §5.11(b)(3), "[P]rovisions for periodic progress reports, including the manner and extent to which information will be shared; and **sufficient time for technical review of the analysis and results**; (emphasis added)…". Once again, FirstLight has effectively stymied, if not precluded, stakeholders' ability to provide comments on Study Plan 3.1.2 within the timeframe dictated by the ILP by: 1) not issuing timely Progress Reports and 2) providing an Initial Study Report (ISR) in 2014 and the 2015 Updated Study Report (UDR) that are both remarkable in their lack of information.

Section 5.15 of the Commission's regulations provides "**an opportunity for all stakeholders to review and comment on the Initial Study Report and to seek improvements where appropriate**" (emphasis added). Stakeholders and FERC staff are not able to provide substantive comments or seek improvements where appropriate for many of the tasks for Study Plan 3.1.2 because FirstLight continues to provide very little information about the methodologies and work conducted under each task. Another field season has passed and again, FirstLight has prevented stakeholders from being effective participants in the relicensing process.

With this introduction, CRSEC offers the following comments on the Updated Study Report Summary for Study 3.1.2. We also include specific requests of FERC, where appropriate.

- <u>No mention of Study Plan Determination Letter (SPDL) Task Regarding Operational Changes</u>. On page B-3 of FERC's September 13, 2013 Study Plan Determination Letter (SPDL), the Commission stated that a longer term trend analysis would inform our understanding of the erosional responses to changes in operation (section 5.9(b)(5)) and provide data for the development of license conditions. FERC recommended that FirstLight include an analysis of operational changes for the period 1999 to 2013 to identify any correlation between operational changes and observed changes in erosion rates and that this analysis be conducted as a part of Study 3.1.2.

  As we noted in our November 14, 2014 comment letter on the ISR, FirstLight provided no information about when this analysis would be done, what the methods might be, or what the final product would look like. One year later, there is still no discussion of how this analysis would be done and incorporated in Study 3.1.2. Stakeholders are once again being denied the ability to review this task or seek improvements to it.

  <u>Request</u>: FirstLight be directed to describe the methodology for this analysis; conduct this analysis; and identify how it will use the information.

[1] FERC's January 22, 2015 Determination on Requests for Study Modifications and New Studies – Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project.

- Task 2: Geomorphic Understanding of the Connecticut River. This is a critical issue for stakeholders and for the ILP. According to the September 13, 2013 SPDL issued by FERC (page B-5), FirstLight provided little detail in their Study Plan regarding the proposed historical trend analysis of bank conditions. To provide more detailed methodology (§5.9(b)(6)), FERC recommended that FirstLight perform its historic geomorphic assessment using available mapping such as the 1970 vintage ground survey of the impoundment as a base map (Exhibit K drawings), comparing it against more recent aerial imagery and available survey data to analyze trends in bank position over time.

In our November 14, 2014 ISR comment letter, the CRSEC requested a complete description of the methodology for this SPDL task and that this information be provided in a Progress Report issued on or before January 31, 2015. This request was not honored. Instead, on March 31, 2015, FirstLight filed a 2015 Quarter 1 Data Deliverable with FERC, which included a discussion of FirstLight's unsuccessful attempts to use the Exhibit K drawings to analyze trends in bank position over time (page A-3) along with a statement that FirstLight "...is currently examining the availability of other historic datasets that could be used for context when discussing the historic geomorphology of the Connecticut River". FirstLight provided no additional information in their Updated Study Report (USR) Summary or when requested to elaborate on this topic at the USR meeting on September 30, 2015. Instead, page 4 of the USR repeats that, "FirstLight is currently examining the availability of other historic datasets that could be used for context when discussing the historic geomorphology of the Connecticut River."

With identical wording between March and September 2015, FirstLight has apparently been reviewing historic datasets for the last six months, with no discernable progress made on this task. CRSEC is concerned that FirstLight is not making meaningful attempts to complete this task as directed by FERC. Moreover, it has now been two years since FERC issued its Study Plan Determination requiring FirstLight to analyze trends in bank position over time. Stakeholders and FERC have still not been provided with information about FirstLight's methodology and data sources.

To be clear, FERC required FirstLight to "analyze trends in bank position over time", a task that requires a detailed, methodical approach. This task is not a general discussion of the "historic geomorphology of the Connecticut River". FirstLight can use the Exhibit K drawings to analyze trends in bank position over time and there are other standard, scientifically accepted methods that FirstLight could use to satisfy the FERC requirement.

For example, TransCanada's USR for their Study 1-Historical Riverbank Position and Erosion Study summarizes what they have done in a simple statement: "A comparison of digitized erosion maps from 1958 and 1979 shows how erosion locations have changed through time and where portions of the riverbank stabilized. Despite variations in location, the overall amount of erosion between 1958 and 1979 remained relatively unchanged. Digitized bank lines created from georeferenced historical aerial photographs from the 1940's, 1950's, 1970's, and 2010 (Kleinschmidt, 2011) were used to calculate the amount and rate of bank erosion along the river."

Request: FirstLight be directed to provide a detailed description of the methodology for the analysis of trends in bank positon over time. We've provided a list of available information and analytical methods that can be used to complete this required analysis. We request that FirstLight incorporate these datasets and methods into their methodology pursuant to FERC's directive to use "available mapping" and "recent aerial imagery and available survey data" pursuant to the September 2013 SPDL.

1. FirstLight should submit a list of the historical information to be evaluated, including: property maps, aerial photographs, and other maps and information that can be compared to assess river channel movement and erosion over time. This is a generally accepted document research methodology. These sources can be digitized and geo-referenced so that different maps can be compared. Large-scale, qualitative analyses and identification of significant areas of bank retreat, bar formation, and channel migration should be possible. The 2007 Field Report commissioned by FirstLight contained aerial photos in .tif format from 1961, 1971, and 1980 in a CD appendix.

2. Use the approach discussed in the Northrop, Devine & Tarbell, Inc. (NDT) 1991 Connecticut River Riverbank Management Master Plan for P-2485 and P-1889 to measure erosion (bank position) over time. This approach used measurements of bank position relative to fixed structures, aerial photographs from **1939, 1952, 1966, 1973, 1980 and 1990**, and made adjustments for various dam crest elevations and river top widths to create a common baseline from which to compare measurements.

   NDT solved the problem FirstLight had with determining the location of the water surface elevations on the Exhibit K drawings and the "problem with where the water level is over time"[2] on the historic aerial photographs by using a hydraulic backwater model to calculate the water surface elevations for various dam crest elevations and different flows that corresponded to the river conditions when the aerial photographs were flown. According to NDT, these calculated water elevations "enable the adjustment of the measured bank positions to a common datum", which provide more accurate comparisons of bank position over time. FirstLight now has several calibrated hydraulic models and should be able to run a series of backwater simulations that correspond to historic aerial photographs.

3. FirstLight has data for the 22 permanent transects that go back to 1990, not 1999 as indicated in its January 22, 2013 filing with FERC. This dataset represents 25 years of bank position at these locations (including surveys done through 2015). In our January 9, 2015 filing with FERC, CRSEC requested that FirstLight provide transect data in a useful format with just the left and right bank shown in cross-section at a scale that makes evaluating trends in bank position over time actually possible. To date, this information has not been provided. This request also has implications for compliance with the current license as we described in our January 9th letter.

[2] See comments of Bob Simons on page 22 of the September 30, 2015 USR Meeting Summary – text under Study 3.1.2.

4. We note that the data for the 22 permanent transects include the water surface elevation at the time the survey was conducted. This information can be used along with more recent aerial photographs (1990-2015) and other available data sets to evaluate trends in bank position for larger sections of the riverbank over the last 25 years.
5. LIDAR mapping from April 26-28, 2013 (leaf off) is available from TransCanada, and FirstLight has already obtained it and used it for Study 3.2.2 (see page 2-8 of the Hydraulic Study). This data should be used for Task 2 of the causation study (Study 3.1.2).
6. Review of the methods involved in the Massachusetts Shoreline Change Project. Though this is a study of coastal erosion, it nevertheless involves overlaying aerial photos as well as LIDAR images over time and incorporating actual transects, all amidst a water level that changes on a sub-daily basis, just like the Connecticut River in the Turners Falls pool. A technical paper put out by the USGS, Open File Report 2012-1189 (online at http://pubs.usgs.gov/of/2012/1189/), lays out the methodology for this analysis. This methodology could be reviewed by FirstLight for consideration in this study requirement. The page for the Shoreline Change Project has an image of what a map showing shorelines and transects could look like: http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/shoreline-change/

- Task 3: Causes of Erosion. There is no mention in the USR of background research in preparation for this winter's required ice study. In the Study 3.1.2 Addendum dated August 12, 2014, also submitted as an appendix to the ISR, FirstLight said that they would research the U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory (CRREL) database, and contact the U.S. Geological Survey (USGS) and TransCanada regarding any information about icing along the Connecticut River. This information search was to be completed in "early 2015."

  In comments dated September 11, 2014, the Connecticut River Watershed Council (CRWC) wrote to FirstLight saying that CRREL had sent CRWC several useful papers. However, in the USR there is no mention of FirstLight contacting CRREL, USGS, or TransCanada about ice effects on the river, and the list of references included in updates and the USR from FirstLight continues to repeat only the study on the Platte River from Simons & Associates dated 1990. The references that CRWC received from CRREL include the following two papers. In addition, there were papers on ice jams and flooding on different sections of the Connecticut River, as well as papers on the process of ice breakup and sediment transport of rivers under ice cover.

  - Prowse, Terry. 2001. River-Ice Ecology. I: Hydrologic, Geomorphic, and Water-Quality Aspects. Journal of Cold Regions Engineering, 15:1-16. March 2001.
  - Ettema, Robert. 2002. Review of Alluvial-channel Responses to River Ice. Journal of Cold Regions Engineering, 16: 191-217. December 2002.

Request: CRSEC requests that FirstLight be required to produce a description of their efforts to research ice along the Connecticut River, and to incorporate relevant and more recent literature related to icing along river banks, such as the ones provided to CRWC from CRREL.

- Task 5 Data Analyses: We object to the variance in methodology for Task 5b that FirstLight has undertaken. FirstLight selected a new boat wave model and proceeded with field studies associated with this variance without consulting FERC or stakeholders.

Task 5b: Evaluation of Hydrodynamic Forces Due to Boat Waves. FirstLight has deviated significantly from this task as it was described in the Approved Study Plan (pages 3-42 through 3-43) and Table 3.1.2-3: Potential Primary Causes of Erosion and Related Analyses. We object to the manner in which FirstLight proceeded with this variance in the study plan. Stakeholders have been prevented from meaningful participation in the ILP; specifically, an opportunity to comment before the work associated with the variance was undertaken.

The first mention of a variance in the boat wave study was in FirstLight's August 18, 2015 Progress Report No. 1, which simply stated "yes" in a box under variances and said "supplemental boat wake data collection." Section 1.3 of the USR (pages 7-8) describes a complicated process for collecting the additional boat wave data and states that "[i]n early 2015, ...it was determined that the historic boat wave data was insufficient for inclusion in BSTEM." We question the timing of this decision being so close to the end of the first field season and submission of Initial Study Reports. The FRCOG hired an expert review of BSTEM, and if we had been aware of FirstLight's intentions to use a new BSTEM sub-model that evaluates boat waves, we would have asked our consultants to comment on the boat wave model. Once again, FirstLight has blocked stakeholders from fully participating and having an opportunity to review and comment on the variance and to seek improvements where appropriate.

It is clear that FirstLight had adequate time to consult with stakeholders prior to implementing the additional field work that was conducted between May and September 2015. There was also ample time to discuss with FERC and stakeholders the merits of using the new sub-model available for BSTEM that analyzes boat wake impacts versus the approach described in the Approved Study Plan.[3]

Request: FERC direct FirstLight to perform the boat wave analysis as described in the Approved Study Plan for Task 5b. Further, FirstLight be required to provide the following additional information about the variance for Task 5b:

1. Discussion of why the approach for Task 5b as originally described in the Approved Study Plan is no longer valid or why this additional work was needed to supplement Task 5b.

[3] "A sub-model that can account for the effect of boat waves on bank erosion has also been recently developed and incorporated into BSTEM through collaboration between Cardno and the National Centre for Computational Hydroscience Engineering (University of Mississippi). This addition marks an advancement in the modelling of stream banks and shorelines by providing the ability to quantify undercutting of banks due to the impact of boat waves." http://www.cardno.com/en-au/AboutUs/Pages/Cardno-model-helps-tackle-stream-bank-erosion.aspx Accessed November 9, 2015.

2. Detailed information about the boat wave sub-model for BSTEM, including data input requirements and the "custom developed image processing tool" mentioned on page 7 of the USR.
3. How the difference in time intervals for the collected boat wave data is being handled. The water surface elevation data is input as hourly figures while the boat wave data is collected every 15 minutes. We raised a concern at the USR meeting on September 30, 2015 that the boat wave data not be input in such a manner that it ends up being cumulative for each hour (four (4) 15-minute intervals). The consultants could not explain how the boat wave data was handled and input into the BSTEM sub-model (see pages 23 and 24 of the September 30, 2015 USR Meeting Summary prepared by FirstLight, which we note for the record does not clearly articulate the CRSEC's concern). This is troubling. The data set will be manipulated in some manner, yet to be described, to match the hourly time step of the rest of the BSTEM inputs.
4. It was stated at the September 30, 2015 USR meeting that boat wave data collected in 2015 would be extrapolated in the sub-model over the same 14-year interval of the other BSTEM input data. Without an explanation of how this can reasonably and accurately be done, this is troubling and could significantly skew the model output. A sensitivity analysis should be provided.
5. Literature citations for peer reviews and other scholarly articles about the application of the BSTEM boat wave sub-model. We could only find information about the sub-model on Cardno's website. See footnote #3, below.
6. The rationale for choosing the 3 monitoring locations described on page 7 of the USR and why data was collected on a different time-step than other BSTEM inputs. We note that the Approved Study Plan for Task 5b states that data will be collected at a sub-set of the fixed riverbank transects (2 to 3 sites) over a range of flow conditions. This doesn't appear to be the case for the 3 new monitoring locations chosen for the BSTEM sub-model.

- <u>Task 5c: Spatial Analysis</u>. The Approved Study Plan for this task states that spatial analysis of the causes of erosion will be conducted based on various GIS datasets and geoprocessing tools, aerial imagery, **2013 FRR results**, as well as other pertinent data. CRSEC continues to believe that Study 3.1.1 (2013 Full River Reconnaissance - FRR) was completed in a way that differed from the Approved Study Plan. In particular, the study did not use the Study Plan's and the QAPP's definition of "stable" in making study conclusions. "<u>Stable</u>" is defined in the 2013 FRR as "<u>riverbank segment does not exhibit types or indicators of erosion</u>."

  Using FirstLight's data and assessment of each segment from the 2013 FRR, we conclude that only 43.3% of the banks meet their definition of stable, in that it does not have a "type" or an "indicator" of erosion associated with that segment. In other words, over 50% of the banks exhibit types or indicators of erosion, a startling finding.

Conclusion

As we stated in our November 14, 2014 letter on the ISR for Study 3.1.2, the so-called "Causation Study", the findings and conclusions of this study are of the utmost importance to the CRSEC and other local stakeholders. Study 3.1.2 focuses on project impacts that directly affect landowners and natural resources of singular value to our region. We have watched as hundreds of acres of prime agricultural riverside soils have been consumed by bank erosion since the Project began operation over 40 years ago. Based on the questionable methodology and biased conclusions of the 2013 Full River Reconnaissance (Study 3.1.1), we continue to be concerned about the integrity of Study 3.1.2. We believe that FirstLight's unwillingness to be transparent about the progress of study tasks and the unilateral decision to significantly deviate from the Approved Study Plan for Task 5b undermine stakeholders' confidence in the study results. We hope that FirstLight's lack of transparency and cooperation is also of concern to FERC.

At several points in these comments we have explained how our participation in the ILP has been hindered or completely prevented by FirstLight. We conclude our comments with a request that FERC recognize our long-standing commitment to and advocacy for the towns, landowners, and the natural and cultural resources affected by erosion in the Turners Falls Pool and direct FirstLight to respond to the specific requests described herein to enable our continued and meaningful participation in the ILP.

Sincerely,

Tom Miner, Chair
Connecticut River Streambank Erosion Committee

Linda L. Dunlavy, Executive Director
Franklin Regional Council of Governments

Cc: Congressman James McGovern
Franklin County Legislative Delegation
FirstLight Hydro Generating Company
NOAA – National Marine Fisheries
U.S. Fish and Wildlife Service
Connecticut River Atlantic Salmon Commission
U.S. Army Corps of Engineers
Massachusetts Department of Environmental Protection
Massachusetts Division of Fisheries and Wildlife
Connecticut River Watershed Council
Franklin Conservation District
Windham Regional Commission
Landowners and Concerned Citizens for License Compliance
Town of Gill, MA Conservation Commission
Town of Northfield, MA Selectboard and Conservation Commission
Town of Montague, MA Planning and Conservation Department
Connecticut River Greenway State Park

Attachment 6. CRSEC Comments on Addendum to Study 3.1.1 FRR

April 2, 2015

Franklin Regional Council of Governments

CONNECTICUT RIVER STREAMBANK EROSION COMMITTEE

April 2, 2015

Mr. John Howard
Director FERC Compliance, Hydro
FirstLight Power Resources, Inc.
99 Millers Falls Road
Northfield, MA 01360

Re: Northfield Mountain Pumped Storage Project No. 2485-063
Turners Falls Project No. 1889-081
Comments on Addendum to Study 3.1.1, the 2013 Full River Reconnaissance

Dear Mr. Howard:

The Connecticut River Streambank Erosion Committee (CRSEC) has reviewed the Addendum to the 2013 Full River Reconnaissance (FRR), a study related to both license compliance and Study 3.1.1 in the Integrated Licensing Process. FERC required an addendum be filed within 90 days of their January 22, 2015 "Determination on Requests for Study Modifications and New Studies for Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project." The Addendum was provided to CRSEC members electronically on February 24, 205, and two of our members were available to attend the meeting held on March 4, 2015. Our comments are as follows.

Comparison of 2007 and 2014 photo logs

A comparison of the photo logs from 2007 and 2014 was to have been part of Task 4 as written in the approved Revised Study Plan (RSP), but it was missing in Study 3.1.1. CRSEC member Connecticut River Watershed Council is on record for having commented that collecting a set of 2014 photos during the middle of summer was not valuable. Despite changes in technology since 2007 and difficulty repeating the same photos, the comparison is more valuable and interesting than we had expected. Looking at the changes in gross vegetation over time has some value, and we think it is interesting to see how some sites have filled in. Going forward, these photo logs can serve as a baseline for future work to document leaf on conditions and monitor changes over time.

2013 Full River Reconnaissance – 2015 Addendum: Riverbank Segment Quality Assurance (QA) Comparison

The 2013 FRR Quality Assurance Project Plan (QAPP) stated: "An appendix to the FRR report will include a comparison of the specific riverbank features and characteristics from the data logging files, or field data sheets, collected during the field surveys to a photograph of that same segment of riverbank captured from the digital geo-referenced video. A discussion will be presented in the FRR report based on this comparison. The process of comparing the data logging files to video/still images of a selected percentage of segments, or any segment of particular interest, provides a high level of quality assurance and control on the field data collection. This approach also provides a method for reference checking any subsequent interpretation of the field survey data after the survey has been completed."

This appendix was missing in the 2013 FRR submitted as Study 3.1.1 with the Initial Study Report in September 2014. The 2015 draft riverbank segment QA comparison submitted by FirstLight lacks key information that would "provide a high level of quality assurance" and a "method for reference checking any subsequent interpretation of the field survey data." A complete data set for the QA comparison should be provided so that FERC staff and stakeholders can replicate the QA methods and have a high degree of confidence in the results of the 2013 FRR.

Methods:

FirstLight looked at every 10th segment, identified gaps, and added six supplemental segments, for a total of 65 QA segments.[1] While FirstLight indicated they found gaps that led to adding certain segments, they did not indicate whether or not there was an over-abundance of any riverbank characteristic. FirstLight had said in their QAPP that the QA comparison would be done using video, but they used still images instead. FirstLight states that the QA analysis led to several revisions mainly consisting of adding indicators of potential erosion to segments, but did not change overall conclusions.

Analysis:

CRSEC continues to believe that sections of the 2013 FRR need to be re-done pursuant to section 5.15(d) of the Commission's regulations because the study was not conducted as provided for in the approved study plan. Specifically, the bank characterization (stage and extent of erosion) should be redone. Both the 2013 FRR and the QA comparison indicate that FirstLight did not follow the definitions laid out in Table 3.1.1-3 of the approved RSP dated August 14, 2013, for Study 3.1.1. Table 3.1.1-3 is attached to this letter.

For example, CRSEC has determined that 24 of the segments used in the QA analysis do not meet the definitions laid out in Table 3.1.1-3. These segments were classified as *stable* but had one or multiple *indicators of erosion* and often a *type of erosion* (e.g., undercut). In Table 3.1.1-3, stable is defined as "riverbank segment does not exhibit types or indicators of erosion." The 24 segments characterized as both "stable" and with an Erosion Type and/or Indicator of Erosion are: 20, 30, 40, 50, 110, 130, 160, 180, 240, 290, 320, 390, 400, 410, 430, 440, 450, 460, 510, 520, 530, 550, 279, and 89. The following table summarizes our analysis of the segments labeled as stable.

[1] CRSEC believes that stratified random sampling would have been a more effective sampling method to cover the entire Turners Falls impoundment and range of stream bank categories present, but we think that the methods that FirstLight used are adequate.

	# of Riverbank Segments (excluding islands)	# of Segments categorized as *Stable*	# "Stable" segments with an Erosion Type and/or Indicator of Erosion
2013 Full River Reconnaissance Report	596	459	226
2015 Addendum QA	65	47	24

Segment 230 (Addendum page A-76 and slides 21 and 22 of PowerPoint presentation for 3/4/15 meeting) exhibited three indicators of potential erosion. The stage of erosion is listed as "Potential Future Erosion" and the Extent of Current Erosion is listed as "Some," which is defined as 10-40% of the bank has active erosion. The bank indeed has erosion based on the photos. It appears that a fall has occurred where a tree that had been growing on the upper bank is now sitting on the lower bank. We are surprised that, on further analysis, it was not determined that this segment merited a state of erosion as "active erosion or eroded." When asked about this at the March 4, 2015 meeting, Bob Simons said that it was a good question, but he thought this segment had good indicators of erosion. To CRSEC, this is an indication that the FRR does not follow its approved RSP and is very subjective.

A review of the pictures and summary table information provided in the QA comparison indicates the stage and extent of erosion were not properly identified using the definitions in Table 3.1.1-3. We've discussed our concerns about characterizing banks as stable (stage of erosion). We also have concerns about the same segments being characterized as having none/little erosion (extent of erosion), which is defined as "generally stable bank where the total surface area of the bank segment has approximately less than 10% active erosion present". The stage and extent of erosion for the segments cannot be verified because FirstLight provided only partial information for each of the QA segments. We believe the data set for each QA segment should include:

1. The length of each segment clearly identified with start and end points. Part of the QA process should be verifying the characteristics that differentiate one segment from another. We noted in our November 14, 2014 comment letter that Extent of Erosion is highly dependent on the breakdown of river segments and how these segments were mischaracterized in the FRR segments.
2. The field data sheets and data logging files for each segment. This is the only record, other than photographs, of the river bank characteristics, including the stage and extent of erosion for each segment. (See our November 14, 2014 letter for a list of deliverables in the approved RSP that were not provided to stakeholders.)
3. All pictures for each segment, presented sequentially (downstream to upstream) and clearly labeled with the downstream and upstream limits of the segment and the riverbank features and erosion classifications pursuant to Table 3.1.1-3. We found that most segments are missing pictures or have pictures that show the same area. For example, the pictures for segment 10 are the same. We further note that the location of segment 10 on the map does not align with the location of the pictures included in the QA addendum.

The QA documentation for Segment 20 does not include a photo of the upstream portion of this segment and segments 450 and 520 do not have a complete photo log.

4. A discussion of how the stage and extent of erosion was determined. When viewed in their entirety, the pictures for each segment should clearly reflect the information in the QA summary table for each segment. Most of the QA segments indicate that the bank is "stable" with "none/little" erosion. These classifications do not meet the definitions in Table 3.1.1-3 and are not supported by the QA data presented by FirstLight. (See our November 14, 2014 comment letter that included a table of segments that had been mischaracterized by FirstLight.)

Using the definition from the approved RSP that "stable" is having no types or indicators of erosion, then only 233 segments of the 459 segments categorized as "stable" meet the definition of stable (459-226 from table above). These 233 segments add up to approximately 97,500 feet of river bank length, which is about 43% of the total river bank length (not including islands). This is in stark contrast to Table 6-1 in the FRR which stated that 83.5% of the length of river bank was categorized as "stable."

Based on the information provided in the FRR Addendum, the QA/QC effort did not correct the error of interpreting stage and extent of erosion categorization differently from the definitions laid out in the approved RSP. CRSEC continues to assert that the 2013 FRR was not conducted as written in the approved RSP and instead was conducted based on subjectivity skewed to interpreting the banks as stable. The stages of erosion and extent of erosion for the 2013 FRR should be re-calculated according to FirstLight's own definition of the stages and extent (Table 3.1.1-3).

In summary, the QA addendum and the interpretation of the data collected for the 2013 FRR do not support the conclusion of overall bank stability reached by FirstLight.

Thank you for the opportunity to comment.

Sincerely,

Tom Miner
Chair
Connecticut River Streambank Erosion Committee

Linda L. Dunlavy
Executive Director
Franklin Regional Council of Governments

Cc: Congressman James McGovern
Franklin County Legislative Delegation
Kimberly Bose, FERC

FERC Project No. 2485-063

Brandon Cherry, FERC
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NOAA – National Marine Fisheries
U.S. Fish and Wildlife Service
Connecticut River Atlantic Salmon Commission
U.S. Army Corps of Engineers
Massachusetts Department of Environmental Protection
Massachusetts Division of Fisheries and Wildlife
Connecticut River Watershed Council
Franklin Conservation District
Windham Regional Commission
Landowners and Concerned Citizens for License Compliance
Town of Gill, MA Conservation Commission
Town of Northfield, MA Selectboard and Conservation Commission

ATTACHMENT: Table 3.1.1-3

Table 3.1.1-3: Riverbank Classification Definitions

RIVERBANK CHARACTERISTICS *(Upper and Lower)*[9]	
Riverbank Slope	**Overhanging** – any slope greater than 90º
	Vertical – slopes that are approximately 90º
	Steep – exhibiting a slope ratio greater than 2 to 1
	Moderate – ranging between a slope ratio of 4 to 1 and 2 to 1
	Flat – exhibiting a slope ratio less than 4 to 1[10]
Riverbank Height	**Low –** height less than 8 ft above normal river level[11]
	Medium – height between 8 and 12 ft above normal river level
	High – height greater than 12 ft above normal river level
Riverbank Sediment	**Clay –** any sediment with a diameter between .001 mm and 2 mm
	Silt / Sand – any sediment with a diameter between .062 mm and 2 mm
	Gravel – any sediment with a diameter between 2 mm and 64 mm
	Cobbles – any sediment with a diameter between 64 mm and 256 mm
	Boulders – any sediment with a diameter between 256 mm and 2048 mm
	Bedrock – unbroken, solid rock
Riverbank Vegetation	**None to Very Sparse –** less than 10% of the total riverbank segment is composed of vegetative cover
	Sparse – 10-25% of the total riverbank segment is composed of vegetative cover
	Moderate – 25-50% of the total riverbank segment is composed of vegetative cover
	Heavy – 50 % or greater of the total riverbank segment is composed of vegetative cover
Sensitive Receptors	Descriptions of important wildlife habitat use on or near the riverbank such as bank swallow colonies, kingfisher nests, eagle nests, prime odonate and mussel habitat, etc.
EROSION CLASSIFICATIONS	
Type(s) of Erosion[12]	**Falls –** Material mass detached from a steep slope and descends through the air to the base of the slope. Includes erosion resulting from transport of individual particles by water.
	Topples – Large blocks of the slope undergo a forward rotation about a pivot point due to the force of gravity. Large trees undermined at the base enhance formation.
	Slides – Sediments move downslope under the force of gravity along one or several discrete surfaces. Can include planar slips or rotational slumps.
	Flows – Sediment/water mixtures that are continuously deforming without distinct slip surfaces.
Indicators of Potential Erosion	**Tension Cracks –** a crack formed at the top edge of a bank potentially leading to topples or slides (FGS, 2007)
	Exposed Roots – trees located on riverbanks with root structures exposed, overhanging.
	Creep – defined as an extremely slow flow process (inches per year or less) indicated by the presence of tree trunks curved downslope near their base (FGS, 2007)
	Overhanging Bank – any slope greater than 90º
	Notching – similar to an undercut, defined as an area which leaves a vertical stepped face presumably after small undercut areas have failed.
	Other – Indicators of potential erosion that do not fit into one of the four categories listed above will be noted by the field crew.
Stage(s) of Erosion	**Potential Future Erosion –** riverbank segment exhibits multiple or extensive indicators of

[9] All quantitative classification criteria (e.g. slope, height, vegetation, extent, etc.) will be based on approximate estimates made during field observations of riverbanks. The FRR is a reconnaissance level survey that will not include quantitative analysis.
[10] Beaches are defined as a lower riverbank segment with a flat slope
[11] For the purpose of this study, Normal Water Level will be defined as water levels within typical pool fluctuation levels, but below Ordinary High Water (186').
[12] FGS, 2007

	potential erosion
	Active Erosion – riverbank segment exhibits one or more types of erosion as well as evidence of recent erosion activity
	Eroded – riverbank segment exhibits indicators that erosion has occurred (e.g. lack of vegetation, etc.), however, recent erosion activity is not observed. A segment classified as Eroded would typically be between Active Erosion and Stable on the temporal scale of erosion.
	Stable – riverbank segment does not exhibit types or indicators of erosion
Extent of Current Erosion	**None/Little**[13] **–** generally stable bank where the total surface area of the bank segment has approximately less than 10% active erosion present.
	Some – riverbank segment where the total surface area of the bank segment has approximately 10-40% active erosion present
	Some to Extensive – riverbank segment where the total surface area of the bank segment has approximately 40-70% active erosion present
	Extensive – riverbank segment where the total surface area of the bank segment has approximately more than 70% active erosion present

[13] Riverbanks consist of an irregular surface and include a range of natural materials (silt/sand, gravel, cobbles, boulders, rock, and clay), above ground vegetation (from grasses to trees), and below ground roots of different densities and sizes. Due to these characteristics, there are small areas of disturbance which often occur at interfaces between materials, particularly in the vicinity of the water surface. These small disturbed areas can be considered as erosion, or sometimes can result from deposition or even eroded deposition. No natural riverbank exists which does not have at least some relatively small degree of disturbance or erosion associated with the natural combination of sediment types/sizes and vegetation. As such, the extent of erosion for generally stable riverbanks that include these relatively small disturbed areas is characterized as little/none.

Attachment 7. U.S. Army Corps HEC-RAS USDA-ARS Bank Stability & Toe Erosion Model (BSTEM) Technical Reference and User's Manual

March, 2015

US Army Corps
of Engineers
Hydrologic Engineering Center

HEC-RAS
USDA-ARS Bank Stability & Toe Erosion Model (BSTEM)

Technical Reference & User's Manual

March 2015

CPD-68B

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14. ABSTRACT
The HEC-RAS (Hydrologic Engineering Center's (HEC) River Analysis System) software has included mobile bed capabilities since Version 4.0. These capabilities compute vertical bed changes in response to dynamic sediment mass balance and bed processes. However, many riverine sediment problems involve lateral bank erosion that does not fit in the current computational paradigm. The Bank Stability and Toe Erosion Model (BSTEM) developed by the National Sediment Laboratory, United States Department of Agriculture (USDA), Agricultural Research Station (ARS) is a physically based model that accounts for the dominant stream bank processes but requires an intermediate level of complexity and parameterization. This method was selected for implementation in HEC-RAS.

15. SUBJECT TERMS
HEC-RAS, BSTEM, USDA-ARS, Bank Stability & Toe Erosion Model, bank failure, soil forces, failure block, hydrostatic, pore water pressure,

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HEC-RAS
USDA-ARS Bank Stability & Toe Erosion Model (BSTEM)

DRAFT

Technical Reference & User Manual

February 2015

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CPD-68B

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Background

The HEC-RAS (Hydrologic Engineering Center's (HEC) River Analysis System) software has included mobile bed capabilities since Version 4.0. These capabilities compute vertical bed changes in response to dynamic sediment mass balance and bed processes. However, many riverine sediment problems involve lateral bank erosion that does not fit in the current computational paradigm. There are a number of published methodologies for computing bank failure. The methodologies span a spectrum from basic angle of repose methods that require very few parameters but simplify bank processes considerably, to comprehensive geotechnical bank stability models that require a full suite of geotechnical parameters yet lack a framework for hydraulic toe feedbacks. The Bank Stability and Toe Erosion Model (BSTEM) developed by the National Sediment Laboratory, United States Department of Agriculture (USDA), Agricultural Research Station (ARS) is a physically based model that accounts for the dominant stream bank processes but requires an intermediate level of complexity and parameterization. This method was selected for implementation in HEC-RAS.

BSTEM (Simon, 2000; Langendoen, 2008; Simon, 2010) couples iterative, planer bank failure analysis based on a fundamental force balance, with a toe scour model that allows feedback between the hydraulic dynamics on the bank toe which could exacerbate failure risk (in the case of toe scour) or decrease failure risk (in the case of toe protection). The goal of coupling HEC-RAS with BSTEM is to build a model that simulates feedbacks between bed and bank processes. For example, if HEC-RAS computes a decrease in the regional base level or local channel scour it will decrease bank stability and increase the risk of a failure. Similarly, when a bank does fail, the bank material will be added to the sediment mass balance of the mobile bed model which will simulate the river's capacity to "metabolize" and transport these point sources.

USDA-ARS Bank Stability and Toe Erosion Model (BSTEM) in HEC-RAS

Technical Reference Manual

As the name suggests, BSTEM includes two major, interacting components, a bank failure model and toe scour algorithms:

1. **Bank Failure:** A geotechnical bank failure model computes failure planes through the bank to determine if the gravitational driving forces exceed the frictional resisting forces (and the interactions of pore water pressure).

2. **Toe Scour:** An erosion model simulates lateral bank migration, hydraulic forces that undercut the bank. As the toe scours, the bank becomes less stable, so toe scour can initiate bank failure.

These two processes also interact with a third process native to the classic sediment methodology in HEC-RAS computations:

3. **Vertical Erosion or Deposition:** The vertical adjustment of the cross section can also decrease the stability of the bank and interact with toe scour computations. Conversely, a large bank failure could add enough sediment mass to the system to deposit downstream and increase the stability of downstream banks.

Modeling the interactions and feedbacks between these three processes were the main motivation for including the USDA-ARS BSTEM algorithms into HEC-RAS. The science, methods and math of vertical erosion and deposition are covered in the HEC-RAS User's Manual (HEC, 2016a) and the HEC-RAS Hydraulic Reference Manual (HEC, 2016b).

TR.1 Bank Failure

The bank failure methods employ classical, planar, analyses to compare gravitational driving forces of the soil, soil water and overburden, and frictional resisting forces (including the influences of pore water pressure) to determine the most likely failure plane through the bank and to compute whether that failure plane is stable. If the weakest failure plane is unstable, the bank fails and the sediment from the failed bank is added to the sediment transport model.

The bank stability model goes through a series of iterative computations to select potential failure planes, evaluate the factor of safety, and converge on the failure plane most likely to fail by following the following steps:

1. Find the Factor of Safety (FS) for nodes at several vertical locations on the bank.
2. Select the bounding Failure Planes (minimum and maximum angles) and compute a critical factor of safety (FS_{cr}) for each vertical location (in Step 1).

3. Select a most probable critical failure plane ($FS_i \sim FS_{cr}$)
4. Compute the FS_i
5. Use that information to update the critical failure plane ($FS_{i+1} \rightarrow FS_{cr}$) using the "bracket and Brent" optimization algorithm (Teukolsky, 2007)
6. Decide when the FS is close enough to FS_{cr} to stop
7. If FS_{cr} is less than one, fail the bank, update the cross section, and transfer the bank sediments to the routing model

The failure plane selection and optimization algorithms are covered Sections TR.1.1 and TR1.1.2. Since most of the physical algorithms are embedded in the FS computation for each failure plane (Step 3), the description starts with these basic physics and then moves to the optimization scheme.

BSTEM includes two computational approaches to computing the FS of a failure plane through the bank:

i. Layer Method
ii. Method of Slices

TR.1.1 Layer Method

The Layer Method is based on Simon (2000) and is the default method (Figure 1) in USDA-ARS BSTEM Version 5.4. This method was developed specifically for bank failure applications and is derived superficially to compute failure planes through vertically heterogeneous bank

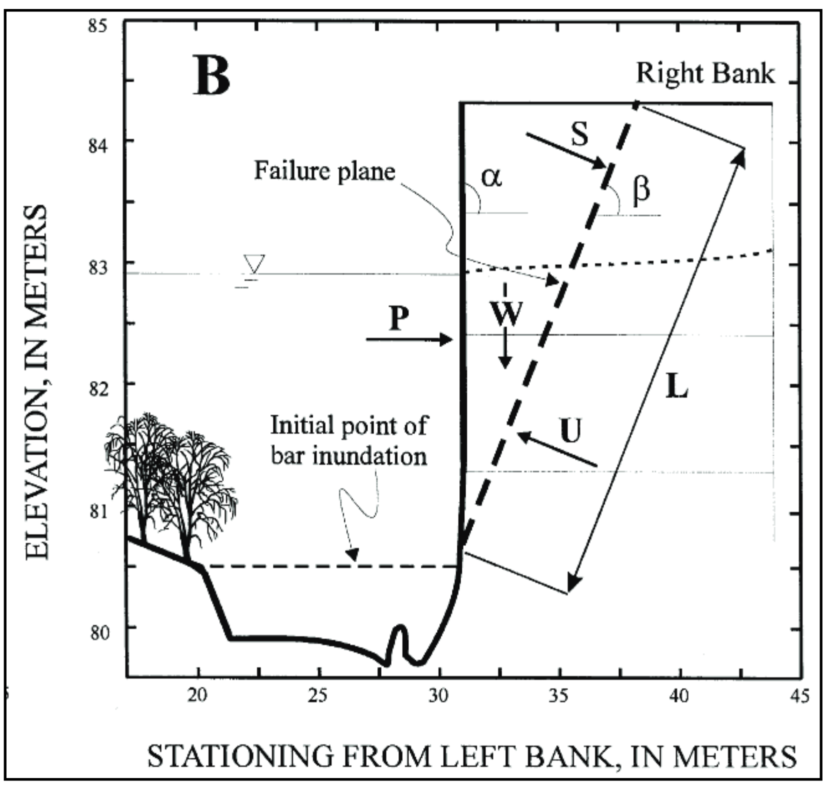

Figure 1. Force diagram for the "Layer Method" from Simon, 2000.

sediments. The layered configuration makes it easier to formulate a stability equation for bank sediments divided into discrete horizontal layers (which is the basic configuration of BSTEM stratigraphy). The Layer Method also eliminates one cycle of iteration required in the Method of Slices, which reduces runtimes in long simulations.

The Layer Method solves a non-iterative equation (Equation 1, Layer Method Force Balance) for the FS that compares driving forces to resisting forces:

$$FS = \frac{\sum_{i=1}^{I}\left(c'_i L_i + S_i \tan\phi_i^b + \left[W_i \cos\beta - U_i + P_i \cos(\alpha-\beta)\right]\tan\phi'_i\right)}{\sum_{i=1}^{I}\left(W_i \sin\beta - P_i \sin[\alpha-\beta]\right)} \tag{1}$$

where:

- i = layer
- L = length of the failure plane
- S = matrix suction force
- U = hydrostatic uplift
- P = hydrostatic confining force of the water in the channel
- ϕ' = friction angle
- ϕ^b = relationship between matrix suction and apparent cohesion
- c' = effective cohesion
- b = angle of the failure plane

However, Equation 1 combines the driving forces in the numerator and resisting forces in the denominator, because both the numerator and denominator have negative components. Equation 2 displays the components of the Layer Method Force Balance equation, with the driving forces indicated in red and resisting forces in green.

$$FS = \frac{\sum_{i=1}^{I}\left(\overbrace{c'_i L_i}^{\text{Cohesion}} + \overbrace{S_i \tan\phi_i^b}^{\text{Suction}} + \overbrace{\left[\overbrace{W_i \cos\beta}^{\text{Weight of the soil}} \overbrace{- U_i}^{\text{Hydrostatic uplift}} + \overbrace{P_i \cos(\alpha-\beta)}^{\text{Confining force normal to failure plane}}\right]}^{\text{Frictional Resistance}}\tan\phi'_i\right)}{\sum_{i=1}^{I}\left(\underbrace{W_i \sin\beta}_{\text{Gravitational force along the inclination of the failure plane}} \underbrace{- P_i \sin[\alpha-\beta]}_{\text{Hydrostatic confining force acting against the weight}}\right)} \tag{2}$$

The forces in Equation 2 can be categorized into soil forces (weight of soil block, cohesion) and hydraulic forces (hydrostatic confining forces, pore water pressure). Equation 3 distinguishes the hydraulic and soil forces of the Layer Method Force Balance equation:

$$FS = \frac{\sum_{i=1}^{I}\left(\overset{\text{Soil}}{\boxed{c_i^{'}L_i}} + \overset{\text{Hydraulic}}{\boxed{S_i \tan\phi_i^{b}}} + \left[\overset{\text{Soil}}{\boxed{W_i \cos\beta}} \overset{\text{Hydraulic}}{\boxed{-U_i}} + \overset{\text{Hydraulic}}{\boxed{P_i \cos(\alpha-\beta)}}\right]\tan\phi_i^{'}\right)}{\sum_{i=1}^{I}\left(\underset{\text{Soil}}{\boxed{W_i \sin\beta}} \underset{\text{Hydraulic}}{\boxed{-P_i \sin[\alpha-\beta]}}\right)} \qquad (3)$$

TR.1.1.1 Soil Forces

Weight of the Soil in the Failure Block

The weight of the soil in the failure block is an instrumental parameter in both the driving and resisting forces. The gravitational force on the mass of the bank "inside" of the failure plane is the primary driver of bank failure. However, the component of this weight normal to the failure plane also increases the frictional resistance to failure.

$W_i \sin\beta$ = The component of the weight down the failure plane, driving the soil into the water.

$W_i \cos\beta \tan\phi_i^{'}$ = The frictional resistance of the soil along the failure plane, where:

$W_i \cos\beta$ = component of the weight normal to the failure plane

$\phi_i^{'}$ = friction angle (which can be measured in the laboratory with triaxial testing or *in situ* with borehole shear equipment).

Cohesion

Cohesion is the inter-particle attraction in a soil matrix. For very fine soils (generally less than 0.0625 mm), particularly those composed of clay minerals, the electrochemical forces between particles can be stronger than the frictional forces. These electrochemical binding forces resist failure in cohesive soils such that:

$c_i^{'}L_i$ = The effective cohesion per unit length $\left(c_i^{'}\right)$ acting along the length of the failure plane in a soil layer L_i. (Note: cohesion is actually a shear strength that acts over an area, but L_i becomes an area when it is projected along the stream wise or longitudinal direction).

TR.1.1.2 Hydraulic Forces

For hydraulic forces there are two terms that consider the weight of the water and two terms that consider the pore water pressure.

Hydrostatic Confining Forces

The terms that consider the force of the water in the channel:

$P_i \cos(\alpha - \beta) \tan\phi_i'$ = The normal component of the hydrostatic confining force of the water in the channel. This is a resisting force because it adds to the normal force acting on the failure plane and, therefore, increases the frictional strength.

$-P\sin(\alpha - \beta)$ = The component of the hydrostatic confining force acting along the failure plane against the direction of failure. The weight of the soil (the primary driving force) is reduced by this component.

α = is the angle between vertical and the vector the hydrostatic force (Figure 2) exerted by the channel water (orthogonal to the weighted average of the inundated bank slope) are both resisting forces

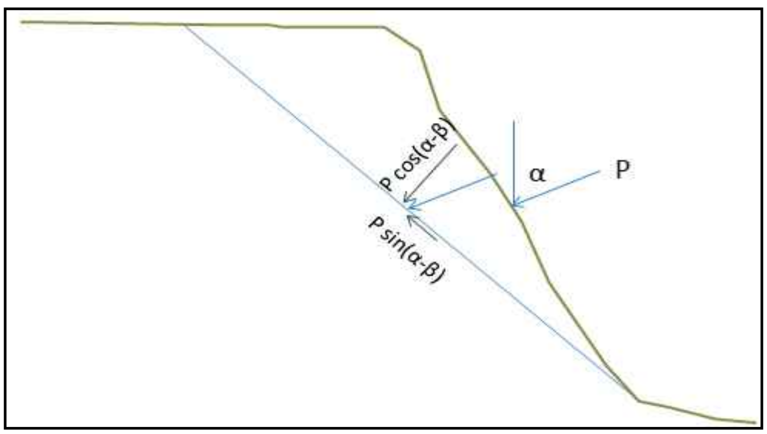

Figure 2. Components of the hydrostatic forces acting normal to and along the failure plane.

Pore Water Pressure

The pore water pressure is divided into two components in the numerator:

$-U_i \tan\phi_i'$ = Hydrostatic uplift force (buoyancy is a driving force while suction is a resisting force). Water exerts a vertical force on submerged sand grains, reducing the normal force along the failure plane and, therefore, the frictional resistance to failure. U_i is simply the hydrostatic force, which increases linearly with depth below the groundwater table (Figure 3). In the saturated zone $\phi_b = \phi'$ so the hydrostatic force is multiplied by tan ϕ' and can be included in the frictional term of the numerator.

$S_i \tan\phi_i^b$ = The suction forces increase the soil strength due to the development of negative pore water pressure in the unsaturated zone of the soil which pulls the soil grains together. In the unsaturated zone, as water drains, evaporates, transpires, and is not replaced with atmospheric air, negative pressures (suction) develop.

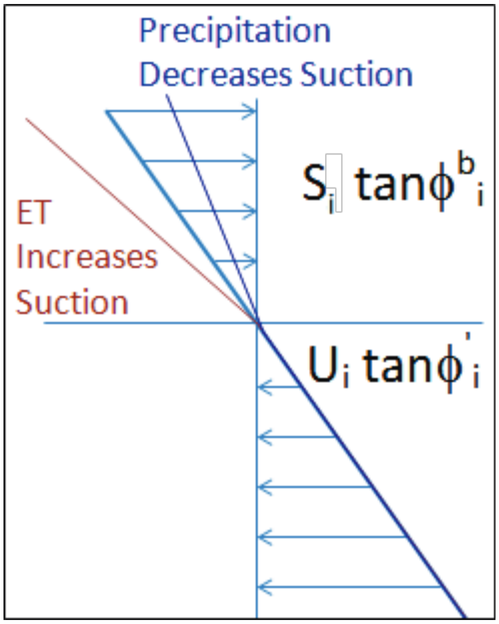

Figure 3. Idealized hydrostatic assumption of positive and negative pore water pressure with respect to the groundwater surface and potential empirical divergence from the assumption.

In general, suction S_i is estimated as a continuation of the hydrostatic force into the unsaturated zone. Suction increases with vertical distance above the water table at the same rate that the hydrostatic force increases with vertical distance below the water table. Positive and negative pore water pressures are assumed symmetrical around the water table. This is an idealized assumption, however, that only accounts for gravity draining. Precipitation and infiltration will add water to the unsaturated zone and decrease suction effects and evapotranspiration will increase negative pore water pressures. If these processes are important, unsaturated pore water pressures will have to be measured (e.g., with a tensiometer).

Translating negative pore water pressures or suction effects into a force in the free body diagram is the most empirical step of computing the factor of safety. Every other parameter can be measured directly or computed. However suction effects are accounted for with an empirical assumption analogous to the friction slope parameter. The suction is translated into "apparent cohesion", (the equivalent amount of cohesion required to produce the same resisting force as the soil suction). Apparent cohesion (Figure 4) is easily included in the force balance, but is not a physical parameter that can be measured and is very difficult to compute. The angle ϕ^b is simply the linear relationship between the matrix suction measured or computed and the corresponding equivalent cohesion force it represents. This angle can be computed but is heavily labor and data intensive to measure so it is often selected based on user judgment. For most materials ϕ^b is generally between ten to thirty degrees depending on soil type. Most applications use a base ϕ^b between ten and fifteen, but it goes to a maximum of the friction angle when the material is saturated (Fredlund, 1996). Since it is one of the least certain parameters it is often considered a calibration parameter.

If the water surface in the channel is close to the groundwater elevation the confining forces of the water in the channel offset most of the driving force of the interstitial water. However, if the

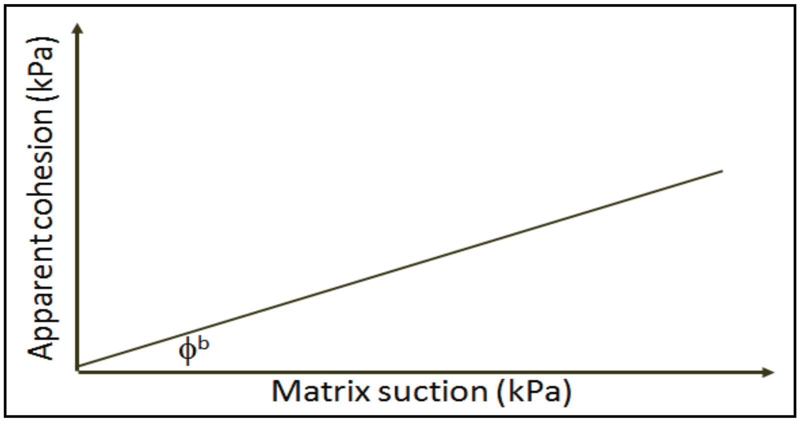

Figure 4. Relationship between measured or computed matrix auction and the empirical strength "apparent cohesion" defined by the ϕ^b parameter.

water in the channel is substantially lower than the soil water elevation (e.g., in the case of a rapid channel drawdown in poorly drained soils, leaving a perched groundwater table), the confining forces of the water will be removed while the driving forces (the weight of the water and the buoyant reduction in soil friction) remain. This is why the **critical failure condition** is often a case of substantial differential between groundwater and surface water elevations.

TR.1.2 Method of Slices

The Method of Slices algorithm included in HEC-RAS follows the more classical geotechnical approach to planar failure. The formulation of the method of slices for bank failure analysis comes from Langendoen (2008). Before the analysis the algorithm divides each user specified material layer into vertical slices of equivalent width (Figure 5). This ensures that the force and momentum balance computed for each segment of the failure plan will not include more than one material type.

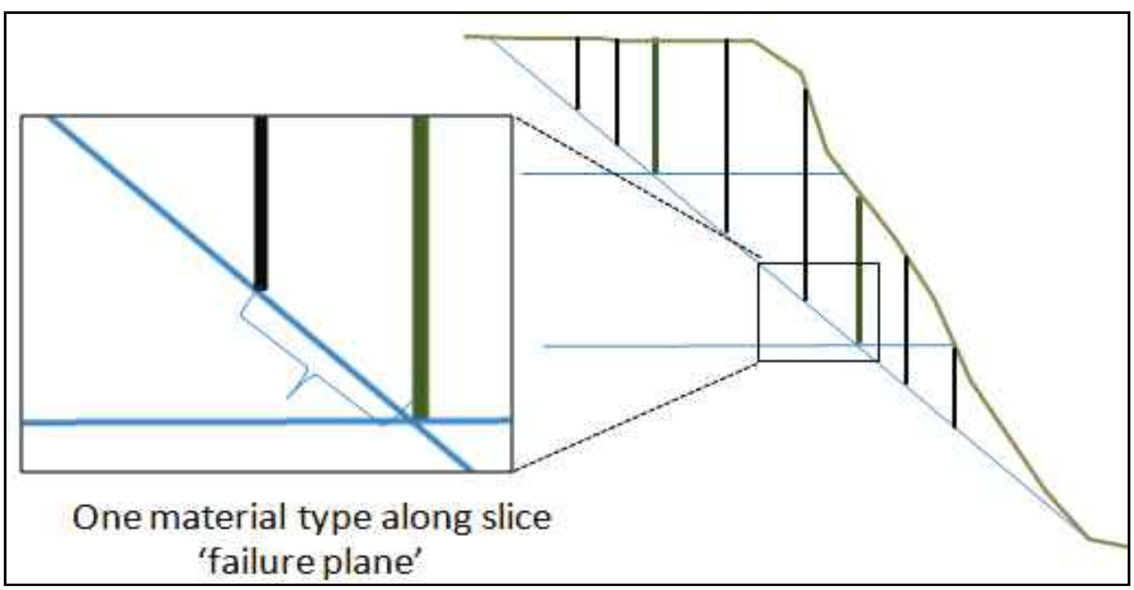

Figure 5. Subdivision of layers into slices. The failure block through each layer is divided into three slices of equivalent width.

The initial formulation of the method of slices (Bishop, 1955) considered forces acting at the base of each slice (along the failure plane) and included force (Figure 6) and momentum balances that were both vertical and normal to the slip surface. Morgenstern and Price (1965) added inter-slice forces in their analysis of earthen dams. The algorithms in USDA-ARS BSTEM for HEC-RAS include both inter-slice forces. The forces that act on each slice include: the weight of the slice W_j, the normal force acting on the base of the slice N_j, the shear force induced at the base of the slice S_j, inter-slice normal forces E_j, and the vertical shear forces between slices X_j.

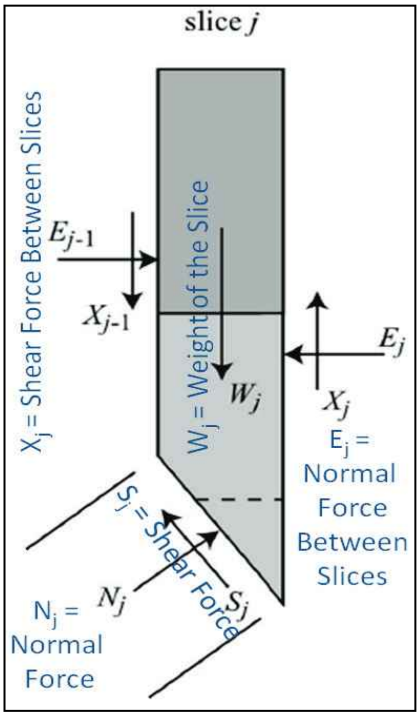

Figure 6. Forces acting on a slice.

E_j and X_j = The inter-slice normal (E_j) and shear (X_j) forces are unique to the method of slices and deserve attention before the algorithm is described. Calculating inter-slice normal forces (E_j) from a horizontal force balance on the slice is relatively straight forward (Equation 4, Inter-slice Shear Forces). However, there is not an elegant theoretical approach to computing inter-slice shear forces. Stress-strain soil data demonstrate that there is a reasonably reliable empirical relationship of the ratio of inter-slice normal (E_j) and shear (X_j) such that:

$$X_j = \lambda E_j f(x) = 0.4 E_j \sin\left(\pi x / L_x\right) \tag{4}$$

where:

λ = the maximum ratio (forty percent),

f(x) = a non-linear function between zero (0) and one (1) that apportions the ratio spatially,

x = the lateral distance into the bank

L = lateral width of the failure plane

In other words, at its maximum (in the center of the failure block) the shear force is forty percent of the normal force (Figure 7), and the shear-to-normal ratio decreases for slices farther from the center and closer to the margins.

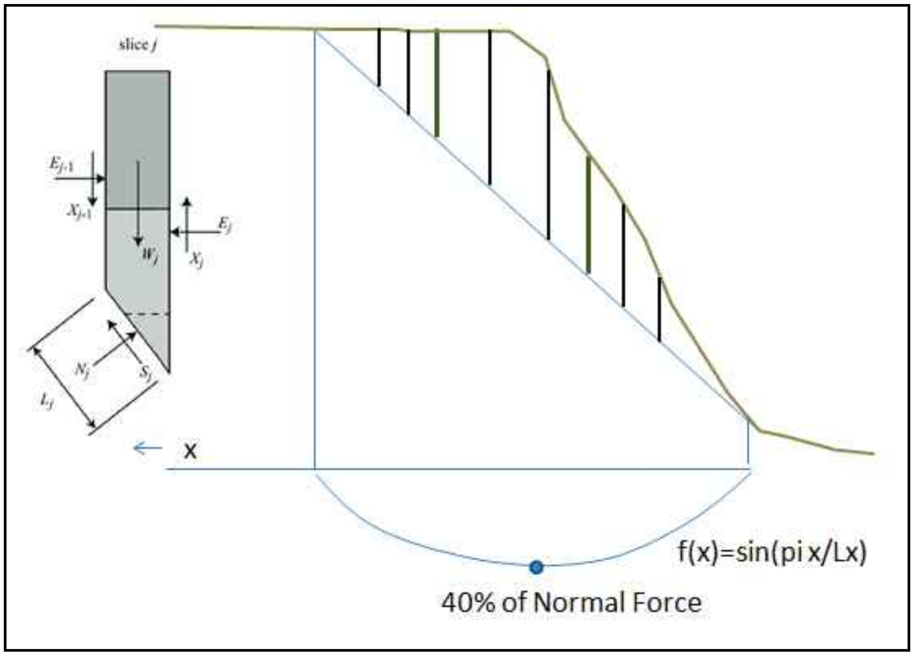

Figure 7. Schematic of how the ratio of inter-slice shear stress to inter-slice normal stress (λ=0.4) is reduced by f(x) depending on the proximimity of the slice to the center of the failure block.

FS can be computed by summing (for all slices, j) the forces acting along the failure plane. The equation for computing FS along the failure slope is a familiar mix (from the Layer Method) of driving (red labels) and resisting (green labels), soil (brown circles) and hydraulic (blue circles) forces in Equation 5 (Force Balance).

$$FS = \frac{\sec\beta \sum_{j=1}^{J} \left(\underbrace{\boxed{L_j c_j'}}_{\text{Cohesion}} + \underbrace{\boxed{N_j \tan\phi_j'}}_{\text{Frictional resistance}} - \underbrace{\boxed{U_j \tan\phi_j^b}}_{\text{Hydrostatic uplift}} \right)}{\tan\beta \sum_{j=1}^{J} \underbrace{\boxed{W_j}}_{\text{Weight of soil}} - \underbrace{\boxed{F_w}}_{\text{Hydrostatic confining force}}} \tag{5}$$

where:

- FS = factor of safety
- U = hydrostatic uplift
- P = hydrostatic confining force of the water in the channel
- ϕ' = friction angle
- ϕ^b = relationship between matrix suction and apparent cohesion
- c' = effective cohesion
- W = weight of the soil
- F_w = hydrostatic confining force

This is the Bishop (1955) approach that accounts only for the forces native to the individual slice. However, the normal force at the base of the slice is not a function of the forces intrinsic to the slice itself. The normal force is modified by the inter-slice normal forces on either side (E_j and E_{j-1}) or the inter-slice shear (X_j and X_{j-1}) on either side of the slice. An iterative solution including two additional equations is required to compute these effects.

The inter-slice forces are calculated from the horizontal force balance (Equation 6, Horizontal Force Balance) for the slice:

$$E_j - E_{j-1} = \left[W_j - \left(X_j - X_{j-1}\right)\right]\tan\beta - \left(c'_j L_j + N_j \tan\phi'_j - U_j \tan\phi^b_j\right)\frac{\sec\beta}{FS} \qquad (6)$$

Equation 6 has FS imbedded and uses the FS computed in Equation 5. With FS being computed in Equation 5, and the shear forces between neighboring slices (X_j and X_{j-1}) coming from Equation 6, a Normal force at the base of the slice that is modified for inter-slice effects, can be computed from the vertical force balance (Equation 7) of the slice:

$$N_j = \frac{W_j + X_{j-1} - X_j - \left(L_j c'_j - U_j \tan\phi^b_j\right)\dfrac{\sin\beta}{FS}}{\cos\beta + \dfrac{\tan\phi'_j \sin\beta}{FS}} \qquad (7)$$

The new normal force at the base of the slice is then substituted back into Equation 5 to compute a new FS, which is used to update the inter-slice forces in Equation 6 and to update the Normal force in Equation 7. The Method of Slices iterates on these three equations (Figure 8) until the change in FS between iterations drops below 0.5 percent.

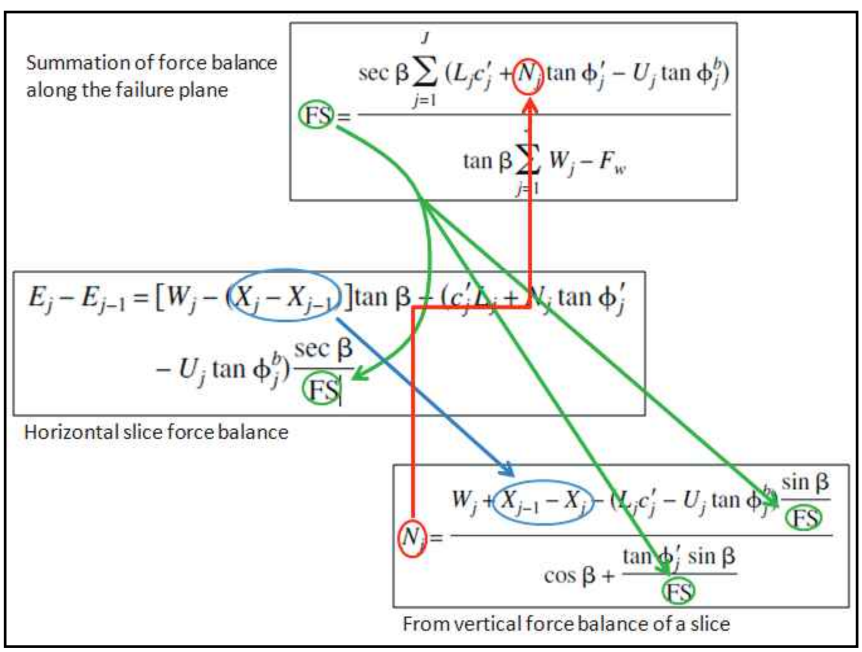

Figure 8. Iterative scheme to compute FS for the method of slices including the dependency of the normal force at the base of the slice on the inter-slice forces.

There are some considerations in the code to decrease the computational expense of iteration. The code checks the denominators of the equations for FS and N_j to determine if iteration is necessary.

TR.1.2.1 Tension Cracks

Tension cracks are a special case of the Method of Slices computation. Because of the vertical nature of tension cracks, tension cracks can only be computed by the Method of Slices. The USDA-ARS standalone version of BSTEM uses the Layer Method by default but switches to the Method of Slices if the tension crack parameter is defined and a tension crack is identified.

If the inter-slice normal forces are negative "E less than zero" the slice is in "tension". Soil generally performs very poorly under tension. Tension slices tend to be on the "upslope" portion of the failure block because there is more material "sliding away" pulling on the slice. Therefore, the code starts at the (channel side) and works inland, checking each slice interface for "E less than zero".

When a slice in tension is found, the software compares the height of the slice interface to the user specified (or internally calculated) "maximum tension crack depth". If the slice interface is greater than maximum tension crack, then no tension crack is computed at that location and the next inland interface is analyzed. Therefore the tension crack happens at the slice interface closest to the channel that fulfills the two following criteria:

1) E less than zero (i.e., the slice interface is "in tension")
2) The height of the interface between the slices is less than the maximum tension crack (Figure 9)

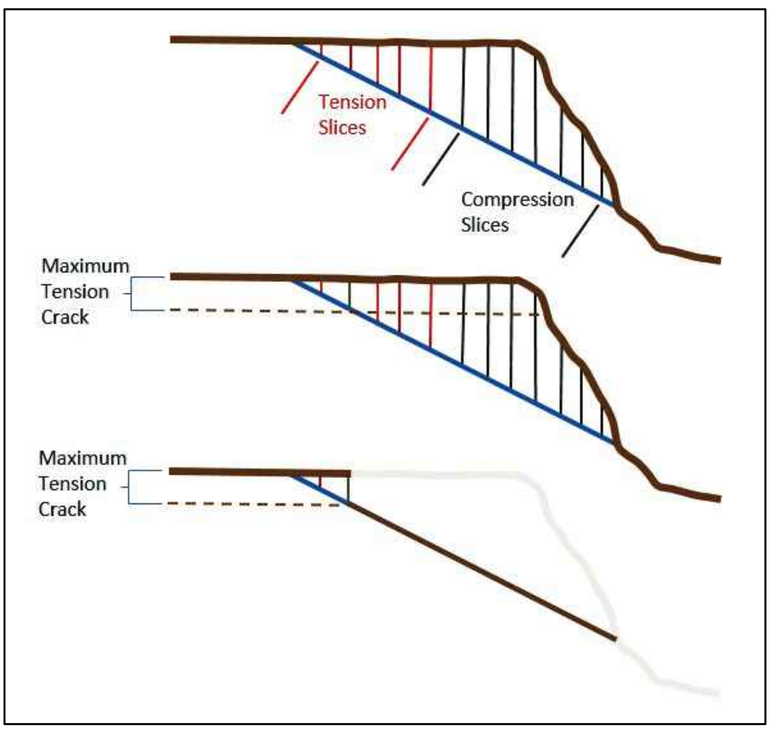

Figure 9. Tension crack computation criteria.

The vertical thickness of tension cracks is soil specific and can be determined by visual field inspection of the vertical cut at the upper portion of existing bank failures. Tension cracks vertical thickness can also be computed with Equation 8 for the depth at which active pressure goes to zero (Lambe, 1969):

$$z_c = \frac{2c'}{\gamma}\tan\left(45^\circ + \phi'/2\right) \tag{8}$$

HEC-RAS currently uses Equation 8 by default for the method of slices. The standalone version of BSTEM can override this value with a user specified maximum tension crack, but this is not available in HEC-RAS at this time.

If a tension crack is identified, the slices inland from the tension crack are excluded from the stability analysis. Because the failure plane along these inland slices is higher, the inland slices will tend to have higher suction forces and lower buoyant forces. Therefore, a tension crack that excludes these inland slices will reduce the FS and make the bank more likely to fail.

If FS is less than zero and a tension crack is computed, the failure block on the river side of the tension crack is removed from the bank and added as sediment load to the sediment model, while the inland slices remain fixed to the bank, resulting in a vertical wall.

TR.1.2.2 Cantilever Failures

Cantilever failures, mass wasting of overhanging soil blocks, are also a special case of the Method of Slices. Thorne and Tovey (1981) established three types of cantilever failures (Figure 10) that include three distinct processes:

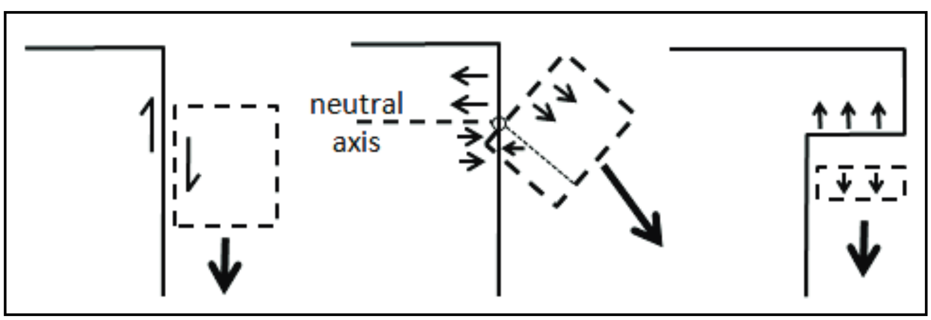

Figure 10. A taxonomy of cantilever failure mechanisms (after Thorne and Tovoy, 1981).

1. The soil block shears off along the vertical or obtuse failure plane.
2. The soil block rotates off the bank due to the tension (e.g., inter-slice normal forces go to zero and cohesion is not sufficient to keep the overhanging block in place).
3. The lower layer of the block falls off.

There is no special cantilever case algorithm in HEC-RAS. The methods available in HEC-RAS can only apply the Method of Slices to overhanging bank configurations, and therefore can only simulate the first (sliding) mechanism of cantilever failure. Ninety degrees is the maximum failure angle that HEC-RAS will consider.

To identify cantilever failure, HEC-RAS checks to see if the maximum β (the maximum failure plane angle that is entirely included in the bank soil) at any evaluation point is greater than or equal to ninety degrees (Figure 11). This indicates an overhanging bank and that Method of Slices was used for the evaluation at that point even if the Layer Method is selected.

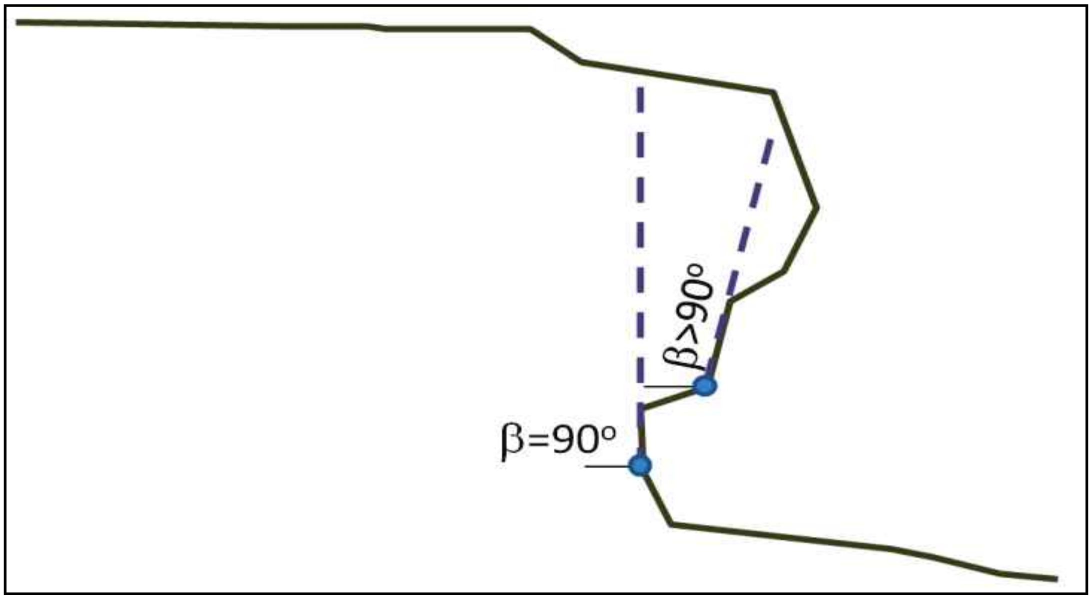

Figure 11. Example of maximum failure plane angles for overhanging bank situations where β_{max} is greater than or equal to ninety degrees. These classify as cantilever failures and the software will force a Method of Slices analysis.

TR.1.3 Selecting a Method

The Layer Method and the Method of Slices generally produce very similar results. Differences between the two methods are summarized in Table 1. The standalone version of the USDA-ARS BSTEM model uses the Layer Method unless it has to compute tension cracks or cantilever failure, which cause it to switch to the Method of Slices. The choice mainly involves a trade-off between a theoretical consideration (the normal force distribution) and a practical consideration (run time).

Table 1. Method selection criteria

Layer Method	Method of Slices
Customized for bank failure applications.	Closer to the comparable geotechnical analyses.
Higher normal stresses along the failure plane generally computed for the higher layers.	Higher normal stresses along the failure plane generally computed for the deeper layers.
Non-Iterative. More computationally efficient.	Apportions normal stresses according to more physically based assumptions.
Switches to method of slices if tension cracks or overhanging banks form.	Computes tension crack and cantilever failures.

Method of Slices computes a somewhat more realistic distribution of normal stresses along the failure plane (Figure 12). The Layer Method computes larger normal stress for larger layers, which tend to be along the top of the failure plane while the Method of Slices computes larger normal stresses for larger slices which tend to exert their forces at the base of the failure plane

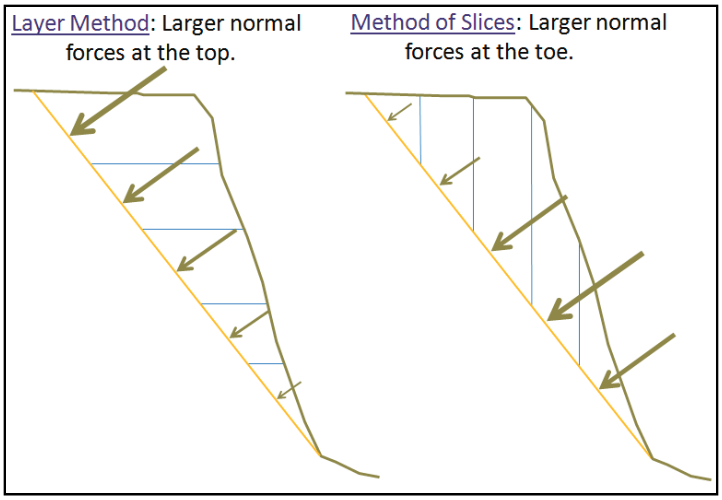

Figure 12. Theoretical difference in normal stress computed by Layer Method and Method of Slices.

(which is a more realistic assumption). Therefore, without tension cracks, the Method of Slices will generally compute a slightly higher FS for the same dataset. However, because the Method of Slices allows tension cracks, which tend to remove more resisting forces than driving forces, the Method of Slices often returns a lower FS, and more failures.

However, because the Method of Slices is iterative and the Layer Method is not, the Layer Method is more computationally efficient and can decrease run times. Since there are already two iterative computations in BSTEM outside of the FS computation (e.g., analysis for several nodes up the bank face and the selection of the critical failure plane for each node) bank failure analysis can be computationally expensive for big projects or long runs. The Layer Method may reduce those run times.

TR.1.4 Steps in a Bank Failure Analysis

The physics described in the sections above, computes FS for a single failure plane. However to determine if the bank will fail and where it will fail several failure planes 1) with different starting elevations on the face of the bank, and 2) with different angles have to be evaluated (Figure 13).

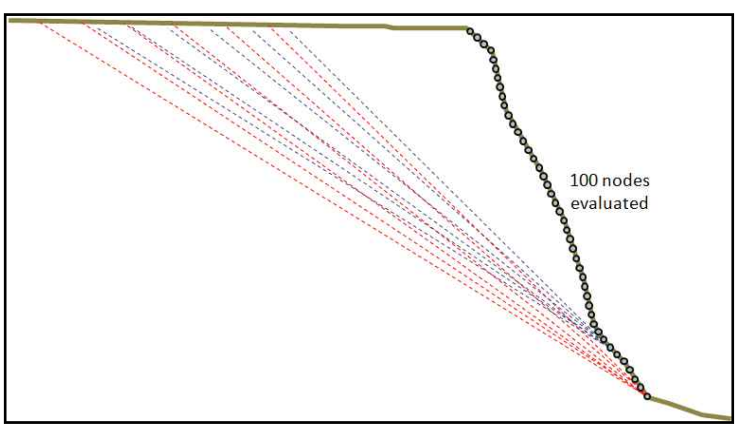

Figure 13. Multiple failure planes have to be evaluated at multiple nodes.

Therefore, regardless of what method was used to compute the physical FS, the following is a six step iterative evaluation for each bank and time step analyzed:

1. Evaluate nodes at several vertical locations up the bank. Then for each node follows Step 2 through 6.
2. Select the bounding failure planes (minimum and maximum angles) and an initial guess for the critical factor of safety - FS_{cr}
3. Compute the factor of safety for the current proposed failure plane - FS_i
4. Use that information to select a more likely critical failure plane (using the "bracket and Brent" optimization algorithm) ($FS_{i+1} \rightarrow FS_{cr}$)
5. Decide when FS is close enough to FS_{cr} to stop, otherwise repeat Step 3
6. Select the FS_{cr} for all nodes and if FS_{cr} is less than one, fail the bank, update the cross section, and send the bank sediments to the routing model

The following describes the above steps in more detail.

1. Evaluate nodes at several vertical locations up the bank

The software will find a critical failure plane that starts at several vertical locations along the face of the bank. HEC-RAS evaluates 100 points which are evenly spaced vertically between the user specified toe and top of bank (one percent evaluation intervals) by default. Fewer evaluation points can be specified under BSTEM to improve run time. However, bank points that are evenly spaced will not be evenly spaced along an irregular bank.

For each elevation, the bank failure algorithms will find a critical FS failure plane. Instead of running many angles for each node at very small increments, a minimization algorithm with quadratic convergence "bracket and Brent" (Teukolsky, 2007; page 388) is used to find the failure plane with the minimum FS at each node with as few failure planes as possible. This process includes the next Steps 2 through 6.

2. Select the bounding failure planes (minim and maximum angles) and compute a FS for each

The first step of finding the critical FS of a given bank node is to bound the possible angles (the "bracket" in "bracket and Brent"). The minimum angle is set to half of the friction angle, which is a reasonable angle below which most bank configurations would be expected to remain stable. The maximum angle is the largest angle that is entirely in the soil matrix (Figure 14).

Then the bank failure method makes an initial guess for the critical failure plane to start the parabolic search, which is 45 degrees plus half the friction angle.

However, sometimes it is not as simple as the classical configuration in Figure 14. A number of unique configurations posed by natural channel banks can cause the default maximum angle to be less than half the friction angle or can generate an initial guess ($45^o+\phi'/2$) to fall outside of the bracket among other complications. Therefore, there are special cases to deal with unique configurations.

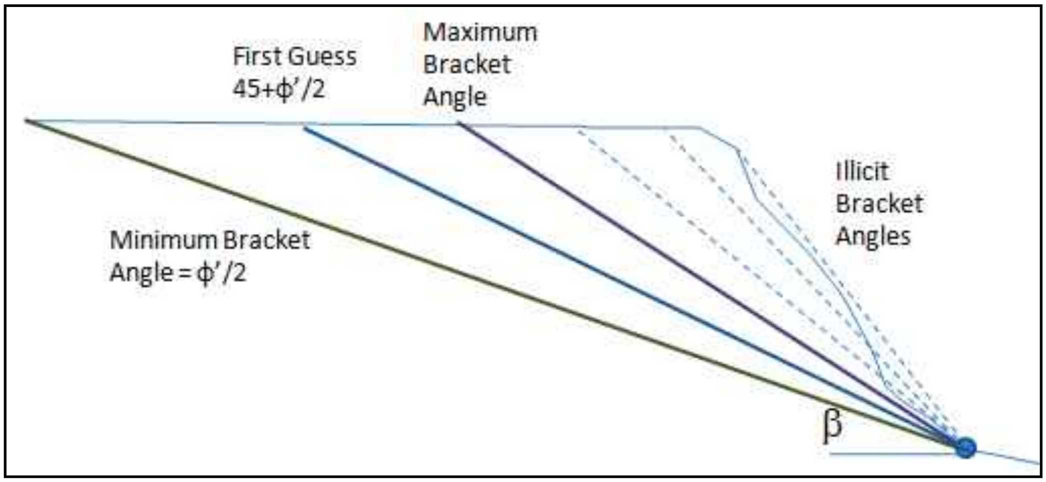

Figure 14. Computing the maximum and minimum failure angles and the first guess.

With the maximum and minimum angles set and a first estimate established, the bank failure algorithm is prepared to start the iterative search to determine a critical failure plane angle.

In the initial iteration, an FS is computed for the maximum, minimum, and initial estimate failure plane angles by the methods described above (Figure 15). In each successive iteration, an FS is computed for the new failure plane angle selected by the parabolic search.

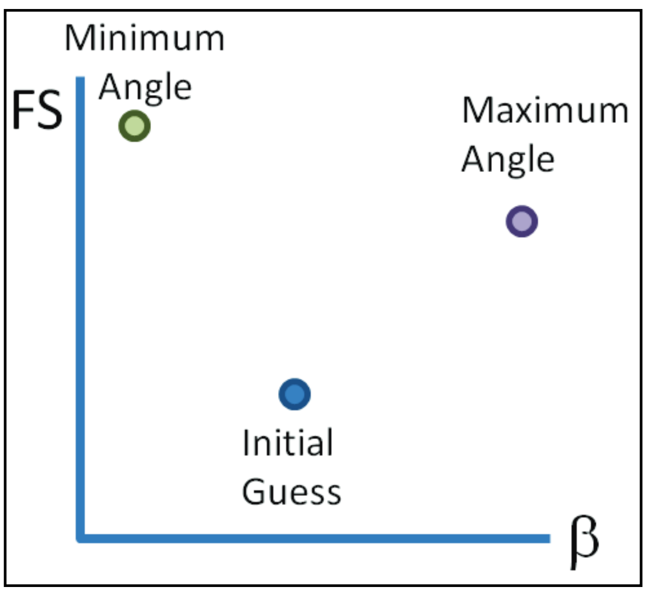

Figure 15. FS computed for the maximum and minimum angles and the initial estimate

FS is computed for the maximum, minimum and best guess angles with the physics described above, and then the three angle-FS pairs are passed to the "bracket and Brent" routine, which fits a parabola to the FSs associated with the three angles and then iterates to find the minimum. With each iteration, the bracket shrinks (the maximum and minimum possible angles converge) and the algorithm completes when the bracket drops below 0.5 degrees.

3. Compute FS_i

The algorithm computes an FS for the β_i selected by the methods described in Step 2.

4. Use that information to select a more likely critical failure plane

Next HEC-RAS uses a parabolic optimization algorithm ("bracket and Brent") to find an angle (β) that is likely to have a lower FS. The software fits a second order quadratic equation through the three factors of β - FS points and identifies the angle (β_i, Figure 16a) associated with the parabolic minimum.

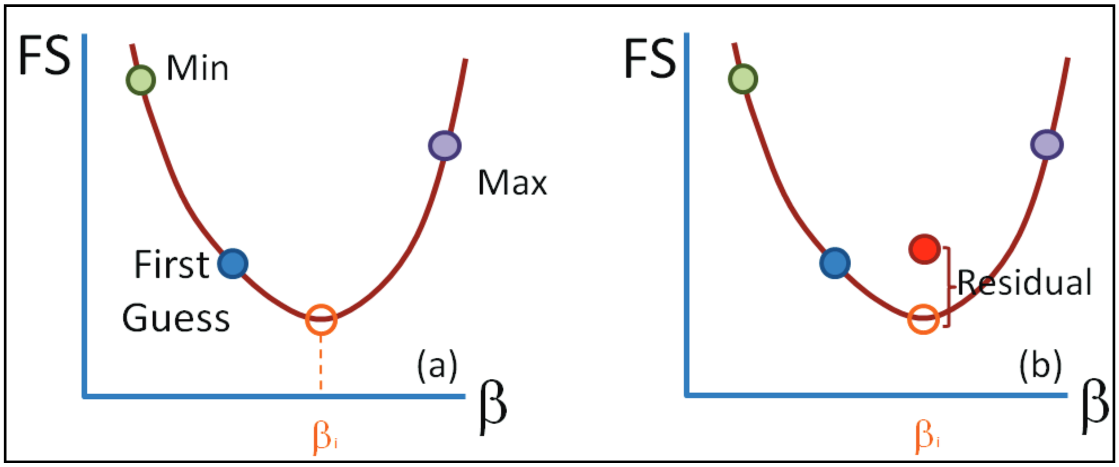

Figure 16. A parabolic function is fit to the three points and a) the function minimum is selected as the next failure plane, and b) compute a FS associated with that failure plane and the residual between the FSs predicted by the method.

5. Decide when the FS is close enough to FS_{cr} to stop, otherwise Iterate

The actual relationship between β_i and FS does not necessarily fit a second order quadratic equation. Therefore, the FS computed for the angle selected (β_i) will not precisely match that predicted by the function. The bank failure algorithm evaluates the difference between the computed FS and the predicted FS ("Residual", Figure 16b). If the difference is less than half a percent (i.e., residual less than 0.5 percent) then the algorithm considers the parabolic function a good approximation of the relationship between FS and β and the β_i is adopted as the critical failure plane for this bank node.

However, if the residual is greater than 0.5 percent, the algorithm will iterate and return to Step 3, by trying to identify the most likely critical failure plane angle given the new information. The new FS_i for the new β_i becomes the new maximum or minimum (depending on which side the last β_i is on) and a new, narrower, second order quadratic is fit to the new three points (Figure 17). A new β_{i+1} is selected at the minimum of the function. The FS is calculated (Step 4) and the residual evaluated (Step 5). As this algorithm iterates the range between the maximum and the minimum shrinks as the function converges (usually within a few iterations) to a solution.

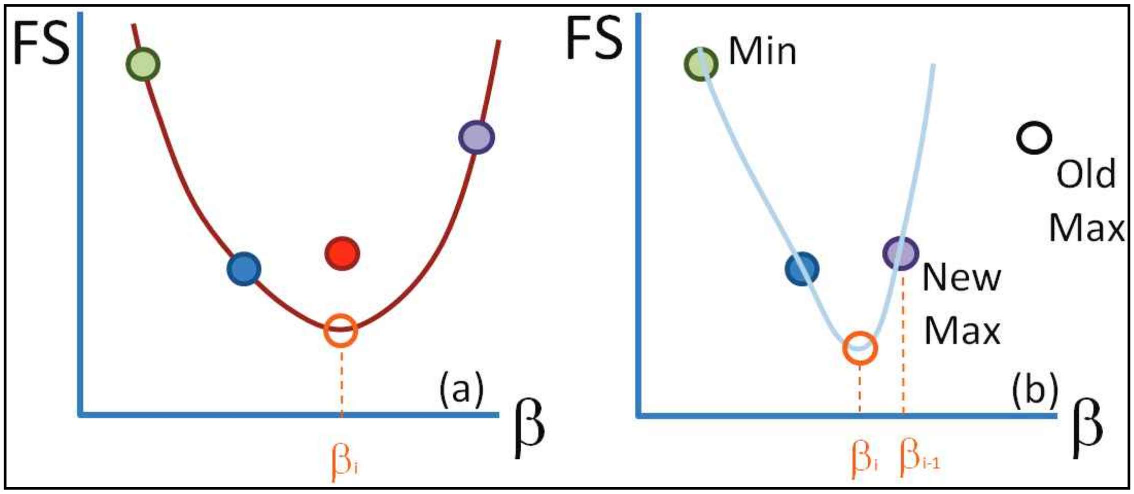

Figure 17. The new FS computed for β_i becomes the new maximum or minimum and a tighter polynomial is fit to the new three points to identify a new function minimum.

However, sometimes the relationship between β and FS depart substantially from the parabolic model, which can return false, local minimums. For example, the theoretical function in Figure 18a passes through the same points as Figure 17b but would not be predicted by the "narrowing parabolic" method. Therefore, the iteration optimization includes occasional searches to find other β regions with low FSs.

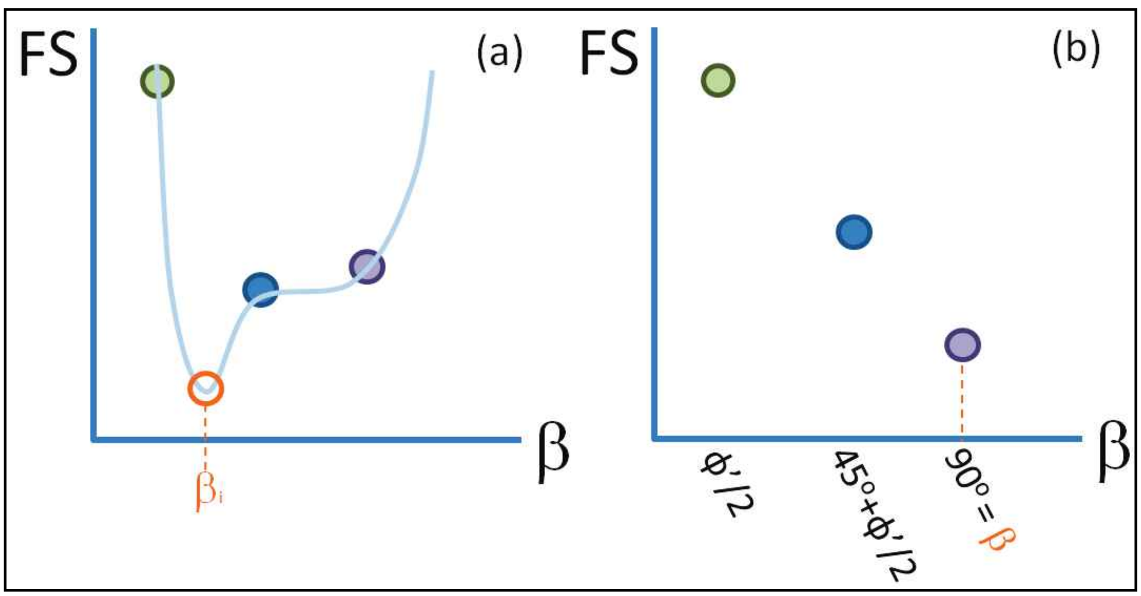

Figure 18. Monotonic β - FS function associated with a cantilever failure.

Additionally, sometimes the relationship between β and FS is monotonic (Figure 18b). This occurs in the case of cantilever failures where the highest factor of safety is often associated with the maximum angle. If the maximum angle is has the lowest factor of safety in Step 2, this is automatically accepted as the critical failure plane and the model does not iterate.

6. **Select the FS_{cr} for all nodes and if FS_{cr} is less than one, fail the bank, update the cross section, and send the bank sediments to the routing model**

   Finally, after the critical failure plane is iteratively computed for each of the vertical evaluation points on the bank, the failure plane with the lowest overall failure plane is selected. If the FS is greater than one, the bank is stable. However, if the FS is less than one, then the bank fails and the bank material inside of the failure plane is removed from the bank and added to the control volume of the sediment routing model associated with the cross section. The material inside of the failure plane is removed, the cross section is updated, and the material is introduced into the sediment routing model as a lateral load.

TR.2 Toe Erosion (Fluvial or Hydraulic Erosion) – Flow Driven

The combination of vertical bed change algorithms in the classical HEC-RAS mobile bed computations and the bank failure algorithms can model interaction between channel incision and bank failure. As a channel incises (the potential failure plane through the new exposed toe), the bank steepens, and the FS drops. Therefore incision can induce bank failure (or conversely deposition can stabilize banks). However, a third important bank evolution process is not captured by this interaction: toe scour.

Toe scour is a fluvial, hydraulic process driven by the flow (versus bank failure which is primarily a gravity driven geotechnical process). The classical mobile bed algorithms in HEC-RAS only compute vertical movement of the bed, but hydraulic forces can undermine the toe of a bank, which can reduce the length of the failure plane (and the frictional resistance) and decrease the factor of safety of the critical failure plane faster than incision.

TR.2.1 Determining the Zone of Scour

The movable bed limits in the HEC-RAS sediment transport module define the transition between incision and scour. Inside of the movable bed limits, the channel is modified by the movable bed model (incision and deposition translated into vertical node movement). Outside of the movable bed limits, scour equations are used. Separate scour limits are not provided as a user input option because nodes should either incise or scour to avoid double counting. The model is very sensitive to the selection of these limits.

The scour equations in the USDA-ARS BSTEM that are implemented in HEC-RAS compute lateral bed change of the wetted nodes outside the movable bed limits for cohesive or cohesionless soils based on a radial shear distribution.

TR.2.2 Determining τ_{node}

Unlike channel deposition or erosion, toe scour does not affect all nodes equally. This is important for its interaction with the bank failure model because the failure plane will likely pass through the vertical location of maximum scour. However, to compute differential lateral scour, the software must compute a local shear stress for each node.

There are several ways to post process one-dimensional hydraulics to compute local shear stress. The most common is to subdivide the cross section into vertical "prisms" (blue lines, Figure 19) and compute a local shear stress based on the hydraulic radius of each one. However, the assumption of zero inter-prism friction only holds along the planes normal to the isovels (contours of constant velocity). Vertical divisions violate this assumption because they are not perpendicular to the isovels.

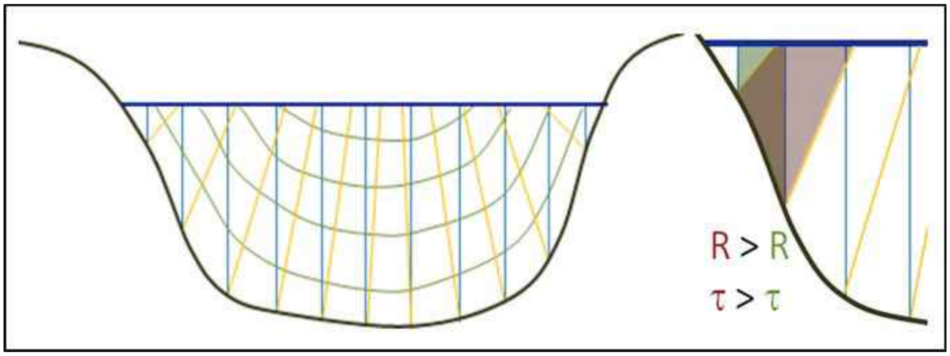

Figure 19. Subdividing the cross section into vertical conveyance prisms (blue) versus zones (yellow) perpendicular to the isovels (green).

Alternately, the one-dimensional cross section can be divided into "radial prisms", non-vertical zones by partitions perpendicular to the isovels (yellow lines, Figure 19). These approaches will compute different hydraulic radii (a sensitive variable for computing the shear stress) especially in the zone closest to the bank where the toe scour computations are applied. The radial prisms tend to have higher hydraulic radii, and therefore, higher shear stress that the vertical prism associated with the same bank segment and represent a more realistic shear stress distribution (Figure 19). Therefore, the bank erosion algorithms use a radial distribution, dividing the flow field, hydraulic radius, and shear stress with radial prisms.

If bed and bank roughness are approximately the same, then we can assume that the line that bisects the toe is normal to the isovels (Kean, 2001). Therefore, the first step in developing the radial shear distribution is finding the angle bisecting the toe (Figure 20a). Bank and channel segments are computed by connecting the scour toe (the movable bed limit) to the edge of bank and the next interior channel point respectively (Figure 20a). This segment determines the zone of the one-dimensional cross section dedicated to toe scour.

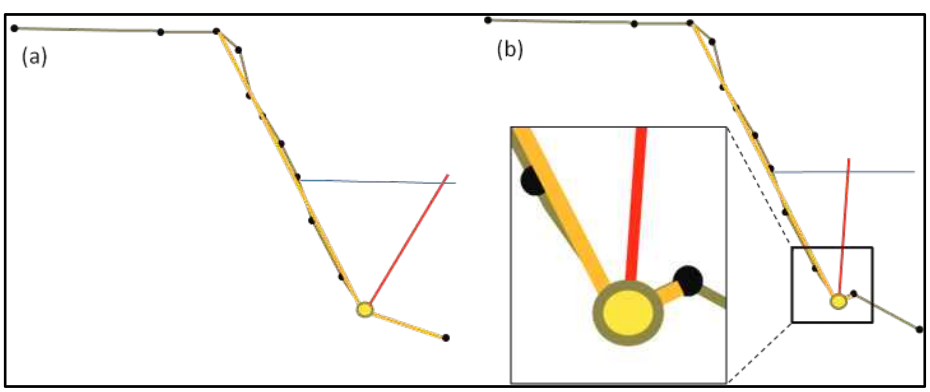

Figure 20. Finding the bisecting angle at the toe which will determine the portion of the water column that is contributing to toe scour.

Note: This computation makes the scour computations sensitive not only to the selection of the mobile bed limits but also to the elevation of the interior node. Random bed fluctuations can cause this node to diverge from the basic lateral channel slope (Figure 20b) which could artificially affect scour.

Next a "radial prism" is associated with each node (cross section station-elevation points in the toe scour zone). The water surface intersection point connects the midpoint between wetted bank nodes. The water surface intersection point is a relative proportion of the water depth of the midpoint between nodes and the total depth to the midpoint of the movable bed limit and the next interior node (Figure 21).

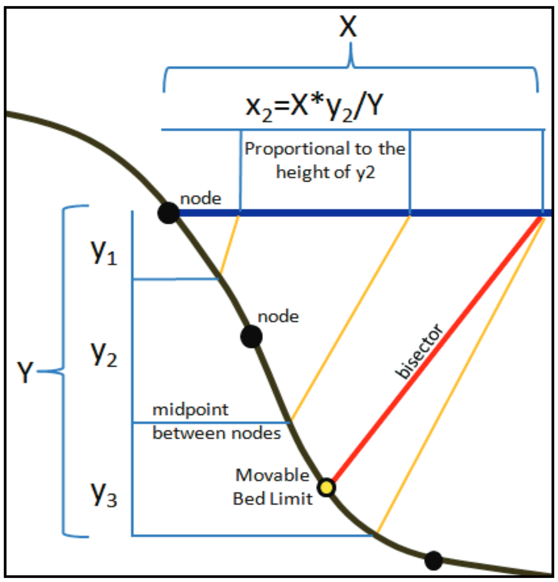

Figure 21. The orientation of the radial prisms used to compute a shear at each node is computed by proportioning the intersection of the water surface with the depth within the scour zone.

Once the radial flow prism is computed for each wetted bank node (Figure 22), the hydraulic radius of the prism is computed from the area and wetted perimeter (water-water boundaries are ignored). Then the shear stress for each radial prism is computed from the average one-dimensional shear stress as a ratio of:

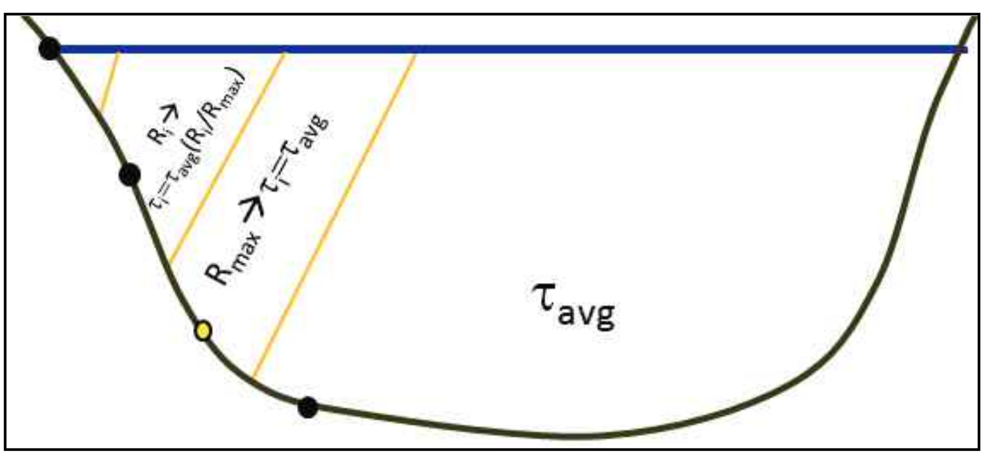

Figure 22. Apportioning the local shear by a ratio of the hydraulic radius of the radial prisms.

$$\tau_i = \tau_{avg}\left(R_i / R_{max}\right)$$

where R_{max} which is typically R_{toe} is the largest hydraulic radius among the radial flow prism.

TR.2.3 Scour

If the clay content of the layer is greater than twenty percent, the software uses an excess shear cohesive equation, scoring material based on the erodibility and shear. For clay content less than twenty percent, scour is computed using a transport function. Different nodes (Figure 23) can invoke different transport equations depending on the associated layer material. Then the nodes in the toe scour region of the model are adjusted laterally.

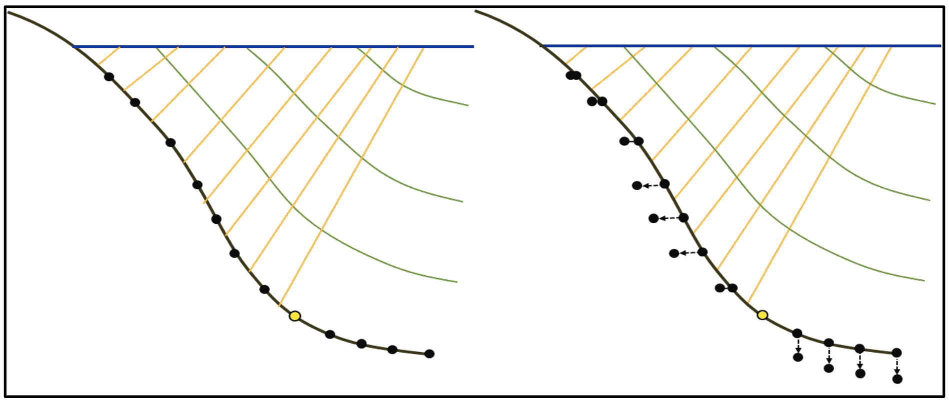

Figure 23. Nodes between the movable bed limits are adjusted vertically (and uniformly) and the wetted nodes outside the movable bed limits are adjusted laterally (and independently).

This radial shear distribution commonly computes maximum shear stress at the toe. Therefore, the toe will often scour more than the other nodes, yielding an overhanging bank like the one in Figure 24a. HEC-RAS requires increasing station values, so it cannot retain or represent overhanging banks in Version 5.0. Therefore, HEC-RAS assumes that overhanging banks fail vertically, as depicted in Figure 24b. Because overhanging banks eventually fail, this should not introduce substantial error in long term models.

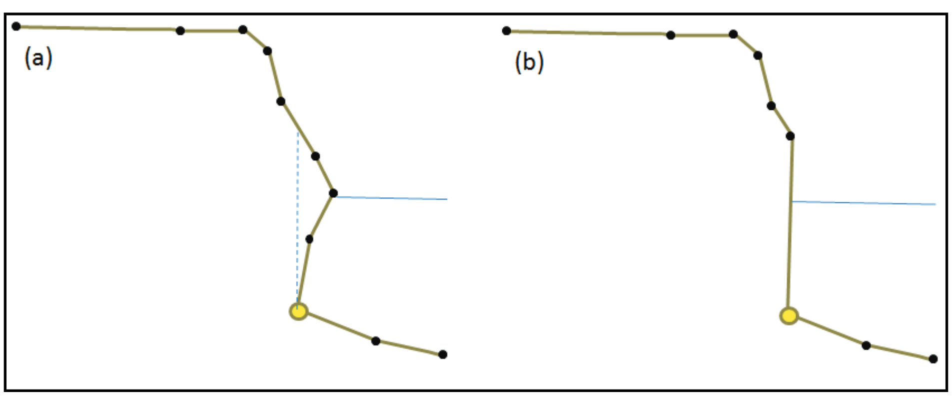

Figure 24. Overhanging bank simplification method.

USDA-ARS Bank Stability and Toe Erosion Model (BSTEM) in HEC-RAS

User's Manual

UM.1 Getting Started

BSTEM toe erosion and bank failure analysis will be performed as part of a sediment transport analysis on any cross section bank that has all the necessary parameters. Computing bank failure at every bank will increase run times. Therefore, it may be advantageous to only specify BSTEM parameters for banks that have a probability of failure. The BSTEM algorithms run before the vertical bed change algorithms each time step (i.e., HEC-RAS BSTEM cross-sections will first widen, then incise or fill).

To enter BSTEM data in HEC-RAS, from the HEC-RAS main window, from the **Toolbar**, click **Sediment Boundary Conditions** (Figure 25). Bank failure analysis is currently only computed as part of a sediment transport analysis. The **Sediment Data Editor** will open (Figure 26). From the **Sediment Data Editor** the user will enter standard sediment transport data on the first two tabs (Figure 26). To enter BSTEM information, click the **USDA-ARS Bank Stability & Toe Erosions MODEL (BSTEM)** tab (Figure 26).

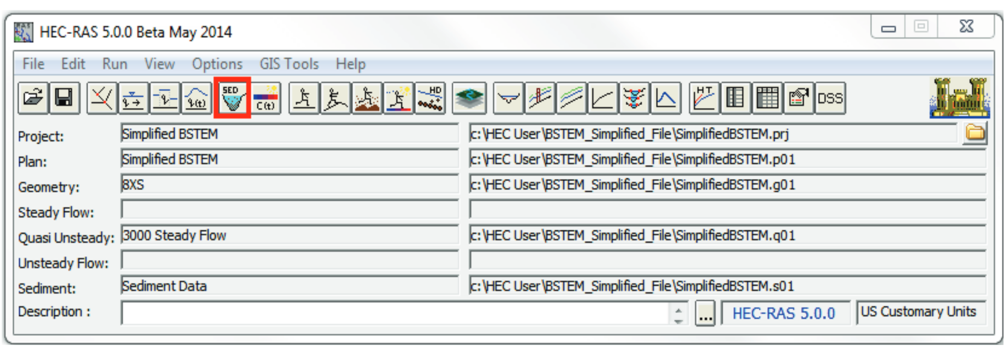

Figure 25. HEC-RAS Window.

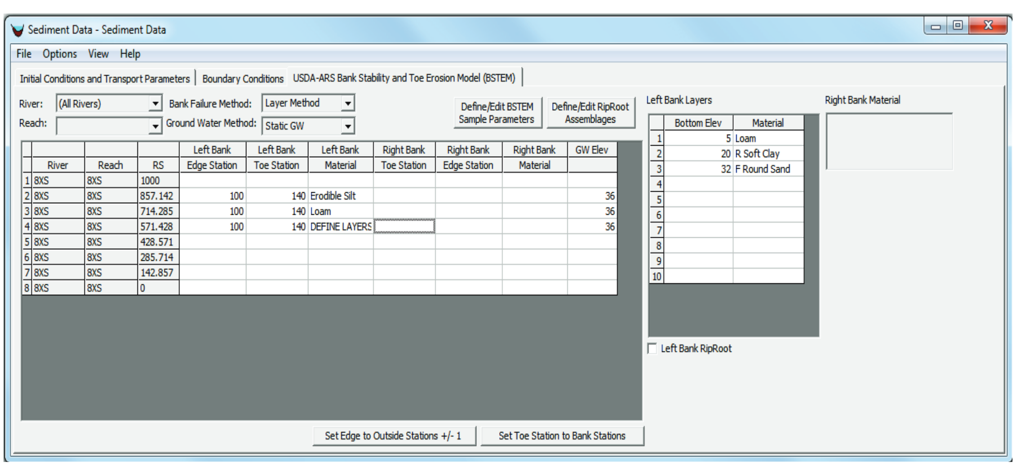

Figure 26. HEC-RAS Sediment Data Editor - USDA-ARS BSTEM Tab.

UM.2 Defining Cross Section Configuration

BSTEM can be applied to the left, right or both banks of an HEC-RAS cross section. Setting up a half-cross section (for the left or right bank) in such a way that it is also compatible with BSTEM is an extremely important step in getting physically appropriate failures from the BSTEM computations. The conceptual BSTEM half cross section (Figure 27) is composed of four segments (green labels, Figure 27) with unique slopes:

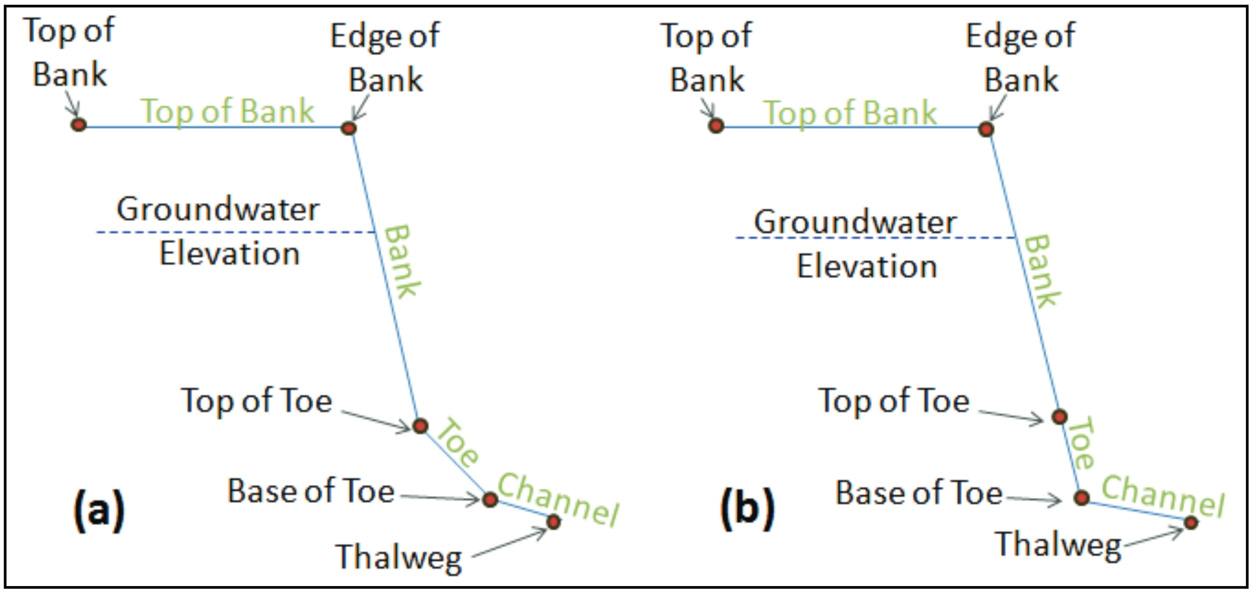

Figure 27. Definition of station points for BSTEM half cross sections

1. The **Top of Bank** which is the relatively flat portion of the cross section above the bank.
2. The **Bank** which is the steepest part of the cross section.
3. The **Toe** which is a mild slope between the bank and the channel, presumably composed of blocks of material that have fallen and accumulated at the base of the bank and are protecting the toe or some sort of rip rap or toe protection.
4. The **Channel** which is the region between the toe and the thalweg.

Each bank of each cross section BSTEM analyzes requires two user defined points, an **Edge of Bank** station and a **Top of Toe** station. These points are defined by their station across the cross section, not their elevation. These points are depicted in Figure 28 and are entered on the HEC-RAS **Sediment Data Editor** (Figure 26) and are defined below. HEC-RAS will automatically select the lowest station-elevation point in the cross section to be the **Thalweg**. HEC-RAS divides a cross section at the thalweg and uses the station-elevation points to the left of the thalweg for the left BSTEM half-cross section and those to the right of the thalweg for the right BSTEM geometry.

Left Bank Edge Station: This should be the inflection point between the bank and the top of the bank. All failure planes considered will intersect the top of bank between the edge of bank and the first cross section station-elevation point.

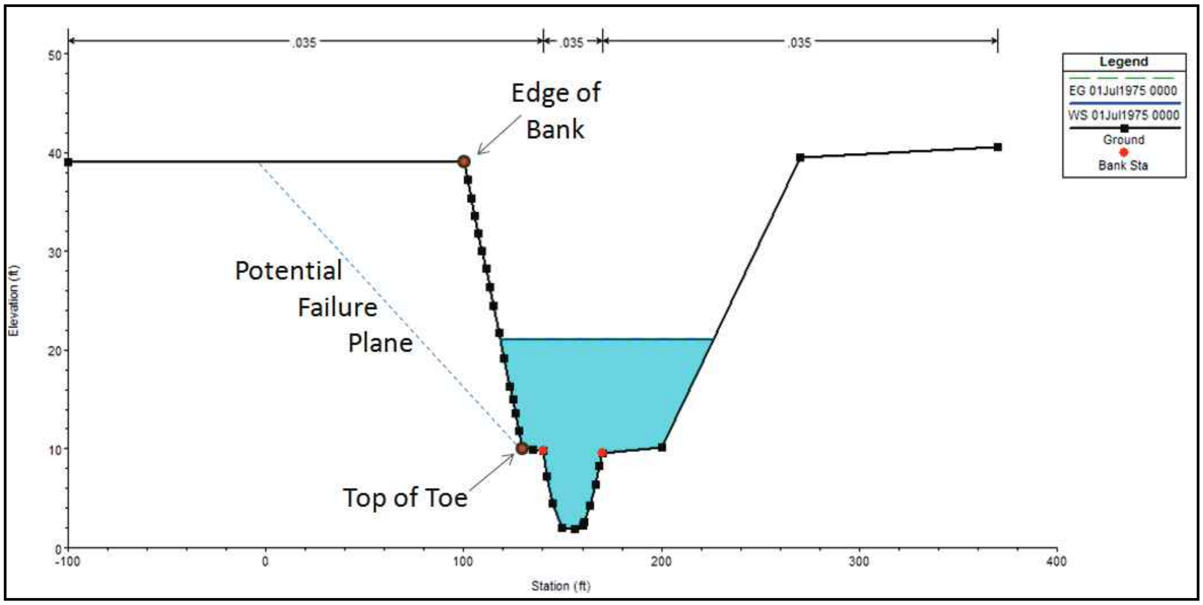

Figure 28. Reasonable location for **Edge of Bank** and **Top of Toe** definitions on an HEC-RAS cross section.

Right Bank Edge Station: Analogous to the **Left Bank Edge** station, the **Right Bank Edge Station** should be the inflection point between the bank and the top of the bank on the left side of the cross section. All failure planes considered will intersect the top of bank between the edge of bank and the last cross section station-elevation point

Left Bank Toe Station: BSTEM divides the bank into two sections, the **Bank** and the **Toe** (Figure 29) sections. Conceptually, the toe is material composed of blocks of failed material or engineered toe protection. Therefore, failure planes are only computed through the bank surface *above* the **Top of Toe**. The **Top of Toe** often corresponds to a break in slope or material type but it does not have to (Figure 29). In future versions of BSTEM, users will be able to select a separate material type for the toe but in the first alpha version of BSTEM, the software adopts the material type of the bank or layer associated with the toe. This parameter can be

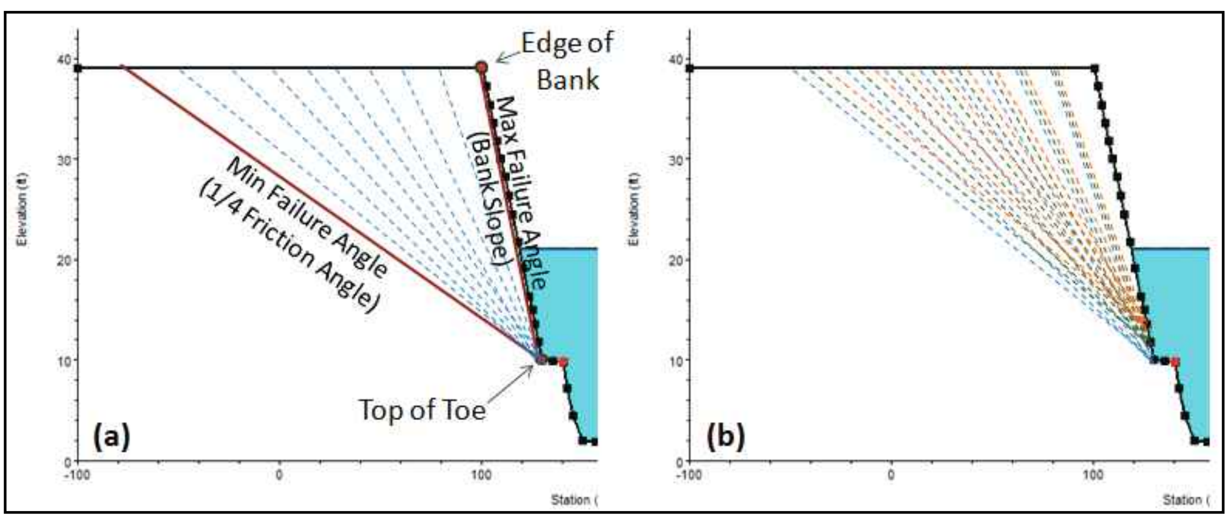

Figure 29. (a) The maximum, minimum and incremental angles evaluated. (b) at each node between the **Top of Toe** and **Edge of Bank**.

automatically set to the HEC-RAS left bank station for every cross section that has **Left Bank Material** defined. From the HEC-RAS **Sediment Data Editor** (Figure 26), click **Set Toe Station to Bank Stations** and click the **Set Toe Stations to Movable Bed Stations** (movable bed limits). Setting movable bed limits and toe stations at the same node is strongly recommended.

Right Bank Toe Station: The **Right Bank Toe** is analogous to the **Left Bank Toe** section and can be set to the right bank station for every bank that has **Right Bank Material** defined**.** From the HEC-RAS Sediment Data Editor (Figure 26), click **Set Toe Station to Bank Stations** and click the **Set Toe Stations to Movable Bed Stations** (movable bed limits). Setting movable bed limits and toe stations at the same node is strongly recommended.

GW Elev: In order to compute bank failure on either side of any cross section a **Groundwater Elevation** must be specified. Results will be very sensitive to this parameter. BSTEM does not yet have a physical limit to negative pore water pressure so a very low groundwater table could generate nearly infinite bank stability.

*Note: The **Edge of Bank** station defines the range of failure planes as shown in Figure 28. The **Edge of Bank** stations limit the maximum distance of toe scour in the absence of bank failures. Bank failure events move the **Edge of Bank** out from the channel, recognizing a new edge at the top of the failure plane. However, if the BSTEM does not compute bank failures, and toe-scour is primarily responsible for lateral migration, the **Edge of Bank** will not migrate as the bank erodes, and can artificially limit scour, generating near vertical banks at the edge station. In a toe scour-driven model, the edge of bank should be specified far enough to allow the maximum reasonable toe scour.*

If the static groundwater option is selected, BSTEM will use this groundwater elevation for the entire cross section simulation. If the dynamic groundwater option is selected, the user specified groundwater elevation will become the initial elevation, and groundwater will rise and fall in response to changes in channel stage. The overbank is modeled as a "linear reservoir" with a volume determined by the distance between cross sections and the user specified "Reservoir Width" parameter, and is moved between the groundwater reservoir and the channel at the rate of the user specified saturated hydraulic conductivity. The reservoir width and hydraulic conductivity are properties of the cross section material (next section).

UM.3 Defining Cross Section Materials

To define cross section materials for BSTEM, the user will enter information from the HEC-RAS **Sediment Data Editor** (Figure 26) from the BSTEM tab:

Left or Right Bank Material: HEC-RAS requires at least one set of material properties to be specified for each bank it performs bank failure analysis on. Three levels of detail are available for specifying this parameter including:

a. Selecting Pre-Defined Default Parameters
b. Select a Single Set of User Defined Material Parameters for a Bank
c. Define Layers of Unique Material at a Bank

The material specification approach is bank-specific, so different approaches can be used for different banks within the same model.

1. **Selecting Pre-Defined Default Parameters**

The standalone version of BSTEM includes sixteen default material types that are also included in HEC-RAS. These default material types are each populated with characteristic soil properties distilled from a database of field data collected by the USDA-ARS. The unit weight, friction angle (ϕ'), cohesion, ϕ^b, critical shear stress (τ_c), and erodibility are listed in Table 2. (See the description of these parameters in *Soil Strength Parameters*.)

Table 2. Default materials and material parameters

Default Material Type	**Saturated Unit Weight** (lb/ft^3)	**Friction Angle** (ϕ')	**Cohesion** (lb/ft^2)	ϕ^b	**Critical Shear** (lb/ft^2)	**Erodibility** (ft^3/lb-s)
Boulders	127.3	42.0	0	15	10.4	2.85E-05
Cobbles	127.3	42.0	0	15	2.59	5.73E-05
Gravel	127.3	36.0	0	15	0.23	1.92E-04
Coarse Angular Sand	117.8	32.3	8.354	15	0.0106	8.95E-04
Course Round Sand	117.8	28.3	8.354	15	0.0106	8.95E-04
Fine Angular Sand	117.8	32.3	8.354	15	0.00267	8.95E-04
Fine Round Sand	117.8	28.3	8.354	15	0.00267	8.95E-04
Erodible Silt	114.6	26.6	89.81	15	0.00209	2.01E-03
Moderate Silt	114.6	26.6	89.81	15	0.1044	2.86E-04
Resistant Silt	114.6	26.6	89.81	15	1.0443	8.91E-05
Erodible Soft Clay	112.7	26.4	171.26	15	0.00209	2.01E-03
Moderate Soft Clay	112.7	26.4	171.26	15	0.1044	2.86E-04
Resistant Soft Clay	112.7	26.4	171.26	15	1.0443	2.01E-03
Erodible Stiff Clay	112.7	21.1	263.16	15	14.6	2.01E-03
Moderate Stiff Clay	112.7	21.1	263.16	15	0.1044	2.86E-04
Resistant Stiff Clay	112.7	21.1	263.16	15	1.0443	2.01E-03

Note: These parameters are extremely site specific, and the default parameters are central tendencies of very noisy data sets, particularly for cohesive material types. Therefore, default parameters will often generate substantial errors.

Coupling these bank failure algorithms with the mass balance computations in the mobile bed capabilities in HEC-RAS introduced one additional parameter requirement. Any mass that is "failed" into the channel requires a gradation so HEC-RAS can partition it into grain classes for transport. Therefore, idealized gradations were selected for each material type based on their description. These gradations are depicted in Figure 30.

In order to select one of the default material types, from the table on the **Sediment Data Editor**, **BSTEM Tab** (Figure 26), from the columns labeled **Left Bank Material** or **Right Bank Material** click at the cross section of interest. A list of default material types that are available will appear (Figure 31). Ignore the option "**DEFINE LAYERS**", from the list and select the desired material type and it will associate it with that bank (Figure 31).

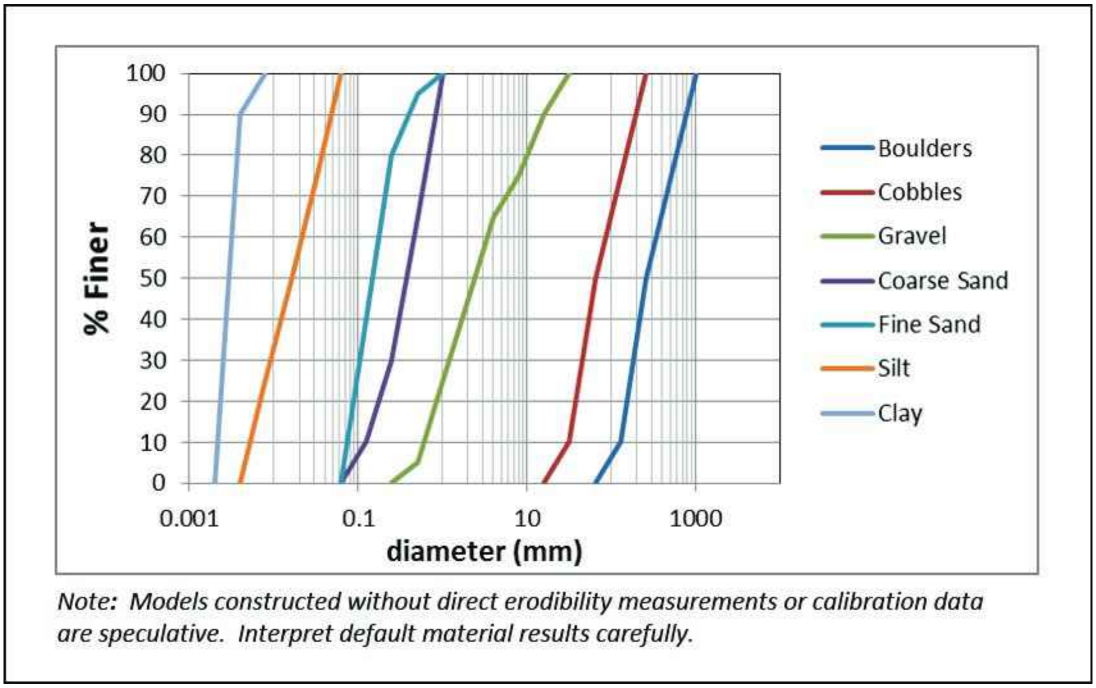

Figure 30. Idealized gradations selected for the default material types.

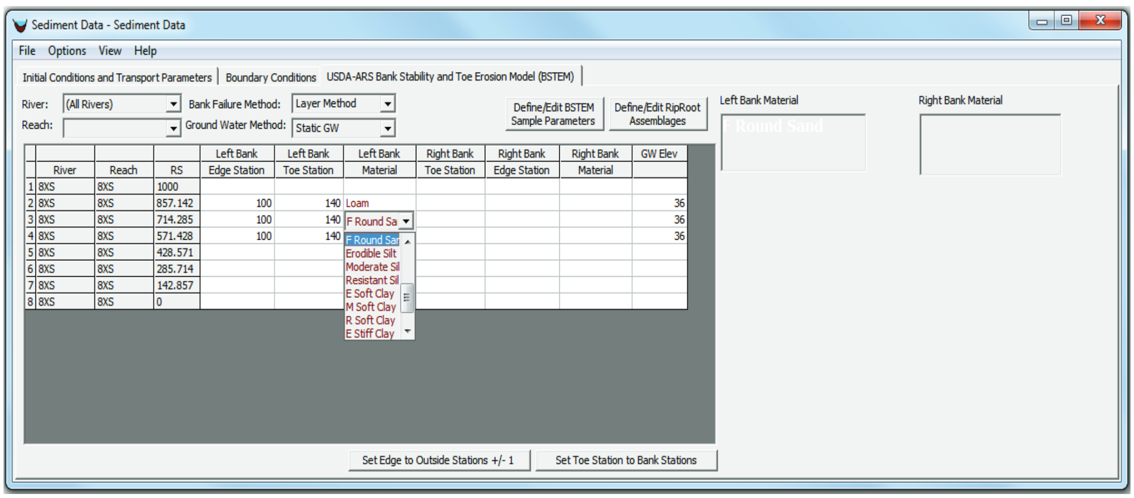

Figure 31. HEC-RAS - Sediment Data Editor - BSTEM Tab - Selecting Cross Section Materials.

2. **Select a Single Set of User Defined Material Parameters for a Bank**

   Because of the inherent variability of these parameters, site specific measurements are recommended. If data is available, customized material types can be associated with a bank. This is analogous to the process for defining sediment gradations in the **Initial Conditions and Transport Parameters Tab** of the **Sediment Data Editor** (Figure 31), where gradation records are defined and then associated with the appropriate cross section.

   Before selecting customized materials a user must define the materials by clicking **Define/Edit BSTEM Sample Parameters**. The **BSTEM Material Parameters Editor** will open (Figure 32). To create a new BSTEM material, click **New Record** and

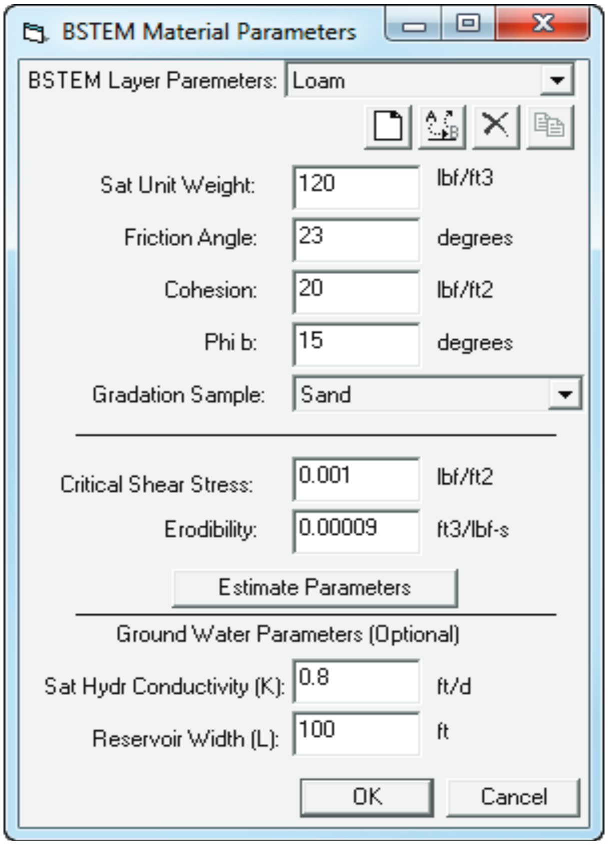

Figure 32. BSTEM Material Parameters Editor.

specify the name. HEC-RAS will reject any names that are identical to existing or default material names. Five mandatory intrinsic soil strength parameters (used to compute the failure plane and factor of safety), two mandatory erodibility parameters (used to compute toe scour) and one optional parameter can then be entered.

Soil Strength Parameters

The first five parameters are intrinsic soil strength parameters and are associated with the computation of a critical failure plane and the FS associated with that failure plane. These five parameters emerge from classical geotechnical measurements that most soils labs would be able to handle. HEC-RAS uses four user defined parameters with hydrodynamic and geometric data to compute a factor of safety for a range of possible failure planes by computing the ratio of the resisting forces to the driving forces: cohesion (c'), saturated unit weight (W), the angle of internal friction (ϕ'), and the angle representing the relationship between shear matrix suction and apparent cohesion (ϕ^b). These four user defined parameters are entered in the **BSTEM Material Parameters Editor** (Figure 32) and are described below.

Unit Weight: This is the *saturated* unit weight (combined weight of the solids and water of the soil when saturated). Note that this is different than the unit weight used elsewhere in HEC-RAS sediment transport computations. The unit weight used elsewhere in HEC-RAS sediment transport computations is the mass of the solids per unit volume.

Friction Angle (ϕ'): The friction angle is a classic geotechnical parameter that is a measurement of the soil strength that quantifies the friction shear resistance of soil. The "angle" of the "friction angle" is derived from the Mohr-Coulomb failure criterion (Labuz, 2012) and is the angle of inclination in the classical Mohr diagram. The angle of inclination is a theoretical angle (the rate of increasing strength with increasing normal force) used to compute soil strength and should not be confused with physically intuitive angles like the angle of repose. Also, the angle of inclination is not the minimum angle of the failure plane. In cases where groundwater elevation is higher than the water surface elevation the bank can lose frictional strength and be left only with cohesion, allowing for a shallower failure plane angle. The friction angle can be determined by collecting "undisturbed" cores for tri-axial testing in a soils laboratory or it can be measured *in situ* with a borehole shear test. The Iowa Borehole Shear device (Thorne, 1981) is a hand held instrument that is commonly used to collect this parameter from hand augured eight centimeter boreholes for BSTEM studies.

Cohesion: Cohesion is the attractive force of particles in a soil mixture, usually as a result of electrochemical or biological bonding forces. These forces increase the strength of a soil matrix. Cohesion is generally a minor consideration in granular soils but can account for a substantial amount of soil strength in cohesive materials. Cohesion is computed from the same data as the friction angle and, therefore, must be measured either by tri-axial laboratory tests or *in situ* borehole shear measurements.

Phi b (ϕ^b): As soil drains, capillary tension induce negative pore water pressure or matrix suction. Suction resists bank failure and increases the shear strength of the soil matrix. In the bank failure algorithms, suction is quantified as an "apparent cohesion" or the equivalent increase in cohesion required to generate the same increase in shear strength (Figure 33). ϕ^b is a function of soil moisture and maximizes at the friction angel (ϕ') at saturation. For most materials ϕ^b is generally between ten to thirty degrees

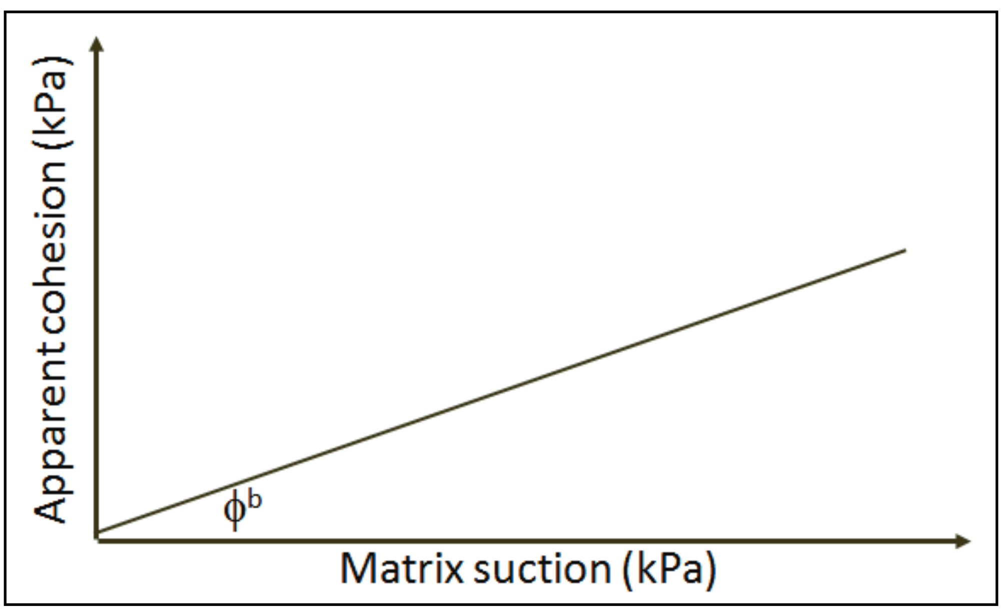

Figure 33. ϕ^b is the slope of the relationship between matrix suction and apparent cohesion.

depending on soil type. ϕ^b is very difficult to go out and fundamentally measure ϕ^b. ϕ^b has been measured a handful of times in research settings. Most applications start between ten and fifteen degrees but ϕ^b goes to a maximum of the friction angle when the material is saturated (Fredlund, 1996). Because of the estimated nature of this parameter it can be used as a calibration factor.

Gradation Sample: HEC-RAS requires a fifth bank material parameter that is required but not used until after the failure calculation. In order to partition any failed material into grain classes for transport by the sediment transport model, the bank material has to have a bed gradation associated with it. Bed gradations are defined by clicking **Define/Edit Bed Gradation** from the **Initial Conditions and Transport Parameters** Tab of the **HEC-RAS Sediment Data Editor** (Figure 34).

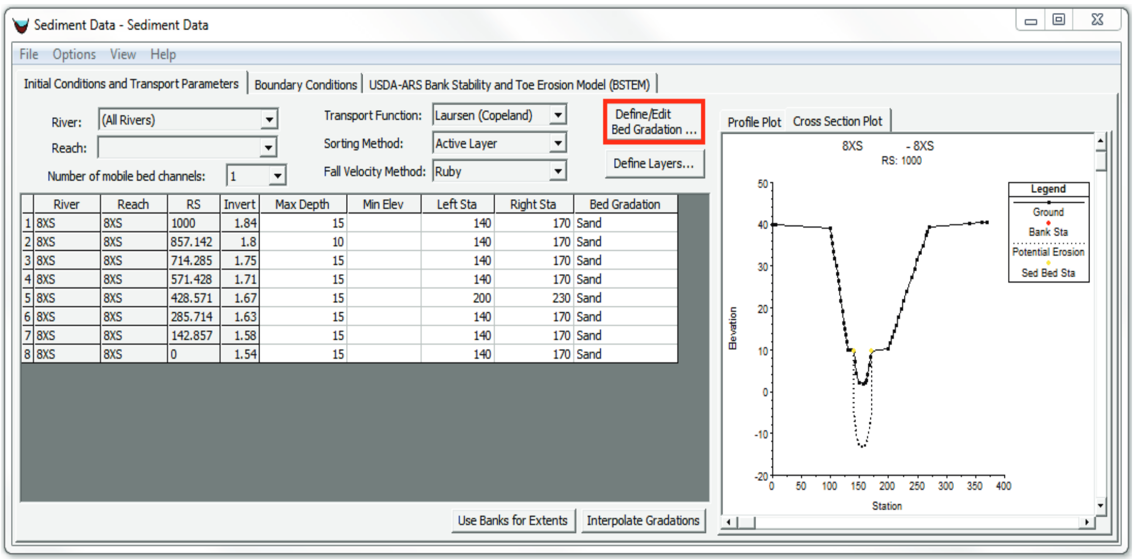

Figure 34. Defining bed gradations.

Any gradations defined here become automatically available in the **Gradation Sample** list on the **BSTEM Material Parameter Editor** (Figure 32).

Erodibility Parameters

The second set of parameters on the **BSTEM Material Parameters Editor** (Figure 32) are the erodibility parameters. These parameters are specialized for bank failure analysis. Erodibility parameters are measurements of the erodibility of the soils in response to hydrodynamic forcing. Standard soil testing laboratories are not likely to have the capabilities to collect these parameters. However, the USACE Coastal and Hydraulic Lab (ERDC-CHL), other federal agencies, and several universities can quantify these parameters. Bank jet tests (Hanson, 2001) and Sedflume laboratory tests (Borrowman, 2006) are the best ways to estimate these parameters.

Critical Shear Stress: Critical shear stress is when the bank begins to scour.
Erodibility: The rate of sediment removal in response to a unit shear stress.

In the absence of these parameters, Casagli (1999) described a relation between critical shear stress and erosion of the cohesive and non-cohesive banks based on the shear stress relations of Komar (1987) and Millar (1993). Additionally, Simon (2000) summarized their database of *cohesionless* measurements to find a relationship between critical shear stress and erodibility:

$$E = 1.42\tau_c^{-0.824}$$

This relationship is based on the regression depicted in Figure 35 which includes a great deal of scatter in log space. This underscores the variable and site specific nature of these parameters, therefore local measurement of these parameters is highly recommended. Also note that this relationship does not account for cohesion and, therefore, should not be used for cohesive soils.

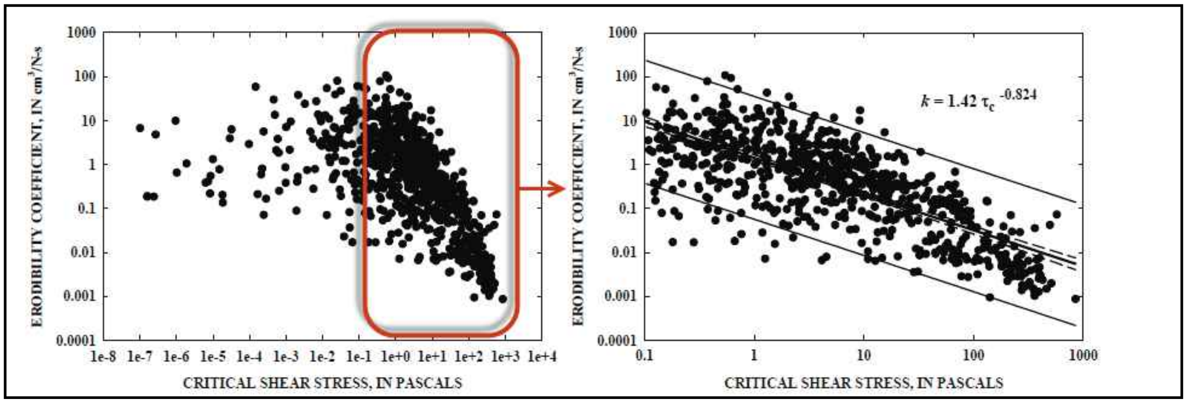

Figure 35. Relationship between erodibility and critical shear stress from Simon et al. (2000).

Groundwater Parameters (Optional)

Groundwater parameters are optional and are only used if the dynamic groundwater option is selected in the HEC-RAS BSTEM interface. There are two parameters that determine the rate that water can drain from or infiltrate into a bank. In turn, this determines the lag between the rising or falling of groundwater elevation with respect to the water surface elevation.

Hydraulic Conductivity: The hydraulic conductivity for this model is the standard Darcy "K" parameter used in groundwater modeling. The hydraulic conductivity is a linear parameter that determines velocity of groundwater proportional to a gradient. Hydraulic conductivity can be measured with field or laboratory tests but is also often documented in regional literature or estimated by expert intuition (analogous to Manning's n).

Reservoir Length: Groundwater dynamics follows a simple linear reservoir model that assumes the banks store water. Water can be added to or drained from the rate of the saturated hydraulic conductivity. The "length" of this reservoir is the bank thickness (perpendicular to the river) that contributes water to the river on pertinent time scales.

If the soils are very permeable or the reservoir is small (high K or low L) the groundwater elevation will track the channel water surface elevation (Figure 36a). If the soils are impermeable or the reservoir is very large, the groundwater will not respond much to flow depth in the channel (Figure 36b). However, intermediate hydraulic conductivities will introduce a lag between channel water surfaces and

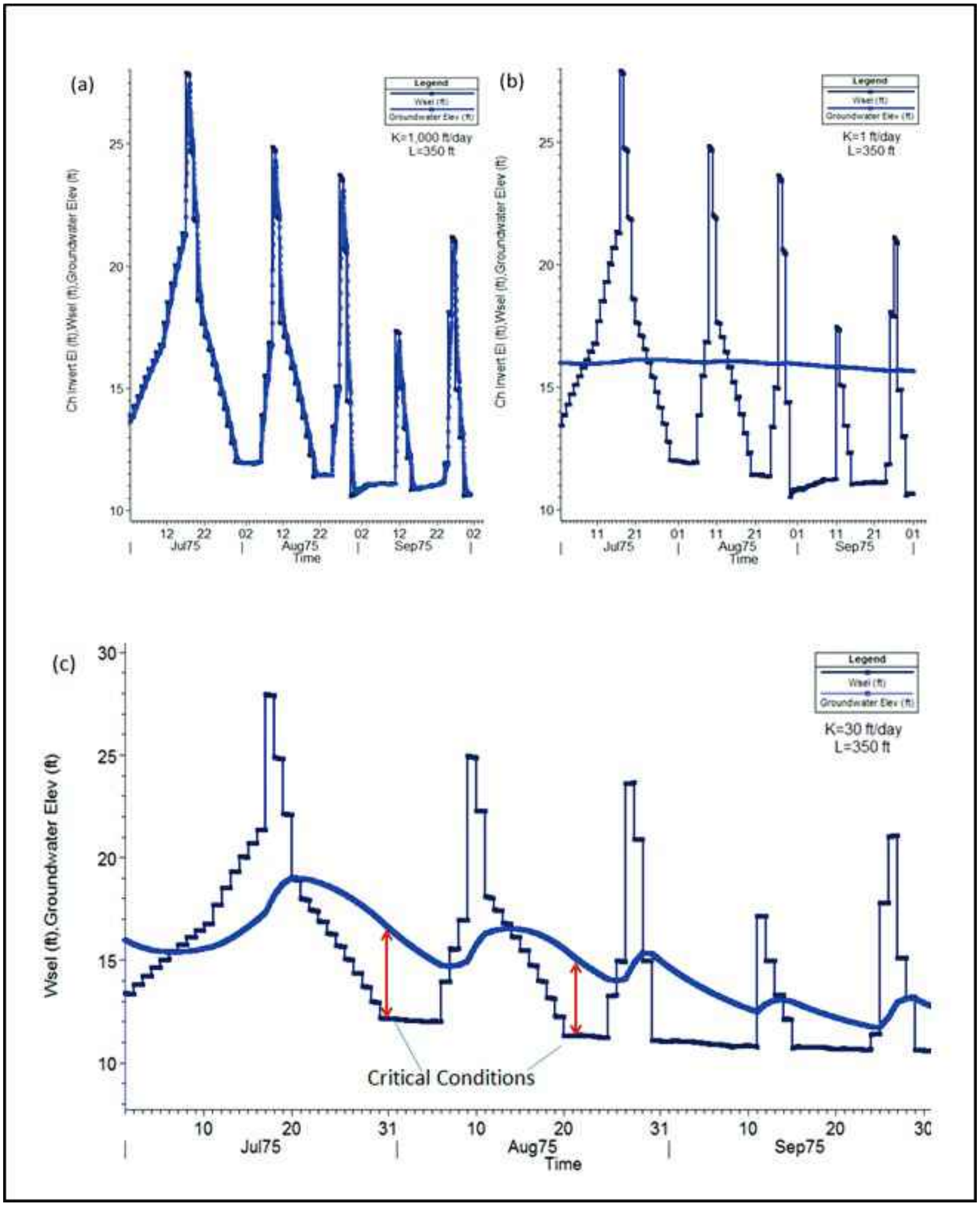

Figure 36. Groundwater response to (a) high (b) low and (c) moderate hydraulic conductivities.

groundwater elevation (Figure 36c). Because groundwater elevations higher than the confining water surface elevation are the critical condition, groundwater lag can induce failures on the falling limb of the hydrograph, both in the field and in the model.

3. Define Separate Parameters for Multiple Layers for Each Cross Sections

Finally, it is often advantageous to define several bank material layers. Some banks have distinct stratigraphy, stacking soil layers. Sometimes vegetation is modeled by introducing a surface layer with the same friction angle as the parent material but with a higher cohesion. To specify layers, select **Define Layers**, from the **Left/Right Bank Material** lists available in the **HEC-RAS Sediment Data Editor** (Figure 37). If the **Define Layers** option is selected, a new table will appear on the right side of the editor (Figure 37).

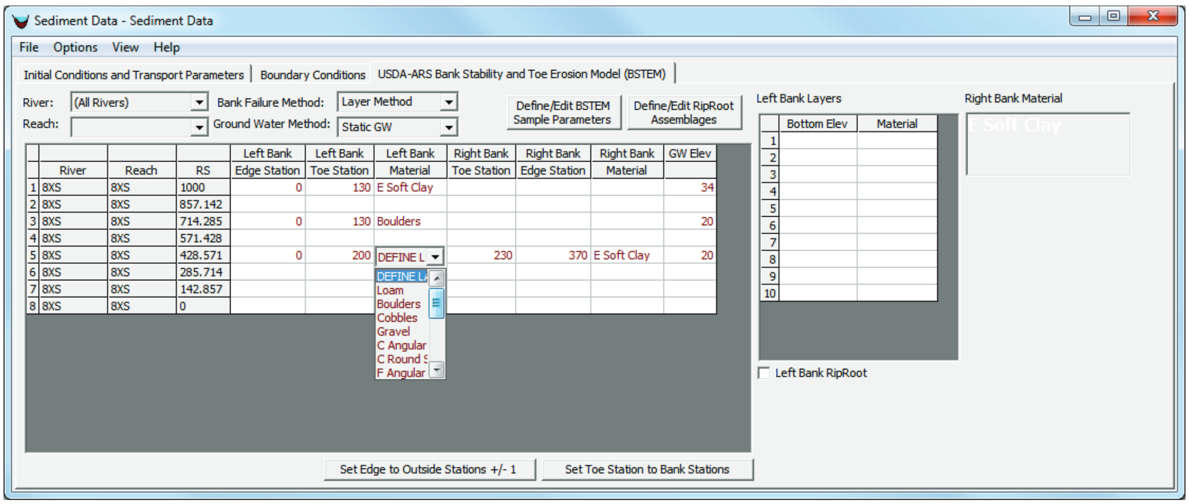

Figure 37. Selecting the layer mode for a bank failure.

The bank material layer table requires two parameters: a bottom elevation and a material. Layers must be ordered from top to bottom, i.e., the upmost layer in the first row, the next lowest layer in the second row, etc. The first layer will extend from the highest point on the half-cross section to the specified **Bottom Elevation**. Subsequent layers will use the bottom elevation of the preceding layer as an upper boundary. Add layers until the lowest layer's **Bottom Elevation** extends below the conceivable bottom of the model (i.e., the lowest elevation the model is likely to scour to). The bottom of the deepest layer has to at least extend to the thalweg elevation for the model to run. Then, just like the **Bank Material Type** option in the main BSTEM editor, a list of bank materials can be accessed by clicking on the **Material** column (Figure 38). Each layer has to have its own material specified, but the materials do not have to be unique and can be any combination of default or user specified material types.

Guidelines for Selecting Layer Elevations: Setting layer elevations according to a couple conventions can make an HEC-RAS/BSTEM model more stable. First, set the bottom of the top layer below the lowest point of the overbank, so the layer only intersects the cross section at one point, between the toe and the top of bank (Figure 39). Second, set the bottom of the bottom layer below the deepest possible thalweg elevation (e.g., thalweg max erodible depth) so the model never scours below the defined layers (Figure 39).

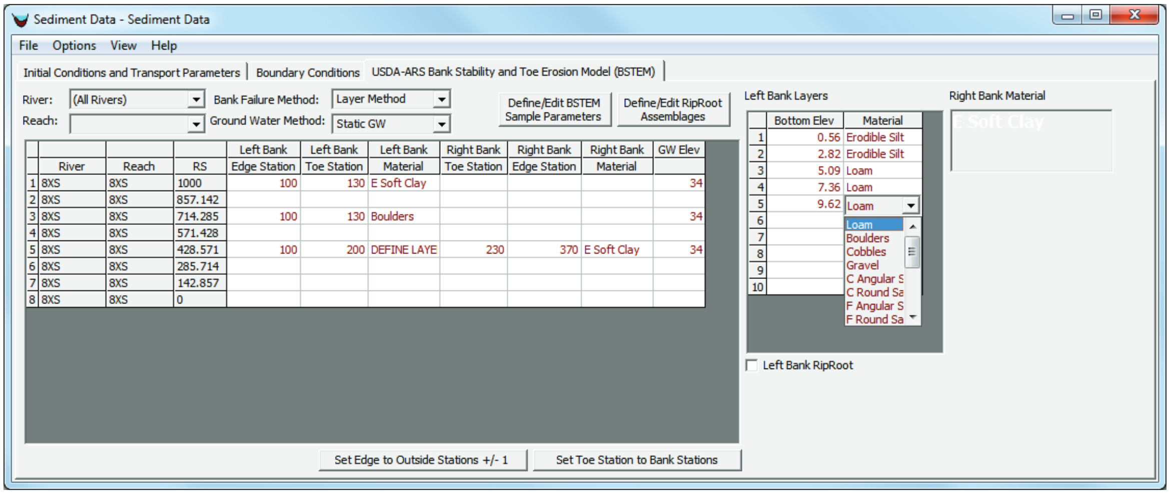

Figure 38. Defining layers and layer material types.

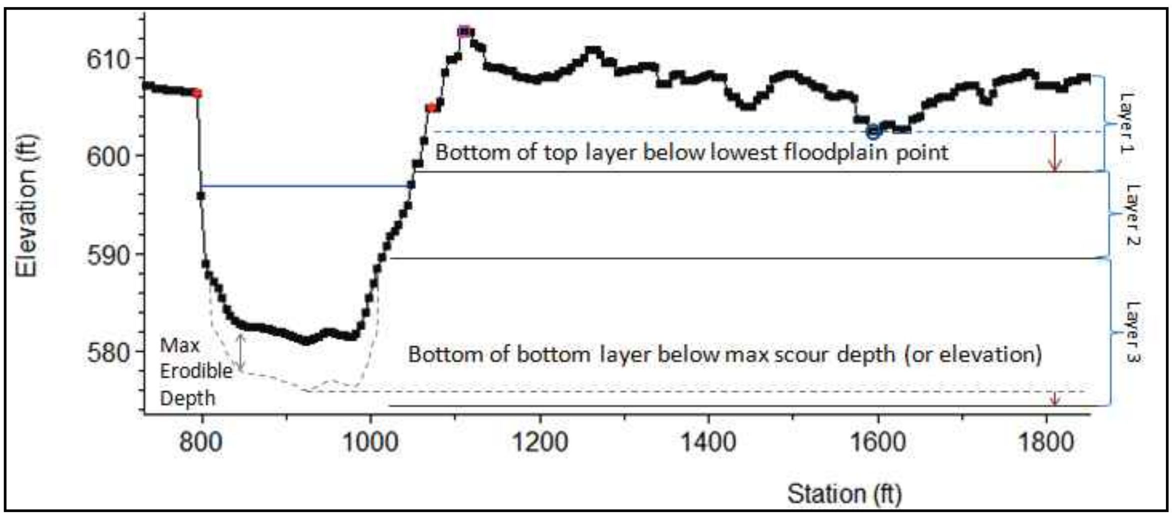

Figure 39. Guidelines for setting layer elevations.

UM.4 USDA-ARS BSTEM Options

The HEC-RAS/BSTEM model integration includes several arbitrary parameter thresholds and two processes with multiple methods. These parameters and methods influence results and run times. The **BSTEM Options Editor** (Figure 40) exposes them so users can adjust or select them.

UM.4.1 Number of Failure Plane Computation Nodes

The bank failure algorithm computes a critical failure plane at every one percent of the elevation between the toe and edge stations, computing critical failure planes at 100 evenly spaced vertical bank intersection points (Figure 13). This is computationally expensive and often much more detail than necessary. From HEC-RAS this parameter is available from the **BSTEM Options Editor** (Figure 40). Users can specify the number of vertical computation bank failure points. HEC-RAS will evenly distribute the computation points vertically, between the bank toe and edge elevations.

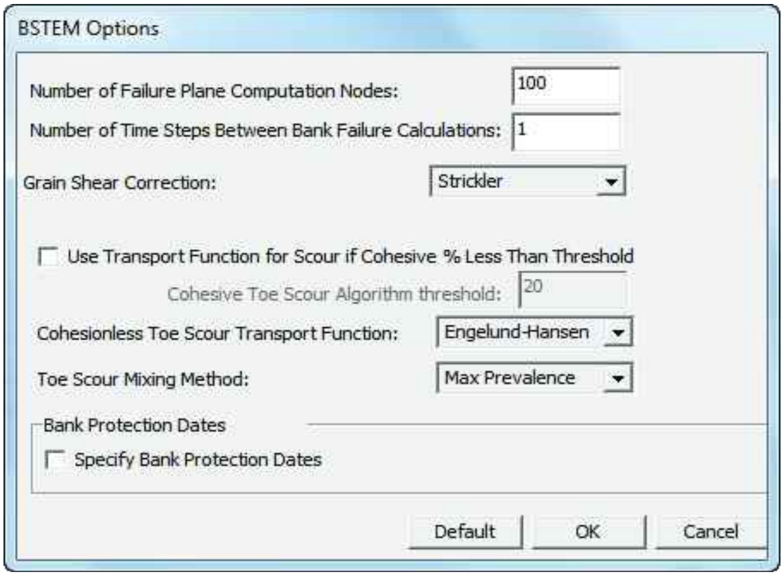

Figure 40. BSTEM Options Editor.

UM.4.2 Number of Time Steps between Failure Computations

Bank failure algorithms are computationally expensive. These algorithms can increase sediment model run times by an order of magnitude. Users can reduce run times by defining BSTEM parameters only at the half-cross sections where bank processes are expected. Bank failure conditions (i.e., FS less than one) are not usually instantaneous. If FS drops below one, the failure condition generally lasts for several time steps. Skipping bank failure computations will introduce error, but given the uncertainties of the model, the error may be acceptable tradeoff for run time.

UM.4.3 Grain Shear Correction

Only part of the shear stress water exerts on soils translates into transport. Shear partitioning theory for bed transport is more mature, parsing shear into form and grain shear (and sometimes into other components). This theory is not as applicable to banks. However, the isolated measurements, either by jet tests in the field or Sedflume in the lab, tend to isolate grain shear effects. Therefore, the toe scour mechanisms apply a **Strickler** grain shear correction by default. From the **BSTEM Options Editor** (Figure 40), from the **Grain Shear Correction** list, select **None,** this will turn the correction off. Turning the grain shear correction off will increase the shear stress on the bank and will increase scour.

UM.4.4 Minimum Percent Cohesive to Use Toe Scour Algorithms

BSTEM has two approaches to toe scour. The cohesive algorithms use the excess shear equation to compute scour rates based on measured erodibility data. The cohesionless algorithms apply transport functions (Section UM.4.5) to compute scour. The cohesionless methods are generally less accurate, but it is difficult to estimate cohesionless erodibility either in the lab or in the field.

By default, HEC-RAS/BSTEM uses the cohesionless methods. The **Use Transport Methods** check box in the **BSTEM Options Editor** (Figure 40), is off by default, forcing HEC-RAS to use the cohesionless, excess shear method. Applying the transport functions to individual nodes often wildly over predicts transport and scour, so users must intentionally turn the cohesionless methods on by checking the **Use Transport Methods for Scour if Cohesive % is Less than Threshold** feature.

If cohesionless methods are selected, HEC-RAS/BSTEM decides between the methods for each soil layer by computing the percentage of the bank soil that is cohesive (i.e., in the first five HEC-RAS grain classes, which is less than .063 millimeters in the default grain class definition). HEC-RAS computes this percentage from the gradation defined in the sediment editor and selected in the **BSTEM Material Parameter Editor** (Figure 32) from the soil type list, or the narrow gradations of the default soil types (Figure 30). By default, if **20 percent** or more of the soil is cohesive, (clay or silt), BSTEM uses the cohesive methods, applying cohesionless equations if the cohesive fraction is less than **20 percent**.

The twenty percent threshold is not entirely arbitrary. Around twenty percent cohesive content, the fine particles fill the soil voids enough for their cohesive properties to dominate the erodibility of the larger particles. However, in reality, the transition from cohesive matrix support to cohesionless framework support is a gradient not a step function. Therefore, the cohesive percentage threshold is exposed as an option in the **BSTEM Options Editor** (Figure 40). If the transport functions return unreasonable scour rates, as often happens, users can model cohesionless materials with the cohesive erodibility approach.

UM.4.5 Transport Function

As described in Section UM.4.4, if a soil layer has less than 20 percent (or a user specified percentage) cohesive material, BSTEM will apply a transport function to compute toe scour (Figure 41). The USDA-ARS BSTEM model uses an NCED (National Center for Earth Surface Dynamics) transport function library to compute transport. This library includes six transport functions, including:

- Engelund-Hansen (1967)
- Parker (1990)
- Wilcock and Crowe (2000)
- Meyer-Peter Muler
- Wu (2000)

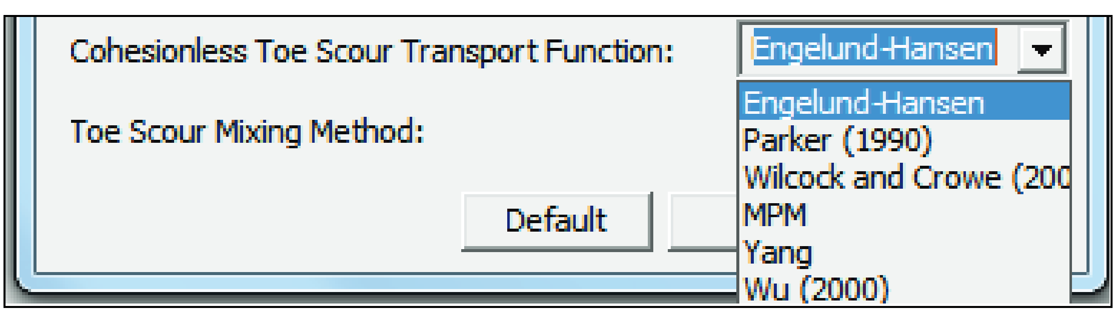

Figure 41. BSTEM Options Editor - Transport functions available for cohesionless toe scour in BSTEM.

Select and apply transport functions with ***extreme caution*** recognizing the intent and range of applicability of each. Transport functions are notoriously uncertain, computing transports that commonly differ by at least one order of magnitude. The Engelund-Hansen (1967) and Yang (1973) transport equations work best for sand. The Meyer-Peter-Mueller (MPM) transport function will probably perform best for coarse materials. Parker (1990) and Wilcock and Crowe (2003) are both **surface-based** methods, intended for heterogeneous soil mixtures with sand and gravel components. These two methods account for mixing, hiding and armoring implicitly, which tends to moderate transport and sometimes makes the methods more appropriate for toe scour in heterogeneous materials.

Also, it should be noted that most of these transport functions were derived for one-dimensional alluvial transport at the cross section scale. BSTEM applies these transport functions to bank scour at the node scale. This makes transport functions, already uncertain in their intended setting, loose process analogies in toe scour. The transport functions often over predict scour substantially and results should be interpreted carefully.

UM.4.6 Toe Scour Mixing Method

The HEC-RAS sediment transport follows HEC-6 and most sediment transport models by apportioning transport across available grain classes in proportion to the gradation of the bed.

$$T_c = \sum_{j=1}^{n} \beta_j T_j$$

Where T_c is the total transport capacity, n is the number of grain size classes, β_j is the fraction of material in grain size class j, and T_j is the transport potential computed for material in grain class j. This approach generally works when coupled with an "active layer" bed model that tracks the gradation of a surface layer separately. Without an active layer, transport functions compute huge masses for small particles, removing these materials from deep within the bed, much deeper than physically possible.

The toe scour method does not have an active layer. Therefore, transport methods have unrestricted access to all the fine materials in the bank. Apart from the standard uncertainty of the transport functions, this is the primary reason that the cohesionless method over predicts transport; it can numerically wick fine materials deep in the bank, while the coarser materials remain.

The HEC-RAS/BSTEM development team experimented with three mixing methods to mitigate this numerical artifact:

Cumulative: Applies the same assumption as the bed, apportioning capacity by the prevalence in the bank layer. However, since the bank layer has no active layer and does not update, this provides an unlimited supply of finer material and usually over-predicts scour.

Maximum Prevalence (default): This method apportions capacity according to the relative proportion of the bank gradation. However, it only erodes the most prevalent grain class.

This assumes that the dominant grain class moderates scour. This method is more appropriate if trace fines and low percentage fine sands cause the other methods to over-predict scour and was designed for framework supported materials.

Maximum Capacity: This method was designed for matrix supported materials. It assumes that the prevalent fine material, the one with the largest product of transport potential and prevalence, controls the scour distance. So the scour distance associated with the largest capacity grain class is applied, assuming that the other particles are larger clasts that will fall into the channel when released from the scoured fine matrix.

UM.5 Output

HEC-RAS does not compute USDA-ARS BSTEM results by default. BSTEM output can be selected from the **Sediment Transport Analysis** dialog box, from the **Options** menu**,** click **Sediment Output Options.** The **Sediment Output Options** dialog box will open. From the **Output Level** list box select **6**. After running the model, go to the **View** menu of the HEC-RAS main window (Figure 25) and select **Sediment Output**. The **Sediment Plot** viewer will open. In general, the new sediment output (which reads HDF5 output), is more complete and user friendly. However, the legacy sediment output viewers from HEC-RAS Version 4.1 were retained because they have a few capabilities (e.g., plotting multiple variables and creating new geometry files) that the new viewers lack.

HEC-RAS computes several commonly used BSTEM results for display in the **Sediment Output** interface. The total mass eroded from a cross section in a computation increment (for both banks and both processes) is reported under **BSTEM All**. The total mass eroded from the banks can also be reported by grain class (e.g. BSTEM (7)) or by bank and process (Figure 42). Finally, FS for each bank (Figure 43) and **Groundwater Elevation** (Figure 44) are available. All of these variables can be viewed as profiles (all the cross sections in a reach at a selected time step) or as time series, (all values over time at a selected cross section). The BSTEM output variables are defined in Table 3.

HEC-RAS modifies cross sections when the sediment model computes bed change or when BSTEM computes bank migration. Viewing cross section changes is often the most valuable output to understand and troubleshoot an HEC-RAS/BSTEM model. Cross section output files can be very large. HEC-RAS only outputs starting and final cross sections by default. The user can request more frequent cross section output from the **Sediment Output Options** dialog box (Figure 45). From the **Sediment Transport Analysis** dialog box, from the **Options** menu**,** click **Sediment Output Options.** The **Sediment Output Options** dialog box will open (Figure 45), users can request cross section data and specify the increment, an example is provided in Figure 46. The new **Sediment Output Viewer** also plots the water surface elevation and the BSTEM toe associated with the cross section (Figure 47).

UM.6 Model Validation

Model testing was conducted to demonstrate the reliability of the HEC-RAS/BSTEM algorithms. Several test scenarios were constructed and modeled with HEC-RAS, the standalone version of BSTEM 5.4 and the standalone FORTRAN version of BSTEM used in the integration (which

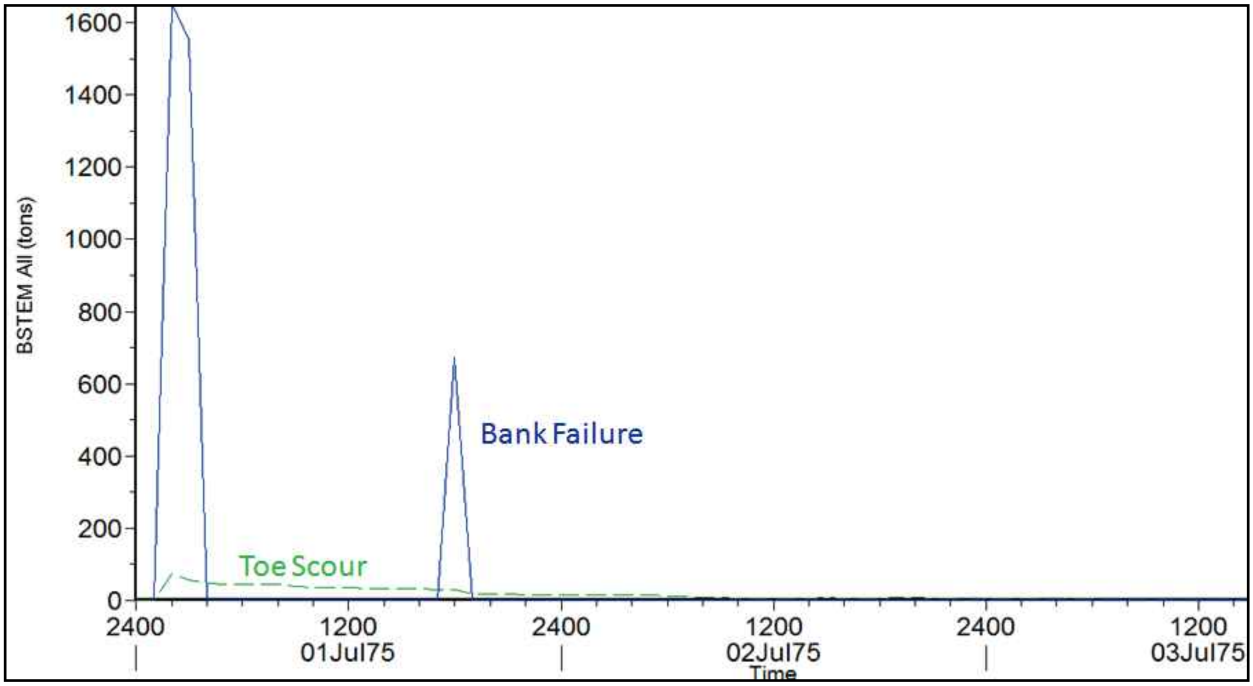

Figure 42. Time series of bank mass eroded by process.

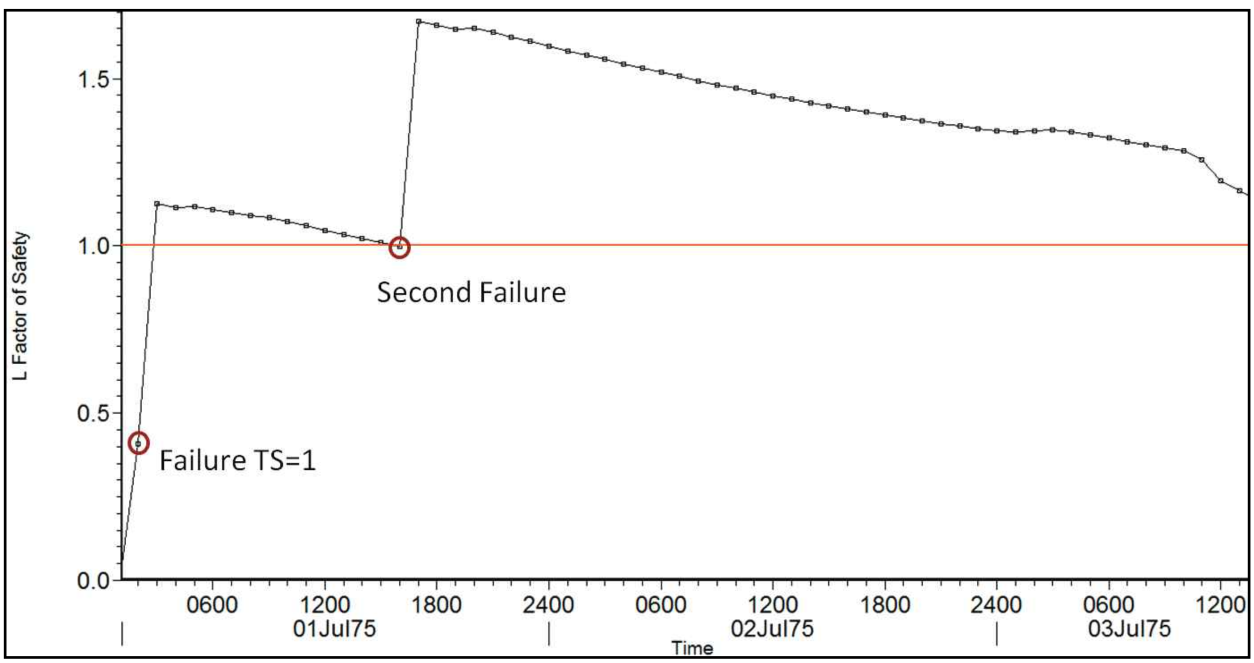

Figure 43. Time series of FS.

was subjected to rigorous independent validation against BSTEM 5.4 (Simon, 2010)). The before and after cross sections for a bank failure event are displayed in Figure 48. The FORTRAN version of the algorithms in HEC-RAS replicates BSTEM 5.4 very closely. Small divergence can be explained by a couple of algorithm differences between the FORTRAN version and BSTEM 5.4.

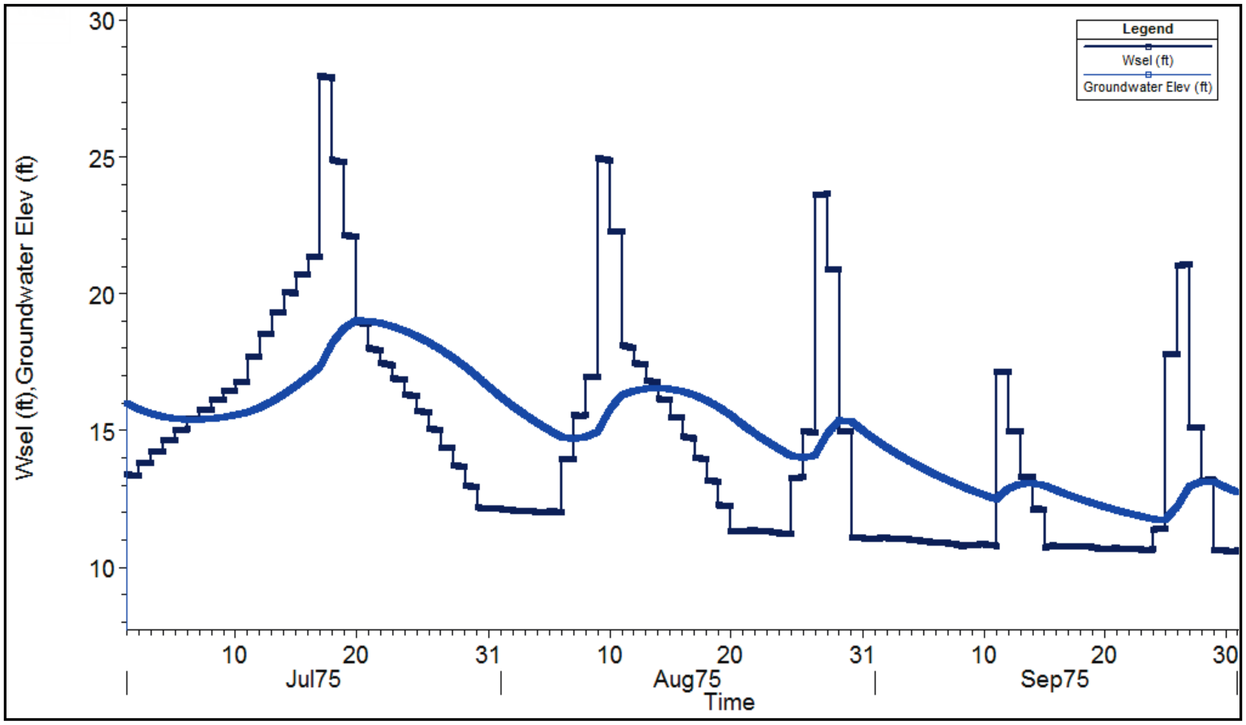

Figure 44. Groundwater and water surface time series plot demonstrating the lag between water surface and groundwater elevations.

Table 3. USDA-ARS BSTEM Output Variables in HEC-RAS.

Variable	Descriptions
BSTEM All (tons or cubic feet)	Total sediment mass (or volume) removed by both banks by toe scour and bank failure for each cross section for each computation increment.
BSTEM (for every grain class) (tons or cubic feet)	The previous variable, subdivided by grain class.
L BSTEM Mass Failure (tons or cubic feet)	Mass removed from the left bank by failure processes for each computation increment.
L BSTEM Mass Toe (tons or cubic feet)	Mass removed from the left bank by toe scour for each computation increment.
L Factor of Safety (Decimal Fraction)	Minimum factor of safety computed in the left bank for each computation increment.
R BSTEM Mass Failure (tons or cubic feet)	Mass removed from the right bank by failure processes for each computation increment.
R BSTEM Mass Toe (tons or cubic feet)	Mass removed from the right bank by toe scour for each computation increment.
R Factor of Safety (Decimal Fraction)	Minimum factor of safety computed in the right bank for each computation increment.
Groundwater Elev (feet)	Groundwater elevation computed in BSTEM, either static, user specified, or computed with the groundwater lag method.

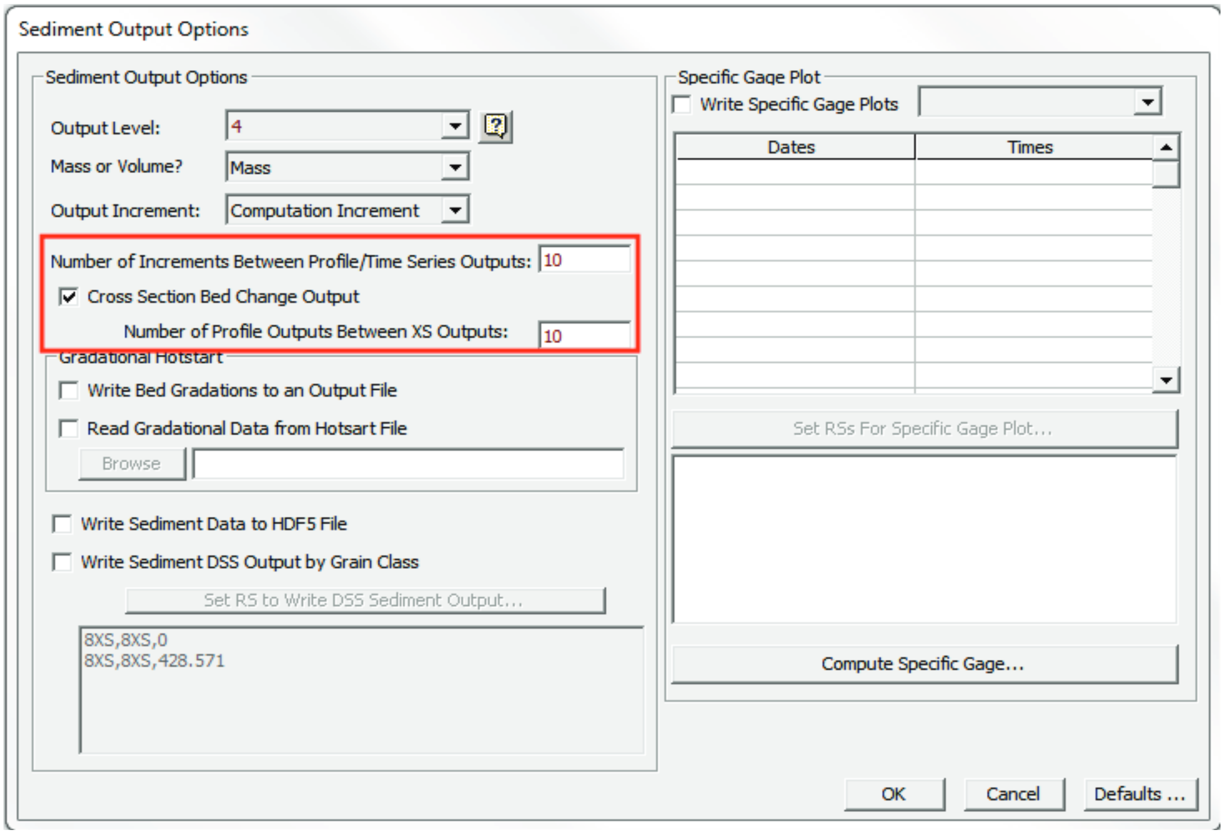

Figure 45. Requesting and specifying the frequency of sediment cross section output in the **Sediment Output Options** dialog box.

Gibson (2015) also applied the model to Goodwin Creek, following the work of Langendoen (2008). Goodwin Creek is a highly instrumented reach with substantial bank migration, carefully measured over a decade with dozens of repeated cross sections, making it an ideal site for evaluating a bank process model. Gibson (2015) used the parameters from Langendoen (2008), to test the model against a known calibration. The integrated HEC-RAS/USDA-ARS BSTEM model performed well compared to prototype data (Figure 49) and the CONCEPTS model runs in Langendoen (2008).

UM.7 Modeling Guidelines, Tips, and Troubleshooting

The HEC-RAS/BSTEM development team has compiled several modeling tips and guidelines that can make coupled bed-bank modeling more stable and less frustrating. Consider the following approaches and tips before setting up a model or to help troubleshoot models that are crashing or behaving poorly.

UM.7.1 Stepwise Modeling Process

Sediment transport modeling with HEC-RAS was already complete and highly parameterized before bank failure. Bank failure makes it more complex. Complex models that account for more processes explicitly make careful, strategic, sequential modeling practice more important.

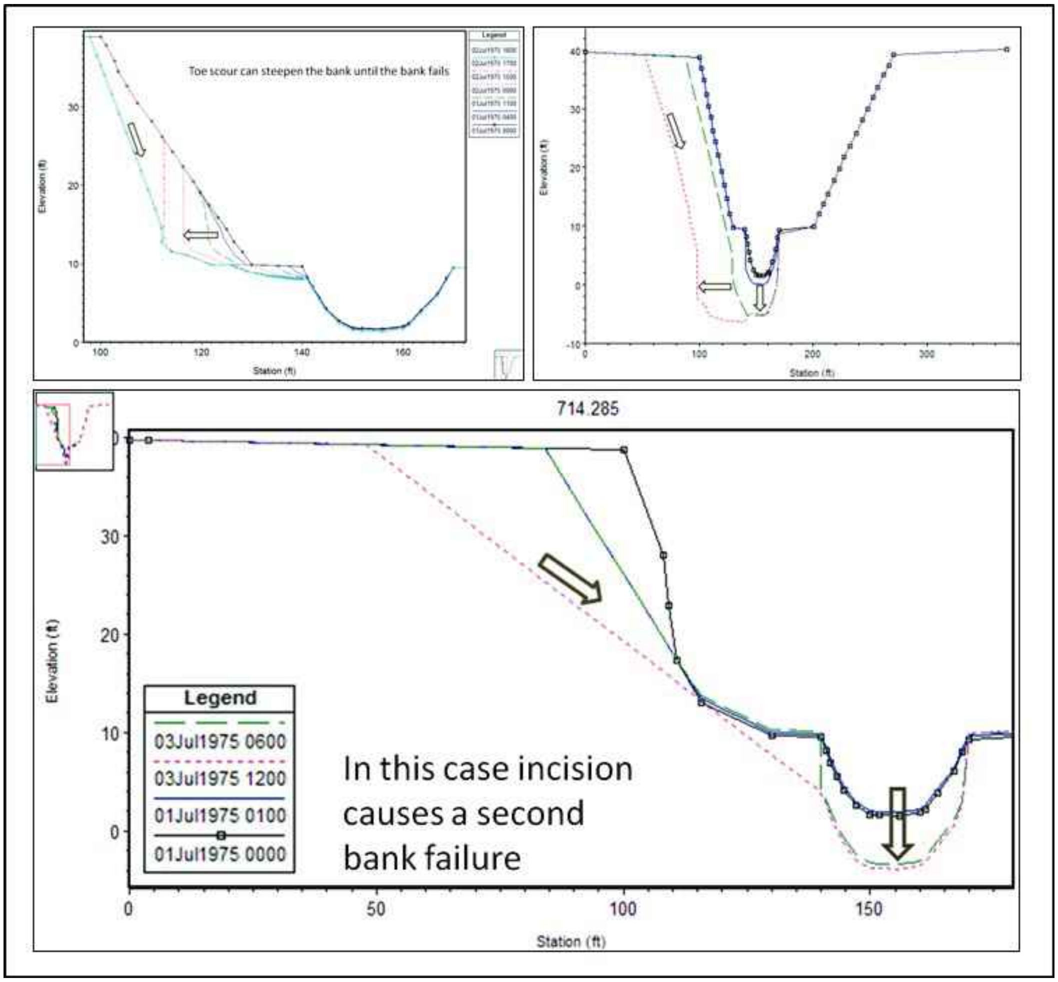

Figure 46. Example HEC-RAS cross section outputs including toe scour, incision and bank failure at various stages in the simulations.

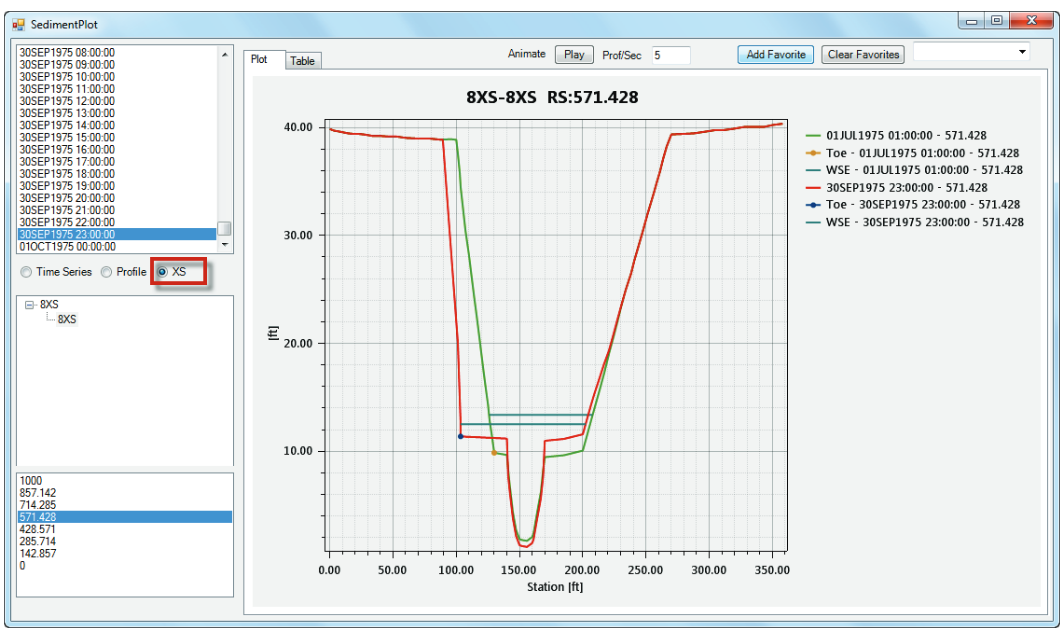

Figure 47. Bank migration cross section output with the new Sediment Output viewer.

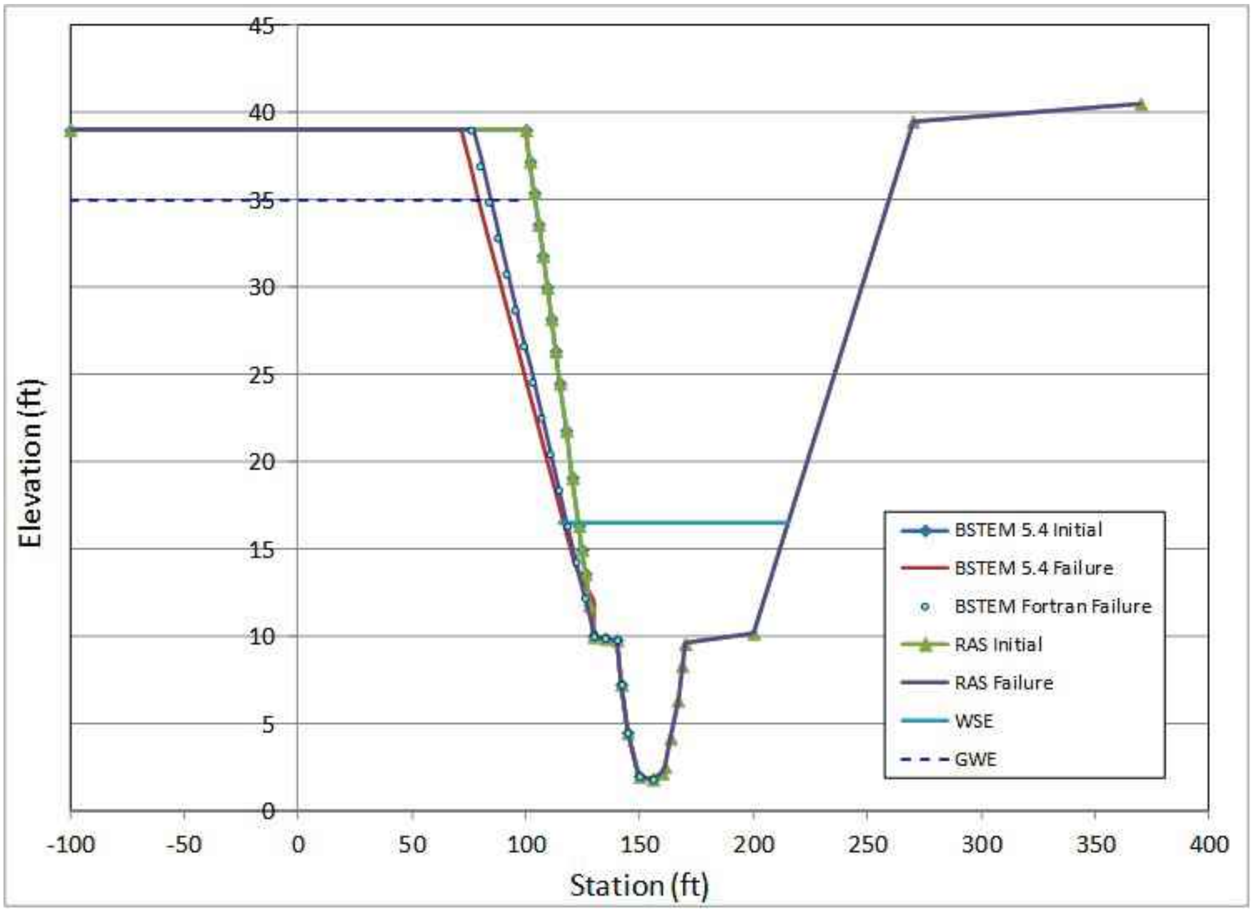

Figure 48. Output from a validation test of the HEC-RAS implementation of the bank failure capabilities and the standalone models.

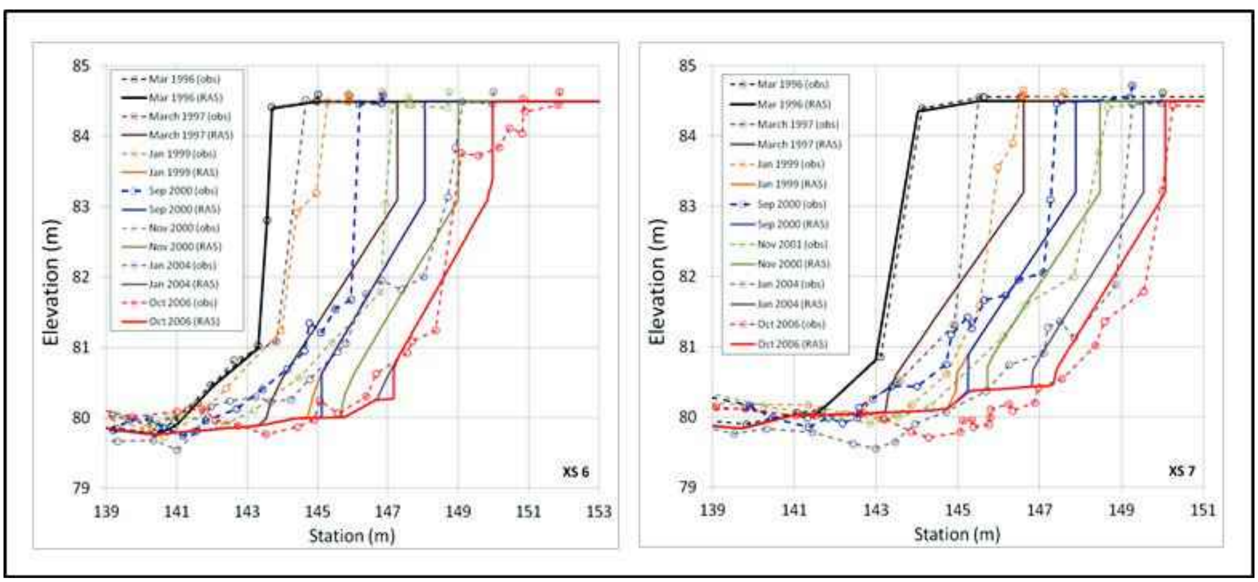

Figure 49. Select Goodwin Creek repeated right bank surveys at the two central cross sections with HEC-RAS/BSTEM cross section migration from Gibson (2015).

Model processes from simple to complex. Add complexity one step at a time. A stepwise modeling process, that adds complexity incrementally, carefully calibrating and evaluating results of each modeling step, will produce more accurate models and sane modelers.

Create an HEC-RAS/BSTEM model in the following incremental steps, carefully completing, evaluating, and calibrating each step before adding the complexity of the next step.

1. **Calibrate Hydraulics:** Create the geometry and calibrate model hydraulics in the steady flow module over the range of expected flows.

2. **Model/Calibrate Sediment Transport**: Isolate the sediment transport mechanics by carefully modeling bed sediment without bank processes first. Build a robust (Thomas, 2007; Gee, 1982) calibrated model, or at least, evaluate results to understand the sensitive parameters.

3. **Model/Calibrate Bank Erosion and Bank Failure**: By setting the cross sections as **Pass-Through Nodes** (under the **Options** menu in the **Sediment Data Editor**), users can isolate bank processes and refine bank methods and parameters without the complexity bed process feedbacks.

4. **Integrate Bank Erosion and Failure plus Mobile Bed Sediment Transport Model**: After the hydraulics are calibrated and the bed and bank sediment models have been refined independently, then combine all the components, and calibrate the coupled model to bed and bank change.

UM.7.2 Selecting a Toe

The USDA-ARS BSTEM model is very sensitive to the toe node selected. Tips for selecting the toe include:

1. Make the **BSTEM Toe Station** the same as the **Movable Bed Limit** (**Left Station** and **Right Station** in **Initial Conditions and Transport Parameters** in the **Sediment Data Editor**). While there is a tool to set the **Toe Stations** to the **Movable Bed Limits**, it is often better to go the other way, selecting a toe and then setting the **Movable Bed Limit** station equal to the **Toe Station**.

2. HEC-RAS distorts cross sections vertically in the cross section display of the **Geometry Editor**. This makes them easier to visualize, but can make it difficult to select a toe. When selecting toe stations, change the aspect ratio of the cross section plotter. Adjust the cross section view window to a short-vertical, maximum-horizontal configuration and zoom in along the horizontal axis until one foot or meter of station spacing is equal to one foot or meter or elevation spacing (e.g., a 1:1 H:V ratio; Figure 50). This adjustment will make it easier to pick an actual toe from an undistorted cross section plot.

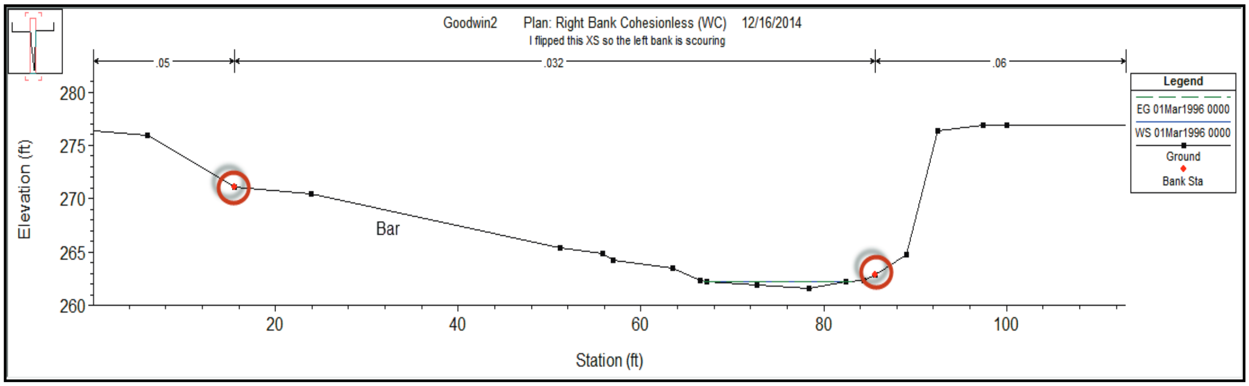

Figure 50. Cross section viewer adjusted to approximately a 1:1 aspect ratio to help select the toe station.

UM.7.3 Monotonic Bank Geometry

HEC-RAS allows complex cross sections. USDA-ARS BSTEM idealizes cross sections in a couple of important ways. HEC added logic to adapt BSTEM to complex cross sections, but some cross sections shapes still tend to be unstable. In particular, avoid "bank depressions" (Figure 51) if possible. Cross section node elevations should increase from the toe to the edge of the bank.

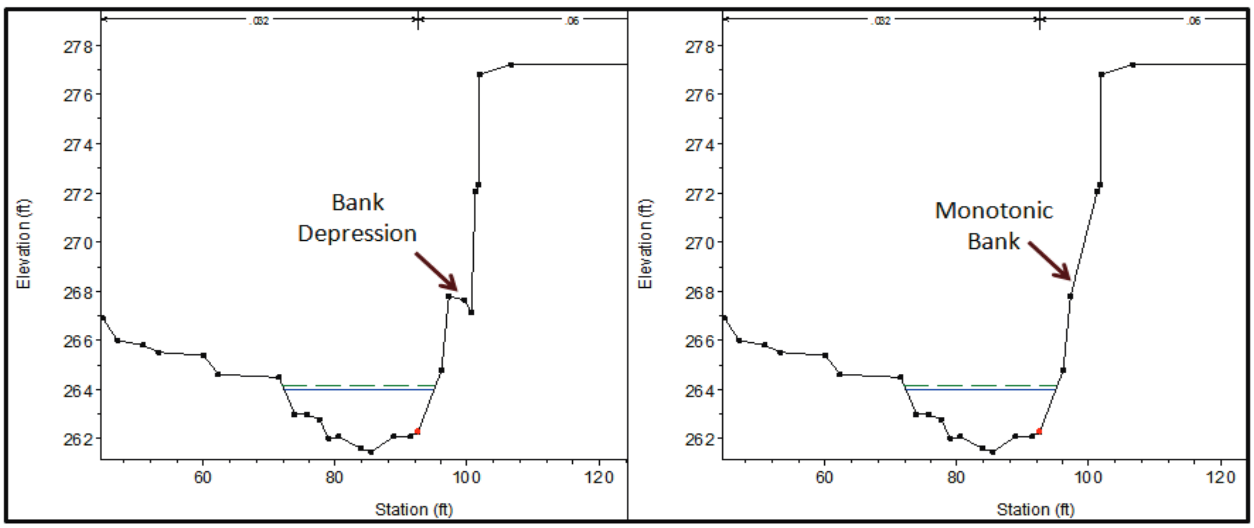

Figure 51. Avoid bank depressions (left) where possible, particularly with soil layers. Monotonic banks (cross section nodes that increase from the toe out to the bank edge) are more stable.

The model can become unstable when a soil layer boundary crosses the cross section more than once. Therefore, if the cross section includes an important bank depression, make sure that the soil layer does not pass through it.

UM.7.4 Floodplain Geometry

The portion of the cross section outside the **Edge of Bank Station** must conform to three conventions to provide optimal results:

1. The floodplain must be wide enough to include the maximum failure plane angle. For long term simulations this includes the maximum failure plane from the maximum scour location. As a rule of thumb, include a floodplain wide enough to encompass at least a ten degree angle from the toe station.

2. The floodplain (or Top of Bank, Figure 27) needs intermediate station-elevation points between the edge of the bank and the end of the cross section (Figure 52) for BSTEM to compute failure planes effectively.

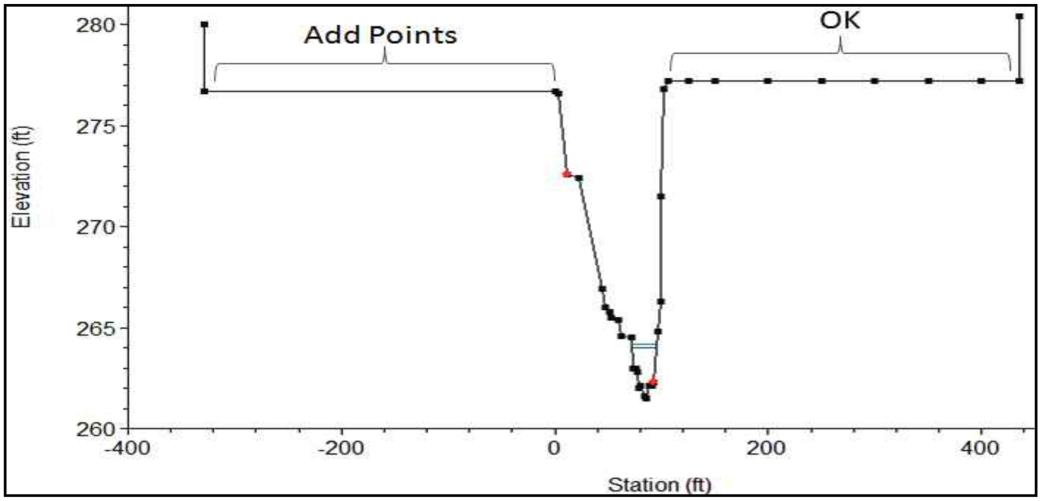

Figure 52. BSTEM requires cross section station-elevation points between the Bank Edge Station and the end of the cross section.

3. If the floodplain is irregular (Figure 39) it should not intersect with a layer more than once. If the cross section includes multiple soil layers, the top layer should include all of the cross section nodes outside of the bank edge station.

4. HEC-RAS should be able to handle wet depressions and ineffective flow areas outside the bank edge, but the more floodplain complexity in a cross section the more likely that the failure plane algorithm will converge on a false maximum or that the cross section update will encouter a problem. Avoid incidental cross section complexity, particularly in the overbank.

UM.7.5 Too Much Toe Scour

Most HEC-RAS/BSTEM model failures come from having too much toe scour. Since soil erodibility data can vary by orders of magnitude, even in the same site, selecting high cohesive erodibility will compute excessive scour. Cohesionless methods (Figure 53), that compute toe scour with transport equations almost always over predict scour, sometimes dramatically.

UM.7.6 Common Runtime Error Messages

The **unrealistic vertical adjustment** error (Figure 54) is the most common sediment error in general and HEC-RAS/BSTEM in particular. This error indicates that HEC-RAS computed very large bed changes at the indicated cross section in the last timestep before the program stopped.

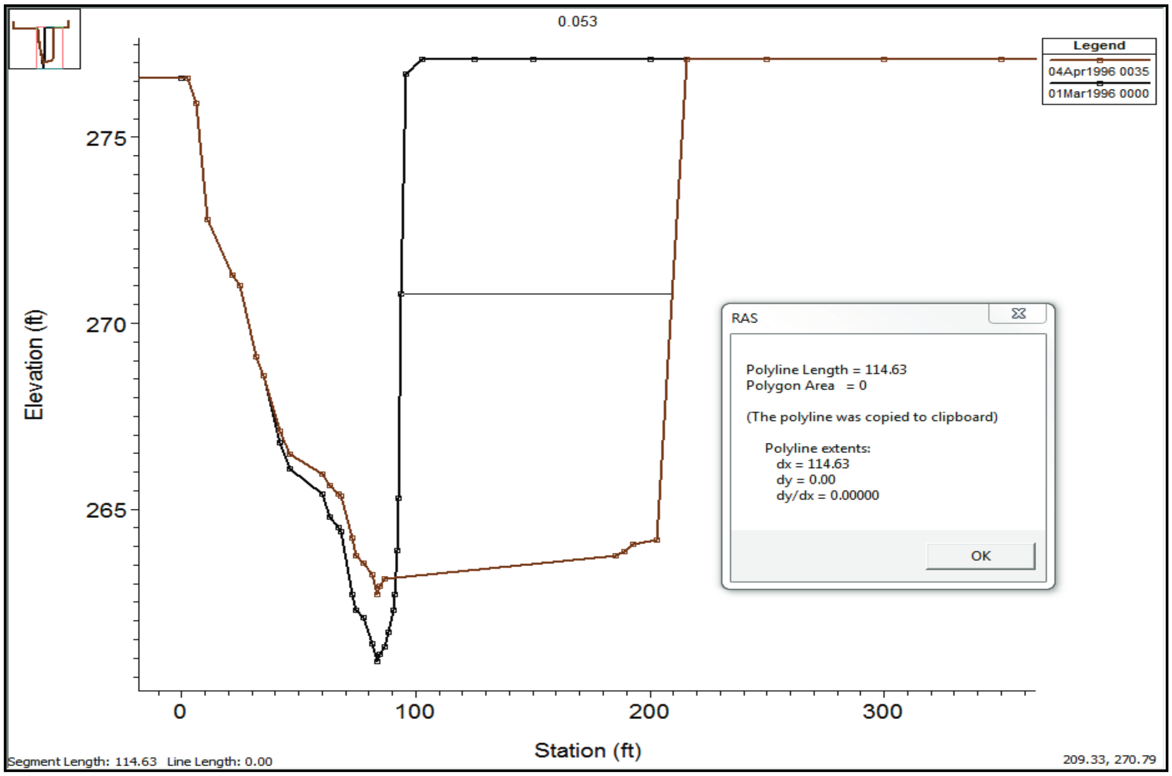

Figure 53. In this model, the cohesionless transport methods computed more than 100 feet of bank scour in just over a month, which is order of magnitude faster than the actual bank recession rate.

ERROR during Sediment Simulation

Unrealistic vertical adjustment at
8XS 571.428

Figure 54. The Unrealistic Vertical Adjustment Error.

This error is often resolved by reducing the computation increment. However, sometimes more systemic model or data problems make the error persist at very small computational increments. The most common causes include:

1. Excessive toe scour: The most common cause of model failure is excessive toe scour (Section UM.7.5). Lower the erodibility substantially or turn off the cohesionless transport methods (go to the **BSTEM Options Editor** under the **Options** menu in the **Sediment Data Editor**) to stabilize the model.

2. Bed material does not match transport function: If the bed material is too fine for the transport function, or if the transport function over predicts transport in the reach, the mismatch can lead to large, rapid bed changes, destabilizing the model. A common error involves assigning fine bank material gradations to the bed.

3. Equilibrium Load: If the equilibrium load boundary condition is used with bed gradations that include non-trivial amounts of silt or clay, this boundary condition can compute enormous fine-grained sediment loads at the boundary. Small decreases in transport

downsteam can cause large bed changes. User-defined rating curves are almost always better sediment boundary condition options, even if they are speculative.

UM.7.7 Unusual Cross Section Shape

Sometimes active cross sections can produce strange shapes, like the example shown in Figure 55. First, make sure the toe station and the movable bed limits are set to the same station. Second, the USDA-ARS BSTEM features often work best if HEC-RAS allows deposition outside the movable bed limits. From the **Sediment Data Editor**, from the **Options** menu, select **Bed Change Options**. Then, under **Deposition,** select **Allow Deposition Outside of the Movable Bed Limits**. This will constrain erosion to the movable bed limits (which will migrate with the toe if they have the same staring station) but will deposit at any wetted node in the cross section. The model in Figure 55 was re-run in Figure 56 with this option selected and produced more realistic results.

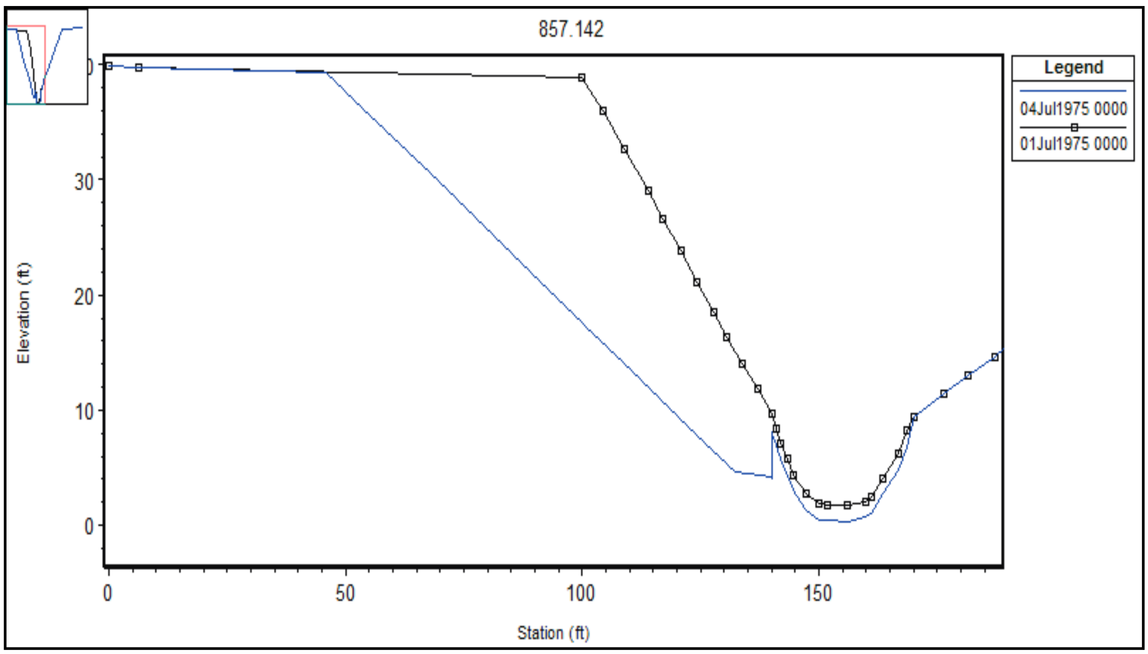

Figure 55. Strange cross section shape caused by deposition inside the movable bed limits, but not outside.

UM.7.8 Groundwater Table

Results can be very sensitive to groundwater. Two particular groundwater errors that can create model problems:

1. Never specify a starting or static groundwater table that is higher than the bank edge.

2. Groundwater elevations far below the channel water surface elevation will keep the bank from failing. The USDA-ARS BSTEM applies a hydrostatic assumption, computing suction according to a hydrostatic gradient from the groundwater elevation. Therefore, in ephemeral streams or situations where the groundwater table is unknown, estimate the groundwater elevation or put it at an average surface water elevation at which banks should fail.

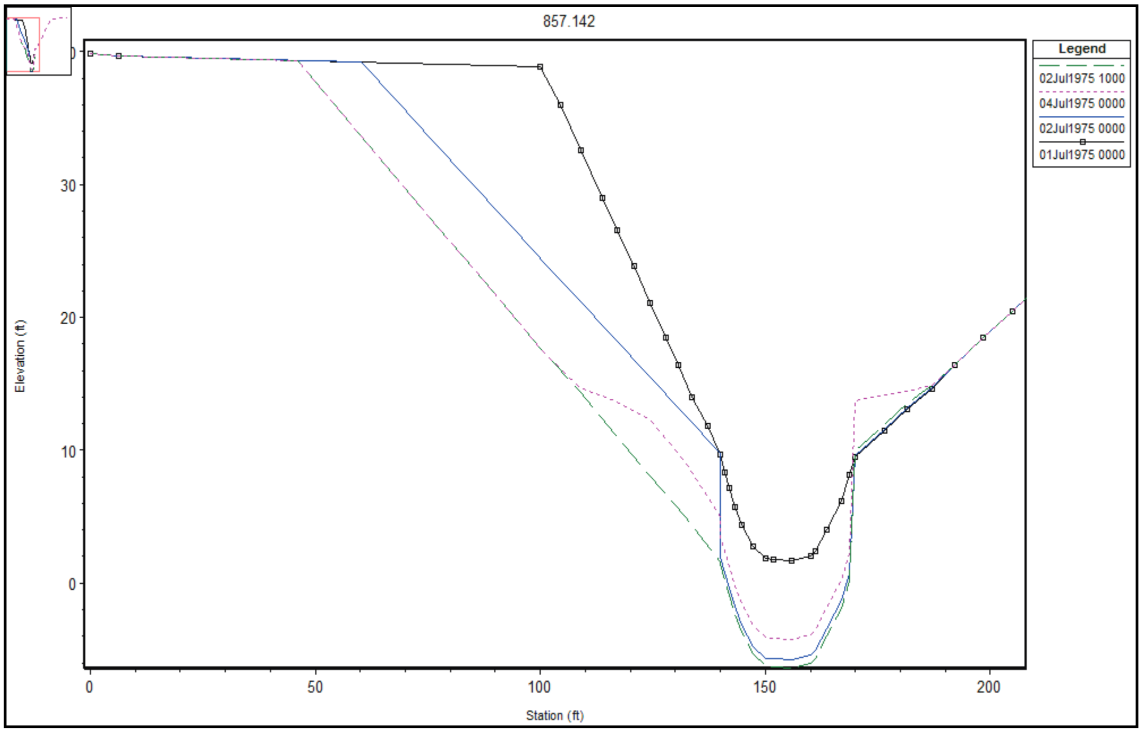

Figure 56. The same simulation as Figure 55, but allowing for deposition in the overbanks.

UM.7.9 Scour Outside of a Bend

In natural systems, banks are usually most active on the outside of a bend or meander. HEC-RAS is a one-dimensional model and does not simulate the multi-dimensional forces that cause this preferential erosion. Banks migrate more on the outside of bends because multi-dimensional effects produce higher shears there. Because HEC-RAS uses an excess shear equation to compute scour, users can simulate preferential bank scour by decreasing the critical shear at bend cross sections. This will approximate the physical process, increasing the (τ-τ_c) shear difference by decreasing the critical shear instead of increasing the shear.

UM.8 Acknowledgements

The integration of the USDA-ARS Bank Failure and Toe Erosion Methods (BSTEM) in HEC-RAS has been a significant effort with multiple funding partners including:

- Regional Sediment Management Program (USACE)
- Missouri River Recovery Project (USACE)
- The Australian Rivers Institute
- Flood and Coastal Storm Damage Reduction R&D Program (USACE)

HEC has also collaborated with and received code and/or technical guidance from:

- Andrew Simon PhD and Natasha Bankhead PhD (Cardno Entrix)
- Eddy Langendoen PhD and the USDA-ARS
- U.S. Bureau of Reclamation

The integration of HEC-RAS and BSTEM has been a substantial undertaking including multiple contributors in the USACE, the private sector, other Federal agencies, and even international interests. Andrew Simon (PhD - Cardno ENTRIX, formerly of USDA-ARS) partnered with HEC to initiate, envision and facilitate the integration. Eddy Langendoen (PhD - USDA-ARS) has provided essential technical support and advice throughout the process. The integration utilized code developed by Rob Thomas (PhD - University of Hull, formerly of University of Tennessee) and Yong Lai (PhD - USBR), funded by the Bureau of Reclamation and the Taiwanese Water Resources Agency, with input from Yavuz Ozeren (PhD - University of Mississippi). John Shelly (PhD - NWK) and Paul Boyd (PhD - NWO) provided District guidance and feedback on the development. Stanford Gibson (PhD - HEC) and Steve Piper (RMA) worked on the integrated HEC-RAS code. Funding for the development, troubleshooting, and documentation of the integrated HEC-RAS/BSTEM product has come from multiple sources including two USACE R&D Programs (Regional Sediment Management and Flood & Coastal Storm Damage Reduction), the Australia Rivers Institute, and the Missouri River Recovery Program.

UM.9 Scour Units

The cohesive model used in the bed model is different than that used in the bank model. The bed model removes sediment by mass. Mass is removed per area, per time in response to a force (e.g., N/m2-hr/Pa which translates to the slope of the relationship between mass removed per area per time and the force, which is one/time). In the bank model a volume is removed in response to a force, so the units are volume/force-time (e.g., M3/Pa-hr).

This difference is because bulk mass is removed from the bed and applied uniformly over the bed. The bank model shifts each node laterally, independently. Therefore, a "volume" is translated into a lateral shift, per node.

The following table provides conversion factors to move between SI and U.S. customary units.

Table 4. Conversion Factors.

From	Multiply by	To
$m^3/N/s$	0.42	1/hr
Pa	0.0208	psf
m^3/N-s	6365.9	ft^3/lbf-s
1/hr	2.39	$m^3/N/s$
psf	47.9	Pa
ft^3/lbf-s	0.000157	m^3/N-s

UM.10 SI Table

Table 5. Default materials and material parameters.

Default Material Type	**Saturated Unit Weight** (kN/m^3)	**Friction Angle** (ϕ')	**Cohesion** (kPa)	ϕ^b	**Critical Shear** (Pa)	**Erodibility** (m^3/N-s)
Boulders	20.0	42.0	0	15	498	4.48E-09
Cobbles	20.0	42.0	0	15	124	9.00E-09
Gravel	20.0	36.0	0	15	11	3.02E-08
Coarse Angular Sand	18.5	32.3	0.4	15	0.506	1.41E-07
Course Round Sand	18.5	28.3	0.4	15	0.506	1.41E-07
Fine Angular Sand	18.5	32.3	0.4	15	0.128	1.41E-07
Fine Round Sand	18.5	28.3	0.4	15	0.128	1.41E-07
Erodible Silt	18.0	26.6	4.3	15	0.1	3.16E-07
Moderate Silt	18.0	26.6	4.3	15	5	4.50E-08
Resistant Silt	18.0	26.6	4.3	15	50	1.40E-08
Erodible Soft Clay	17.7	26.4	8.2	15	0.1	3.16E-07
Moderate Soft Clay	17.7	26.4	8.2	15	5	4.50E-08
Resistant Soft Clay	17.7	26.4	8.2	15	50	3.16E-07
Erodible Stiff Clay	17.7	21.1	12.6	15	699.1	3.16E-07
Moderate Stiff Clay	17.7	21.1	12.6	15	5	4.50E-08
Resistant Stiff Clay	17.7	21.1	12.6	15	50	3.16E-07

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Attachment 8. CRSEC Memo to John Howard re: FRR Prioritized Site List

March 3, 2015

Franklin Regional Council of Governments

CONNECTICUT RIVER STREAMBANK EROSION COMMITTEE

MEMORANDUM

TO: John Howard, Director - FERC Hydro Compliance

FROM: Kimberly Noake MacPhee, P.G., Land Use & Natural Resources Program Manager

DATE: March 2, 2015

RE: Request for Prioritized Site List, Relicensing Study No. 3.1.1, 2013 Full River Reconnaissance

In February 2015, FirstLight requested a meeting with the Connecticut River Streambank Erosion Committee (CRSEC) to discuss a draft list of preventative maintenance sites that was included in the 2013 Full River Reconnaissance (FRR). In follow-up emails sent to Charles Momnie, Senior Engineer, on 2/11 and 2/22, the CRSEC requested that FirstLight provide us with a prioritized list of sites to consider for this next phase of work. We requested that this list be provided to us by mid-March so that we have time to review it before meeting with FirstLight in early April 2015.

Pursuant to the 1999 Erosion Control Plan (ECP) for the Turners Falls Pool, appropriate erosion control applications will be planned, permitted and constructed in accordance with a periodically updated prioritization schedule. Since the “top 20” priority sites from the 1999 ECP have either been constructed or the licensee has provided justification for not working on some of the sites, a new prioritized site list should have been included with the 2013 FRR. The prioritized site list for the next phase of work should be 1) based on the quantitative methodology described in the ECP and used for the 2013 FRR; and 2) prioritized according to the segments that “are contributing the most sediment to the river.” The ECP states that the goal is to identify the sites that are contributing the most sediment to the river and further states that these sites are to be repaired first.

We do not believe that the list of sites in the 2013 FRR is in compliance with the ECP. We question why all of the sites (except Shearer) are classified as preventative maintenance and how these sites are contributing more sediment to the river than other sites. According to the 2013 FRR, there are 1,387 ft. of active erosion; 22,642 ft. of eroded banks; and 13,705 ft. of potential future erosion. The Stages of Erosion Maps in Appendix G show many long segments (sites) of river bank classified as eroded and potential future erosion. Why weren’t any of these segments included in a prioritized list so they could be evaluated by the CRSEC? These sites are likely to be contributing much more sediment to the river that the short segments identified by FirstLight. The total length of work proposed by FirstLight, excluding the Shearer site, is 1,285 feet over 3 years, which is inadequate given that FirstLight has repaired sites this long in one year.

FirstLight is currently working to obtain permits for the Shearer site. This site was constructed years ago and for years has had an undercut toe because the stone was not placed at the proper elevation to address the fluctuating river levels due to project operations. The CRSEC has, on numerous occasions over the years, encouraged FirstLight to repair the Shearer site. This site is classified by FirstLight as Stable and should be viewed as a maintenance project. The Shearer site should not be substituted for a priority erosion site or a preventative maintenance site.

FirstLight has chosen not to engage the CRSEC in a discussion of the sites until now despite having completed the FRR in 2013. The ECP states that "[t]he licensees and the ad hoc committee will meet on sufficient intervals to evaluate and prioritize the following years [sic] erosion control work." This has not happened and we are now in "catch up" mode. We look forward to receiving the new list of prioritized sites by mid-March so that we have time to review it prior to a meeting in early April.

If you have any questions regarding the requested information, please contact me at 413.774.3167 x130 or kmacphee@frcog.org.

cc: Christopher Chaney, FERC
Brandon Cherry, FERC
David Cameron, DEP
David Foulis, DEP
Robert Kubit, DEP
Brian Harrington, DEP
Bill McDavitt, NOAA

Attachment 9. CRSEC Request for Transect Report

January 9, 2015

Franklin Regional Council of Governments

January 9, 2015

VIA ELECTRONIC FILING

Honorable Kimberly D. Bose Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project No. 2485-063
Turners Falls Project No. 1889-081
Request for erosion transect information

Dear Secretary Bose:

On November 14, 2014, the Connecticut River Streambank Erosion Committee (CRSEC) submitted comments on Relicensing Studies 3.1.1 and 3.1.2, also known as the 2013 Full River Reconnaissance and the Erosion Causation Study. Our comment letter on November 14, 2014 primarily focused on issues related to compliance with the Integrated License Process (ILP) because of tight deadlines. In the course of our review of these two studies, however, we have reviewed other documents submitted by FirstLight, and in this letter we are submitting a compliance-related request.

On January 22, 2013, FirstLight submitted to FERC a series of cross-section plots of long-term transects within the Turners Falls impoundment. Though FirstLight's cover letter to the transect report explained that FERC requested FirstLight to provide information on long-term monitoring of cross-sections, we could find no documentation of this request from FERC. The report was submitted outside of any particular filing process and there was no comment period or FERC response to this submission. As such, CRSEC members were largely unaware of the filing and reviewed it only briefly. The information provided in the January 22, 2013 report covers the years 1999-2012 (not the full history of the transects), and the figures are difficult to review and interpret. The diagrams cover the full river width including the river bottom, making the scale tiny for viewing, and the colors are repetitive such that it is difficult to interpret which line corresponds to which year.

By comparison, in 2004, Northeast Generation Services (NGS), FirstLight's predecessor, submitted a Full River Reconnaissance Report (FRR) with an Appendix B showing the details of cross-section monitoring along the bank. The cross sections in the 2004 FRR Appendix B were easily readable and gave a good indication of the shape of the bank. Table 3 of the 2004 FRR even included total estimated sediment loss at each transect. The report on page 14 states, “The bank locations will be re-evaluated during subsequent years, beginning in 2005, and these data will be used to quantify actual rates of erosion and sediment loss.” See page 14 attached.

In 2007, a report prepared for the Northfield Mountain Pumped Storage Project by Field Geology Services titled, “Fluvial Geomorphology Study of the TF Pool on the CT River between TF, MA and Vernon VT” included an analysis of transect data for the years 1990-2005. Table 5 showed rates of change for each transect on east and west banks, identifying greatest change between surveys and which years the greatest change occurred. Data problems were identified and described. Appendix 8 to the 2007 Field Report contained transect data, but the data were not summarized and there were no diagrams. To our knowledge, no other document provided the information promised in the 2004 FRR on page 14.

We would like to request that FERC require a different transect report be submitted to focus on the river banks, not the river bottom. For each transect on each bank, a figure be provided showing the bank shape over the years for the full monitoring period (1990-2012 or later), with the years being easily readable. If any years have data problems, as indicated in the 2007 Field Report but possibly resolved since then, the data should be flagged in this report. Using that information, the actual rates of erosion and sediment loss or sediment accumulation should be calculated for intervals of time, as promised in the 2004 FRR. We have looked through the 2013 FRR and the revised study plan for study 3.1.2, and do not think this information will be provided in the relicensing studies. We view our requested report as useful for compliance purposes for license articles 19 and 20 for P-1885 and P-2485. Our request is consistent with the intent of the 1999 Erosion Control Plan (ECP) for the Turners Falls Pool of the Connecticut River, which in its Executive Summary, states that riverbank segments were [and are] prioritized for repair and preventative maintenance based on “those segments that are contributing the most sediment to the river.” We also note that the ECP on page 12 said that the licensees will include an ad hoc erosion committee to serve as an advisory group in planning the work to be done under this Plan. CRSEC did not play a role in developing the list of recommended sites for future work that was included in the 2013 FRR submitted to FERC.

Sincerely,

Linda Dunlavy, Executive Director
Franklin Regional Council of Governments

Tom Miner, Chair
Connecticut River Streambank Erosion Committee of the Franklin Regional Planning Board

ATTACHMENT: Page 14 and one page from Appendix B from 2004 FRR

Cc: Christopher Chaney, FERC
Brandon Cherry, FERC
Patrick Crile, FERC
David Cameron, MassDEP
David Foulis, MassDEP

Table 3. Estimated Sediment Loss

Mile Marker (approx.)	Site Name	Cross Section #	BEHI Rating	Bank Height	Reach Length	Total Sediment Loss cubic yards/foot/year
15.6 right	Split River Farm	1	48.2 extreme	13'	405'	0.202
14.8 right	Split River Farm	2	46.3 extreme	14'	900'	0.217
14.1-14.5 right	Upper Split River Farm (former Kaufold)	3,4,5	46.3 extreme	17.5	1740	0.272
13.2-14.2 left	L'Etoile	1,2,3,4,5	45.5 very high	17.0'	5,600'	0.113
9.1-9.3 left	Rt. 10 Bridge	1,2	48.3 extreme	17.0'	775'	0.264
5.0-5.2 right	Kendall	1,2,	47.6 extreme	20.0'	750'	0.311

Actual Sediment Loss. The results in Table 2 provide an estimated sediment contribution from the sites evaluated based on data from Colorado stream banks, which is the closest model available to the Connecticut River. The actual sediment loss can be determined only by direct measurement. NGS has incorporated 20 survey cross sections to measure existing conditions (See Figure 2) which have been used to determine actual rates of erosion. In addition, at each of the sites which were evaluated for the BEHI, three foot long bank pins were installed (thin metal rods) horizontally into the banks, along with permanent vertical reference points to measure rates of erosion. The attached figures in Appendix B show the profile at each of the surveyed bank locations. The bank locations will be re-evaluated during subsequent years, beginning in 2005, and these data will be used to quantify actual rates of erosion and sediment loss.

L'Etoile Cross Section #3

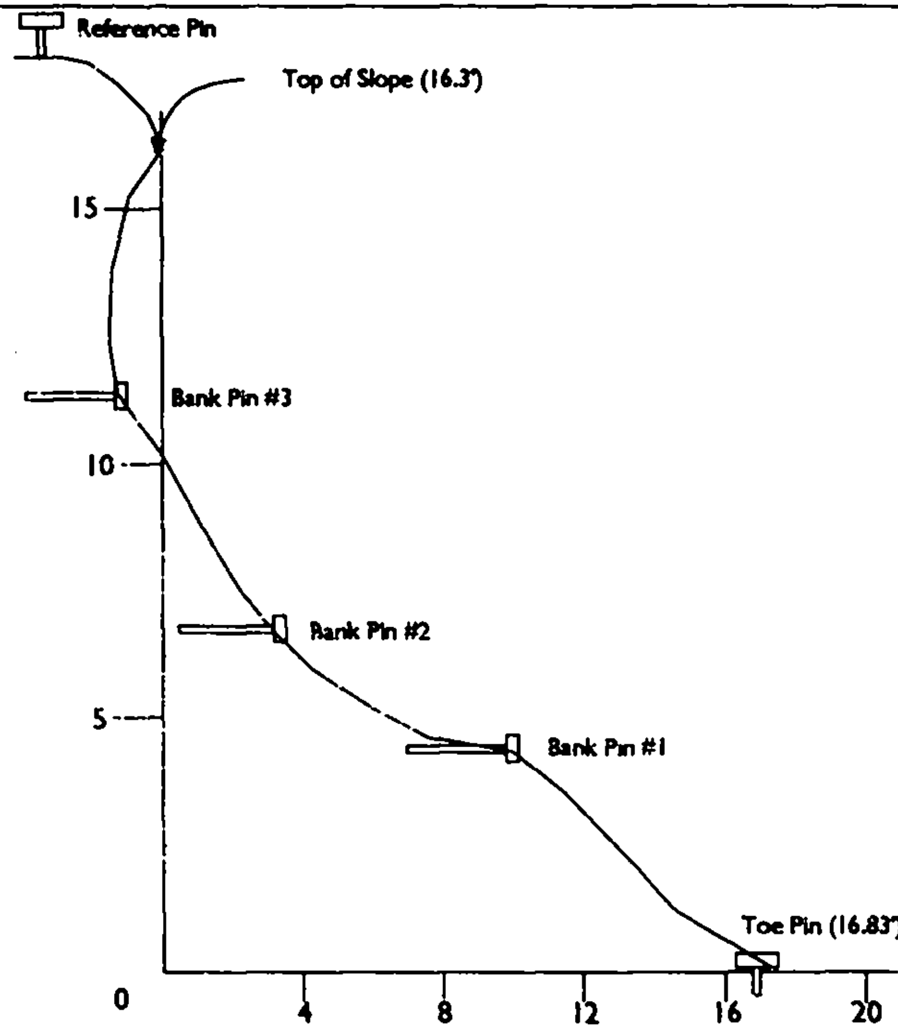
Toe Pin to Ref. Pin Horz. = 29.67'
Toe Pin to Ref. Pin Vert. = 19.2'
Toe Pin to Top of Slope Horz. = 16.83'
Toe Pin to Top of Slope Vert. = 16.3'

Bank Pin #3
To Toe Pin Horz. = 18'
To Toe Pin Vert. = 11.3'

Bank Pin #2
To Toe Pin Horz. = 13'
To Toe Pin Vert. = 6.8'

Bank Pin #1
To Toe Pin Horz. = 6'
To Toe Pin Vert. = 4.3'

Bank Pin #1 = 3.17'
Bank Pin #2 = 3'
Bank Pin #3 = 2.04'



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NEE

CONNECTICUT RIVER
FULL RIVER RECONNAISSANCE
TURNERS FALLS POOL

L'Etoile
Cross Section #3

NEE File #04-2430

Attachment 10. CRSEC Comments on Interim Study Report for Study 3.1.2 Causation Study

November 14, 2014

Contains peer review of study plan by University of Illinois at Urbana-Champaign

Franklin Regional
Council of Governments

CONNECTICUT RIVER STREAMBANK EROSION COMMITTEE

November 14, 2014

VIA ELECTRONIC FILING

Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project No. 2485-063
Turners Falls Project No. 1889-081
Comments on the Initial Study Report, Study 3.1.2

Dear Secretary Bose:

Study 3.1.2, Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability, the so-called "Causation Study," is a critical relicensing document of great importance to the Connecticut River Streambank Erosion Committee (CRSEC) and the Franklin Regional Council of Governments (FRCOG) (See 11/14/2014 comments on Study 3.1.1 for background on the CRSEC). The Project Study Plan calls for evaluating the causes of erosion in the Turners Falls Impoundment, determining if they are related to project operations, and identifying measures to stabilize the sites. To accomplish this, FirstLight is collecting data on the susceptibility of riverbanks in the Turners Falls Impoundment to erosion and will seek to allocate responsibility, i.e., causes, for the erosion.

Our experience with Study 3.1.1, the 2013 Full Reconnaissance Study, was that complex findings and conclusions were withheld from stakeholder review until the final report was issued and underlying data promised in the final report were not given until stakeholders requested it. CRSEC and the FRCOG are therefore greatly concerned by the request by FirstLight to withhold details and data from the Causation Study until March, 2016. The Initial Study Report issued on September 15, 2014 provided little or no information on the study, not even for tasks reported as complete. There is an inherent public interest in the timely issuance of substantive progress reports so that stakeholders and the Commission can review and comment on data that will be the underpinning of findings and recommendations affecting the new project license. With this introduction, CRSEC offers the following comments on Study 3.1.2.

Comments on Study 3.1.2

We note for the record that FirstLight did not include a schedule for issuing Progress Reports for the studies in the FERC approved Revised Study Plan (RSP), dated August 14, 2013, as stipulated in §5.15(b) and §5.11(b)(3). As stated in §5.11(b): "The potential applicant's proposed study plan **must** (emphasis added) include with respect to each proposed study: §5.11(b)(3), "[P]rovisions for periodic progress reports, including the manner and extent to which information will be shared; and **sufficient**

time for technical review of the analysis and results; (emphasis added)…". At the Initial Study Report meeting on October 1, 2014, we requested a progress report for Study 3.1.2 and were told that "FirstLight would rather not issue the study results in pieces, but rather as a complete assessment at the conclusion of the study." (Attachment A-19 of the Meeting Summary). This is not acceptable, and we urge FERC to address FirstLight's disregard of the ILP requirements. We note that the TransCanada ISR on studies 1-3 contain an appropriate level of detail for the upper section of the river and see no reason why FirstLight cannot provide a similar level of detail in their ISR for the Turners Falls Impoundment.

FirstLight has effectively stymied, if not precluded, stakeholders' ability to provide comments on Study Plan 3.1.2 within the timeframe dictated by the ILP by: 1) not issuing Progress Reports and 2) providing an Initial Study Report (ISR) that is remarkable in its lack of information. As stated on page B-7 of the September 13, 2013 Study Plan Determination Letter (SPDL) issued by FERC, "[it] is incumbent on FirstLight to provide an Initial Study Report that satisfies §5.15(c)(1) of the Commission's regulations. Section 5.15 of the Commission's regulations provides **an opportunity for all stakeholders to review and comment on the Initial Study Report and to seek improvements where appropriate**" (emphasis added). Stakeholders and FERC staff are not able to provide substantive comments or seek improvements where appropriate for many of the tasks for Study Plan 3.1.2 because FirstLight provided so little information in the Initial Study Report (ISR) and at the ISR meeting held on October 1st.

A Progress Report for Study Plan 3.1.2 at this point in the ILP is critical. We request that FERC direct FirstLight to issue a Progress Report for Study 3.1.2, including the missing items described below, on or before January 31, 2015 to provide FERC staff and stakeholders with the opportunity and "sufficient time for technical review of the analysis and results" of Tasks 1, 2 and 3. FirstLight has said these tasks are complete. The PowerPoint presentation for the ISR meetings listed Tasks 1-3 for Study 3.1.2 as complete with no work remaining to be done for these tasks.

FirstLight provided no information in the ISR about how the work completed under Tasks 1-3 informed the 2014 Field Studies or will inform the 2015 Field Studies. FirstLight did not propose any modifications to ongoing studies or propose new studies pursuant to §5.15 (c)(1). We find this position troubling and completely unsupported by the information provided in the ISR. FirstLight should be able to support their position that no data gaps were identified, no modifications to ongoing studies are needed, and there is no need to propose new studies. We request copies of all the data sets reviewed by FirstLight as well as a discussion of the analysis and conclusions associated with completed Tasks 1-3 on or before January 31, 2015, pursuant to §5.15(b). We also request an opportunity to comment on the Progress Report.

In support of our requests, we note the following:

- <u>Task 1: Data Gathering and Literature Review</u>: We request a complete list of all the existing data and literature sources for the topics listed on pages 2 and 3 of the Initial Study Report Summary-Relicensing Study 3.1.2. Stakeholders request the missing text for the 2004 FRR be provided immediately. This is a request we've made repeatedly for almost a decade yet the report has not been provided to us. We request all the available boat wave data, including the data for the Flagg site, downstream of the Route 10 bridge, and in the vicinity of the Northfield Mountain tailrace and from 1997 and 2008, and the groundwater elevation data from 1997-1998.

  Related to Task 1 is an omission from the Meeting Summary filed by FirstLight for the Initial Study Reports. On page 20 of Attachment A, the summary notes that Kimberly Noake MacPhee (FRCOG) asked about the data gaps identified under Task 1. Missing from the Meeting Summary is FirstLight's answer to Ms. MacPhee that "no data gaps were identified". Stakeholders question this assertion and, therefore, we are requesting the list of all the data and literature sources reviewed by FirstLight under Task 1 so that we can identify any data gaps and offer suggestions to improve the field studies for 3.1.2 prior to the Second Field Season.

- Task 2: Geomorphic Understanding of the Connecticut River. This is a critical issue for stakeholders and for the ILP.[1] Two sentences in the ISR and one slide in a PowerPoint presentation for a completed task are not acceptable and do not meet the requirements of §5.15(c)(1)(2). We request that FERC direct FirstLight to provide a list of the existing data that was reviewed, as stated in the RSP, "to gain a better understanding of the geomorphology of the Impoundment and Connecticut River within the study area" and a complete discussion of this task, as outlined in the RSP and the FERC Study Plan Determination Letter (SPDL), in a Progress Report issued on or before January 31, 2015.

  According to the September 13, 2013 SPDL issued by FERC (page B-5), FirstLight provided little detail in their Study Plan regarding the proposed historical trend analysis of bank conditions. To provide more detailed methodology (§5.9(b)(6)), FERC recommended that FirstLight perform its historic geomorphic assessment using available mapping such as the 1970 vintage ground survey of the impoundment as a base map, comparing it against more recent aerial imagery and available survey data to analyze trends in bank position over time, at an estimated price of $20,000.

  There was no mention of this SPDL work in the ISR. The Meeting Summary (Attachment A-19) indicates that FirstLight will provide this analysis in the final report and "that FirstLight surveyors are comparing aerial images with project boundary maps to try to get a sense of the movement of the riverbank over time." As this task is listed as complete by FirstLight in the ISR with no additional activities proposed for this task in 1.4 Remaining Activities (p. 4 of the ISR for Study Plan 3.1.2), we request that FERC direct FirstLight to provide stakeholders and FERC staff with 1) the digital data set for this task and 2) a complete description of the methodology for this task as outlined in the FERC Study Plan Determination Letter (SPDL). This information should be provided in a Progress Report issued on or before January 31, 2015.

  We also note that on page B-3 of the September 13, 2013 SPDL, FERC recommended that FirstLight include an analysis of operational changes through the period 1999 to 2013 to identify any correlation between operational changes and observed changes in erosion rates, and that this analysis should be conducted as part of study 3.1.2 at an estimated price tag of $10,000. The ISR contained no indication that this analysis would be done, what the methods might be, or what the final product would look like. Stakeholders are once again being denied the ability to review this task or seek improvements to it.

- Task 3: Causes of Erosion. Two sentences are provided in the ISR for this completed task. FirstLight states that the potential causes of erosion and potential primary cause of erosion identified

[1]We once again note that a section of the 2007 Field Fluvial Geomorphology Study of the Turners Falls Pool conducted for FirstLight was devoted to this topic, and we don't know what gaps in understanding FirstLight identified and needed to fill in this task.

in the RSP were reviewed and no changes are proposed at this time. For Task 3, the RSP states that "Task 2 will identify and summarize the principal potential causes of erosion." The list in the RSP and any additional identified under Task 2 will "form the basis for all field studies under Task 4 and data analysis Task 5." We request a detailed discussion of this completed task be provided to stakeholders and FERC staff on or before January 31, 2015 pursuant to §5.15(b) so that we have the opportunity to propose modifications to the study plan "in light of the progress of the study plan and data collected." (§5.15(c)(2)).

- <u>Task 4: Field Studies and Data Collection</u>. FirstLight listed this task as ongoing. We are shocked that the ISR provided six very brief, one to two line bullet point updates for this complex task that spans 7 pages in the Revised Study Plan. Remaining Activities were described in one line as "[c]omplete field data collection efforts." This is not acceptable. Once again, the paucity of information in the ISR reaffirms our position that FERC staff and stakeholders have been denied sufficient time for technical review of the analysis and results and a meaningful opportunity to seek improvements in Study Plan 3.1.2, and especially for this critical and complex Task 4.

  Task 4c: Identification and Examination of Fixed Riverbank Transects: This task is listed as complete in the ISR. In their SPDL, the FERC recommended that FirstLight consult with stakeholders prior to final transect selection. In our opinion, this task is not complete for three important reasons. First, the list of fixed riverbank transects and data collected from these sites during the 2014 Field Season should be evaluated against the concerns and limitations of the BSTEM model, discussed in the next section. Second, the findings and conclusions of the 2013 Full River Reconnaissance (FRR) have been called into question. In their RSP, FirstLight states that the selection of the fixed transects will be based on field observations made during the 2013 FRR and analysis of the 2013 FRR data, all of which we assert is seriously flawed (see CRSEC comment letter on Study 3.1.1). Finally, the CRSEC has recently corresponded with FirstLight about information to be included for each of the detailed study sites and there are issues that remain unresolved. CRSEC will be preparing a response to John Howard's November 4, 2014 letter.

The FRCOG has very limited funding for expert technical review, and we were unable to secure funding in 2013 for expert review services during the Study Plan development process. When the ISR was filed, it was obvious that we required expert assistance to review Study 3.1.2 properly. Given the importance of Study 3.1.2 to the CRSEC, FRCOG found funding and contracted with the UMass Center for Economic Development to help us retain experts to evaluate the information we expected to receive in the Initial Study Report (ISR). Experts from the University of Illinois at Urbana-Champaign, Department of Civil and Environmental Engineering Hydrosystems Laboratory were hired to assist the FRCOG and CRSEC.

We asked the Univ. of Illinois experts to comment on the suitability and limitations of the BSTEM, HEC-RAS and River2D models and data collection methods with respect to the unique conditions of the Turners Falls Impoundment. The experts identified several significant data gaps and limitations in the FirstLight methodology. A Progress Report for Study Plan 3.1.2 at this point in the ILP is critical so FERC staff and stakeholders have an opportunity and "sufficient time for technical review of the analysis and results" and make appropriate recommendations for the Second Field Season. The letter from Drs. Garcia and Waterman is attached.

Conclusion

Study 3.1.2 is of the utmost importance to the CRSEC and other local stakeholders. It focuses on project impacts that directly affect landowners and natural resources of singular value to our region. We have watched as prime agricultural riverside soils have been consumed by bank erosion since the Project began operation 40 years ago. Based on the questionable methodology and biased conclusions of the 2013 Full River Reconnaissance, we are concerned about the integrity of Study 3.1.2, the so-called Causation Study. We believe that full transparency provided by regular progress reports during the study are essential to providing confidence in the study results.

At several points in these comments we have asked the Commission to require FirstLight to provide progress reports with sufficient detail to allow for an independent, expert review. We conclude our comments with a repeated, and we believe reasonable request for a Progress Report by January 15, 2015 and follow up report as each study task is completed.

Sincerely,

Tom Miner, Chair
Connecticut River Streambank Erosion Committee

Linda L. Dunlavy, Executive Director
Franklin Regional Council of Governments

Attachment: Letter from University of Illinois

Cc: Congressman James McGovern
Franklin County Legislative Delegation
FirstLight Hydro Generating Company
NOAA – National Marine Fisheries
U.S. Fish and Wildlife Service
Connecticut River Atlantic Salmon Commission
U.S. Army Corps of Engineers
Massachusetts Department of Environmental Protection
Massachusetts Division of Fisheries and Wildlife
Connecticut River Watershed Council
Franklin Conservation District
Windham Regional Commission
Landowners and Concerned Citizens for License Compliance

Town of Gill, MA Conservation Commission
Town of Northfield, MA Selectboard and Conservation Commission
Town of Montague, MA Planning and Conservation Department
Connecticut River Greenway State Park

Attachment: Letter from University of Illinois

UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

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November 13, 2014

Kimberly Noake MacPhee
Land Use & Natural Resources Planning Program Manager
Franklin Regional Council of Governments
12 Olive Street, Suite 2
Greenfield, MA 01301

Dear Ms. Noake MacPhee:

At your request, we have performed a review of various materials prepared as part of the FERC relicensing of the Northfield Mountain / Turners Falls operations on the Connecticut River. In particular, our review has focused on the analyses pertaining to river hydraulics and bank retreat included in the following documents:

- Revised Study Plan (FirstLight Power Resources, 2013a), Sections 3.1.2 and Sections 3.2.2.
- Initial Study Report Summary for Section 3.1.2 (Choi, 2014a)
- Initial Study Report Summary for Section 3.2.2 (Gomez and Sullivan Engineers, 2014)

For additional background information regarding the river characteristics, we also reviewed the following project documents that were provided:

- Fluvial Geomorphology Study of the Turners Falls Pool on the Connecticut River Between Turners Falls, MA and Vernon, VT (Field Geological Services, 2007)
- Hydraulic Modeling Assessment Of The Turner Falls Impoundment (FirstLight Power Resources, 2013b)
- 2013 Full River Reconnaissance report (Choi, 2014b)

Our review has primarily focused on the models (BSTEM, HEC-RAS, RIVER2D) and the data collection methods used by the project consultants. We need to preface our analysis by clearly stating that we have not performed any onsite analysis of the Connecticut River; we also have not performed a thorough review of the abundant analyses that have been completed dating back to the 1970s associated with bank retreat for this reach of the river. Our site-specific knowledge pertaining to the river is derived from a review of the above-referenced documents.

We deem the following physical river characteristics particularly important to our assessment of the bank retreat issue in the Turner Falls impoundment:

- The river banks in the reaches that have experienced the most pronounced bank retreat are alluvial deposits of predominantly sand and silt; stratigraphic analysis reveals inter-bedded layers of sand and silt (Field Geological Services, 2007; p.18, p.25, p.66)
- Narrow "beach" landforms are common - these are described as mild transverse slopes extending riverward from the toe of the steep portion of the river bank and extending out a short distance from the bank before dropping off more steeply into the deeper part of the channel (Field Geological Services, 2007; p.17, p. 43)

- Bank retreat is occurring in locations that are apparently independent of high boundary shear stresses (Field Geological Services, 2007; p.20, p. 25)

The majority of our analysis will discuss the proposed modeling of bank retreat per Section 3.1.2 of the Revised Study Plan (RSP). The suitability of any model is dependent on the objectives of the modeling effort; the most sophisticated model is not necessarily the most appropriate for all purposes. In this case, the objective has been defined as evaluating and identifying the causes of erosion in the impoundment and determining to what extent they are related to project operations; the modeling is one part of an effort to satisfy that objective. We recognize that this is an extremely challenging task, due to the inter-related nature of the various causes of bank retreat. The BSTEM model has been proposed to quantify the effect of two of the identified causative factors in bank retreat: fluctuating water levels and fluvial boundary shear stresses. BSTEM was designed to couple the processes of fluvial erosion and mass failure that are both integral to bank erosion analyses; to our knowledge, that model (along with its predecessor, the ARS Bank Stability Model) was the first model available for engineering practice outside an academic research setting to couple those processes using physics-based formulations. The model was developed at the USDA National Sedimentation Laboratory; for the last several decades that group has been at the forefront of developing techniques to quantify bank erosion and develop models for practical usage. We will discuss the model's suitability and limitations with respect to the unique conditions in the Turners Falls impoundment.

The issue of fluctuating water levels, in its most basic form, is a rapid drawdown problem that has conventionally been treated by geotechnical engineers considering earthen embankments (Morgenstern, 1963; Desai, 1977; Lane and Griffiths, 2000). When the water level is drawn down, pore water remains in the embankment which maintains the weight of the soil (the gravitational force is the primary driving force behind potential failures) while the confining pressure acting on the surface of the soil mass is removed, thus reducing the factor of safety. An integral part of the problem is the knowledge of the water level in the water body and the phreatic surface (or more accurately, the pore pressure distribution) of the groundwater. The BSTEM model includes the effect of the water level difference that is of primary importance to the problem, but the water levels are specified as parameters. Therefore how the water level difference is specified in the proposed analysis is very important. Accurate treatment involves not only the magnitude of the drawdown but also the rate of drawdown, as the water table does not adjust at the same rate as the stage of the water body. An appropriate treatment would involve an unsteady state 2D groundwater model (e.g., SEEP/W) applied to a cross-section using the maximum drawdown rate over the maximum magnitude of drawdown (the boundary conditions of the groundwater model) to determine the appropriate values of the input parameters pertaining to the water levels used in BSTEM. In review of the Revised Study Plan (RSP), there is no mention of proposed groundwater modeling; mention is made that a single transect of three piezometers was established and monitored at a site and that the groundwater responded to the river water stage quickly. We would recommend that such data be used with caution in the absence of a site-specific model on which such data would serve as calibration, which could then allow the full range of potential boundary conditions to be evaluated. We would also caution that such data should not be extrapolated to all sites in the system as the stratification and hydraulic conductivities along the ~20-mile long impoundment are certainly not uniform. For example, the 2013 Full River Reconnaissance (FRR) includes geotechnical site data sheets that include sites where the bank profile is dominated by sand (USCS classification SM) and profiles dominated by silt (USCS classification ML); the hydraulic conductivities of such soils are likely to differ by an order of magnitude or more. In the absence of a groundwater model to establish the appropriate water level difference used in BSTEM, then conservative assumptions would be required regarding how fast the groundwater table responds to the river water level. For example, in the analysis of Morgenstern (1963), the pore water pressure distribution (a linear function of the groundwater level in a free-draining incompressible material) was assumed to be maintained at its pre-drawdown level throughout much of the embankment for the stability analyses. In more sophisticated analyses such as Lane and Griffiths (2000), the pore pressure distribution is solved numerically before the stability calculation proceeds. Some justification will need to be provided for conservative estimates of groundwater table levels in the absence of calibrated groundwater models. Note that in all of the cited conventional geotechnical analyses, the seepage forces are neglected; the significance of seepage forces are discussed later in this letter.

In terms of the magnitude and rates of variation in the river stage (the river stage input as a parameter in the BSTEM model), we understand that an unsteady state HEC-RAS model will be developed and calibrated. We feel that HEC-RAS is an appropriate model for this purpose. Even though impounded, the river is generally curvilinear and the flows can be reasonably approximated as 1D for the purpose of determining stage. The primary data used in HEC-RAS is the bathymetry and bank/floodplain topography. Cross-sections are spaced more closely in steep rivers and where the geometry changes significantly over short distances. The modeling proposed includes cross-sections at 500 feet longitudinal spacing sampled from longitudinal bathymetric transects. For a river with mild slopes such as the Connecticut River where the bankfull width is typically 600 to 700 feet, having cross-sections spaced at 500 feet is quite resolute for a 1D model and will characterize spatial geometry variations at an appropriate scale. Utilizing stage recorders to obtain calibration data as proposed is also appropriate. Calibration of roughness coefficients using the steady flow calculation procedure as indicated in the RSP should be performed when flow through the system is confirmed to be steady (flow input equal to flow output from the system).

Regarding other aspects of the geotechnical slope stability calculations used in BSTEM, beyond the issue of rapid drawdown, we feel it would be appropriate if the project geotechnical engineer confirmed that the factor of safety values calculated by BSTEM for planar failure are indeed less than that calculated from the analysis of rotational failure. BSTEM was designed for use on short steep slopes typical of most river banks where planar failures and cantilever failures resulting from undercutting are the dominant modes of failure. In some areas in the Turners Falls impoundment there are fairly high slopes (some reported >50 feet in height) and some of these areas have soils classified as being silt-dominated (ML classification). If the cohesiveness of these silty soils turns out to be substantial, a more deep-seated rotational failure might be the actual mode of failure as opposed to shallow planar failures. In fact, on Table 7-2 of the Initial Study Plan Summary for 3.1.2, a number of the representative and calibration sites have indicated rotational failures.

Proceeding to the issue of fluvial erosion of the bank toe used by BSTEM, we feel that the proposed use of RIVER2D for the determination of boundary shear stresses is appropriate. While a 1D model such as HEC-RAS will provide cross-sectional average values, RIVER2D will provide variation across the cross-section, including in the near-bank region, which is the preferable approach. The domain of RIVER2D modeling would preferably include the entire impoundment; however, if local domains are used for each of the calibration sites, the domain should be confirmed to be sufficiently long both upstream and downstream of the calibration sites such that the velocity field calculated at the calibration site is relatively insensitive to the specific velocity fields specified for the upstream and downstream boundaries.

Quantifying the parameters used in the fluvial entrainment routine of BSTEM has been proposed using both a submerged jet test in the field and by determining grain-size distributions which can then be used to specify the critical shear stress parameter when the soil is non-cohesive. The submerged jet test is generally considered to be the standard to quantify the parameters used in the entrainment rate formulation for bank erosion. The field methods proposed and the specific formulations used by BSTEM are the best that are currently available to quantify the fluvial entrainment of bank materials. However, the entrainment rates thus determined must be understood to still involve substantial uncertainty. Thus the issue of calibration as proposed in the study becomes important.

The issue of calibration must be treated with some caution in a study where causality is intended to be quantified (as specified in the objectives). For example, it has been observed that areas of significant bank retreat exist in areas of low boundary shear stress. One approach of calibration would be to modify the critical shear stress parameter to a very low value and modify the erodibility coefficient to a very high value in the entrainment rate formulation to achieve the magnitude of fluvial entrainment and subsequent mass failure observed in the low fluvial shear areas – thus achieving a calibrated model. However, a calibrated model does not guarantee that the physics of the model is correct; in other words, if the original values used in the model did not yield the observed bank deformation, it is also possible that other causative factors are involved that are not accounted for in the models. With this in mind, one causative factor that we feel is of high importance pertaining to the issue of bank retreat and not incorporated into the modeling is erosion associated with seepage from water continually being transported into and out of the banks associated with frequent stage changes; (note that this is a separate issue from the rapid drawdown problem described previously, but it is a related issue). The processes where the seepage forces are dominant involve the gradual sapping of soil grains from a soil stratum, potential development of soil pipes, and the associated structural weakening of the soil; the processes are discussed in limited detail in the following paragraphs. This physical factor is not accounted for in the BSTEM model - although this is not a fault of the model or the choice of model, but rather a limitation in the current state of the science. This makes the issue of assigning causality to various factors very difficult.

In geotechnical engineering practice, seepage forces are typically accounted for by ensuring that a critical hydraulic gradient is not exceeded along a flow path through the soil, which is particularly important when considering groundwater flow beneath dams or excavations below the water table (e.g., Terzaghi et al., 1996). In sophisticated models analyzing slope stability, the seepage forces may be accounted for with respect to their reduction of the effective stress and thus the frictional shear resistance along potential failure planes. However, quantifying processes associated with gradual sapping of soil grains which may eventually lead to the development of piping is still a developing field. The following statement in Terzaghi et al. (1996, p.475) is particularly pertinent to the current discussion: "*In nonhomogeneous material the locations of lines of least resistance against subsurface erosion and the hydraulic gradient required to produce a continuous channel along these lines depend on geologic details that cannot be ascertained by any practicable means.*" Advances are currently being made in this field of research as it relates to stream bank erosion, including substantial contributions by the USDA National Sedimentation Laboratory (the agency that developed the BSTEM model); but to our knowledge, quantitative models are still in the research stage and have not advanced to the level of practical engineering usage.

The current state of the science associated with bank retreat due to seepage forces is well described in a review paper by Fox and Wilson (2010). The essential aspects are that the hydraulic gradient of the groundwater is associated with a pressure force that reduces grain-to-grain friction, which can lead to entrainment of particles into the groundwater flow path. In its most extreme form, the seepage forces can exceed the weight of soil grains and cause a non-cohesive soil mass to fully liquefy. However, in cases of bank erosion, where hydraulic head gradients are generally more limited, the gradual process of grain by grain entrainment is the expected mode. Fox and Wilson (2010) use the term seepage erosion to describe this entrainment process. In its most developed condition, it can lead to development of soil pipes and cavities and collapse of overlying soil strata as described in Hagerty (1991a; 1991b); in those papers, the terms piping and sapping are used to describe the removal of soils by seepage exfiltration from a bank face. Hagerty (1991a) indicates the issue to be most prevalent in alluvial soil deposits where the natural layering favors concentration of groundwater flow in the more pervious strata; he also indicates the necessary conditions for the process to occur, which include the presence of a free exfiltration face, a source of water, and stratification of layers of different hydraulic conductivity that promotes flow concentration. Hagerty (1991a) states: "*The variations in texture and porosity among alluvial strata in a bank may not be noticeable and may appear to be slight, but even seemingly minor changes in soil texture can change hydraulic conductivity by orders of magnitude……a silty sand may be 100 times more pervious than a sandy silt, even though both soils look and feel very similar*." Fox et al. (2007) provide evidence that lateral flow can be generated in more pervious strata when the vertical component of the hydraulic conductivity between layers is less than an order of magnitude different. The hydraulic gradient, and thus the seepage force, will generally be steepest at the free exfiltration face as a groundwater level adjusts to a new surface water level; thus the tendency for particle entrainment will be greatest at the exposed face and may not necessarily be maintained deeper into the bank. The sapping of grains from a strata, particularly when the grains being removed are fine-grained and provide some cohesion to the strata, is also expected to reduce the resistance of the surface to fluvial erosion. Therefore fluvial erosion may still be eroding the toe of the bank, but the effect of stage changes on sapping grains from strata and its effect on fluvial erosion cannot currently be decoupled.

Due to the fact that the science has not yet advanced sufficiently to quantitatively model the process of seepage erosion and its effect on bank retreat, correlation to other sites where this process has been observed to be a dominant process is appropriate. The shape of the Connecticut River near-bank region described by Field Geology Services (2007) and bulleted above on p.1-2 of this letter warrants special consideration and provides an indication of the dominant processes occurring in the near-bank region. Hagerty et al. (1995) considered a gently sloping bench just below the ordinary low water level to be characteristic of rivers having controlled stage; the particular case considered was navigation pools on the Ohio River, although examples were also provided from observations elsewhere in the country. They clearly state that the process of bench formation is not fully demonstrated, but that the evidence suggests a process whereby the permanently submerged portion of the bank becomes more stable, and the above-water portion of the bank migrates at a faster rate than the below-water portion of the bank – even though both may be migrating more slowly than the pre-controlled condition. In each of the cases described by Hagerty et al. (1995), a primary cause of bank migration in the portion of the bank above the maintained low water stage was associated with the piping / sapping mechanism. A stable bench at a migrating bank is not a typical landform in an unregulated river. When a bank is eroding due to fluvial entrainment, migration of the deeper portions of the bank will generally drive the migration of the upper portion of the bank because the shear stresses generally increase with depth. Therefore, for a bench to form on or above the lower bank, at some point in time the lower portion of the bank must not be driving migration of the upper portion of the bank. This is not meant to imply that fluvial action cannot still erode the toe of the bank above the bench; rather it is simply meant to point out that the process is not typical of a migrating bank and that other processes may be involved. The presence of the undercut "notches" located near the normal water stage with the maximum extent of the cut not extending deeper below the water surface also suggests other mechanisms are likely acting in concert with fluvial erosion; note that Table 6.1 of the FRR indicates that approximately 43% of the river banks show evidence of this feature. A notch whose maximum extent is located near the normal water surface suggests the effect of both wave action and sapping associated with the steepest part of the groundwater table following a period of drawdown, and its influence in making the bank material more susceptible to fluvial erosion.

Finally, we would like to reiterate that the objectives for which the modeling is intended to satisfy (decoupling and quantifying the various causative factors) is daunting, if not impossible in a strict sense, given the current state of the science regarding the physical processes and our ability to contend with physics occurring at a variety of spatial scales and with high spatial heterogeneity. This does not imply that a modeling approach, which will always require simplifications, is without value. In general, we feel the proposed approach of using BSTEM is a sound practical approach that will provide insights into which processes are important in a relative sense. However, such findings should be strongly qualified; a finding that suggests that the fluctuating stages associated with the pumped storage operations has no impact on the bank retreat or, conversely, that it is entirely responsible for the bank retreat would not be defensible given the uncertainties involved.

Sincerely,

Marcelo Garcia

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M.T. Geoffrey Yeh Chair in Civil Engineering
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University of Illinois at Urbana-Champaign

David M. Waterman
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Appendix A: References

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Education

National Litoral University, Argentina,	Water Resources	Dipl. Ing.	1982
University of Minnesota	Civil Engineering	M.S.	1985
University of Minnesota	Civil Engineering	Ph.D.	1989

Academic Experience

2012-present	Faculty Fellow, National Great Rivers Res. and Ed. Center, Alton, Illinois
2006-present	Professor of Geology (adjunct), Department of Geology, University of Illinois
2001-2014	Chester and Helen Siess Endowed Professor of Civil Eng., University of Illinois
2000 – present	Professor, Dept. of Civil and Environmental Eng., University of Illinois
1999 (1 month)	Visiting Assoc. Prof., Ecole Polytech. Federale de Lausanne, Switzerland
1997 (4 months)	Visiting Associate Professor, California Institute of Technology
1997 – present	Director, Ven Te Chow Hydrosystems Laboratory, University of Illinois
1996 - 2000	Associate Professor, Dept. of Civil and Env. Eng., University of Illinois
1990 - 1996	Assistant Professor, Department of Civil Eng., University of Illinois
1993 - present	Visiting Professor, School of Water Resources Eng., UNL, Santa Fe, Argentina
1993 (4 months)	Contract Professor, Istituto di Idraulica, University of Genoa, Italy
1988 - 1989	Research Fellow, St. Anthony Falls Hydraulic Lab., Univ. of Minnesota
1983 – 1987	Research Assistant, St. Anthony Falls Hydraulic Lab., Univ. of Minnesota

Honors: : ASCE Hilgard Prize (1996, 1999), Huber Research Prize (1998), H.A. Einstein (2006), Housner Award (2012), Rouse Award Lecture (2012); Borland Lecture (2009), IAHR Ippen Award ('01); National Academy of Engineering, Argentina (2005), Enrico Marchi Lecture (2012), Distinguished Member, American Society of Civil Engineers (2013), Yeh Chair (2014).

Five Relevant Publications (total of 130 archive journal publications)

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2. Motta, D., Abad, J.D., Langendoen, E., and M.H. Garcia (2012). The effects of floodplain soil heterogeneity on meander planform shape, Water Resources Research, AGU, DOI:10.1029.
3. Czuba, J A.; Best, J.L.; Oberg, K.A.; Parsons, D. R.; Jackson, P. R.; Garcia, M. H.; Ashmore, P. (2011) "Bed morphology, flow structure, and sediment transport at the outlet of Lake Huron and in the upper St. Clair River." Journal of Great Lakes Resarch, 37(3), 480-493. Recognized with the IAGLR Chandler-Misener Award for most notable paper published in Journal of Great Lakes Research in 2011.
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5. Fernandez, R.L.; Cauchon-Voyer, G.; Locat, J.; Dai, H.; Garcia, M. H.; Parker, G. (2011) "Co-evolving delta faces under the condition of a moving sediment source."Journal of Hydraulic Research, 49(1), 42-54.

Five Other Publications

1. Abad, J. D., Rhoads, B. L., Guneralp, I., García, M. H. (2008) "*Flow structure at different stages in a meander-bend with bendway weirs*". Journal of Hydraulic Engineering, 138 (8): 1052-1053.
2. Abad J. D. and García, M. H. *RVR Meander: A toolbox for re-meandering of channelized streams.* Computers & Geosciences, 32: 92-101, 2006.
3. Abad, J. D., Buscaglia, G. and Garcia, M. H. (2008) "*2D Stream Hydrodynamic, sediment transport and bed morphology model for engineering applications*". Hydrological Processes, 22: 1443-1459.
4. Motta, Davide; Abad, Jorge D.; Garcia, Marcelo H.(2010) "Modeling Framework for Organic Sediment Resuspension and Oxygen Demand: Case of Bubbly Creek in Chicago." Journal of Hydraulic Engineering - ASCE, 136(9), 952-964. Recognized with the ASCE 2012 Wesley Horner Award for best publication.
5. García, M. H., "Modelling Sediment Entrainment into Suspension, Transport, and Deposition in Rivers," Chapter 15 in *Model Validation: Perspectives in Hydrological Science*, M.G. Anderson and P.D. Bates (Editors), 389-412, John Wiley & Sons, England, 2001.

Synergistic Activities

Member, Steering Committee, Community Surface Dynamics Modeling System (CSDMS), 2013-2018.
Editor-in-Chief, ASCE/EWRI "Sedimentation Engineering," Manual of Practice 110, May 2008.
Member, National Research Council Panel on "River Science at the US Geological Survey." 2005-2006.
Expert Panel Member, Mississippi River Hydrodynamic and Sediment Transport Modeling, Battelle & US Army Corps of Engineers, 2013-2016.
International Scientific Committee on Flooding, Firenze 2016, Florence, Italy, 2014-2016.

Ph.D. Advisees(total: 27): Yarko Niño (Prof., University of Chile); Fabian López, (Minister for Public Works, Cordoba, Argentina); Sung-Uk Choi (Prof., Yonsei University, South Korea); Jeffrey Parsons (Consultant, WA); David Admiraal (Assoc. Prof., University of Nebraska-Lincoln), Xin Huang (Software Engineer, Motorola, Inc.), Fabian Bombardelli (Assoc. Prof., University of California-Davis), Jose Rodriguez (Senior Lecturer University of Newcastle, Australia), Michelle Guala (PhD, Univ. of Genoa; Asst. Prof. Minnesota), Robert Holmes,Jr. (National Flood Hazard Coordinator, USGS), Arthur Schmidt (Res. Asst. Prof., University of Illinois), Juan Fedele (ExxonMobil), Yovanni Catano (Sr.Eng., Alden Research Lab, MA), Michael Yang (Consulting, Shaw Group), Octavio Sequeiros (Researcher, Shell Co, The Netherlands, w/ Gary Parker), Carlos M. Garcia (Prof. Universidad Nacional de Cordoba), Mariano Cantero (Asst. Prof., Instituto Balseiro, Argentina), Jorge Abad (Asst. Prof., Univ. of Pittsburgh), Albert Dai (Asst. Prof., Tamkang University, Taiwan); Xiaofeng Liu (Asst. Prof., Penn State), Arturo Leon (Asst. Prof ., Oregon State University), Francisco Pedocchi (Asst. Prof., Universidad de la Republica, Uruguay), J. Ezequiel Martin (Res. Assoc., Univ. of Iowa), Blake Landry (Post-Doc, UIUC), Sumit Sinha (Res. Assoc., Helmholtz Inst., Germany), Davide Motta (Cons. PA), Tatiana Garcia (PostDoc USGS).

Currently: 12 graduate students. MS Thesis Students Advised to date: 40

Graduate Studies Advisor: Gary Parker, University of Minnesota (currently at UIUC)

List of Collaborators: Bruce Rhoads, Jim Best, Gary Parker, University of Illinois, Eddy Langendoen (USDA), S. Balachandar, University of Florida, Colin Stark, Columbia University, Mohamed Ghidaoui, Hong Kong University of Science and Technology, Mario Amsler and Ricardo Szupiany, Universidad Nacional del Litoral, Argentina, Daniel Brea, Instituto Nacional del Agua, Argentina, Kevin Oberg and Ryan Jackson (Hydroacoustics, USGS), Faith Fitzpatrick (USGS).

DAVID M. WATERMAN
PhD Graduate Research Assistant
Department of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign

EDUCATION

Bachelor of Science, Engineering (BSE), 1996
Interdisciplinary Engineering program; Ecological Engineering option
PURDUE UNIVERSITY, West Lafayette, Indiana

Master of Science, Civil Engineering, 2011
Environmental Hydrology and Hydraulic Engineering program
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Currently in PhD program, Civil Engineering, 2011-present
Environmental Hydrology and Hydraulic Engineering program
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

HONORS

Ben Chie Yen Fellowship Award, 2012

ACADEMIC EXPERIENCE

Graduate Research Assistant, *University of Illinois at Urbana Champaign* *2009-present*

- Bubbly Creek sediment oxygen demand study [Masters project]

  Waterman, D. M., Waratuke, A. R., Motta, D., Cataño-Lopera, Y. A., Zhang, H., & García, M. H. (2011). In situ characterization of resuspended-sediment oxygen demand in Bubbly Creek, Chicago, Illinois. *Journal of Environmental Engineering*, 137(8), 717-730.
- Physical modeling of stepped canoe chute / fish passage facility; Arkansas River, KS
- Field and laboratory experiments on oil-sediment aggregation processes associated with submerged oil; Kalamazoo River, MI
- Physically-based bank erosion formulation implementation into the model RVR Meander model; Mackinaw River, IL
- Morphodynamics of bank accretion; Green River, UT

PROFESSIONAL EXPERIENCE

Environmental Scientist / Project Engineer / Project Manager, *Environmental Technology Consultants (A Division of Sisul Enterprises, Inc.), Vancouver, WA* *1996-2008*

- Performed civil engineering design and plan preparation for residential and commercial development projects.
- Performed modeling of open channel systems using HEC-RAS as part of conveyance design and floodway / floodplain analysis.
- Performed wetland delineations in a variety of ecoregions throughout the Pacific Northwest
- Performed all aspects of Section 404 wetland/stream permitting.

CONTINUED…

Civil Engineering Technician, *US Army Corps of Engineers, Operations Division, Navigation Section; Louisville, KY* *1994-1995 (Summer)*

- Produced hydrographic survey maps from raw field data for channel maintenance dredging.

Geotechnical Engineering Technician, *Greenbaum Associates, Inc., Louisville, KY* *1993 (Summer)*

- Assisted drill operator in soil core sampling and installation of monitoring wells. Prepared well logs.
- Inspected structural foundations at construction sites.

Attachment 11. CRSEC Comments on Study Report for Study 3.1.1 Full River Reconnaissance (FRR)

November 14, 2014

Franklin Regional Council of Governments

CONNECTICUT RIVER STREAMBANK EROSION COMMITTEE

November 14, 2014

VIA ELECTRONIC FILING

Honorable Kimberly D. Bose Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project No. 2485-063
Turners Falls Project No. 1889-081
Comments on Relicensing Study 3.1.1, 2013 Full River Reconnaissance (FRR)

Dear Secretary Bose:

The Connecticut River Streambank Erosion Committee (CRSEC) herein submits comments on Relicensing Study 3.1.1, 2013 Full River Reconnaissance, dated September 2014. CRSEC is a committee of the Franklin Regional Planning Board acting under the authority of the Franklin Regional Council of Governments (FRCOG). The CRSEC was created over two decades ago as a forum for stakeholders, including landowners, public agencies, nonprofits, and the licensee, to come together and work cooperatively to address the substantial erosion problems occurring in the Turners Falls Impoundment. Pursuant to Articles 19 and 20 of the Project's licenses, the CRSEC has worked for over 20 years in conjunction with FirstLight and its predecessor project owner, Northeast Generating Company, towards stabilizing thousands of feet of actively eroding shoreline along the Turners Falls Impoundment.

The CRSEC has been an active participant in the Commission's relicensing proceedings for the Northfield Pumped Storage Project. We have also had a direct role in riverbank stabilization projects carried out over the past 15 years pursuant to the 1998 Erosion Control Plan, including oversight of four past Full River Reconnaissance studies. Our governmental sponsor, the FRCOG, secured numerous state and federal grants to support bank stabilization and repair projects. Our members include individuals with personal knowledge of the Connecticut River and lands bordering the Turners Falls Impoundment, and others with advanced degrees and decades of professional expertise in water resources management, geology, land use planning and ecology.

At the initiative of the Commission, the 2013 Full River Reconnaissance (FRR) was folded into the relicensing studies, giving it the dual role of a relicensing study and a compliance requirement. As a result, relicensing and compliance issues are inextricably intertwined and the comments presented here apply to both.

Despite its length and detail, we find the FRR has misleading, undocumented, and incorrect statements and conclusions, and does not follow its own Quality Assurance Project Plan (QAPP). These flaws call into question the conclusions of the entire study and any use of the FRR to inform Study 3.1.2, the so-called "Causation Study." The FRR does not provide enough sufficiently accurate information to allow a valid determination of compliance with the current licenses.

1. Statements from FirstLight indicate a bias that calls into question its ability to carry out studies in a scientific way.

FirstLight extensively cites an unvetted 2012 comparison of erosion on the Turners Falls Impoundment with other sections of the Connecticut River ("Riverbank Erosion Comparison Along the Connecticut River") conducted by Simons & Associates, the consultant that prepared the 2008 and 2013 FRRs. The 2012 Simons study is not a relicensing study and was commissioned by FirstLight outside of the FERC process and any CRSEC process. The final bullet cited by FirstLight from Simons 2012 states, "Based on the state of erosion in the northern un-impounded reach as well as the state of continued erosion in the Bellows Falls, Vernon and Holyoke impoundments, *it can be concluded that the riverbanks in the Turners Falls Impoundment are in the best condition (more stable and less eroding) than in any other part of the Connecticut River*" (emphasis added).

This is an incredible statement to put in the FRR, the purpose of which was to document riverbank conditions in the Turners Falls impoundment "at a reconnaissance level without reference to the cause of erosion (Revised Study Plan, p. 3-2)." It indicates bias that leads one to wonder how the studies could possibly be conducted and written in a manner that will simply document existing conditions. Additionally, in its October 10, 2014 "Answer of FirstLight Hydro Generating Company to Motion to Intervene and Comments" regarding an application for a temporary license amendment, FirstLight also stated on page 3, "FirstLight does not believe the current reservoir elevation limits are needed for engineering, environmental or any other reason…" This statement further demonstrates that FirstLight has already assumed a position that erosion is neither a significant issue nor caused by their project's operations.

The CRSEC finds a number of problems with the 2012 Simons study. One of the serious flaws in the report is that it completely ignores a body of scientific literature about erosion in impoundments and the impacts of water level fluctuations on bank stability.[1] Comparing free-flowing, alluvial reaches of the upper Connecticut River (or any other river) to the Turners Falls Impoundment is a red herring. While it is true that alluvial rivers are prone to natural erosion, the Turners Falls Impoundment exhibits only some of the characteristics of an alluvial river. The unanswered question remains: how do project operations impact bank stability in the unique geomorphic and hydrologic conditions of the Turners Falls pool? This is a question for Study 3.1.2, not 3.1.1.

The 2012 Simons study obscures a vital fact that <u>is</u> known – increased erosion is and has been occurring in the Turners Falls Impoundment since the Project began operating 40 years ago. Citing the study report in the FRR is not a scientifically valid approach and indicates a bias by both FirstLight and Simons & Associates, the consultant conducting the FRR, i.e., the types, severity and extent of erosion had been prejudged.

2. The FRR definition of "stable" was written one way, and then interpreted in another.

In Table 6.1 (page 6-6), the FRR reports the stages of erosion in the Impoundment, and calculates that 83.5% of the banks were stable, 9.1% eroded, 5.5% potential future erosion, 1.3% in the process of being stabilized, and 0.6% active erosion. "<u>Stable</u>" is defined in Table 5.2 (page 5-5) as "<u>riverbank segment does not exhibit types or indicators of erosion</u>."

Looking at the Table in Appendix I of the FRR, it is evident that many segments were characterized as having types or indicators of erosion, but were nevertheless classified as being "stable." In fact, using the FRR GIS database, we were able to calculate that, *using their own definition that stable is having no types or indicators of erosion, only <u>43.5% of riverbanks were "stable.</u>"* The percentage of banks that had an erosion type and/or an

[1] See references cited in the expert opinion letter provided by the University of Illinois and included with our comments on Study 3.1.2.

indicator of erosion, seemingly not stable according to their definition but nevertheless labeled as stable by FirstLight, was 40.0% of the banks. The percentage of banks that had both a type of erosion and at least one indicator of erosion labeled as "stable" was 26.2% of the banks.

On page 6-5, the FRR explains the rationale behind the designations of stage and extent of erosion as follows:

> "Based on observations made during the FRR it was common to find some small degree of undercutting (even at the interface of bedrock and soil layers), exposed roots, and creep/leaning trees in many segments of the river even if those segments were classified as Stable with None/Little erosion. However, in many cases these features were not considered significant unless they reached beyond the previously defined classification thresholds or appeared in significant combinations to warrant elevating the classification of a segment from Stable or None/Little to another Stage or Extent of Current Erosion category."

It appears here that FirstLight has interpreted their definition of "stable" to be: riverbank segment does not exhibit *significant* types or indicators of erosion. FirstLight did not provide a threshold or definition of what "significant" means in the Revised Study Plan when it comes to Stages of Erosion. As discussed above, extent of erosion does have thresholds, and FirstLight has chosen to ignore and aggregate the data to fit its biased conclusions. The accepted definitions for Stages of Erosion do not include thresholds for moving from one category to the next. FirstLight has ignored the definition of stable as listed in the Revised Study Plan and Table 5.2 of ISR and inserted a high degree of subjectivity into the classification process. This is unacceptable and results in unsupported conclusions presented in the FRR.

3. Extent of Erosion is highly dependent on breakdown of river segments and how these segments were characterized in the FRR.

Page 5-2 of the FRR explains that the boat-based survey identified a total of 641 riverbank segments covering both banks and the islands. It also states, "Transition points where riverbank features and characteristics changed from one classification to another were identified…" Table 5.2 in the FRR defines the different riverbank characteristics, but does not define a "feature." There are 18 different riverbank characteristics. Transition points were apparently identified if one of 18 different riverbank characteristics changed from the segment that was previously being surveyed. A transition point was never determined based on an erosion classification because these are not riverbank characteristics defined in Table 5.2. Perhaps this implies that similar bank characteristics should behave similarly in terms of erosion.

As a result, many areas of erosion were missed, and some were incorrectly categorized. Some examples of areas that were missed are shown below.

Cropped version of FirstLight photo DSC_1164. Shot November 2013. Located along segment 513, classified as **none/little** extent of erosion.

Cropped version of FirstLight photo DSC_1192. Shot November 2013. Located along segment 515, classified as **none/little** extent of erosion.

Cropped version of FirstLight photo DSC_1203. Shot November 2013. Located along segment 515, classified as **none/little** extent of erosion.

The goal of the 2013 FRR was “to identify and define riverbank features and characteristics and the types, stages, indicators, and extent of erosion throughout the Turners Falls Impoundment” (Revised Study Plan page 3-2). Section 6.2 and Table 6.2 of the ISR states that the 2008 FRR found that 83.3% of impoundment riverbanks had none/little extent of erosion, while in 2013 84.8% had little/none erosion.

It is clear to us that splitting the riverbank into segments based on features other than erosion observations and then assessing the overall erosion in each segment is not a way to truly identify the extent of erosion along the banks. Therefore, the percentage numbers in 2013 and 2008 are meaningless, and in reality, using their methodology, no determination can be made about the extent of erosion and whether or not the riverbanks are getting more or less eroded over time.

4. Mischaracterization of extent erosion at a sampling of sites brings into question the FRR findings.

With two decades of experience reviewing bank erosion on the Impoundment, the CRSEC questioned the conclusion presented by the FRR that 84.8% of the riverbanks had none-to-little erosion (Table 6-2). Accordingly, we have reviewed photos of a selection of riverbank sites. The following are two examples.

A. Detailed examination of the 3,000 feet of bank downstream of the Kendall site (between river marker 790 and 760) demonstrate that the FRR maps in Figure 6.4 and Appendix J do not accurately characterize the extent of erosion. These riverbank segments (right side, looking downstream) are characterized as having “none-little erosion” in Figure 6.4 and Appendix J. We reviewed every photo along this stretch of riverbank and in every photo find two or more indicators of erosion, most extending along the entire length of the bank in each photo. See Attachment presenting these photos with an accompanying table comparing the bank characterizations in the FRR with CRSEC’s observations.)

B. The Northern Connecticut River Fluvial Geomorphology Assessment done by Field Geology Services in 2004 says, “Reaches downstream of tributary confluences will generally have a morphology different than reaches immediately upstream of the confluence because of the introduction of sediment at the confluence….Delineating the reach breaks and understanding the morphological conditions present in each reach are critical for identifying the natural and human conditions leading to erosion and channel instability." (pages 10-11 in Field, 2004).

A look at the segments shown in Appendix G of the FRR indicate many segments straddle the upstream and downstream ends of tributary confluences. These include the Ashuelot River (segment 308), Newton Brook (517), Bottom Brook (509), Mallory Brook (499), Bennett Brook (465), Merriam Brook (126), Otter Run (441), and Ashuela Brook (438). Two segments shown on Appendix G maps seem to mostly be composed of a confluence: segment 88 at Pine Meadow Brook and segment 55 at the Millers River. How these could have bank characterizations is a mystery. For example, if one looks at DSC_0606 (below), one can see the Shearer house on the downstream end of segment 89. Segment 88, a segment 200 ft long, is to the right and shows submerged aquatic vegetation at the confluence of Pine Meadow Brook on the left, and then bank on the right. This segment was characterized as steep upper river bank slope, low upper river bank height, indicators of erosion (notch, exposed roots, creep/leaning trees), stable stage of erosion, and none/little extent of erosion. Though there is no erosion in the part of the segment that is a tributary meeting the Connecticut River, one would have a hard time concluding that the remaining bank has <10% of erosion, even though we could not know for sure where the segment break point was. Certainly including the tributary would "dilute" the extent of erosion in this segment.

FirstLight photo DSC_0606. Shot November 2013. Shearer property is on downstream end of segment 89. Tributary and downstream bank located along segment 88, classified as **none/little** extent of erosion.

5. Key observations and trends of Detailed Site Assessments are unsubstantiated and incomplete.

Page 6-3 of the FRR lists 11 key erosion observations and trends identified during the detailed site assessments conducted as part of the FRR land-based survey. Two of the 11 key observations (#5 and #9) refer to historical floods on the order of 50 years ago or older. We could find no reference to these observations in the Appendix H datasheets or the GIS files for the land-based or boat-based field work. When we asked for an example of these observations at the October 15, 2014 meeting on the FRR, FirstLight's representatives said they would have to get back to us with the information. To date, we have not received these examples. Observations #7 and 8 mentioned that there were several sites that were stable or had received deposition in 2011 from Tropical Storm Irene. Observations were glossed over for those sites such as 2, 12, 15, 18, and 31 that showed slumps, overhangs, tension cracks, undercuts, or exposed roods in the lower 0-8 feet above the water line.

6. The FRR is not in compliance with several elements of the QAPP.

Overall, the FRR contains no mention about following QAPP procedures or quality assurance tasks. Additional comments follow.

A. On page 14 of the QAPP and again on page 33, the QAPP states, "An appendix to the FRR report will include a comparison of the specific riverbank features and characteristics from the data logging files, or field data sheets, collected during the field surveys to a photograph of that same segment of riverbank captured from the digital geo-referenced video. A discussion will be presented in the FRR report based on this comparison. The process of comparing the data logging files to video/still images of a selected percentage of segments, or any segment of particular interest, provides a high level of quality assurance and control on the field data collection. This approach also provides a method for reference checking any subsequent interpretation of the field survey data after the survey has been completed." The FRR did not contain an appendix like this as promised.

B. Kit Choi is listed as the author of the FRR report on the cover. Section 4 of the QAPP did not list Mr. Choi as being involved in this project. It is very odd that the FRR was authored by someone not anticipated to be working on the FRR when the QAPP was written. What was his role and were other roles changed? Andrew Simon and Natasha Bankhead are listed on page 1-3 of the FRR, and these personnel were also not listed in the QAPP. Was the QAPP distributed to each new staff person such that they were familiar with the quality assurance requirements?

C. Page 20 of the QAPP says that for Task 2a, identify and define riverbank features and characteristics, "observations made as part of this task will occur from a boat approximately 50-100 ft from shore, or closer if possible." The FRR on page 5-2 says, "All field work associated with the boat-based survey was conducted from a slow moving boat located a relatively short distance from shore." The FRR does not provide the actual distance from shore that the boat personnel made observations, nor the speed at which the boat was traveling.

D. Field forms were not done or not provided in the FRR. There is thus no way to find out who did what on boat survey and how long it took.

7. Several deliverables listed in the RSP were either not provided or delayed.

Several items promised in the RSP were either not provided or were delayed, hindering any reviewer's ability to adequately review and comment on the report by the November 14th deadline.

The following items were listed as deliverables in the final report, according to the August 14, 2013 Revised Study Plan (RSP), but were not provided. What follows is commentary on each deliverable.

Task 1 – Land-Based Observations

- Data logging and field forms.

CRSEC comment: Appendix H includes datasheets for the 38 detailed geotechnical sites. A field form for the land-based surveys shown as Table 4 on page 18 in the Appendix D QAPP was not used. Six weeks after release of the FRR, on October 30th, in response to requests by CRSEC, Gomez and Sullivan sent CRSEC the GIS files and reported using a pentop computer to record field observations. We request copies of the digital data logging and field forms that were used instead of the forms described in the QAPP.

Task 2 – Classify Riverbank Features, Characteristics, and Erosion

- Data logging and field forms.

CRSEC comment: Boat-based field forms were specified in the QAPP. On October 30th, Gomez and Sullivan sent CRSEC the GIS files and reported using a pentop computer to record field observations. The GIS files included the same information as Appendix I, which had no locational information associated with it, making it difficult to utilize in assessment of the findings. We request copies of the digital data logging and field forms that were used instead of the forms described in the QAPP.

Task 3 – Spatially Define Riverbank Transition Points

- GPS data points denoting the start and end points of all riverbank segments.

CRSEC comment: Appendix G of the FRR showed all the riverbank segments on maps; however, no feature information, including GPS data points denoting the start and end points of all riverbank segments, was included with this, making it cumbersome to compare the Appendix I segment table with the Appendix G maps. In response to a request for the data, including a specific request for the GPS start and end points for the segments, Gomez and Sullivan sent CRSEC the GIS files on October 30th. No geo-referencing information was provided by FirstLight for the segments and FRCOG GIS staff had to create the GPS information data layer so that the other GIS data layers could actually be used.

- Data logging and field forms.

CRSEC comment. Again, no data logging and field forms, as specified in the RSP deliverables list and the QAPP, were provided to us as part of our data request. We again request copies of the digital data logging and field forms that were used instead of the forms described in the QAPP.

Task 4 – Video and Photographic Documentation

- Geo-referenced video of the entire Turners Falls Impoundment.

CRSEC comment: Appendix K simply states, “DVD available upon request.” We requested it and received a thumb drive on September 25th that contained the videos and all photographs – but the video had no geographic references. In response to another request, it was not until October 13th that we received an email from Tim Sullivan of Gomez & Sullivan with a link to a website (http://bit.ly/1uBADod) that had information allowing us to know which video covered what river segment, and the time stamps associated with each video.

- Comparison of 2007 and 2014 photo logs, where applicable.

CRSEC comment: The FRR did not include this. One CRSEC member, the Connecticut River Watershed Council, notes that their August 19, 2013 comment letter on the RSP expressed confusion about the purpose of this task and also recommended against taking photos while the leaves were still on trees. [2] It appears that FirstLight also saw little value in this task, despite adding it between the updated study plan and the RSP. Did it serve as data control and reference checking?

The RSP stated only "FirstLight is seeking to file the final report for the FRR in September 2014, as opposed to April 2014, to match the timeline for filing other relicensing studies and to allow for the inclusion of the photo log which will be collected and analyzed in the summer of 2014." FERC did grant the requested extension to FirstLight. Ironically, the photo log and its analysis were never included in the FRR. For the reasons described above, CRSEC submits that there has not been sufficient time for technical review of the analysis and results of the 2013 FRR, and we would like to emphasize that sufficient time for technical review and analysis of results are required under 18 CFR 5.15(b) and 5.11(b)(3).

8. CRSEC has no evaluation of recommended Stabilization/Preventative Maintenance Sites in the FRR.

The 1998 Erosion Control Plan (ECP) established the approach the licensee would take to comply with License Articles 19 and 20. The ECP's objective was to minimize or prevent erosion in the Turners Falls Pool, and the ECP identified key steps to meet the objective. One step was prioritizing erosion sites to apply erosion control methodologies or treatments. Section 3.0 of the ECP identifies the two top criteria for priority erosion sites: potential and imminent threat to structures, and sites that contribute the greatest quantity of sediment to the river. The FRR was developed to document riverbank conditions and to provide information later used in ranking erosion conditions along the river. The 2013 FRR does not provide CRSEC with enough information to rank the sites that might contribute the greatest quantity of sediment to the river. In the previous 15 years, CRSEC has worked closely and in partnership with the licensee to assess erosion sites and develop a priority list for bank stabilization or preventive maintenance. The 2013 FRR is the first instance of unilateral decision making by FirstLight. We hope it will rejoin CRSEC in a collaborative effort to reduce erosion and protect the river and its prime agricultural riparian lands.

SUMMARY

The 2013 FRR has involved the collection of a great deal of useful data with regard to previous stabilization activities, land use along the banks, and information about detailed sites. However, CRSEC has long had problems with the FRR methodology as a means of documenting the amount of erosion and changes over the years (we refer the Commission to the Project docket since 1999 for the full suite of all our comments). What we want to emphasize here is that the 2013 FRR does not accomplish the goal of adequately analyzing the extent of active and potential erosion along the banks. We have the following recommendations for the Commission:

[2] From CRWC's 8/19/2013 letter, pages 2-3: The task of repeating the riverbank photo log completed by Field Geology Services in June of 2007 has been newly introduced in the RSP. The RSP states that this task will be done in June of 2014. In Field's 2007 report, recommendation #11 was that, "The photo log of the banks completed for this study (Appendix 6) should be repeated with each full river reconnaissance and comparisons made with previous years to identify changes visible along the banks. Digital image logs taken in 2001 and 2004 (NEE, 2005) should also be incorporated into this analysis where the bank position can be confirmed relative to the photo log." In the RSP, it is stated that this is to be done "as a means of data control and reference checking," which sounds different than Field's recommendation #11. We recommend that the purpose of this task be clarified. We recommend that digital image logs from 2001 and 2004 be included in this task. We also recommend that the photo log be taken at the same time as the FRR video, which is the fall of 2013, not June 2014. While leaf-off conditions in 2013 may not reflect observations in June 2007, it is not desirable to set up a pattern for future FRRs that involves different seasons of documentation like this.

1) The FRR introduction should be re-written to explain the purpose of the FRR and how it resulted from serious concerns about erosion in the Turners Falls pool by stakeholders and the Commission. All mention of the 2012 Simons report should be deleted.
2) The methodology for assessing the extent of erosion should be revised to eliminate the current segment-based analysis. The video and photos from 2008 and 2013 should be assessed to analyze extent of erosion, and a new set of statistics determined. CRSEC feels that ideally a third party chosen by FERC should do this analysis.
3) The stages of erosion should be re-calculated according to FirstLight's own definition of the stages, or re-defined to follow the recommendations of the Field Geology Services 2007 Fluvial Geomorphology study of the Turners Falls Pool.

Sincerely,

Tom Miner
Chair
Connecticut River Streambank Erosion Committee

Linda L. Dunlavy
Executive Director
Franklin Regional Council of Governments

Attachment – Table comparing riverbank characterizations

Cc: Congressman James McGovern
Franklin County Legislative Delegation
FirstLight Hydro Generating Company
NOAA – National Marine Fisheries
U.S. Fish and Wildlife Service
Connecticut River Atlantic Salmon Commission
U.S. Army Corps of Engineers
Massachusetts Department of Environmental Protection
Massachusetts Division of Fisheries and Wildlife
Connecticut River Watershed Council
Franklin Conservation District
Windham Regional Commission
Landowners and Concerned Citizens for License Compliance
Town of Gill, MA Conservation Commission
Town of Northfield, MA Selectboard and Conservation Commission

Town of Montague, MA Planning and Conservation Department
Connecticut River Greenway State Park
The Nature Conservancy – CT River Program

Attachment – Table comparing riverbank characterizations

ATTACHMENT to CRSEC and FRCOG Comment Letter on 2013 Full River Reconnaissance Report, Study 3.1.1.

FirstLight Characterization of Segment 517 Photos DSC_1216-1218
Length 190 m
Bank Height - High >3.7 m
Extent of Current Erosion: **None/Little** (Less than 70 square meters of erosion along the 700 sq. m segment)
Stage of Erosion: **Stable** (Riverbank does not exhibit types or indicators of erosion)
All Indicators of Potential Erosion: Creep/Leaning Trees

		
Photo DSC _1216	Photo DSC _1217	Photo DSC _1218

CRSEC Notes: Other Indicators of Erosion Observed: Notching (undercut); Exposed Roots.
Other Types of Erosion Observed: Slides, Falls

FirstLight Characterization of Segments 518-521. Photos DSC_1219-1224
Total Length 760 m
Bank Height - High >3.7 m
Extent of Current Erosion: **None/Little** (Less than 562 square meters of erosion along the 5,620 sq. m segment)

Stage of Erosion: **Stable** (Riverbank does not exhibit types or indicators of erosion)
All Indicators of Potential Erosion: Creep/Leaning Trees, Exposed Roots.
Type of Erosion: Undercut


Photo DSC _1219


Photo DSC _1220


Photo DSC _1221


Photo DSC _1222


Photo DSC _1223


Photo DSC _1224

FirstLight Characterization of Segments 522-525. Photos DSC_1225-1233.
Total Length: 403 m. (1,322 feet)
Bank Height - High >3.7 m
Extent of Erosion: **None/Little** (298 meters); Some:105 meters.
Stage of Erosion: **Stable** (Riverbank does not exhibit types or indicators of erosion - 298 meters); Eroded (105 meters).
All Indicators of Potential Erosion: Overhanging Bank, Creep/Leaning Trees, Exposed Roots.
Type of Erosion: Undercut, Topples

Photo DSC _1225

Photo DSC _1226

Photo DSC _1227

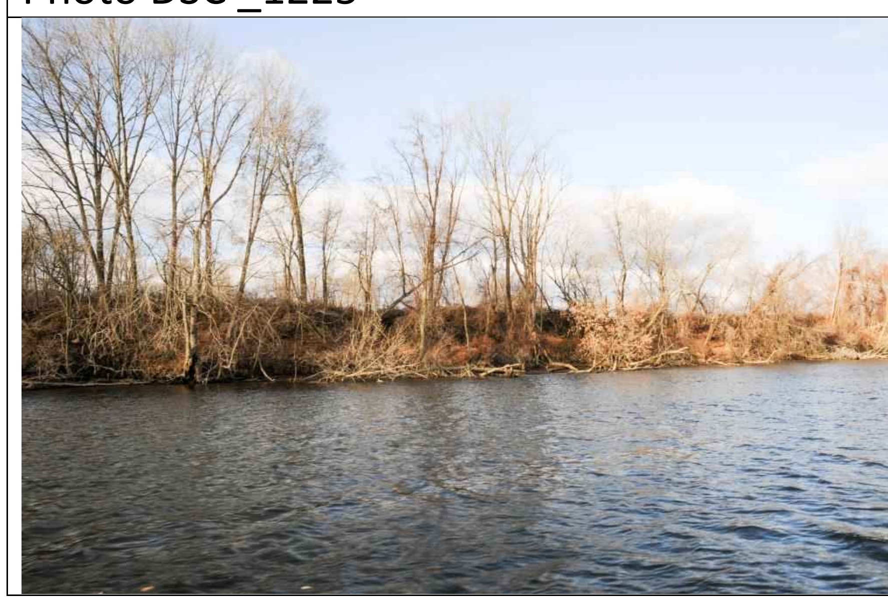


Photo DSC _1228	Photo DSC _1229	Photo DSC _1230
		
Photo DSC _1231	Photo DSC _1232	Photo DSC _1233
	Photos DSC_1232 and 1233 taken downstream of Kendall Restoration Site	
Land-Based Observation Point #21 done just downstream of Kendall Restoration Site. Representative Segment 3,000 feet (Station Number 765 to 795). Includes all of Segments 517-525 described above and shown in photos DSC_1216-1233. CRSEC Notes: Description of Land-Based #21 and profile of bank conditions are a more accurate representation of conditions. This information does not align with the 2013 FRR classification of these segments as None/Little and Stable.		

Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *21* **Personnel:** *YKC, AS, MM, CM, TS*

Date: *November 15, 2013* **Time:** *1:50 pm*

Station Number: *792+50* **Photo Reference Numbers:** *664 - 668*

Left or Right Bank (Looking Downstream): *Right*

Length of Representative Segment, From Station Number *765+00* **To Station Number** *795+00*

Previously Stabilized? *No (Just downstream of Kendle Restoration Site)*

Geologic / Geotechnical Observations:

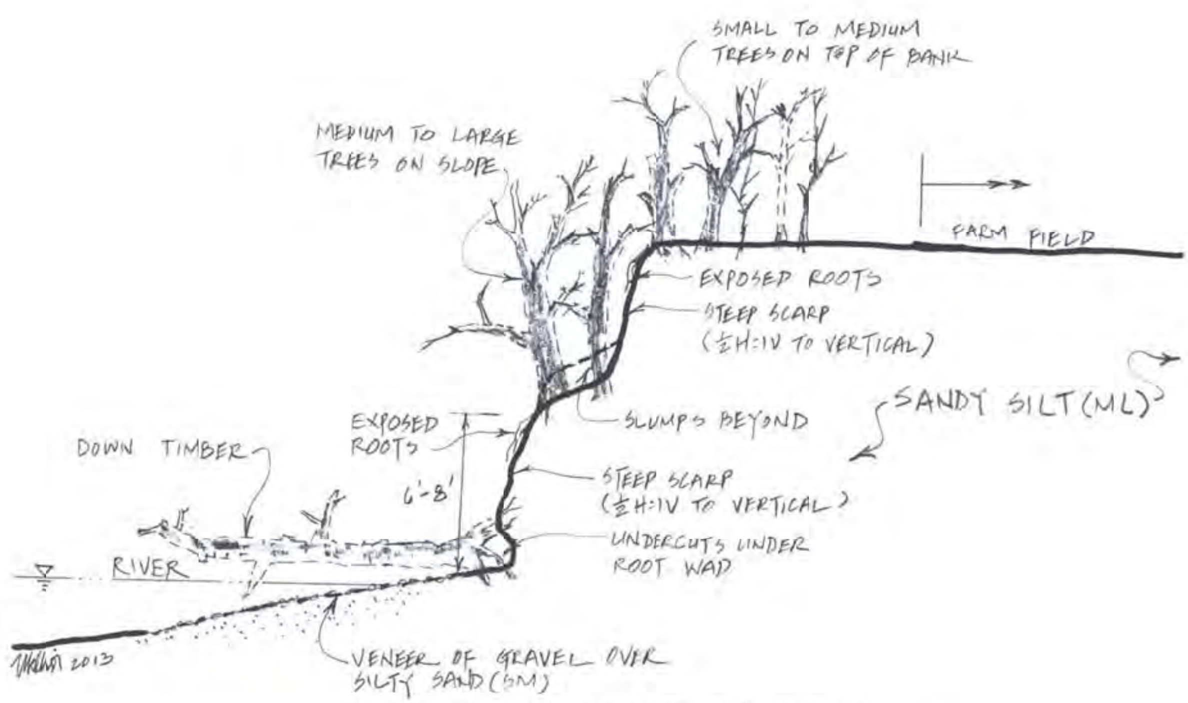
Stratigraphy:
(Refer to Site Sketch below for locations of soil/rock layers
Notations in parentheses are based on Unified Soil Classification System)

SANDY SILT (ML) – Nonplastic, 10% - 20% fine sand, gray.
Beach: GRAVEL (GP) to SILTY SAND (SM). Likely thin veneer.

Observed Erosion Features:

- *Significant erosion, with steep scarps and slumpings.*
- *Very steep banks, entire slope, with overhangs and undercuts near river level.*
- *Some slumpings.*
- *Exposed roots along scarps.*

Site Sketch:



SECTION - OBSERVATION PT. NO. 21
NOT TO SCALE

Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *21* **Date:** *November 15, 2013*

Station Number: *792+50*

Maximum Root Depth:

-

Erosion Classification:

Types of Erosion: mass wasting

Indicators of Potential Erosion: Exposed roots
Overhanging bank
Undercuts

Notes: overhangs to near vertical scarps at the top of the bank, with sparse vegegation
Mass wasting & slumping at mid-slope
Sandy/silty soils on bank face, gravelly beach

Bank Vegetation:

Top: Heavy (>50%), Broad-leaved deciduous sapling/shrub
Staghorn sumac, winged euonymus, barberry, bittersweet, ag fields*

Face: None to Very sparse (0-10%), broad-leaved deciduous shrub
Winged euonymus, barberry, bittersweet, rye, solidago

Toe: None to Very sparse (0-10%), herbaceous
Gravel beach

NOTE: The dominant plant is noted with an *

Adjacent Land Use:
Agricultural

Sensitive Receptor:
No

Notes: *Eroding banks*

Agricultural gullies

Significant invasive plant colonization (euonymus, barberry, bittersweet, autumn olive, honeysuckle)

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 664 - 668
Observation Point No. 21 - November 15, 2013

Photo No. 664

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 664 - 668
Observation Point No. 21 - November 15, 2013

Photo No. 665

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 664 - 668
Observation Point No. 21 - November 15, 2013

Photo No. 666

Photo No. 667

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 664 - 668
Observation Point No. 21 - November 15, 2013

Photo No. 668

Attachment 12. CRSEC Comments on upper vs. lower riverbank definition

August 29, 2014

Franklin Regional Council of Governments

CONNECTICUT RIVER STREAMBANK EROSION COMMITTEE

MEMORANDUM

TO: John Howard

FROM: Connecticut River Streambank Erosion Committee

DATE: August 28, 2014

RE: Upper vs. lower riverbank working definition

At the August 4, 2014 meeting held at Northfield Mountain Visitor Center, we discussed the set of transects to be used in Study 3.1.2 *Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability*. We told you at that meeting that we would respond more formally to Tim Sullivan's June 27, 2014 Memorandum (sent to us via email on June 30) on the working definition of "upper" vs. "lower riverbank" of the Turners Falls Impoundment. This memorandum documents the Connecticut River Streambank Erosion Committee's response as of this time.

The definition of upper vs. lower riverbank is central to understanding the extent and causation of bank erosion in the impoundment. Our primary desire is that the designation and the definition remain consistent throughout the relicensing process and beyond. We have found the past shifting of methodologies, site names, and definitions from one Full River Reconnaissance (FRR) to the next to be confusing and problematic. We worry when we read in the second paragraph of the 6/27/14 Memorandum that "It is anticipated that these definitions will continue to evolve….".

No scientific basis is given for the current definition and no scientific rationale for having an evolving definition is provided by FirstLight. In fact, we would argue that an evolving and non-cited, not scientifically accepted and replicable definition runs counter to accepted academic, professional and regulatory practices. Stakeholders and regulatory agencies should not be asked to accept a random definition of bank that is unsupported by citations and examples from current literature that clearly document why this definition is valid for the Turners Falls Pool.[1]

The relicensing process is governed by state and federal regulatory agencies. Further, the relicensing studies cross several related disciplines. Any definition of the river bank should be grounded in acceptable science and be consistent with the US Army Corps of Engineers' and MassDEP's definition of bank. The definition of bank, according to the attached references (US Army Corps of Engineers, BSTEM and King County, Washington) is

[1] We note that the riverbank profiles created by Kit Choi for the transect study call the base of the bank "the bank toe" and the beach is outward of that. This confirms our position, which is supported by the attached references, that the toe of the bank should always be taken as the base of the bank.

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consistent, understandable and grounded in the scientific literature, unlike the "continuing to evolve" definition of bank proposed by FirstLight. It defies logic that some arbitrary definition of bank is used to describe the conditions in the Turners Falls Impoundment now, and the definition of bank will evolve and likely be different for the 401 Water Quality Certificate and US ACOE jurisdictional review. How is the bank defined in the VT/NH reach of the river? Consistency and validity of a bank definition is a critical component of the relicensing studies.

Previous FRR investigations of the Turners Falls Pool have been plagued by inconsistencies in terminology, to wit:

- Earlier FRRs did not include the mudflat/beach area as part of river bank. This has been changing over time. The most recent available FRR (2008) apparently treated mudflat/beach area as comprising the entirety of what FirstLight now calls the lower bank.
- <u>Turners Falls Impoundment, Lower vs. Upper Riverbank</u>, June 27, 2014, defines lower bank as "frequently below water" (lower than average height of water level fluctuations "high water mark"?) and "mostly barren of vegetation other than some scattered aquatic vegetation" and demonstrates those conditions, especially lack of vegetation, in photos on pp. 3, 4, and 5. The document also defines upper bank as "frequently above water" and "supports various types of terrestrial vegetation."
- <u>RSP Study No. 3.1.2 *Northfield Mtn./Turners Falls Operations Impacts on Existing Erosion and Potential Bank Instability* Selection of Detailed Study Sites – Stakeholder Response</u>**,** August 4, 2014, asserts there is "heavy" lower bank vegetation at Site 303B (pg. 13), but it appears that the area in question is neither frequently under water nor barren of vegetation - and that the vegetation shown is terrestrial, not aquatic.
- <u>Erosion Control Plan - Status and Update of Activities</u>, August 15, 2014, appears to characterize lower bank and beach area as different entities. The section on the Split River Farm site (no location, station or river mile information provided) states "no new lower bank erosion has occurred" and "several inches of sediment have settled on the lower bank and beach area." (Photos # 1 and 2)

It seems evident from the above examples that the definition of various areas of bank and land under water (at least below ordinary high water level fluctuation) need clarification and, most importantly, consistent usage.

We discussed another concern at the August 4th meeting. We asked if previous FRRs counted percentage of eroding riverbank based on the upper riverbank only, and whether the 2013 FRR is going to count percentage of eroding riverbank using lower plus upper riverbank area. Our thought is that the percentage of eroding riverbank could get skewed low if this change from one FRR to the next was made, since lower riverbanks could be disregarded as beach areas. Mickey Marcus of New England Environmental was not present at the August 4th meeting to confirm the methods of previous FRRs, but you assured us that the 2013 FRR would use the upper riverbank only for this calculation. We requested that this be documented in the September 2014 filing of the 2013 FRR, and you agreed to include it. Therefore, we expect to see documentation on how percentage of eroding riverbank is calculated in the forthcoming FRR.

These are our concerns at this time. We may have additional comments and concerns after reviewing the 2013 FRR when it is released in the middle of September.

cc: Ken Hogan, FERC
Robert McCollum, DEP
David Foulis, DEP
Bob Kubit, DEP
Brian Harrington, DEP
Bill McDavitt, NOAA
Tim Sullivan, Gomez & Sullivan
Mickey Marcus, NEE

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References:

CHAPTER 3

MODES AND CAUSES OF BANK FAILURES

To effectively control bank erosion, river bank management must be compatible with the nature of the river system and the composition of its banks. Before restorative methods are applied to eroding banks, it is essential to understand the mechanism of erosion. Otherwise, large investments of time and money may potentially be wasted in projects that fail or require frequent maintenance. This chapter discusses various forms and causes of bank failure.

3.1 STREAMBANK ZONES

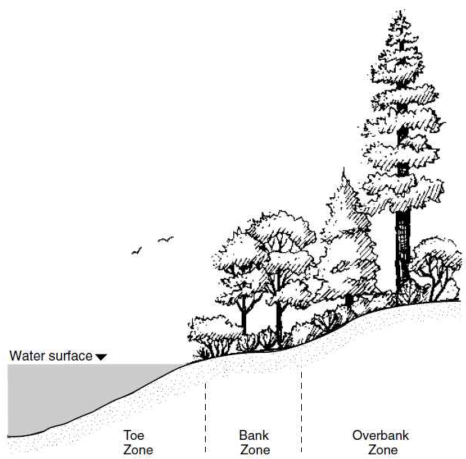
Streambanks can be divided into three general zones: toe, bank, and overbank zones. Although the boundaries between these zones are imprecise because river levels vary seasonally, they are useful in subsequent discussions. These zones are shown in Figure 3.1, and can be described as follows (adapted from Logan 1979):

Toe Zone. The toe zone is that portion of the bank between the ordinary high water (OHW) and low water levels. This is the zone most susceptible to erosion as it is exposed to strong currents, debris movements, and wet-dry cycles. This zone is normally inundated throughout much of the year. In areas where stabilization is necessary, non-vegetative structural protection is normally required in this zone because few woody plants can tolerate year-round inundation.

Bank Zone. The bank zone is that portion of the bank above the OHW mark (OHWM) that is inundated during periods of moderate flows (i.e., up to bankfull flow). Although above OHWM, these sites are still exposed to periodic erosive currents, debris movement, and traffic by animals and humans. The water table in this zone is frequently close to the soil surface because of its proximity to the river.

Overbank Areas. The overbank area is that portion of the bank from the bank zone inland that is subjected to inundation or erosive action only during occasional periods of high water (i.e., greater than bankfull flows). This zone is generally subjected to periodic dry periods in which the soil moisture is primarily dependent on characteristic rainfall of the area. When relatively flat and generally underlain by alluvial deposits, this area is also called a floodplain. When it rises steeply and directly from the streambank, this area is called a bluff.

Figure 3.1 **Section of streambank zones in natural channels.**



In some situations, toe protection with riprap or other structural means may be the only streambank protection required. Usually, structural protection below OHWM will be combined with vegetative designs above OHWM. Combined systems of this sort provide maximum protection against failure and yield greater benefits for aquatic and terrestrial ecosystems. The design of bank protection measures is discussed in Chapter 7.

http://www.kingcounty.gov/environment/waterandland/flooding/bank-stabilization-projects/guidelines.aspx

Technical Report EL-97-8
April 1997

US Army Corps
of Engineers
Waterways Experiment
Station

Environmental Impact Research Program

Bioengineering for Streambank Erosion Control

Report 1
Guidelines

by Hollis H. Allen, James R. Leech

Bioengineering by Zones

Plants should be positioned in various elevational zones of the bank based on their ability to tolerate certain frequencies and durations of flooding and their attibutes of dissipating current and wave energies. Likewise, bioengineering fixes should be arranged by zone, which will be discussed below. The zone definitions given below correspond to those used by the U.S. Army Engineer District, Omaha, and have been used in preparing guidelines for the use of vegetation in streambank erosion control of the upper Missouri River (Logan et al. 1979). These zones are not precise and distinct since stream levels vary daily and seasonally—they are only relative and may be visualized as somewhat elastic depending on the bank geometry. If one carefully copied nature in the planning process, plant species can be chosen that will adapt to that specific zone or microhabitat. Mallik and Harun (1993) lend credence to this zonal concept in a study on the Neebing-McIntyre Floodway, parts of the Neebing and McIntyre River Complex near the Intercity area of Thunder Bay, Ontario, Canada. They describe four microhabitats: bank slope, scarp face, above-water bench, and underwater depositional shelf. Each one had distinctively dominant plant species that generally correspond to the types of plants adapted for this report. Figure 5 illustrates the location of each bank zone for the upper Missouri River example. A description of each and the types of vegetation and appropriate species examples associated with them is given below. This zonal concept can be expanded to other streams to facilitate prescription of the erosion control treatment and plants to use at relative locations on the streambank.

Toe zone

The toe zone is that portion of the bank between the bed and average normal stage. This zone is a zone of high stress and can often be undercut by currents. Undercutting here will likely result in bank failure unless preventative or corrective measures are taken. This zone is often flooded greater than 6 months of the year.

Figure 6 illustrates the plant species prescribed for each streambank zone on the upper Missouri River except for the toe zone. The toe zone would likely have to be treated by some hard material, such as rock, stone, log revetments, cribs, or a durable material such as a geotextile roll (to be discussed later).

Splash zone

The splash zone is that portion of the bank between normal high-water and normal low-water flow rates. This and the toe zone are the zones of highest stress. The splash zone is exposed frequently to wave wash, erosive river currents, ice and debris movement, wet-dry cycles, and freezing-thawing cycles. This section of the bank would be inundated throughout most of the year (at least 6 months/year), but note that a large part of this inundation may occur in the dormant season of plants. The water depths will fluctuate daily, seasonally, and by location within the splash zone.

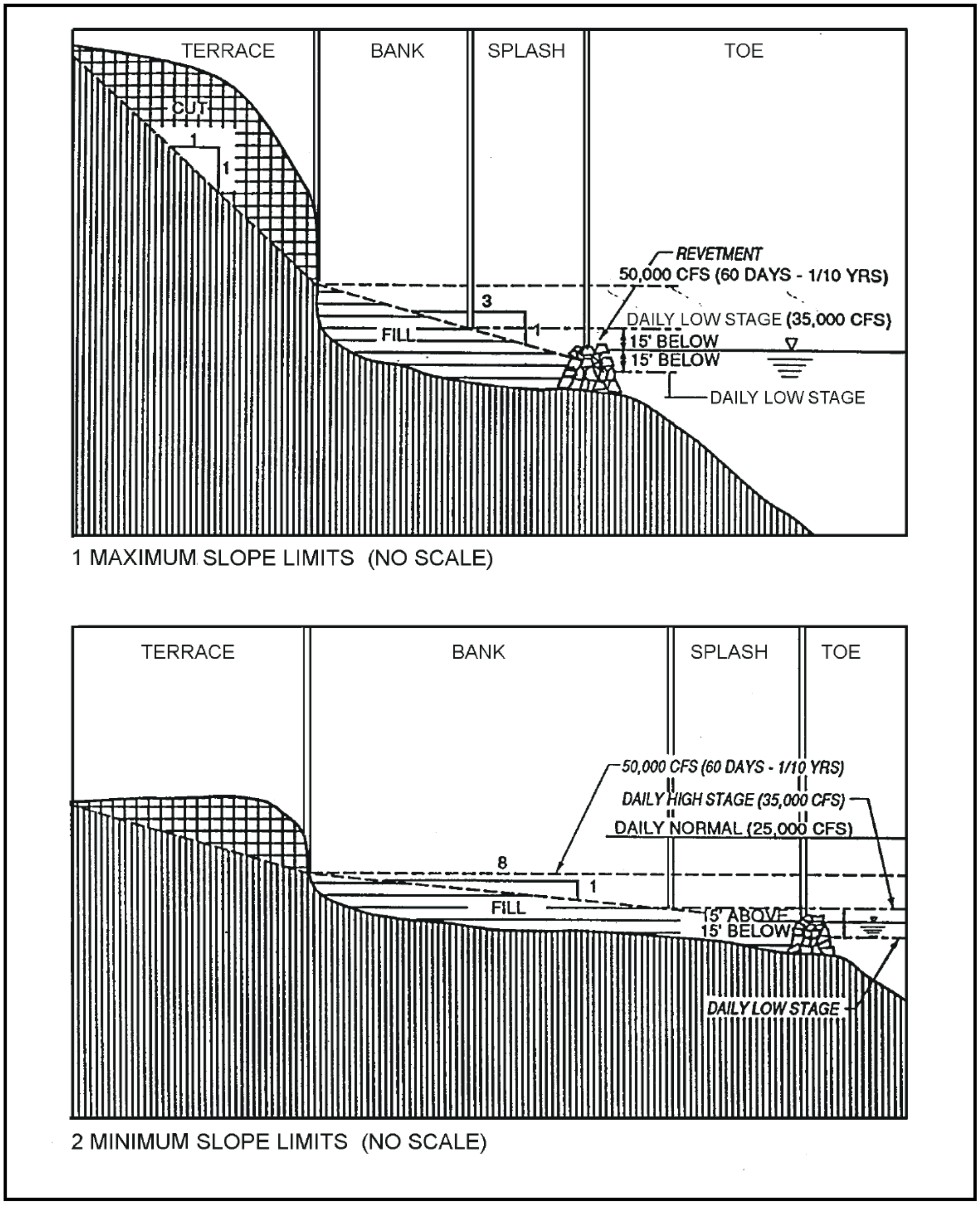


Figure 5. Bank zones defined on constructed slopes

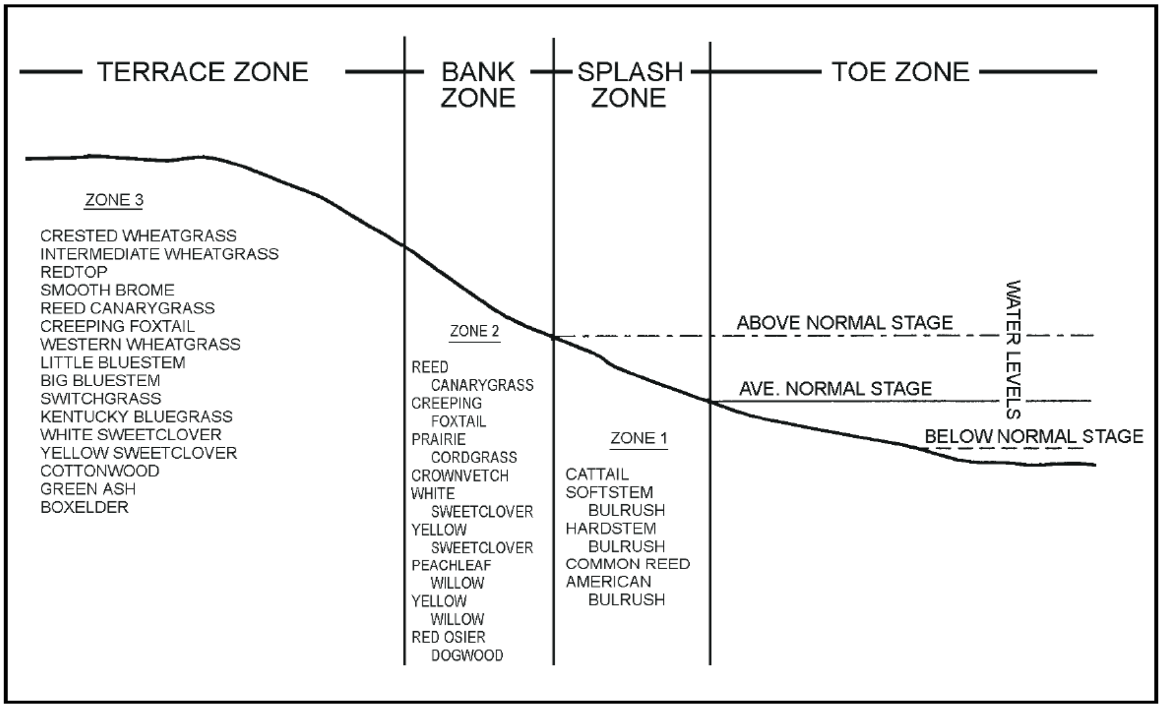


Figure 6. Possible species to plant by zone on Missouri River

Bank zone

The bank zone is that portion of the bank usually above the normal high-water level; yet, this site is exposed periodically to wave wash, erosive river currents, ice and debris movement, and traffic by animals or man. The site is inundated for at least a 60-day duration once every 2 to 3 years. The water table in this zone frequently is close to the soil surface due to its closeness to the normal river level.

Terrace zone

The terrace zone is that portion of the bank inland from the bank zone; it is usually not subjected to erosive action of the river except during occasional flooding. This zone may include only the level area near the crest of the unaltered "high bank" or may include sharply sloping banks on high hills bordering the stream.

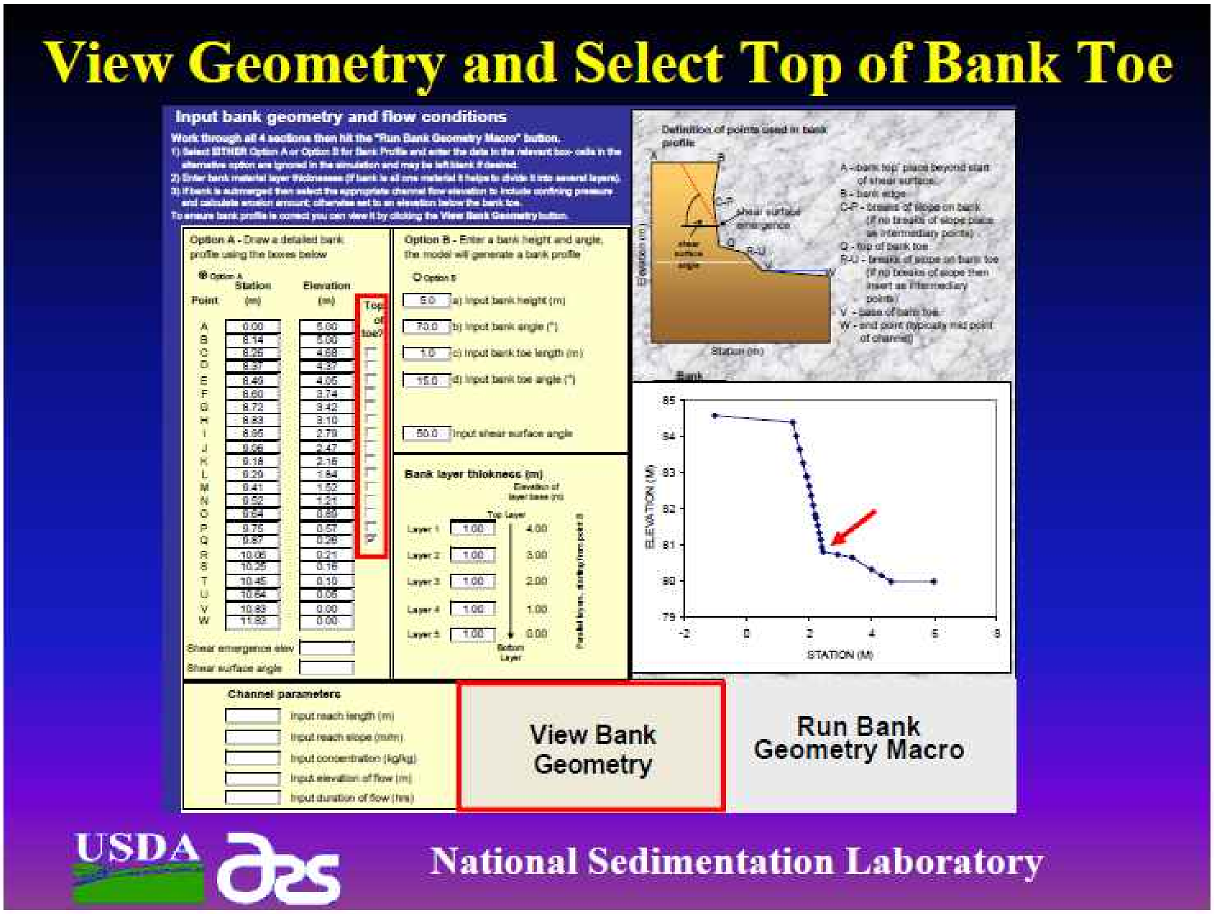
Development of the Bank-Stability and Toe-Erosion Model (BSTEM Version 5.4)

Andrew Simon, Robert Thomas, Andrea Curini and Natasha Bankhead

USDA-ARS National Sedimentation Laboratory,
Oxford, MS

andrew.simon@ars.usda.gov

USDA ARS National Sedimentation Laboratory


View Geometry and Select Top of Bank Toe
Input bank geometry and flow conditions
Option A - Draw a detailed bank profile using the boxes below
Option B - Enter a bank height and angle, the model will generate a bank profile
Station (m)
Elevation (m)
Point
Top of toe?
a) Input bank height (m)
b) Input bank angle (°)
c) Input bank toe length (m)
d) Input bank toe angle (°)
Input shear surface angle
Bank layer thickness (m)
Shear emergence elev
Shear surface angle
Channel parameters
Input reach length (m)
Input reach slope (m/m)
Input concentration (kg/kg)
Input elevation of flow (m)
Input duration of flow (hrs)
View Bank Geometry
Run Bank Geometry Macro
ELEVATION (M)
STATION (M)
USDA
National Sedimentation Laboratory

Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *18* **Personnel:** *YKC, AS, MM, CM, TS*

Date: *November 15, 2013* **Time:** *10:00 am*

Station Number: *870+00* **Photo Reference Numbers:** *642 - 646*

Left or Right Bank (Looking Downstream): *Left*

Length of Representative Segment, From Station Number *867+00* **To Station Number** *925+00*

Previously Stabilized? *No*

Geologic / Geotechnical Observations:

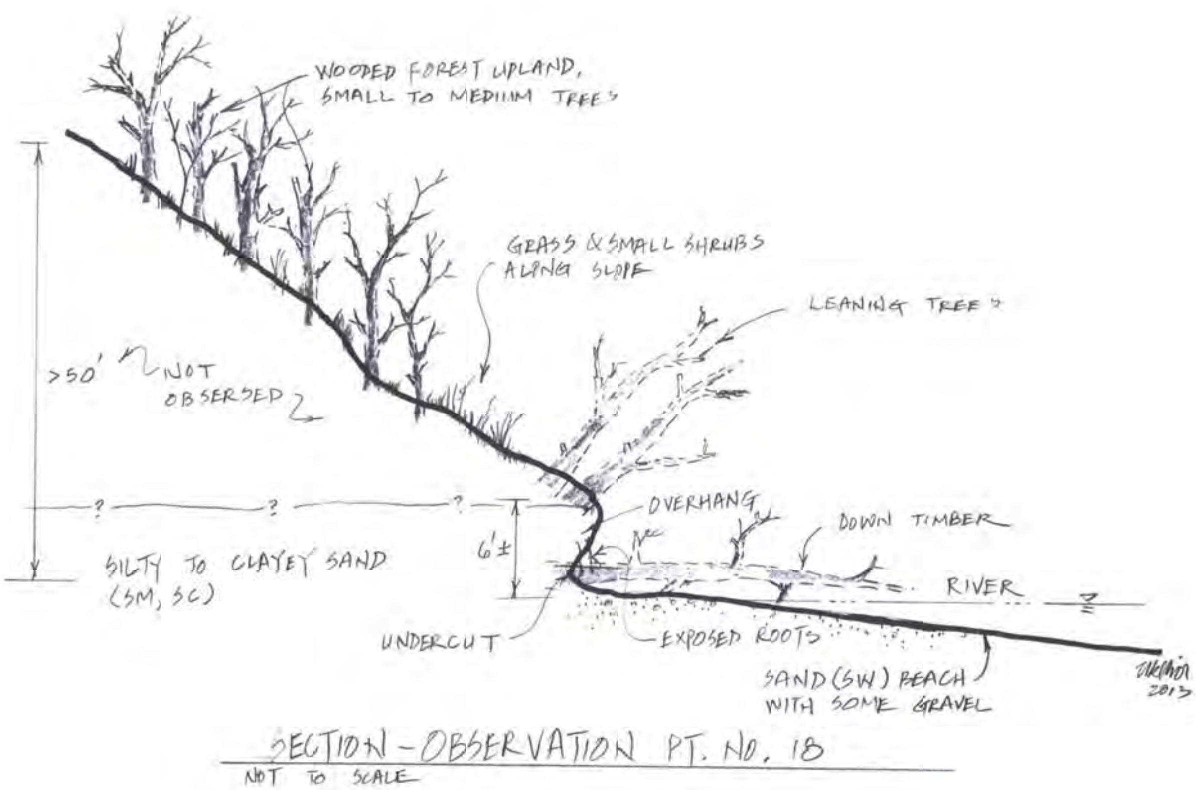
Stratigraphy:
(Refer to Site Sketch below for locations of soil/rock layers
Notations in parentheses are based on Unified Soil Classification System)

SILTY SAND (SM) to CLAYEY SAND (SC) – Mostly fine sand, 20% to 30% low- to medium-plastic fines.

Observed Erosion Features:

- *Overhangs to near-vertical scarps near toe of bank.*
- *Exposed roots of leaning trees near toe of bank at river level, with undercuts behind roots.*
- *Down timber and leaning trees near river level.*

Site Sketch:



DRAFT

Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *18* **Date:** *November 15, 2013*

Station Number: *870+00*

Maximum Root Depth:

-

Erosion Classification:

Types of Erosion: mass wasting

Indicators of Potential Erosion: Exposed roots
Overhanging bank
Undercuts

Notes: overhangs to near vertical scarps at the toe of the bank, exposed roots of leaning trees near toe of bank at river level with undercuts behind roots, downed trees and leaning trees near river level

Bank Vegetation:

Top: Heavy (>50%), Broad-leaved deciduous tree
Red oak, black birch, shag bark hickory, green ash, Japanese barberry, Christmas fern*

Face: Heavy (>50%), Broad-leaved deciduous tree
Red oak, black birch, shag bark hickory, green ash, river rye, sedges, solidago*

Toe: None-Very sparse (0-10%) emergent (nonpersistents)
river rye, sedges

NOTE: The dominant plant is noted with an *

Adjacent Land Use:
Agricultural & forested

Sensitive Receptor:
Yes

Notes: *emergent shelf at toe from ~station 930+00 to 920+00*

High bank, low bench

Lots of herbaceous veg at top of bank

Invasive species present (barberry, bittersweet), although sparse

DRAFT

Attachment 13. CRSEC Memo to John Howard re: follow-up to meeting held August 14, 2014

August 28, 2014

Franklin Regional Council of Governments

CONNECTICUT RIVER STREAMBANK EROSION COMMITTEE

MEMORANDUM

TO: John Howard

FROM: Connecticut River Streambank Erosion Committee

DATE: August 28, 2014

RE: Relicensing Study No. 3.1.2

At the August 4, 2014 meeting held at Northfield Mountain Visitor Center, we discussed comments on Study No. 3.1.2 submitted in writing by CRSEC on August first. This is a follow-up Memo to confirm a commitment that Tom Sullivan made at the meeting to include the following information in the study report:

1. Detailed cross-section drawings for each of the detailed study sites (like those provided by Kit Choi for the land based survey sites).
2. Full cross-section drawings for sites located at permanent transects – include both banks and presented at a scale that can be easily read.
3. Locate the Mean Annual Low Water mark on the cross-section and provide the water level elevation (MSL).
4. Locate the Mean Annual High Water mark on the cross-section and provide elevation.
5. Locate the upper and lower project operational range of water level fluctuations (2000-2013) on the cross-sections and provide elevations.
6. Locate the upper and lower project operational range of water level fluctuations allowed by the current license on the cross-sections and provide elevations.
7. Locate the jurisdictional boundaries for the MA Wetlands Protection Act, MassDEP 401 WQC and US Army Corps of Engineers on each detailed cross-section.

If there are any disagreements or questions regarding the requested information, please contact Kimberly Noake MacPhee at FRCOG.

cc: Ken Hogan, FERC
Robert McCollum, DEP
David Foulis, DEP
Bob Kubit, DEP
Brian Harrington, DEP
Bill McDavitt, NOAA
Tim Sullivan, Gomez & Sullivan
Mickey Marcus, NEE

Attachment 14. FRCOG Comments on Revised Study Plan (RSP)

August 28, 2013

Franklin Regional Council of Governments

August 28, 2013

Honorable Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project, FERC No. 2485-063
Turners Falls Project, FERC No. 1889-081
Comments on the Revised Study Plan (RSP) submitted by FirstLight August 14, 2013.
Section 3.1 Geology and Soils
Section 3.1.1 *2013 Full River Reconnaissance Study*
Section 3.1.2 *Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability*
Appendix D – Quality Assurance Project Plan (QAPP)
Section 4.0 Studies not Included in the RSP
4.1 Geology and Soils, 4.1.1 Study of Shoreline Erosion Caused by Northfield Mountain Pumped Storage Operations

Dear Secretary Bose:

The Franklin Regional Council of Governments (FRCOG) appreciates the opportunity to submit comments on the above-referenced documents. Although the Revised Study Plan contains the fourth version of the study plans for Section 3.1 Geology and Soils, these study plans still do not meet the standard of technically defensible and rigorous scientific investigations with clearly stated goals, objectives and deliverables. We continue to have no confidence that the data collected as part of these studies can be used in a meaningful way to evaluate the potential impacts project operations have on the natural resources of Franklin County.

Bank erosion is the overarching environmental problem associated with the presence and operation of the Project, one that affects all the other resources listed in the Revised Study Plan – Water Resources; Fish and Aquatic Resources; Terrestrial Resources; Wetlands, Riparian and Littoral Habitat; Recreation and Land Use; Cultural Resources; and Developmental Resources. Once again, we urge FERC to require FirstLight to develop clear and scientifically defensible studies that will provide valid and useful data about the impacts of project operations on riverbank stability and erosion in the Turners Falls Pool.

We have several specific comments on the Revised Study Plan (RSP) that we've included in the attached table. We are not providing additional comments on Appendix D – Quality Assurance Project Plan (QAPP) since this document accompanies Section 3.1.1 2013 Full River Reconnaissance (FRR) Study, which continues to be inadequate for relicensing and compliance purposes. The 2013 FRR should be removed from the relicensing process because, as written in the RSP, the data gathered from this study will not provide scientifically defensible information nor will it provide sound data for the other studies that rely upon it. The Connecticut River Streambank Erosion Committee (CRSEC) initially agreed that it would be efficient to include the 2013 FRR in the relicensing process, but we stressed that 1) the 2013 FRR methodology and the Quality Assurance Project Plan (QAPP) still needed significant improvements and the CRSEC wanted to be involved in the process to refine these documents, and 2) tasks would need to be added to the 2013 FRR to gather data to inform relicensing. The 2013 FRR has not been significantly improved from its 2008 predecessor. The 2013 FRR should be confined to the compliance arena, and FirstLight should be directed to work with the CRSEC to develop an appropriate methodology and QAPP.

We are hopeful that FERC will require FirstLight to significantly modify the study plan presented in RSP Section 3.1.2 Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability to reflect standard fluvial geomorphologic practices and scientifically defensible methodologies. Without sound data, appropriate protection, mitigation and enhancement (PME) measures for the Connecticut River cannot be developed.

We again request that FirstLight be required to evaluate the feasibility of alternatives to address erosion, including a study of the "closed loop" option. We look forward to continuing our active engagement in the relicensing of the Connecticut River hydroelectric projects.

Sincerely,

Ann H Banash

Ann Banash, Chair
FRCOG Executive Committee

Jerry Lund

Jerry Lund, Chair
Franklin Regional Planning Board Executive Committee

Tom Miner, Chair
Connecticut River Streambank Erosion Committee

cc: Franklin County Legislative Delegation
US Fish & Wildlife Service
Massachusetts Department of Environmental Protection

Massachusetts Department of Conservation and Recreation
Congressman James McGovern
Town of Gill, MA
Town of Northfield, MA
Town of Montague, MA
Franklin Conservation District
Connecticut River Watershed Council

Attachment: Table of Franklin Regional Council of Governments' Comments on FirstLight's August 14, 2013 Revised Study Plan

Revised Study Plan Section	Summary of FRCOG's Requested Study Plan Modification(s)	FirstLight's Response to Requested Modification(s)	FRCOG's Response to Modification Presented in RSP and Additional Requested Modifications/Recommendations	Applicable Study Plan Criteria[1]
Section 3.1.1 *2013 Full River Reconnaissance (FRR) Study*	2013 FRR study plan is not adequate for compliance or relicensing purposes.	The methodology for the 2013 FRR continues to reflect and reference previous FRR methods, data and conclusions. On page 3-20, Task 6, FirstLight states that the 2013 FRR data will be used for "…comparisons of riverbanks[sic] conditions with past FRRs." and that "The purpose of these comparisons is to evaluate the temporal trends in riverbank erosion and to determine if equilibrium of erosion and stabilization is developing."	We strenuously object to efforts by FirstLight to evaluate temporal trends in erosion using data from previous FRRs. We have meticulously documented our objections to the methodology used by FirstLight for previous FRR in correspondence to FERC. We reaffirm our objections to the findings and conclusions of the 2008 FRR and the references to that study and the use of the 2008 FRR methodology in the 2013 FRR. We assert that the 2013 FRR study plan is still not adequate for compliance or relicensing purposes. See our comments on page 3 of our July 15, 2013 letter.	<u>18 CFR §5.9(b)(1) Goals and Objectives</u>: The goals of FRCOG's study requests and FRCOG's requested modifications to FirstLight's proposed study plans are to determine the environmental impacts from the presence and operation of the licensed facilities on river bank stability, shoreline habitat, agricultural farmland, wetland resources, bed substrate, and water quality in the Turners Falls impoundment. We've listed objectives and specific project tasks in our comments herein and in previous correspondence dated March 1, 2013 and July 15, 2013. <u>18 CFR §5.9(b)(2) Relevant Resource Management Goals and Public Interest Considerations</u>: The FRCOG's resource management goals and public interest considerations are to ensure that the Connecticut River, which is designated as a Class B river for its entire length in Massachusetts, meets its designated uses of habitat for fish, other aquatic life and wildlife, and for primary and secondary contact recreation. Class B waters must also have consistently good aesthetic value and meet minimum criteria for numerous water quality indicators to achieve compliance with the standards set forth in the regulations. The other resource management goals and public interest considerations are to protect prime farmland soils, which are eroding, and riparian habitat. Eco-based tourism and agricultural operations are important to the economy of Franklin County so maintaining the water quality of the river and protecting scenic landscapes and productive farmland along the river from erosion are extremely important. <u>18 CFR §5.9(b)(4) Existing Information and Need for Additional Information</u>: There is a need for additional information to identify and fill existing data gaps. Field Geology Services' 2007 investigation provided several good recommendations for future work in section 9.3 of its report which, if implemented, could provide for: a) an improved understanding of the causes of erosion; b) more accurate
	The 2013 FRR methodology does not identify scientifically defensible criteria for determining the **type, stage and spatial extent of erosion**. Build upon the recommendations in Field, 2007 and eliminate the use of subjective, qualitative terms like "little/none", "some" or "extensive."	Table 3.1.1-2 of RSP lists the Stage(s) of Erosion as: potential future erosion; active erosion; eroded; and stable. The spatial extent of erosion is identified in Table 3.1.1-2 as the Extent of Erosion and is classified as: none/little; some; some to extensive; and extensive.	The RSP still uses qualitative, subjective terminology to describe both the spatial extent of erosion and the temporal or stage of erosion. These terms and definitions are not based on a replicable scientific methodology. No citation is given for use of these terms as representative of standard fluvial geomorphological practices. See FRCOG comments in July 15, 2013 letter, pages 4-5 and Attachments.	
		Table 3.1.1-2 includes a new category of Indicators of Potential Erosion that includes terms used by Field, 2007 to describe types of erosion.	FirstLight's erosion classification system (Table 3.1.1-2) has separated the **description of the type of erosion from the type of erosion** as presented in 3.1.1-4 of the RSP (which was taken from Field, 2007) and created a new category – Indicators of Potential Erosion. No description, justification or citation for this new category is provided in the RSP, which makes the purpose of this category unclear and confusing. Inventorying the conditions listed in the Indicators of Potential Erosion Category should be done as part of the effort to identify the **types** of erosion. Listing these bank characteristics as a separate category will only downplay and mask both the type and extent of erosion occurring along the river.	

[1] To eliminate redundancies, we have addressed the study plan criteria that are relevant to our comments once, since the list of study plan criteria are essentially the same for all of our comments. We do not have the technical expertise to address 18 CFR §5.9(b)(7) but feel that the costs for the work we describe would fall within the range of costs FirstLight has already estimated for their proposed study plans described in section 3.1 of the RSP. Other than the study to evaluate the feasibility of a closed loop system, we are not asking for additional studies, just revisions to the studies described in section 3.1 of the RSP.

Revised Study Plan Section	Summary of FRCOG's Requested Study Plan Modification(s)	FirstLight's Response to Requested Modification(s)	FRCOG's Response to Modification Presented in RSP and Additional Requested Modifications/Recommendations	Applicable Study Plan Criteria[1]
	The 2013 FRR methodology does not identify scientifically defensible criteria for determining the **type, stage and spatial extent of erosion**. Build upon the recommendations in Field, 2007 and eliminate the use of subjective, qualitative terms like "little/none", "some" or "extensive."	Table 3.1.1-2 includes a new category of Indicators of Potential Erosion that includes terms used by Field, 2007 to describe types of erosion.	If the goal is to identify the **potential for future bank erosion** as part of the 2013 FRR, then indicators of erosion potential, such as those listed as part of a commonly accepted methodology, such as the Bank Erosion Hazard Index (BEHI)[2] or other reliable method, should be used. This task of identifying the potential for future bank erosion should be described as a separate task in the 2013 FRR not lumped with the tasks associated with identifying the type, stage and extent of current erosion. The category of Indicators of Potential Erosion should be eliminated from the Erosion Classification section of Table 3.1.1-2.	monitoring of erosion; and c) more successful bank stabilization efforts. This document is a good point of reference. As we described in our March 1, 2013 letter to FERC, the Simons & Associates' (2012) documents filed with FERC are qualitative and based on several unstated assumptions that may not be valid. Full River Reconnaissance efforts have been undertaken using varying methodologies, making for difficult comparisons from one report to the other. <u>18 CFR §5.9(b)(5) Project Nexus</u>: The Turners Falls and Northfield Mountain Pumped Storage projects operate in a peaking mode, with allowable impoundment fluctuations of up to 9 feet, with the intent to continue these fluctuations. FirstLight has also proposed to increase the volume of flow from the Northfield Mountain Pumped Storage Project through the increased use of the upper reservoir, which is expected to result in additional water level fluctuations. Upstream hydroelectric facilities also operate in a peaking mode of operation. Periodically, the upper reservoir at Northfield Mountain and the power canal at the Turners Falls dam need to be dewatered for maintenance purposes. Historically, both procedures have resulted in the discharge of large quantities of sediment. Sediment from shoreline erosion and riverbank failure is one of the major contributors that negatively affect water quality and habitat by increasing the turbidity and sedimentation, and smothering aquatic habitat. Repetitive water level fluctuations and flow alterations caused by hydroelectric peaking operations are known to be a major contributor to shoreline erosion. The Massachusetts Year 2012 Integrated List of Waters shows two river segments, from the VT/NH state line to the Turners Falls dam (MA34-01 & MA34-02) impaired and considered a "Water Requiring a TMDL" due to "Other flow regime alterations", "Alteration in stream-side or littoral vegetative covers" and "PCB in Fish Tissue". In addition, the segment below the Turners Falls dam to the
	The photographic log of the riverbanks compiled during the fluvial geomorphology study (Field, 2007) should be updated during the 2013 FRR.	FirstLight is proposing to reproduce the photo log during the summer 2014.	The photo log should be reproduced during fall 2013 leaf-off conditions as well as the summer of 2014 to more accurately evaluate bank conditions and show how vegetation can mask bank erosion. Leaf-off conditions will also enable comparisons to the 2004 digital image logs.	
Section 3.1.2 *Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability*	We are disappointed that this study does not specifically build upon the findings and recommendations in the Field (2007) report.	FirstLight's revised study plan is essentially the same as the previous three versions.	The fact that this study plan has been revised three times and all four versions have essentially the same flaws and problems speaks to the weakness of FirstLight's methodology. We recommend that FirstLight review TransCanada's Revised Study 3 – Riverbank Erosion Study for guidance on a well-organized, scientifically defensible methodology.	
Task 4a: Install Proposed Water Level Monitors in the Turners Falls Impoundment	We requested that more water level monitors be installed at appropriate locations, including at the fixed recoverable transects and areas where the BSTEM analysis will be conducted.	FirstLight proposes to install one additional gage 6,500 feet upstream of the Northfield Tailrace.	See our comments on pages 6-7 of our July 15, 2013 letter. We reaffirm our opinion that more water level monitors should be installed. In addition, we support the Connecticut River Watershed Council's request for a water level monitor to be installed between the Turners Falls boat barrier line and the tailrace, upstream of the Narrows or French King Gorge.	

[2] http://www.wildlandhydrology.com/assets/Streambank_erosion_paper.pdf http://water.epa.gov/scitech/datait/tools/warsss/pla_box08.cfm http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_025096.pdf

Revised Study Plan Section	Summary of FRCOG's Requested Study Plan Modification(s)	FirstLight's Response to Requested Modification(s)	FRCOG's Response to Modification Presented in RSP and Additional Requested Modifications/Recommendations	Applicable Study Plan Criteria[1]
Task 4a: Install Proposed Water Level Monitors in the Turners Falls Impoundment	Expand data collection to capture a full year.	FirstLight did not expand the data collection period.	The data collection should occur for a full year to provide information on seasonal variations including the spring freshet and low flow periods during the summer months.	confluence with the Deerfield River (MA34-03) is impaired by these causes as well as total suspended solids. <u>18 CFR §5.9(b)(6) Proposed Methodology</u>: Please refer to the comments herein as well as those submitted in our correspondence to FERC dated March 1, 2013 and July 15, 2013.
Task 4 – Field Studies and Data Collection & Task 5 – Data Analysis	We requested that a well-documented data collection methodology be provided for these tasks. The 2013 FRR, as proposed, will not provide adequate and reliable data for Task 5 or Task 6. There is no clear and well documented integrative methodology for these tasks.	FirstLight presented the fourth version of this study plan in the RSP.	This study continues to be fraught with serious flaws despite FirstLight having received extensive comments from stakeholders, including FRCOG, at the stakeholders' meetings on May 15, 2013 and June 14, 2013, and written comments submitted to FERC on July 15, 2013. This speaks volumes about the study's technical and organizational inadequacies. We urge FERC to require that FirstLight completely revise this study and engage a qualified fluvial geomorphologist to assist them in this effort. We urge FERC to require that field data collection for the fixed recoverable transects requested by MassDEP be conducted in accordance with a DEP-approved QAPP. Field work should be conducted in coordination with state regulatory agencies to ensure that the data collected will meet the requirements of these agencies for resource protection. MassDEP and other state regulatory staff should conduct field visits to oversee data collection to confirm the methodology and data collection protocols as established by the QAPP. We recommend that FirstLight review TransCanada's Revised Study 1 – Historical Riverbank Position and Erosion Study; Revised Study 2 – Riverbank Transect Study; and Revised Study 3 – Riverbank Erosion Study for guidance on developing well-organized and scientifically defensible methodology.	
4.1 Geology and Soils, 4.1.1 Study of Shoreline Erosion Caused by Northfield Mountain Pumped Storage Operations	We requested that FirstLight included the Relevant Resource Management Goals (18 CRF Section 5.9(b)(2) listed by NMFS for this study request.	FirstLight did not include our requested modifications.	Please see pages 7-9 of our July 15, 2013 letter and our March 1, 2013 letter. FirstLight should be required to complete a Historical Riverbank Position and Erosion Study exactly like TransCanada's Revised Study 1 in order to provide information useful for resource protection and addressing cumulative impacts. See also our March 1, 2013 letter. We requested that tasks in our Study of Shoreline Erosion Caused by Northfield Mountain Pumped Storage Operations study request be included in FirstLight's 3.1.2 Study Plan.	

Attachment 15. FRCOG Comments on Updated Proposed Study Plan (PSP)

July 15, 2013

Franklin Regional Council of Governments

July 15, 2013

Honorable Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project, FERC No. 2485-063
Turners Falls Project, FERC No. 1889-081

Comments on the Updated Proposed Study Plan (PSP) submitted by FirstLight June 28, 2013.

Section 3.1 Geology and Soils
Section 3.1.1 *2013 Full River Reconnaissance Study*
Section 3.1.2 *Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability*
Section 4.0 Studies not Included in the PSP
4.1 Geology and Soils, 4.1.1 Study of Shoreline Erosion Caused by Northfield Mountain Pumped Storage Operations

Dear Secretary Bose:

The Franklin Regional Council of Governments (FRCOG) is the regional planning agency for Franklin County, Massachusetts. Two committees of the FRCOG, the Connecticut River Streambank Erosion Committee (CRSEC) and the Franklin Regional Planning Board (FRPB), have worked closely with the owner/operator of the Northfield Mountain and Turners Falls Projects for almost 20 years to develop and implement bank stabilization projects that address problems of significant streambank erosion occurring in the Turners Falls Pool on the Connecticut River (the Pool). This cooperative effort set aside differences over erosion causes and focused instead on working together to identify and achieve solutions that protect prime farmland, structures, and other natural resources. Given our long-standing concern with and close involvement with the erosion problems related to the operation of these two projects, we feel uniquely qualified to comment on the above-referenced proposed studies.

Overall, we are disappointed in the quality of the updated study plans for section 3.1 Geology and Soils submitted to FERC by FirstLight on June 28, 2013. We find the updated study plans unacceptable since the detailed comments and concerns expressed by stakeholders at the study plan meetings have been essentially disregarded. The Franklin County reach of the river deserves technically defensible and rigorous scientific investigations with clearly stated goals, objectives and deliverables. FirstLight has not provided a sound approach for these studies and has consistently used language that obfuscates and confuses in each of the three drafts provided to stakeholders. The studies proposed by FirstLight should have clearly stated goals and objectives, and methodologies that are detailed and well documented, scientifically valid and reproducible. How will the mandatory conditioning agencies and stakeholders have confidence in the collection and analysis of data that will be used to evaluate the potential impacts project operations have on the resources?

It appears that FirstLight's strategy is to diminish the importance of the erosion in the Turners Falls Pool by proposing studies that will gather little useful data to inform the relicensing process or to provide the mandatory conditioning agencies, particularly the MassDEP, with the data needed to issue a 401 Water Quality Certificate that is protective of water quality and wetland and riparian resources areas. Ongoing erosion in the Turners Falls Pool is having a significant impact on state and federal listed rare and endangered species that rely upon the river for habitat, as well as on archaeological resources that are lost to bank erosion and prime farmland that is sloughing off into the river. **Bank erosion is the overarching environmental problem and the one that impacts all the other resources listed in the Proposed Study Plan** – Water Resources; Fish and Aquatic Resources; Terrestrial Resources; Wetlands, Riparian and Littoral Habitat; Recreation and Land Use; Cultural Resources; and Developmental Resources. We urge FERC to require FirstLight to develop clear and scientifically defensible studies that will provide valid and useful data about the impacts of project operations on river bank stability and erosion in the Turners Falls Pool.

We have several specific comments on the Study Plan. Unfortunately, we are not able to adequately address all of our concerns with the Updated Proposed Study Plan (Plan) in this letter due to the short timeframe between receiving the updated Plan on June 28, 2013 and the decision by FERC not to extend the comment deadline by two weeks to July 30, 2013. To reinforce our concern regarding the inadequacy of the Plan, we have included several attachments to this letter, including excerpts from the *Fluvial Geomorphology Study of the Turners Falls Pool on the Connecticut River Between Turners Falls, MA and Vernon, VT*, prepared by Field Geology Services of Farmington, ME; we will reference this study as Field (2007). This study was commissioned by the licensee and undertaken to "understand the causes of bank erosion and identify the most appropriate methods for bank stabilization on this section of river." We believe that Dr. Field's work is a comprehensive, well researched and scientifically-based document. To date, many of the recommendations in the study have not been implemented. Even more troubling is the fact that this study, its findings, conclusions and recommendations, has been completely ignored by the licensee in the formulation of their proposed Study Plans to gather information on the geology and soils of the Turners Falls Pool.

For ease of reference, our comments are organized according to the headings in the Updated Proposed Study Plan filed by the licensee on June 28, 2013.

3.1 Geology and Soils

3.1.1 *2013 Full River Reconnaissance Study*

In January 2013, the FERC suggested that the 2013 Full River Reconnaissance (FRR) could both inform the relicensing process and satisfy the compliance requirements under the current license. The Connecticut River Streambank Erosion Committee (CRSEC) agreed but stressed that 1) the 2013 FRR methodology and the Quality Assurance Project Plan (QAPP) still needed significant improvements and the CRSEC wanted to be involved in the process to refine these documents, and 2) tasks would need to be added to the 2013 FRR to gather data to inform relicensing. It was our understanding that the 2013 FRR would be significantly improved from its 2008 predecessor, and accordingly we supported including the FRR in the relicensing process.

Despite detailed, comprehensive comments on the 2008 FRR methodology and final report and the proposed QAPP for the 2013 FRR, which were submitted to both FERC and FirstLight, none has been addressed or included in the 2013 FRR methodology. The proposed methodology for the 2013 FRR is exactly the same as that used in 2008. The QAPP, which the licensee detached from the FRR study plan, is still not adequate. The references to "CRSEC input" in the study plan text are a misrepresentation of what actually happened during the development of the 2008 FRR methodology and the QAPP. As documented in previous correspondence to FERC, input from the CRSEC was neither actively sought nor seriously considered by FirstLight.

We assert that the 2013 FRR study plan is not adequate for compliance or relicensing purposes. Further, we respectfully reserve the right to contest the QAPP and the findings of the 2013 FRR as they relate to the current license and ongoing compliance issues.

<u>Task 1: Document existing riverbank Features and Characteristics</u>
<u>*Task 1a: Identify and Define Current Riverbank Features and Characteristics*</u>

Field (2007) noted that the erosion mapping from previous FRRs suggests that specific points on the bank can change from eroding to stable or vice versa regardless of whether the total amount of mapped erosion increases or decreases from year to year. Consequently, using changes in the overall totals of mapped erosion to understand how the patterns of erosion in the Turners Falls Pool are evolving is not adequate for relicensing data needs. Identifying where the erosion is occurring, the type of erosion and the stage or temporal sequence of erosion must be inventoried and understood before ascribing potential causal mechanisms as FirstLight is proposing to do in Study 3.1.2.

Field (2007) stated that an adequate discussion of the causes and management of erosion depends on *an understanding of the types, distribution, rates, and temporal sequence of erosion in the Turners Falls Pool*. The licensee's proposal to evaluate the causes of erosion in Study 3.1.2 and the management of project and non-project related erosion is of primary concern to the FRCOG, as well as the mandatory conditioning agencies and other stakeholders. Eroding banks degrade water quality, reduce habitat, and result in the loss of prime agricultural land.

Field (2007) stated that future efforts for monitoring erosion in the Turners Falls Pool must utilize a consistent, well documented technique for identifying erosion sites that is conducted in the early Spring or late Fall when bank exposures are least obscured by vegetation: "*such a technique should be based on the <u>types</u> of erosion observed and <u>stage</u> of erosion present not proxies for erosion or erosion susceptibility such as the amount of vegetation, percentage of exposed soil, bank height and slope, or soil type".* [emphasis added]. Dr. Field suggested that the written and visual descriptions of erosion types presented in Tables 1 and 2 and described in Section 7.1 of his report could provide the basis for such an approach (see Field's Tables 1 and 2 which are attached to this letter). However, FirstLight chose to ignore these recommendations and instead both the 2008 and 2013 FRR methodologies (Tables 3.1-1 and 3.1-2) **use all of the "proxies for erosion or erosion susceptibility" described by Field.** Furthermore, the rationale for the grouping of these characteristics (Table 3.1-2) is not explained, nor are citations provided for its origin.

Another fatal flaw in these tables is the use of the category "mass wasting" to characterize the <u>extent of erosion</u>. First, mass wasting describes the movement of material downslope under the influence of gravity. The term lumps three types of erosion - flow, slide and fall - and the term doesn't describe what erosional stage is responsible for the mass movement of the bank material. Mass wasting is a generic term to describe a typically catastrophic event like a landslide or mudslide. It is a term that should be more accurately used (if at all) as a grouping of erosion types. To characterize the spatial extent of erosion, we should be gathering data on the linear and vertical extent of the specific types of erosion as identified by Field (2007), which can be quantified, rather than combining types of erosion into one category and using qualitative terms like "little/none", "some" or "extensive" to describe the erosion. These qualitative terms are not valid due to their extreme subjectivity and should not be used at all in the relicensing studies to describe the erosion in the Turners Falls Pool. According to Field (2007), four of the erosion types described by Lawson (1985) are widely observed in the Turners Falls Pool: falls, topples, slides, and flows (Field (2007) Tables 1 and 2), which are attached to this letter. Dr. Field noted that these four erosion types rarely occur in isolation, but rather work in concert to remove bank material from the upper and lower slope. According to Dr. Field, visual observations of bank conditions at various places in the Turners Falls Pool permit the development of an idealized model that describes a sequence of events occurring through time at a single point (Field, Figure 30), which is attached.

The spatial or temporal extent of the erosion cannot be documented by the methods proposed for the 2013 FRR. Simply put, the type and stage of erosion should be documented according to Field (2007) and then maps could be generated that show, for example, the linear extent and location of all types and stages of erosion. Knowing this information is critical to any efforts to understand the causes of erosion. **Data that are proxies for erosion should not be used as data in the study to determine the causes of erosion**. For the reasons articulated above and because the language is confusing and no citations are provided for the provenance of the 2013 FRR methodology, we disagree with the statement in the updated Proposed Study Plan on page 3-7 that refers to the use of Tables 3.1-1 and 3.1-2 to log and characterize riverbank characteristics as a reliable method. The text we refer to follows:

> Page 3-7 of the Updated Proposed Study Plan states: "*The grouping approach combines riverbank features and characteristics into key associations that can provide insight into which features and characteristics are associated with stability and which are associated with erosion. Statistical distributions of characteristics within each group can aid in further understanding erosion and stability issues such as which combination of features and characteristics trend towards stability, and which trend toward erosion. Such information and understanding can aid in the planning process in developing appropriate approaches in addressing erosion issues.*"

On page 3-8, it is stated that the 2008 and 2013 FRR methodologies include the six stages of erosion identified by Field (2007). We assert that this is a misrepresentation of what Dr. Field identified in his report. He provides definitions for each stage of erosion, along with a picture of a representative site in the Turners Falls Pool and a profile drawing. What is presented in the 2013 FRR methodology (Table 1 on page 3-8 of the Updated Proposed Study Plan) is not comparable to Field's Figure 30. Further, these are stages of erosion as identified by Field (2007) not types of erosion as identified in the 2013 FRR methodology. The 2013 methodology does not identify the stages of erosion. In Appendix C of the proposed QAPP for the 2013 FRR, the types of erosion listed include: none, notching, overhanging bank, undercut toe, and slide. A representative picture is provided. No citations, descriptions, or line drawings are given for the source of these types of erosion. This list of the types of erosion includes only one of the four types of erosion listed by Field (2007) – slide. In fact, it appears that the 2013 FRR methodology has confused the type of erosion with the stage of erosion or perhaps lumped the two categories and picked only a few categories to include as representative of the conditions in the Turners Falls Pool.

More troubling is the Mass Wasting section of Appendix C of the QAPP, which contains pictures showing "little/none", "some" and "extensive" mass wasting. We refer back to our concerns about using the term mass wasting to describe the extent of erosion because mass wasting is a term that refers to collectively to a group of different types of erosion. An examination of the pictures shows that a variety of different types and stages of erosion are occurring in these "representative" mass wasting pictures. This important information is lost when masked by a "little/none" category, for example. To illustrate this point, looking at the attached "little/none" mass wasting pictures, there is clear evidence of different types and stages of erosion as defined by Field (2007). Clearly, the 2008 and 2013 FRR methodologies have not incorporated Field's (2007) recommendations.

In addition to completely revising the 2013 FRR methodology, there are two tasks that could be added to Study 3.1.1 to provide data that would be informative to the relicensing process. They are:

1. The photographic log of the riverbanks compiled during the fluvial geomorphology study (Field, 2007) should be updated during the 2013 FRR to provide a method for visually identifying and confirming the condition and location of eroding banks. Re-photographing the riverbanks periodically from the same locations will provide a means of identifying new erosion sites or, conversely, areas that are stabilizing. Unfortunately, this simple, relatively low cost recommendation was not implemented in the 2008 FRR or proposed for the 2013 FRR. A wealth of information can be easily gleaned from photographs and photographic logs that are updated over time.

2. Field (2007) recommended that the initial photographic log compiled during his study be compared with continuous digital image logs taken during 2001 and 2004 (NEE, 2005). We would add the continuous digital image logs taken for the 2008 FRR and the 2013 FRR to this list.

3.1.2 Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability

We are disappointed that this study does not specifically build upon the findings and recommendations in the Field (2007) report, which was commissioned by the licensee to understand the causes of bank erosion and identify the most appropriate methods for bank stabilization on this section of river. Dr. Field reviewed and summarized the previous work that had been done by the Army Corps of Engineers and others to understand the erosion occurring in the Turners Falls Pool. According to Field (2007), conditions in the Turners Falls Pool create a situation where the riverbanks are near the threshold of erosion. Further, Field (2007) notes:

> *"Minor natural or anthropogenic changes in the Turners Falls Pool, therefore, have the potential to cause significant changes in the extent and severity of bank erosion." (page 37).*
>
> *"The reported increase in erosion since the opening of the Northfield Mountain Pumped Storage Project (U.S. Army Corps, 1977), at a time when flood flow velocities have decreased due to the raising of the Turners Falls Dam and implementation of flood control projects upstream, suggests other factors may also be causing erosion in the Turners Falls Pool. Other observations inconsistent with natural flood flows being the sole cause of erosion is the higher incidence of erosion on the inside bends of meanders compared to outside bends (Table 3). Typically, flow velocities and erosion on unregulated rivers are greatest on the outside bends of meanders (U.S. Army Corps,1979; Easterbrook, 1993). Furthermore, a comparison of mapped erosion sites (Appendix 5) with the hydraulic modeling (Appendix 4) reveal extensive areas of erosion where shear stresses and flood flow velocities are relatively low (Figure 18)." (page 39).*
>
> *"The preponderance of bank erosion of floodplain sediments, where natural groundwater seeps are uncommon, indicate natural seepage forces are not a primary cause of erosion in the Turners Falls Pool. However, human management of river levels has potentially created additional seepage forces that have enhanced erosion where natural groundwater seeps are absent." (page 40).*

An important opportunity has been missed to build upon scientifically sound and well documented work. We urge FERC to require the Study Plan be revised to provide scientifically sound and defensible data.

<u>Task 3: Install Proposed Water Level Monitors in Turners Falls Impoundment</u>

In response to stakeholders' concerns about having adequate data on the rate of change in the water surface elevation of the Turners Falls Pool during project operations and having greater coverage throughout the length of the 22-mile impoundment, FirstLight is proposing to add four gages to the four existing gages. Only one of the four proposed new gages is listed as being located to provide information on water level changes due to the operation of the Northfield Mountain Pumped Storage project. Two of the new gages are located in VT, downstream of the Vernon Dam and the remaining new gage is located 8.5 miles upstream of the tailrace. The number of proposed new gages is not adequate to capture the changes in water elevation and the rate of change, in order to provide a suitable data set for the various tasks proposed to utilize the data (Tasks 3a-3f). The cost of installation of water level monitors is relatively low compared to the potential benefits of the data collected. We urge FERC to require the installation of more water level monitors at appropriate locations, including at the fixed recoverable transects and areas where the BSTEM analysis will be conducted (see below). In addition, it is not clear why data gathering is limited to August-November 2013. It would be important to understand water elevation changes and rate of change throughout the year, particularly during the spring freshet and summer months when electricity demand for air conditioning may require more "peaking" power from the pumped storage project.

<u>Task 5: Field Study and Task 6: Causes of Erosion</u>

The results and data gathered from the 2013 FRR are identified by FirstLight as a significant source of data for Study 3.1.2, specifically Task 5: Field Study and Task 6: Causes of Erosion and their associated sub-tasks. For the reasons articulated above, the 2013 FRR, as proposed, will not provide adequate and reliable data for Task 5 or Task 6.

Assuming that all relevant data has been gathered, that the spatial and temporal resolution of the data set is adequate, and that the appropriate Quality Assurance/Quality Control procedures have been followed during data collection, the crucial task of this study is Task 6: Causes of Erosion. The approach to determining the causes of erosion is presented in a "scatter shot" manner. There is no clear and well documented integrative methodology that ties the results of the sub- tasks together or describes how the results of each of the tasks build upon each other. The clearest methodology presented is the Bank-Stability and Toe-Erosion Model (BSTEM). It appears that the BSTEM approach is appropriate and may yield useful information. However, it is not clear from the text the number and the location of the proposed data collection points and whether the data collection points correspond to the proposed fixed recoverable transects, the 22 existing transects and/or other locations to be determined. We note that TransCanada has proposed installation of 64 data-loggers to provide a thorough picture of river conditions. Task 6 should be revised to present a clear, step-by-step methodology that includes appropriate citations and references to standard practices in the disciplines of fluvial geomorphology and geotechnical and soil evaluation.

4.0 Studies not Included in the PSP

4.1 Geology and Soils

4.1.1 Study of Shoreline Erosion Caused by Northfield Mountain Pumped Storage Operations

As a point of clarification, NOAA's National Marine Fisheries (NMFS), a Federal resource agency, also requested this study (study request 6.14) in their comments filed on March 1, 2013. The goals and objectives of this study, as stated in FRCOG's and NMFS' study requests, would be to determine the environmental effects of the presence and operation of the licensed facilities on river bank stability, shoreline habitat, agricultural farmland, wetland resources, bed substrate, and water quality in the Turners Falls impoundment.

FirstLight dismissed the Relevant Resource Management Goals (18 CFR Section 5.9(b)(2)) listed by FRCOG by stating that we, along with other stakeholders that requested the study, were not resource agencies. NMFS is a federal resource agency. The resource management goals listed by NMFS in their study request include:

> "Our management goal is to ensure high quality habitat for migratory diadromous fish. Shortnose sturgeon, American shad and American eel all require suitable spawning, rearing, migratory and foraging habitat. Eroding banks and subsequent increases in turbidity and deposition of fine
> grained material onto bed substrates in the Turner's Falls headpond, the bypass reach and downstream of the Turner's Falls project reduces the quality of habitat for these species. Elevated levels of suspended sediment are associated with a diminution in water quality which also affects the quality of habitat encountered by ***trust resource species***. [emphasis added]
>
> In addition to habitat effects, soil erosion contributes to nutrient loading. In 2001, the U.S. EPA approved New York and Connecticut's Long Island Sound (LIS) dissolved oxygen Total Maximum Daily Load. As a result, the New England Interstate Water Pollution Control Commission (NEIWPCC) established the Connecticut River Workgroup and the Connecticut River Nitrogen Project. This project is a cooperative effort involving staff from NEIWPCC, the states of Connecticut, Massachusetts, New Hampshire, and Vermont, and EPA's Region 1 and Long Island Sound (LIS) offices. All are working together to develop scientifically-defensible nitrogen load allocations, as well as an implementation strategy, for the Connecticut River Basin in Massachusetts, New Hampshire, and Vermont, which are consistent with Total Maximum Daily Load allocations established for LIS. Since its inception, the Connecticut River Workgroup has participated in a number of projects to better understand nitrogen loading, transport, and reductions in erosion."

We are very concerned that FirstLight omitted the study requested by NMFS, FRCOG and other stakeholders. FERC should direct FirstLight to incorporate the tasks suggested by NMFS, FRCOG and other stakeholders into Proposed Study Plan 3.1.2. The argument that certain requested tasks should not be done because FERC uses current conditions as its baseline for evaluating project effects and alternatives is not valid from a scientific basis. The baseline conditions should bracket the timeframe for data analysis to the year Northfield Mountain pumped storage project came on-line to the present day. Current conditions, meaning what we see today, and future conditions under which the project will operate cannot be evaluated in any meaningful way without an appropriate context. We understand that TransCanada is assembling and reviewing historical data as part of their study plans related to understanding erosion in the upper reach of the river. We assert that a similar level of effort is required for the Turners Falls Pool. We are asking for a reasonable time period, a reasonable context within which collected data will be evaluated to assess the impacts of project operations in the Turners Falls Pool and cumulative impacts of all five projects on the river.

We are surprised that FirstLight would assert that it "is unclear how the requested data would inform potential PME measures." (page 4-3). Understanding how project operations affect the river, its banks and other resources is critical to designing appropriate PME measures. Giving the erosion issue "short shrift" in the Study Plan process will ensure that inadequate and suspect data informs potential PME measures.

We request that FERC direct FirstLight to add the following tasks from NMFS', FRCOG's and other stakeholder's study request – Study of Shoreline Erosion Caused by Northfield Mountain Pumped Storage Operations to FirstLight's proposed study 3.1.2.

1. This study should determine the net soil loss in cubic yards between when Northfield Mountain project operations began and the present; a density estimate of the eroded material should also be provided. Provide an analysis of where the greatest loss has occurred, location of proximity to the tailrace, soil type, riparian land use, and vegetative cover in that area. Calculate nutrient loadings (nitrogen and phosphorus compounds) to the river system based on soil loss.

2. Obtain copies of the original survey plans for the project (Exhibit K), and complete a new survey using the same landmarks used previously. The Field (2007) report states on page 11 that the original survey plans of the river are still retained by Ainsworth and Associates, Inc. of Greenfield MA. Use pre-operation aerial photos and current aerial photos to complete a 10-foot topographic map of the section of river between Turners Falls Dam and Vernon Dam and the 200-foot buffer regulated under the Massachusetts Rivers Protection Act. The Field (2007) report on page 11 states that Eastern Topographics, Inc. determined that sufficient information is known about the 1961 aerial photos (e.g., height of airplane) to create a 10-foot topographic map of that time period, and that 1961 aerial photos could be accurately overlaid with recent aerial photos. Field (2007) states that this analysis would enable a more reliable determination of small-scale shifts in channel position and changes in bank height that may have resulted from the erosion of a low bench that previously existed along portions of the river and help identify areas of the most significant bank recession during the past 45 years. Among other things, create a single map showing areas of erosion and deposition, and also overlay the Field report's hydraulic modeling analysis of the river channel.

3. Complete detailed surficial mapping (topographic map or LIDAR) to identify the various geomorphic surfaces, height of benches/terraces above the river level, and types of sediments underlying the surfaces. This will allow one to determine how erosion varies with geomorphic conditions. One could then normalize the amount of erosion to a specific type of bank material/geomorphic surface/terrace.

FirstLight's reason for not conducting LIDAR, which they said was too expensive and other topographic data was available, is not valid for two key reasons. First, the data FirstLight proposes to use, the USGS 10 meter digital elevation model, does not have sufficient resolution to determine how erosion varies with geomorphic conditions. Second, TransCanada is using LIDAR for the northern reach of the river and consistent data is needed to enable FERC to evaluate both individual project impacts and cumulative impacts.

In closing, we would like to stress our disappointment that a feasibility study of a closed-loop system is not being required at this stage in the relicensing process since we believe a closed-loop system would eliminate many of the environmental problems associated with using the river as the lower reservoir.

Thank you for the opportunity to submit comments on FirstLight's Updated Proposed Study Plan. We regret that the short timeframe between receiving the Updated Proposed Study Plan (June 28, 2013) and the date the comments are due (July 15, 2013) does not provide us an opportunity to submit more detailed comments.

Sincerely,

Ann H. Banash

Ann Banash, Chair
FRCOG Executive Committee

Jerry Lund

Jerry Lund, Chair
FRPB Executive Committee

Tom Miner, Chair
CRSEC

cc: Congressman James McGovern
Franklin County Legislative Delegation
Michael Gorski, Regional Administrator, MassDEP
Robert McCollum, MassDEP
Robert Kubit, MassDEP
Town of Erving
Town of Gill
Town of Montague
Town of Northfield

Attachments

Table 1: Typical types of slope movements on eroding banks. (Field, 2007)

Table 2: Types of erosion occurring in the Turners Falls Pool and their characteristics. (Field, 2007)

Figure 30: Model illustrating idealized sequence of erosion. (Field, 2007)

Table 1. Comparison of Field's Stage of erosion with matrix of riverbank features and characteristics (Updated Proposed Study Plan document submitted by FirstLight, June 28, 2013)

Excerpts from Draft Appendix C of Quality Assurance Project Plan for 2013 FRR (Appendix D of the Proposed Study Plan document submitted by FirstLight, April 15, 2013)

Erosion Type	Description
Falls	- Material mass detached from a steep slope and descends through the air to the base of slope - For the purposes of this study, also includes erosion resulting from transport of individual particles by water
Topples	- Large blocks of the slope undergo a forward rotation about a pivot point due to the force of gravity - Large trees undermined at the base enhance formation
Slides	- Sediments move downslope under the force of gravity along one or several discrete surfaces - Two forms occur: planar slips and rotational slumps - Slumps rotate down and out along a surface that is concave upward - Slips move along shallow planar surface without rotary motion
Lateral spreads	- Transitional form between slides and flows
Flows	- Sediment/water mixtures that are continuously deforming without distinct slip surfaces - Two forms occur depending on rate of movement: slow creep and rapid grain flows

Table 1: Typical types of slope movements on eroding banks.

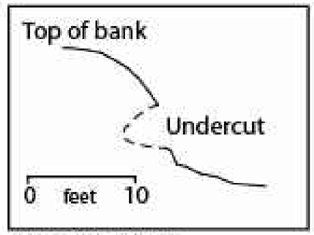
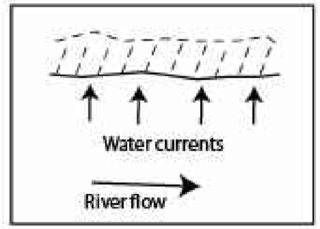
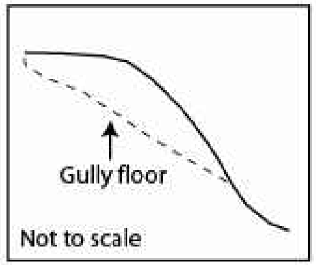
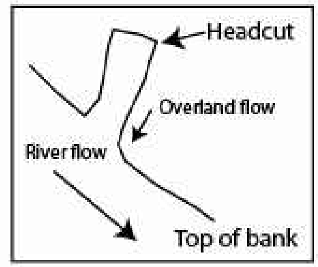
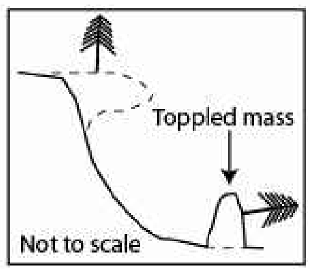
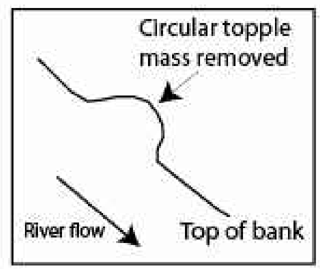
Erosion type	Photo	Profile	Planview	Description
Falls - Undercuts		 Across from tailrace		- Undercutting - Notching and oversteepening at the toe of the slope
- Gullies				- Gullies formed by overland flow and groundwater seeps
Topples				- Vertical tension cracks at the top of slope - Trees lean away from bank - Toppled mass creates mound of soil at base of bank

Table 2: Types of erosion occurring in the Turners Falls Pool and their characteristics.

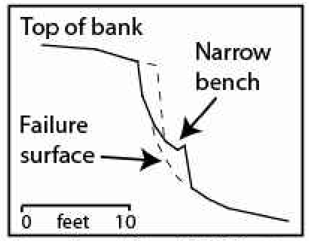
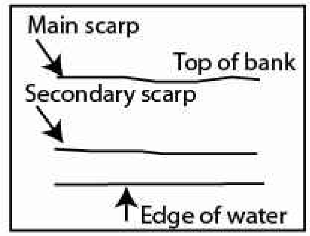
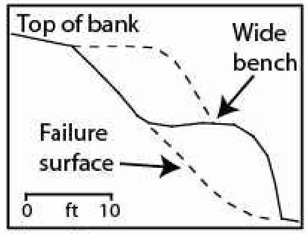
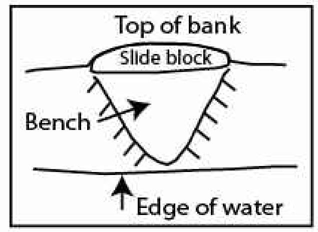
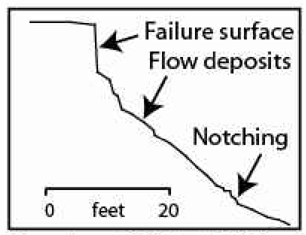
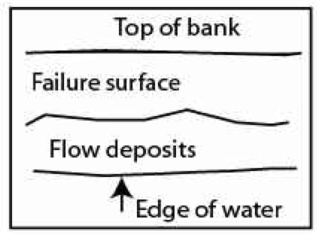
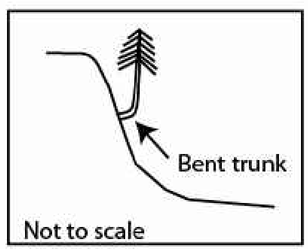
Erosion type	Photo	Profile	Planview	Description
Slides - Planar slip		 Across from tailrace (Split River)		- Vertical tension cracks at top of slope - Top surface of slide mass has flatter slope than rest of bank (narrow bench) - Trees lean in towards bank - Trees can remain in growth position despite sliding
- Rotational slump		 Munns Ferry		- Vertical tension cracks at top of slope - Deeper seated than slips - Trees lean in towards bank - Arcuate failure surfaces
Flows - Grain flows		 Downstream RR Bridge in VT (Kendall)		- Colluvial deposits created by flows accumulate at base of slope to form concave up surfaces
Creep			Not applicable	- Tree trunks bent downslope at base

Table 2 (continued).

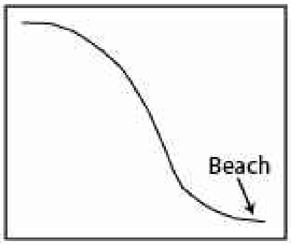
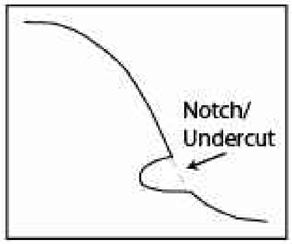
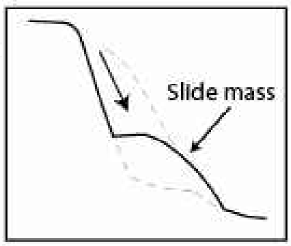
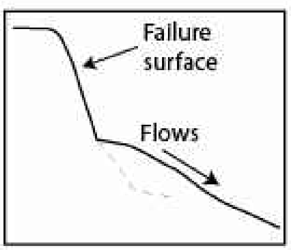
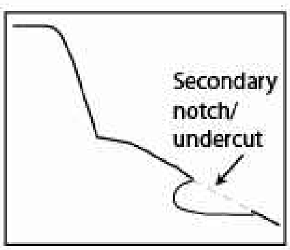
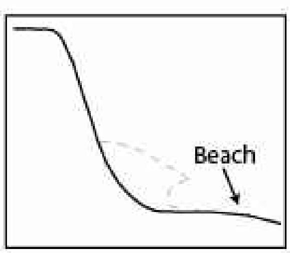
Stage	Profile	Photo	Description
a) Stable bank			- Rounded slope, concave up at base - Beach face protects slope from attack by currents
b) Notching or undercutting			- Bank toe oversteepened by notching or undercutting - Upper slope remains stable
c) Slide or topple			- Upper slope eventually destabilized by oversteppening at toe - Slide or topple mass remains intact with narrow bench at top
d) Flows			- Slide or topple mass becomes disaggregated at base and material flows to toe of slope
e) Secondary notching or undercutting			- Currents notch or undercut flow material to cause further collapse and flow of material
e) Bare bank			- Steep bare bank develops if flow material completely removed from base of bank - Beach development can protect the toe of slope from further current attack - If beach does not develop or persist, then erosion sequence can begin afresh

Figure 30: Model illustrating idealized sequence of erosion. Different stages of erosion can be occurring adjacent to each other along a long continuously eroding bank.

Group	Mass Wasting	Erosion Type	Degree Upper Riverbank Vegetation	Upper Riverbank Slope	Upper Riverbank Sediment	Lower Riverbank Slope	Lower Riverbank Sediment	Upper Riverbank Height	Lower Riverbank Vegetation
			to Heavy				to Rock	High	Heavy
7	None	None	Moderate to Heavy	Flat	non-Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
8	None	None	None to Heavy	Flat to Overhanging	Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy

Comparison of Field's stage of erosion to Table 3.1-1 Matrix of Riverbank Features and Characteristics

Field's Figure 30 presents 6 stages of erosion as presented above. These 6 combinations of riverbanks provide useful information on possible combinations of riverbank features and characteristics. The matrix of riverbank features and characteristics utilized in the 2008 FRR and proposed for the 2013 FRR provide a comprehensive set of key features and characteristics, including those outlined by Field, 2007. The use of the matrix allows for a detailed and comprehensive approach in classifying riverbanks and allows development of a detailed and comprehensive understanding of riverbanks. Each of the stages described in Field's Figure 30 is included in the matrix as shown in Table 1. Inclusion of the six descriptions of riverbanks developed by Field and the numerous other possible sets of riverbank features and characteristics in the matrix provides a comprehensive set of riverbank features and characteristics that both describe the riverbank conditions as observed in the field, as well as the stages of erosion as described by Field.

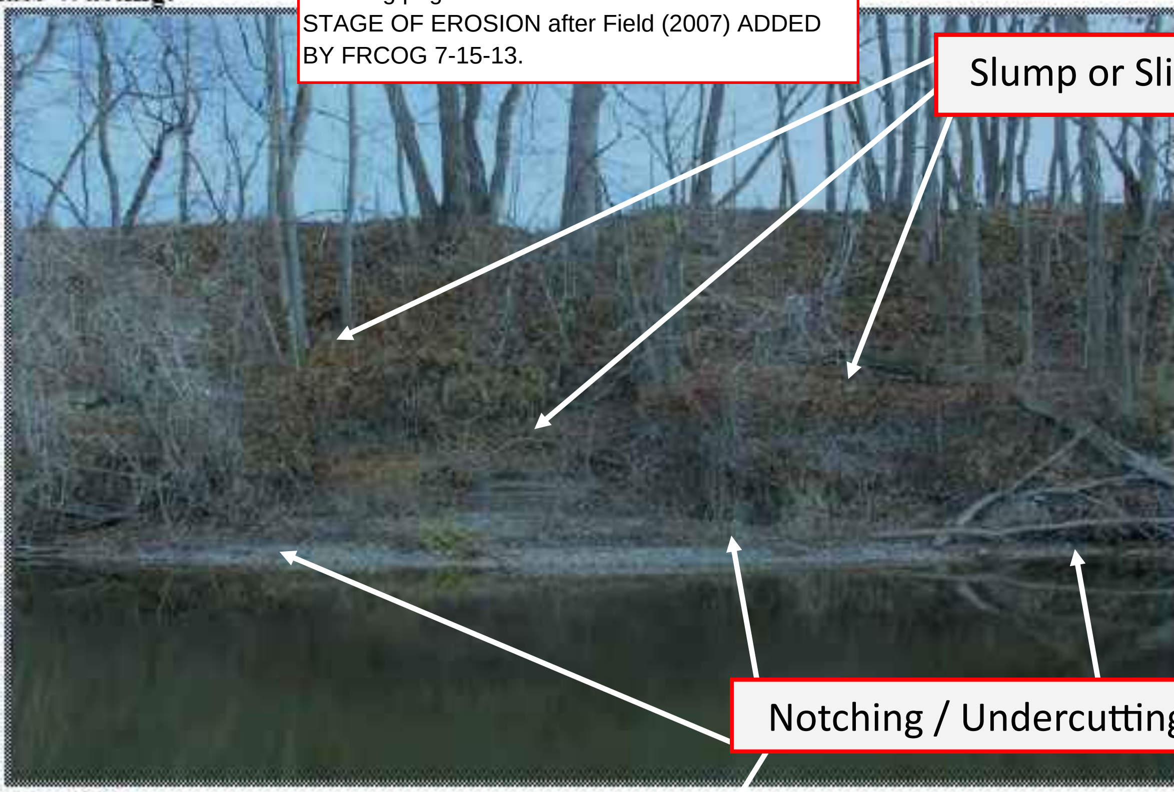
Table 1. Comparison of Field's stage of erosion with matrix of riverbank features and characteristics

Field	Matrix
a) Stable bank	Upper bank slope (flat to steep), Upper bank vegetation (moderate to heavily vegetated as well as even less vegetated conditions), with little to no erosion,
b) Notching or undercutting	Erosion Type: Undercut toe, notching; Degree of erosion: (little/none, some, extensive)
c) Slide or topple	Erosion Type: Slide; Degree of erosion: (little/none, some, extensive)
d) Flows (disaggregated slide)	Erosion Type: Slide; Degree of erosion: (little/none, some, extensive)
e) Secondary notching or undercutting	Erosion Type: Undercut toe, notching; Degree of erosion: (little/none, some, extensive)
f) Bare bank with beach	Upper bank slope with none to very sparse upper bank vegetation, flat lower bank slope

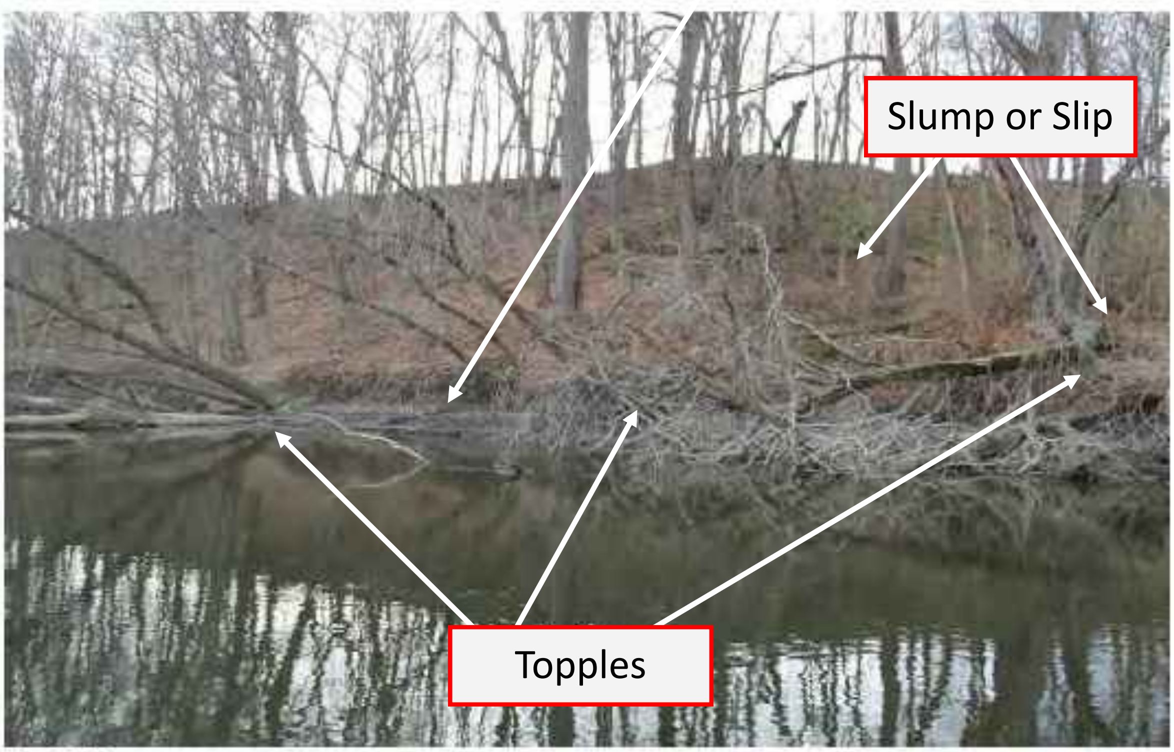
From the 3rd draft of the QAPP for the 2013 Full River Reconnaissance submitted by First Light on April 15, 2013.

TEXT, TEXT BOXES AND ARROWS on the following pages that IDENTIFY THE TYPE AND STAGE OF EROSION after Field (2007) ADDED BY FRCOG 7-15-13.

Mass Wasting:



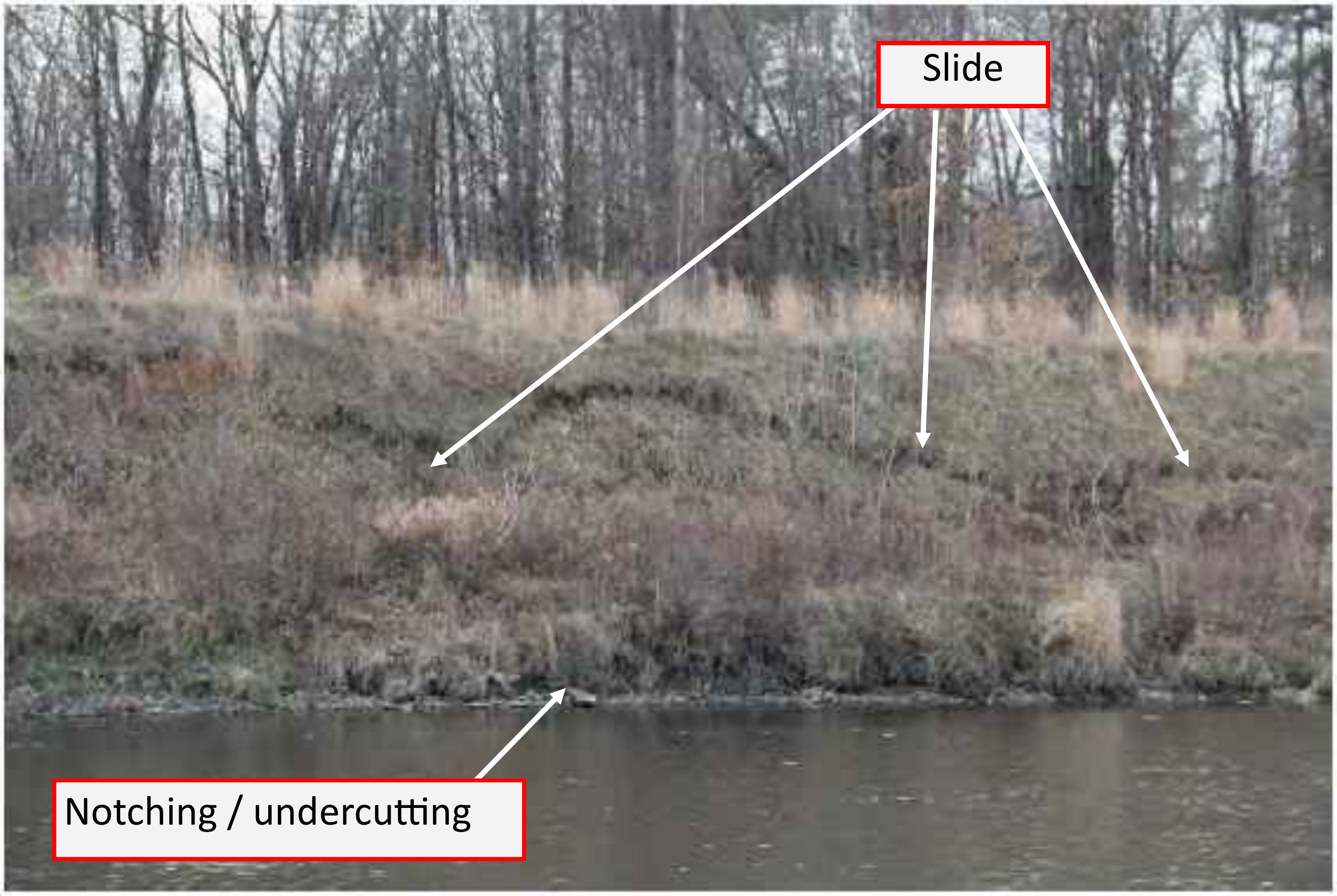
Little/None



Little/None

Stage of Erosion: b and c

Erosion Type: Falls (undercuts, gullies), Topples, Slides (slump, slip)



Little/None

Stage of Erosion: b and c

Erosion Type: Falls (notching, undercutting)
Slides (planar slip)

Slide mass remains intact with narrow bench at top

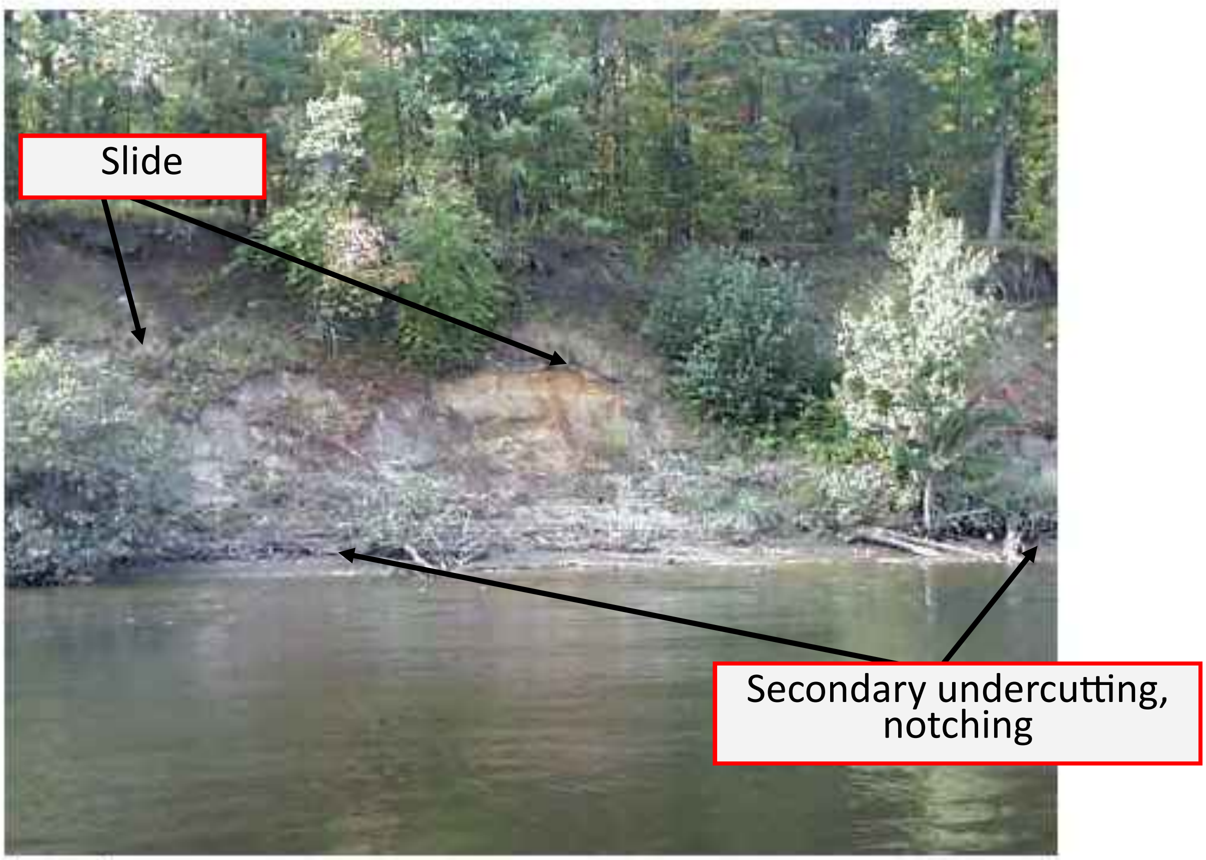
Some

Some

Stage of Erosion: b and c —Slide mass remains intact with narrow bench at top

Erosion Type: Slide

Extensive



Extensive

Stage of Erosion: b and e

Erosion Type: Slide (planar slip), Falls (undercuts)

Extensive

Stage of Erosion: e (End stage)

This is a stabilized site. It is the Flagg property.

Attachment 16. CRSEC Comments on bank stabilization projects under Phase IV

May 13, 2013

Franklin Regional Council of Governments

CONNECTICUT RIVER STREAMBANK EROSION COMMITTEE

May 13, 2015

VIA ELECTRONIC FILING

Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project No. 2485-063
Turners Falls Project No. 1889-081
Compliance with Current License and 1999 Erosion Control Plan

Dear Secretary Bose:

The Connecticut River Streambank Erosion Committee (CRSEC) respectfully requests a determination on the current compliance status of the licensee, FirstLight Power Resources (FirstLight), with the approved 1999 Erosion Control Plan (ECP) for the Turners Falls Pool. In order to meet the objective of the ECP, which is to minimize or prevent erosion in the Turners Falls Pool in compliance with the relevant FERC license articles, erosion sites must be classified and prioritized, and then appropriate erosion control methodologies applied to the priority erosion sites. We do not believe that the list of bank stabilization/preventative maintenance projects for implementing Phase IV of the ECP presented in the 2013 Full River Reconnaissance (FRR)[1] is in compliance with the terms of the ECP and Articles 19 and 20 of the current license (see attached Table 8.3 from the 2013 FRR). Table 8.3 includes small preventative maintenance sites and the repair of an existing bioengineering bank stabilization project (Shearer site). The narrative in the FRR does not describe a prioritization methodology or explain how the sites were selected from hundreds of potential erosion sites.

The 1999 ECP for the Turners Falls Pool states that appropriate erosion control applications will be planned, permitted and constructed in accordance with a *periodically updated prioritization schedule*. Since the "top 20" priority sites from the 1999 ECP have either been constructed or the licensee has provided justification for not working on some of the sites, a new prioritized site list should have been included with the 2013 FRR (it was also lacking in the 2008 FRR).

The prioritized site list for Phase IV should be 1) based on the results of the quantitative ranking system described in the ECP and the results of the 2013 FRR; and 2) prioritized according to the two criteria listed in the ECP: segments where erosion poses an "imminent threat to structures" and segments that "are contributing the most sediment to the river." The ECP states that the goal is to identify the sites that are contributing the most sediment to the river and further states that these sites are to be repaired first. Neither is the case with the projects identified by FirstLight. The information provided in the 2013 FRR to document erosion for Camps 3E,

[1] Relicensing Study No. 3.1.1, 2013 Full River Reconnaissance

4E and 2W – three of the four sites currently proposed for bank stabilization – does not present a convincing case that the structures face an imminent threat from an eroding bank (see attached Appendix M from the 2013 FRR). In fact, it appears that the erosion adjacent to Camp 2W is from overland flow and flow from the roof of the structure.

In February 2015, FirstLight requested a meeting with the CRSEC to discuss the list of Phase IV sites that was included in the 2013 FRR. The CRSEC promptly informed FirstLight that we did not believe that the list of Phase IV sites in the 2013 FRR was in compliance with the ECP and requested that FirstLight provide us with a prioritized list of sites to consider for this next phase of work. We requested that this list be provided to us by mid-March so that we would have time to review it before meeting with FirstLight on April 16, 2015. When we met with FirstLight on April 16, the site list was the same one included in the 2013 FRR, plus work planned for 2014 (Shearer site) that had not been completed and instead was listed for 2015.

We question why FirstLight is claiming that these very small preventative maintenance sites are priority erosion sites. The 2013 FRR identified many sites that are likely to be contributing more sediment to the river than these small sites. The total length of work proposed by FirstLight, excluding the Shearer site, is 1,285 feet over 3 years, which is inadequate given that FirstLight has previously repaired sites this long in one year.

According to the 2013 FRR, there are 1,387 feet of active erosion; 22,642 feet of eroded banks; and 13,705 feet of potential future erosion. The Stages of Erosion Maps in Appendix G show many long segments (sites) of river bank classified as eroded and potential future erosion. After reviewing the 2013 FRR, the CRSEC compiled a list of several priority erosion sites for discussion at our April 16th meeting with FirstLight (see attached). We were told that FirstLight's project list was set and to "take it up with FERC" if we disagreed.

FirstLight is currently working to obtain permits for the Shearer site. This site was constructed almost two decades ago and for years has had an undercut toe because the stone was not placed at the proper elevation to address the fluctuating river levels due to project operations. For many years now, both the CRSEC and the property owner, Tom Shearer, have encouraged FirstLight to repair the Shearer site. This site has been discussed at numerous CRSEC meetings, and we've been told discussions, designs, and permitting were underway but nothing happened. The 2013 FRR classifies the Shearer site as Stable. This is a maintenance project that is long overdue and should be completed in 2015. However, we object to the Shearer site as a substitute for a priority erosion site or a preventative maintenance site. The work at the Shearer site should be done in addition to work on other priority erosion sites.

The ECP states that "[t]he licensees and the ad hoc committee will meet on sufficient intervals to evaluate and prioritize the following years [sic] erosion control work." This has not happened; rather FirstLight has chosen not to engage the CRSEC in discussion of sites. FirstLight did not complete work in 2014 as listed in Table 8.3, and is now proposing to do very minimal work for the remainder of its license. This is not acceptable when there are numerous sites, like the ones the CRSEC has identified, that are contributing large sediment loads to the river.

We respectfully request that FERC require the licensee to provide a prioritized list of erosion sites that are contributing the most sediment to the river in order to comply with the terms of the approved 1999 Erosion Control Plan (ECP) for the Turners Falls Pool. This prioritized list should be accompanied by a narrative that explains the rationale for the prioritization. The ECP states that "Sufficient expenditure will be made each year to satisfactorily remedy the erosion in a reasonable manner." FirstLight may maintain that it is only reasonable to construct the proposed sites given the permitting challenges, but there is time and need to do more.

Finally, we encourage FERC staff to schedule a site visit to the Turners Falls Pool in order to see for themselves the bank erosion that is occurring and warrants priority attention. It was a site visit by FERC staff Julian Flint in the mid-1990's that led to the Erosion Control Plan. The Connecticut River needs that continued, personal attention by FERC no less today.

Thank you for the opportunity to convey our concerns about the current compliance status of the licensee. We look forward to receiving your response.

Sincerely,

Linda Dunlavy, Executive Director
Franklin Regional Council of Governments

Tom Miner, Chair
Connecticut River Streambank Erosion Committee

cc: Congressman James McGovern
Franklin County Legislative Delegation
Christopher Chaney, FERC
Brandon Cherry, FERC
NOAA – National Marine Fisheries
Massachusetts Department of Environmental Protection
Landowners and Concerned Citizens for License Compliance
Town of Gill, MA Conservation Commission
Town of Northfield, MA Conservation Commission

ATTACHMENTS: Table 8.3 from 2013 Full River Reconnaissance
Appendix M from 2013 Full River Reconnaissance
CRSEC Draft List of Phase IV Priority Erosion Sites

Table 8.3 Proposed locations for bank stabilization/preventative maintenance projects

Year of Construction	Segment #	River Station (ft)	Length (ft)	Stage of Erosion	Extent of Erosion	Type of Erosion	Potential Indicators of Erosion
2014	89 (Shearer)	311+00 to 321+00	1056	Stable[36]	None/little	Undercut	Exposed Roots
2015	25 Camp 4E	108+00	95	Eroded	Some	Slide	Creep/Leaning Trees
2015	19 Camp 3E	88+00	118	Eroded	Some	Slide	Other
2016	387-388 Camp 2W	132+00 to 137+00	500	Eroded & Potential Future Erosion	Some	Slide, Undercut	Overhanging Bank, Exposed Roots
2017	12-13 (Montague)	67+00	280	Active Erosion	Extensive	Planar Slip, Overhanging Bank	Overhanging Bank, Exposed Roots, Creep/Leaning trees, Other
2017	70	268+00	105	Active Erosion	Extensive	Slide	Creep/Leaning Trees, Overhanging Bank, Exposed Roots
2017	75	270+00	33	Active Erosion	Extensive	Topple	Creep/Leaning Trees, Overhanging Bank, Exposed Roots
2017	77	273+00	154	Eroded	Some to Extensive	Slide	Creep/Leaning Trees

[36] While this site is stable with a rock toe and heavily vegetated upper riverbank from previous stabilization work, there is an undercut extending along the length of this segment just above the top of rock. The landowner has requested this work be done and FirstLight has agreed to modify the existing stabilization project to eliminate the undercut.

Appendix M: Bank Restoration Recommendations - Riverbank Features and Characteristics

Recommended Bank Stabilization/Preventative Maintenance Sites

Year	Location/Name	River Station (ft)	Length (ft)
* **2014**	Shearer (89)	311+00 to 321+00	1060
2015	Camps 4E & 3E	108+00 & 88+00	100 &120: 220
2016	Camp 2W (387, 388)	132+00 to 137+00	500
2017	70, 75, 77 12-13 (Montague)	268+00, 270+00 & 273+00 67+00	105, 35 & 155: 295 280

No work done in 2014
Shearer site moved to 2015

Shearer (Segment 89, repair of previously stabilized site)

609

Segment #89 Riverbank features and characteristics

Riverbank Features	Characteristics
Upper Riverbank Slope	Moderate
Upper Riverbank Height	High
Upper Riverbank Sediment	Silt/Sand
Upper Riverbank Vegetation	Heavy
Lower Riverbank Slope	Moderate
Lower Riverbank Sediment	Cobbles
Lower Riverbank Vegetation	None-Very Sparse
Type of Erosion	Undercut
Potential Erosion Indicators	None
Stage of Erosion	Stable
Extent of Erosion	None/Little

Camp 4E (Segment 25)

Segment #25 Riverbank features and characteristics

Riverbank Features	Characteristics
Upper Riverbank Slope	Moderate
Upper Riverbank Height	High
Upper Riverbank Sediment	Silt/Sand
Upper Riverbank Vegetation	Moderate
Lower Riverbank Slope	Moderate
Lower Riverbank Sediment	Boulders
Lower Riverbank Vegetation	None-Very Sparse
Type of Erosion	Slide
Potential Erosion Indicators	Creep/Leaning Trees, Other
Stage of Erosion	Eroded
Extent of Erosion	Some

Camp 3E (Segment 19)

233

Segment #19 Riverbank features and characteristics

Riverbank Features	Characteristics
Upper Riverbank Slope	Moderate
Upper Riverbank Height	Medium
Upper Riverbank Sediment	Silt/Sand
Upper Riverbank Vegetation	Heavy
Lower Riverbank Slope	Vertical
Lower Riverbank Sediment	Bedrock (wood wall)
Lower Riverbank Vegetation	None-Very Sparse
Type of Erosion	Slide
Potential Erosion Indicators	Other
Stage of Erosion	Eroded
Extent of Erosion	Some

Camp 2W (Segment 387-388)

439

Segment #387 Riverbank features and characteristics

Riverbank Features	Characteristics
Upper Riverbank Slope	Steep
Upper Riverbank Height	High
Upper Riverbank Sediment	Silt/Sand
Upper Riverbank Vegetation	Moderate
Lower Riverbank Slope	Moderate
Lower Riverbank Sediment	Boulders
Lower Riverbank Vegetation	None-Very Sparse
Type of Erosion	Slide
Potential Erosion Indicators	Overhanging Bank
Stage of Erosion	Eroded
Extent of Erosion	Some

Segment #388 Riverbank features and characteristics

Riverbank Features	Characteristics
Upper Riverbank Slope	Moderate
Upper Riverbank Height	High
Upper Riverbank Sediment	Silt/Sand
Upper Riverbank Vegetation	Heavy
Lower Riverbank Slope	Moderate
Lower Riverbank Sediment	Boulders
Lower Riverbank Vegetation	None-Very Sparse
Type of Erosion	Undercut
Potential Erosion Indicators	Overhanging Bank, Exposed Roots
Stage of Erosion	Potential Future Erosion
Extent of Erosion	Some

Segment #12 Riverbank features and characteristics

253

Riverbank Features	Characteristics
Upper Riverbank Slope	Steep
Upper Riverbank Height	High
Upper Riverbank Sediment	Silt/Sand
Upper Riverbank Vegetation	Sparse
Lower Riverbank Slope	Flat/Beach
Lower Riverbank Sediment	Silt/Sand
Lower Riverbank Vegetation	None-Very Sparse
Type of Erosion	Planar Slip, Overhanging Bank
Potential Erosion Indicators	Overhanging Bank, Creep/Leaning Trees, Exposed Roots, Other
Stage of Erosion	Active Erosion
Extent of Erosion	Extensive

Segment #13 Riverbank features and characteristics

252

Riverbank Features	Characteristics
Upper Riverbank Slope	Moderate
Upper Riverbank Height	High
Upper Riverbank Sediment	Silt/Sand
Upper Riverbank Vegetation	Moderate
Lower Riverbank Slope	Steep
Lower Riverbank Sediment	Bedrock
Lower Riverbank Vegetation	None-Very Sparse
Type of Erosion	Planar Slip, Overhanging Bank
Potential Erosion Indicators	Overhanging Bank, Creep/Leaning Trees, Exposed Roots
Stage of Erosion	Active Erosion
Extent of Erosion	Extensive

Segment #70 Riverbank features and characteristics

122

Riverbank Features	Characteristics
Upper Riverbank Slope	Steep
Upper Riverbank Height	High
Upper Riverbank Sediment	Silt/Sand
Upper Riverbank Vegetation	Sparse
Lower Riverbank Slope	Flat/Beach
Lower Riverbank Sediment	Gravel
Lower Riverbank Vegetation	None-Very Sparse
Type of Erosion	Slide
Potential Erosion Indicators	Creep/Leaning Trees, Overhanging Bank, Exposed Roots
Stage of Erosion	Active Erosion
Extent of Erosion	Extensive

Segment #75 Riverbank features and characteristics

118

Riverbank Features	Characteristics
Upper Riverbank Slope	Vertical
Upper Riverbank Height	High
Upper Riverbank Sediment	Silt/Sand
Upper Riverbank Vegetation	Sparse
Lower Riverbank Slope	Flat/Beach
Lower Riverbank Sediment	Silt/Sand
Lower Riverbank Vegetation	None-Very Sparse
Type of Erosion	Topple
Potential Erosion Indicators	Creep/Leaning Trees, Overhanging Bank, Exposed Roots
Stage of Erosion	Active Erosion
Extent of Erosion	Extensive

Segment #77 Riverbank features and characteristics

117

Riverbank Features	Characteristics
Upper Riverbank Slope	Steep
Upper Riverbank Height	High
Upper Riverbank Sediment	Silt/Sand
Upper Riverbank Vegetation	Sparse
Lower Riverbank Slope	Flat/Beach
Lower Riverbank Sediment	Gravel
Lower Riverbank Vegetation	None-Very Sparse
Type of Erosion	Slide
Potential Erosion Indicators	Creep/Leaning Trees
Stage of Erosion	Eroded
Extent of Erosion	Some to Extensive

CRSEC DRAFT LIST of Phase IV PRIORITY EROSION SITES

Segment ID Number 104-107
Site Length: 1,400 feet
Land Based Segment 6
Extent of Erosion: Some (23 feet of None/Little)

Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *6* **Personnel:** *YKC, AS, MM, CM, PW*

Date: *November 13, 2013* **Time:** *10:00 am*

Station Number: *350+00* **Photo Reference Numbers:** *552 - 559*

Left or Right Bank (Looking Downstream): *Left*

Length of Representative Segment, From Station Number *334+00* **To Station Number** *385+00*

Previously Stabilized? *No*

Geologic / Geotechnical Observations:

Stratigraphy:
(Refer to Site Sketch below for locations of soil/rock layers
Notations in parentheses are based on Unified Soil Classification System)

SILT (ML) – Low to no plasticity, <10% fine sand, dark gray.

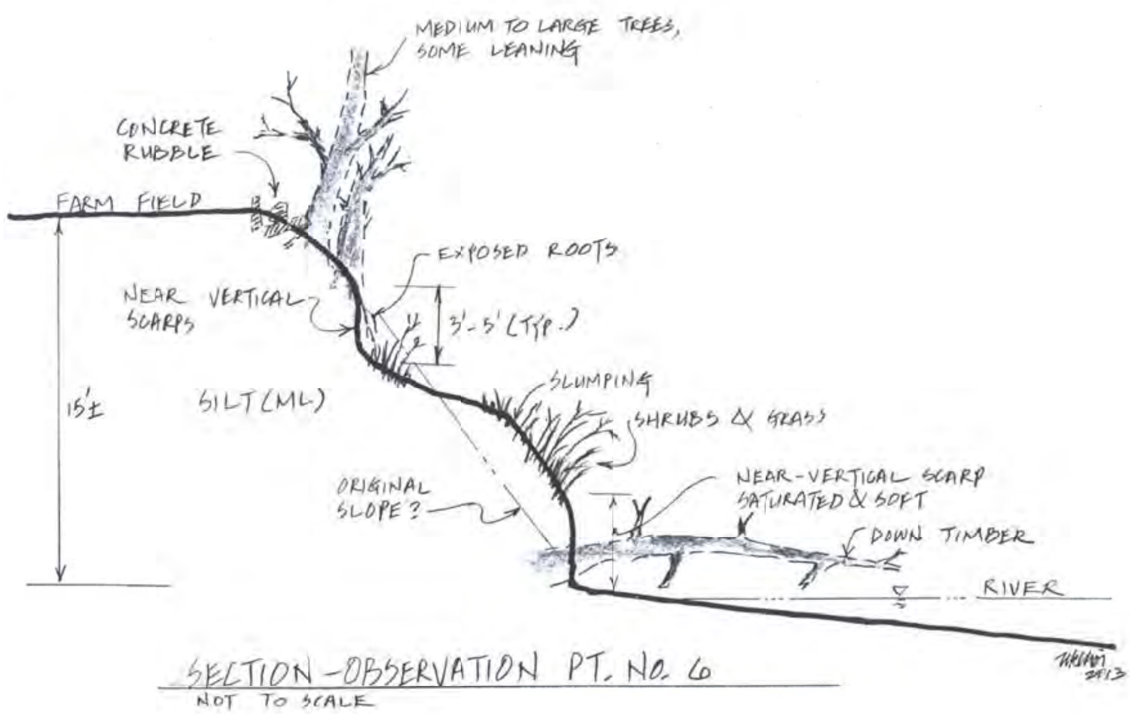
Other observations:

- *Concrete rubble on top of bank did not appear to be for erosion stabilization purpose.*

Observed Erosion Features:

- *Near-vertical scarps, with several intermediate benches from mass-wasting and slumping.*
- *Some down timber and leaning trees.*
- *Little grass, but some shrubs between trees*
- *Some exposed tree roots on upper scarps near top of bank.*

Site Sketch:



Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *6* **Date:** *November 13, 2013*

Station Number: *350+00*

Maximum Root Depth:
<1 m

Erosion Classification:

Types of Erosion: mass-wasting (historical)

Indicators of Potential Erosion: Creep/leaning trees
Exposed roots
Overhanging bank

Notes:

Bank Vegetation:

Top: *Heavy (>50%), Broad-leaved deciduous tree*
Sugar maple, red maple, mix birches, black oak*

Face: *Heavy (>50%), Broad-leaved deciduous tree/sapling*
Sugar maple, red maple, black oak (leaning live trees and saplings)*

Toe: sand bench, no veg

NOTE: The dominant plant is noted with an *

Adjacent Land Use:
Agricultural

Sensitive Receptor:
No

Notes: *Historical mass-wasting, estimated ~12 years old (sigafouse) at L'etoile farm*

Eroded, vertical bank at Shearer Farm

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 552 - 559
Observation Point No. 6 - November 13, 2013

Photo No. 552

Photo No. 553

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 552 - 559
Observation Point No. 6 - November 13, 2013

Photo No. 554

Photo No. 555

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 552 - 559
Observation Point No. 6 - November 13, 2013

Photo No. 556

Photo No. 557

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 552 - 559
Observation Point No. 6 - November 13, 2013

Photo No. 558

Photo No. 559

Segment ID Number 140-142
Site Length: 817 feet
Land Based Segment 11
Extent of Erosion: Some

Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *11* **Personnel:** *YKC, AS, MM, CM, PW*

Date: *November 13, 2013* **Time:** *2:30 pm*

Station Number: *505+00* **Photo Reference Numbers:** *581-588*

Left or Right Bank (Looking Downstream): *Left*

Length of Representative Segment, From Station Number *490+00* **To Station Number** *555+00*

Previously Stabilized? *No*

Geologic / Geotechnical Observations:

Stratigraphy:
(Refer to Site Sketch below for locations of soil/rock layers
Notations in parentheses are based on Unified Soil Classification System)

Upper Bank: SILT (ML) – Nonplastic,<10% sand, dark gray.
Lower Bank: SILT (ML) – Slightly plastic, <10% sand, gray.
Recent sediment from Hurricane Irene: SILT (ML) – Low plasticity, gray.

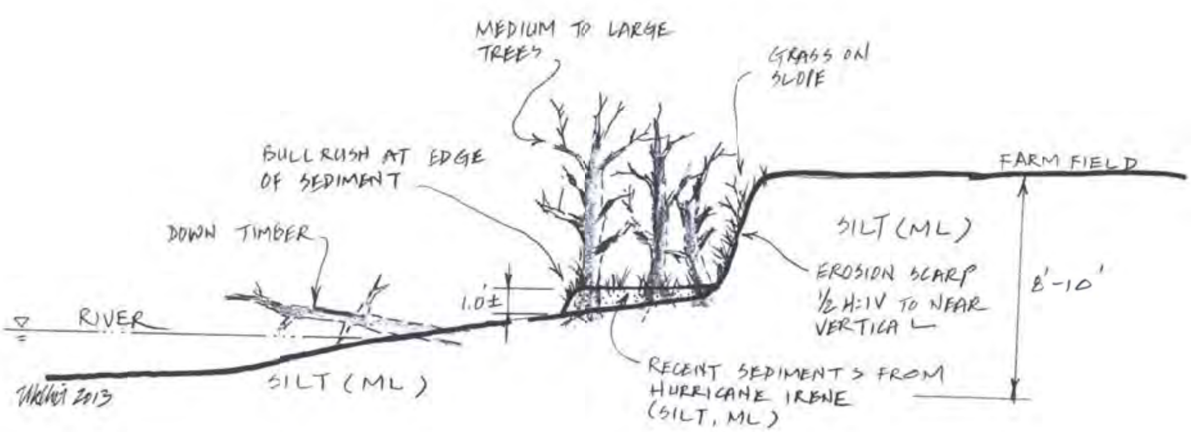
Other observations:

- *Bottom of some trees near river level covered with recent sediments, with bull rush growing.*

Observed Erosion Features:

- *Erosion scarps just below top of bank, very steep.*
- *Exposed roots.*
- *Some trees with bent trunks, may be indication of land creep.*
- *Down timber*

Site Sketch:



SECTION – OBSERVATION PT. NO. 11
NOT TO SCALE

Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *11* **Date:** *November 13, 2013*

Station Number: *505+00*

Maximum Root Depth:
1.2 m

Erosion Classification:

Types of Erosion: Little to no erosion

Indicators of Potential Erosion: Creep/leaning trees
Exposed roots
Downed trees

Notes: Erosion scarps just below the top of the bank (TOB), very steep

No invasive veg at this site

Transitional zone

Bank Vegetation:

Top: Moderate (25-50%), Broad-leaved deciduous tree
Silver maple, red maple*

Face: Moderate (25-50%), broad leaved deciduous sapling/vine
Silver maple, red maple, grape & bittersweet*

Toe: None to Very Sparse (0-10%) Non-Persistent emergent
mixed rushes & sedges but primarily silt

NOTE: The dominant plant is noted with an *

Adjacent Land Use:
agricultural

Sensitive Receptor:
No

Notes: *Transitional zone with emergent vegetation growing on recent deposition of sediments from Hurricane Irene*

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 581 - 588
Observation Point No. 11 - November 13, 2013

Photo No. 581

Photo No. 582

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 581 - 588
Observation Point No. 11 - November 13, 2013

Photo No. 583

Photo No. 584

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 581 - 588
Observation Point No. 11 - November 13, 2013

Photo No. 585

Photo No. 586

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 581 - 588
Observation Point No. 11 - November 13, 2013

Photo No. 587

Segment ID Number 501
Site Length: 905 feet
Land Based Segment 29
Extent of Erosion: None/Little

Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *29* **Personnel:** *YKC, MM, CM*

Date: *November 19, 2013* **Time:** *9:30 am*

Station Number: *659+00 (Note 1)* **Photo Reference Numbers:** *740 – 744*

Note 1 – Observed area is just upstream of Wicky Site. River was high, and beach area was submerged.

Left or Right Bank (Looking Downstream): *Right*

Length of Representative Segment, From Station Number *640+00* **To Station Number** *680+00*

Previously Stabilized? *No*

Geologic / Geotechnical Observations:

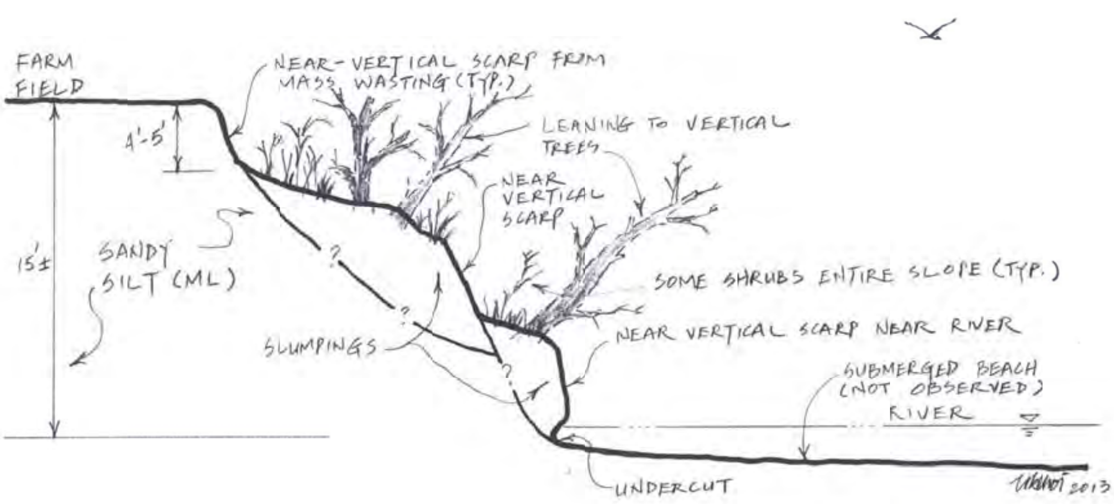
Stratigraphy:
(Refer to Site Sketch below for locations of soil/rock layers
Notations in parentheses are based on Unified Soil Classification System)

SANDY SILT (ML) – Nonplastic, 10% - 20% fine sand, gray.

Observed Erosion Features:

- *Mass-wasting along entire slope, with near-vertical slide scarps exposed.*
- *Slumpings of materials, with some leaning trees.*
- *Undercuts at river level below near-vertical scarps.*

Site Sketch:



SECTION – OBSERVATION PT. No. 29
NOT TO SCALE

Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *29* **Date:** *November 19, 2013*

Station Number: *659+00*

Maximum Root Depth:

>1.2 m (cont. below ground)

Erosion Classification:

Types of Erosion: mass wasting

Indicators of Potential Erosion: overhanging bank
exposed roots
creep/leaning trees

Notes: Mass wasting along entire slope, near vertical slide scarps

Bank Vegetation:

Top: Moderate (25-50%), Broad-leaved deciduous tree
Silver maple, sugar maple, staghorn sumac, multiflora rose, bittersweet*

Face: Moderate (25-50%), Broad-leaved deciduous vine
Bittersweet, grape*

Toe: None to Very sparse (0-10%), unvegetated

NOTE: The dominant plant is noted with an *

Adjacent Land Use:
Agricultural

Sensitive Receptor:
No

Notes: *Wickey site*

Lots of invasives here (multiflora rose, bittersweet, etc)

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 740 - 744
Observation Point No. 29 - November 19, 2013

Photo No. 740

Photo No. 741

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 740 - 744
Observation Point No. 29 - November 19, 2013

Photo No. 742

Photo No. 743

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 740 - 744
Observation Point No. 29 - November 19, 2013

Photo No. 744

Segment ID Number 119 Site Length: 397 Land Based Segment 9 Extent of Erosion: Some to Extensive


Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *9*

Personnel: *YKC, AS, MM, CM, PW*

Date: *November 13, 2013*

Time: *12:30 pm*

Station Number: *435+00*

Photo Reference Numbers: *568 - 575*

Left or Right Bank (Looking Downstream): *Left*

Length of Representative Segment, From Station Number *420+00* **To Station Number** *475+00*

Previously Stabilized? *No*

Geologic / Geotechnical Observations:

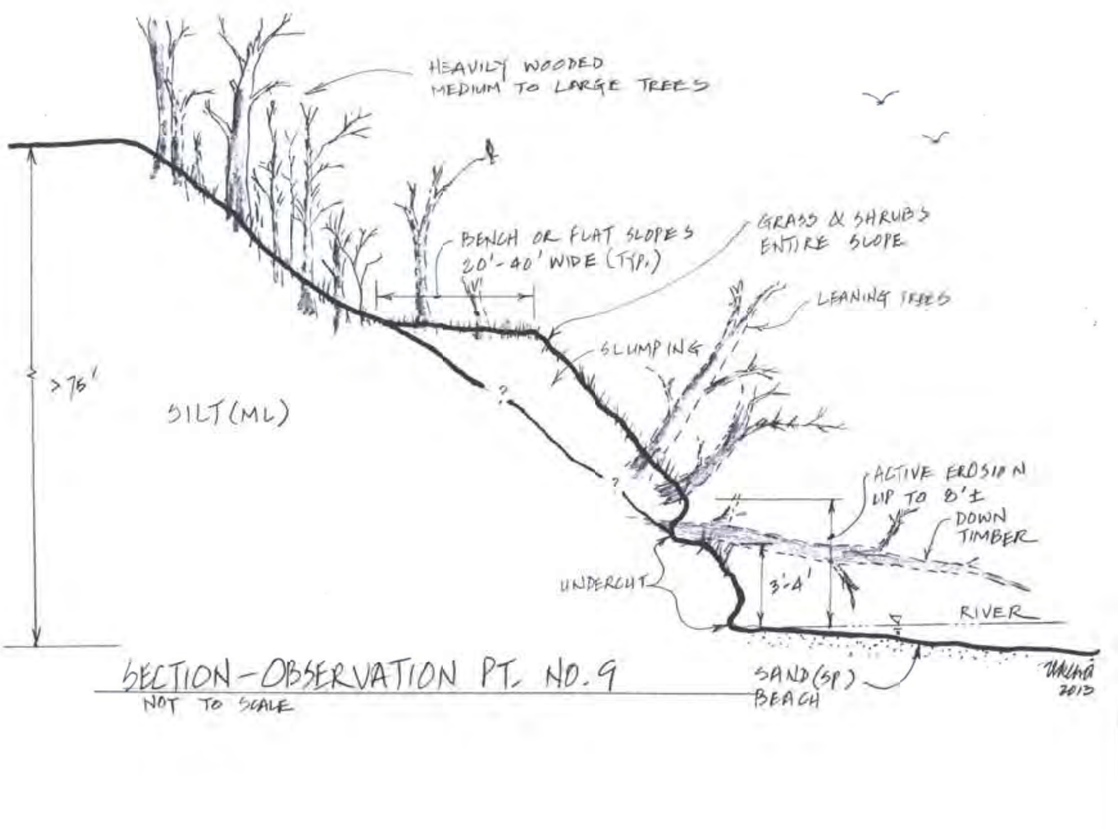
Stratigraphy:
(Refer to Site Sketch below for locations of soil/rock layers
Notations in parentheses are based on Unified Soil Classification System)

SILT (ML) – Nonplastic, little to no sand, gray.
SAND (SP) – Mostly clean fine sand on beach. Likely just veneer.

Observed Erosion Features:

- *Near-vertical scarps up to about 8' high from river level, with undercuts.*
- *Leaning trees to down timber, with exposed tree roots along erosion scarps.*
- *A relatively flat bench at about mid-slope, may be from mass-wasting and slumping.*

Site Sketch:



Connecticut River – Turners Falls Impoundment Riverbank Classification for Land Based Survey

Observation Point Number: *9* **Date:** *November 13, 2013*

Station Number: *435+00*

Maximum Root Depth:
1.5 m

Erosion Classification:

Types of Erosion: Mass wasting & fluvial

Indicators of Potential Erosion: Creep/leaning trees
Exposed roots
Overhanging bank

Notes: near vertical scarps up to ~8' high, with undercuts

Leaning trees to down timber, with exposed tree roots along erosion scarps

A relatively flat bench at ~mid-slope, may be from mass wasting & slumping

Bank Vegetation:

Top: Heavy (>50%), needle-leaved coniferous tree
Hemlock, mixed birches, black cherry, mix of silver/red maples, mixed oaks*

Face: Moderate (25-50%), needle-leaved coniferous tree/sapling
Hemlock, mix maples/oaks*

Toe: sand/silt bench – no veg

NOTE: The dominant plant is noted with an *

Adjacent Land Use:
forested

Sensitive Receptor:
No

Notes: *Beautiful riverfront with a wide forested riparian buffer of well-established forest buffer, including dense hemlock stands*

Forested riparian buffer at top, pockets of eroded bank, many gullies especially at stream/tributary inlset where there is a very deep gorge ~100'deep

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 568 - 575
Observation Point No. 9 - November 13, 2013

Photo No. 568

Photo No. 569

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 568 - 575
Observation Point No. 9 - November 13, 2013

Photo No. 570

Photo No. 571

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 568 - 575
Observation Point No. 9 - November 13, 2013

Photo No. 572

Photo No. 573

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 568 - 575
Observation Point No. 9 - November 13, 2013

Photo No. 574

Photo No. 575

Attachment 17. BSTEM Dynamic User Manual

April, 2013

BSTEM-Dynamic USER MANUAL

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www.blm.gov/snplma

1. Introduction, Technical Background and Model Use

Check that security settings allow macros to open when the model is opened.

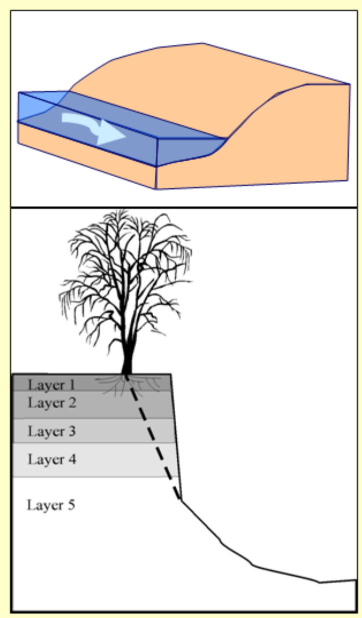
The Bank Stability and Toe Erosion Model (BSTEM) is a combination of equilibrium-method models which run in Microsoft Office Excel ™. There are ten worksheets in the file; the first three worksheets provide technical background for model development, model use, tips and frequently asked questions with a brief history of revisions. The next four sheets are data input sheets necessary for running the model. There is a Unit Converter and a sheet for 'running' the model. Results are output in the 'Calculations' sheet. Below are screen shots of the 'Introduction' (Figure 1), 'Tech Background' (Figure 2) and 'Model use and FAQ' (Figure 3) sheets.

Bank Stability and Toe Erosion Model

Dynamic Version 5.4

Bank Stability Model

The Bank Stability Model combines three limit equilibrium-method models that calculate Factor of Safety (*Fs*) for multi-layer streambanks. The methods simulated are horizontal layers (Simon *et al*., 2000), vertical slices with tension crack (Morgenstern and Price, 1965) and cantilever failures (Thorne and Tovey, 1981). The model can easily be adapted to incorporate the effects of geotextiles or other bank stabilization measures that affect soil strength.



The model accounts for the strength of up to five soil layers, the effect of pore-water pressure (both positive and negative (matric suction)), confining pressure due to streamflow and soil reinforcement and surcharge due to vegetation.

Input the bank coordinates (**Input Geometry**) and run the geometry macro to set up the bank profile, then input your soil types, vegetation cover and water table or pore-water pressures (**Bank Material**, **Bank Vegetation and Protection** and **Bank Model Output**) to find *Fs*.

The bank is said to be 'stable' if *Fs* is greater than 1.3, to provide a safety margin for uncertain or variable data. Banks with a *Fs* value between 1.0 and 1.3 are said to be 'conditionally stable', i.e. stable but with little safety margin. Slopes with an *Fs* value less than 1.0 are unstable.

This version of the model assumes hydrostatic conditions below the water table, and a linear interpolation of matric suction above the water table (unless the user's own pore-water pressure data are used).

The model can either use estimated input data where no field data are available or as a first pass solution, or can be set to run using your own data. Your own data can be added to white boxes. Don't change values in yellow boxes - they are output.

Bank Toe Erosion Model

The Bank Toe Erosion Model can be used as a tool for making reasonably informed estimates of hydraulic erosion of the bank and bank toe by hydraulic shear stress. The model is primarily intended for use in studies where bank toe erosion threatens bank stability. The effects of erosion protection on the bank and toe can be incorporated to show the effects of erosion control measures.

The model estimates boundary shear stress from channel geometry, and considers critical shear stress and erodibility of two separate zones with potentially different materials: the bank and bank toe; the bed elevation is assumed to be fixed.

Figure 1 – 'Introduction' sheet providing a brief description of the Bank Stability and Toe Erosion Models

resisting force (strength).

Streambank stability

The shear strength of saturated soil can be described by the Mohr-Coulomb criterion:

$$\tau_f = c' + (\sigma - \mu_w) \tan \phi' \qquad -1$$

where τ_f = soil shear strength (kPa); c' =effective cohesion (kPa); σ = normal stress (kPa); μ_w = pore-water pressure (kPa); and ϕ' = effective angle of internal friction (degrees).

In incised stream channels and in arid or semi-arid regions, much of the bank may be above the water table and will usually experience unsaturated conditions. Matric suction (negative pore-water pressure) above the water table has the effect of increasing the apparent cohesion of a soil. Fredlund *et al.* (1978) defined a functional relationship describing increasing soil strength with increasing matric suction. The rate of increase is defined by the parameter ϕ^b, which is generally between 10º and 20º, with a maximum value of ϕ' under saturated conditions (Fredlund and Rahardjo, 1993). Apparent cohesion incorporates both electro-chemical bonding within the soil matrix and cohesion due to surface tension on the air-water interface of the unsaturated soil:

$$c_a = c' + (\mu_a - \mu_w) \tan \phi^b = c' + \psi \tan \phi^b \qquad -2$$

where c_a = apparent cohesion (kPa); μ_a = pore-air pressure (kPa); and ψ = matric suction (kPa).

The term ϕ^b varies for all soils, and with moisture content for a given soil (Fredlund and Rahardjo, 1993; Simon *et al.*, 2000). Data on ϕ^b are particularly lacking for alluvial materials. However, once this parameter is known (or assumed) both apparent cohesion (c_a) and effective cohesion (c') can be calculated by measuring matric suction with tensiometers or other devices and by using equation 2.

Driving forces for streambank instability are controlled by bank height and slope, the unit weight of the soil and the mass of water within it, and the surcharge imposed by any objects on the bank top. The ratio of resisting to driving forces is commonly expressed as the Factor of Safety (*Fs*), where values greater than one indicate stability and those less than one, instability.

Mechanical effects of vegetation on bank stability

Soil is generally strong in compression, but weak in tension. The fibrous roots of trees and herbaceous species are strong in tension but weak in compression. Root-permeated soil, therefore, makes up a composite material that has enhanced strength (Thorne, 1990). Numerous authors have quantified this enhancement using a mixture of field and laboratory experiments. Endo and Tsuruta (1969) used *in situ* shear boxes to measure the strength difference between soil and soil with roots. Gray and Leiser (1982) and Wu (1984) used laboratory-grown plants and quantified root strength in large shear boxes. Wu *et al*. (1979, after Waldron, 1977) developed a widely-used equation that estimates the increase in soil strength (c_r) as a function of root tensile strength, areal density and root distortion during shear:

$$c_r = \frac{1}{A}\sum_{n=1}^{n=N}(A_r T_r)_n \left[\sin(90-\zeta) + \cos(90-\zeta)\tan\phi\right] \qquad -3$$

where c_r = cohesion due to roots (kPa); T_r = tensile strength of roots (kPa); A_r = area of roots in the plane of the shear surface; A = area of the shear surface; ϕ' = friction angle of soil (degrees); N = total number of roots crossing the shear plane; subscript n = n^{th} root; and

Figure 2 – 'Tech Background' sheet describes types of streambank failures, the science and algorithms behind streambank stability and the added resistance provided by vegetation, along with references.

Bank Stability and Toe Erosion Model use

How to best use the Bank Stability and Toe Erosion Model

The Bank Stability and Toe Erosion Model is a physically-based model. It represents two distinct processes, namely, the failure by shearing of a soil block of variable geometry and the erosion by flow of bank and bank toe material. The effect of toe erosion, vegetative treatments or other bank and bank toe protection measures can be illustrated by calculating the actual Factor of Safety (*Fs*) of the bank. To obtain a *Fs* value or to accurately model toe erosion, it is recommended that you collect your own data for each site and enter these values in the appropriate boxes. However, in many field situations these data are not all available or collectable given the resources of the investigation. In addition, the failure mechanism may not ***exactly*** match one of the models, or water column sediment loads may be so high as to reduce erosion potential. In these situations the model can be ***cautiously*** used as an ***approximate*** or ***relative*** indicator of streambank or bank toe stability in a similar way to a BEHI or other index-based method. To use the model in this way the user can input the bank profile and divide the bank into stratigraphic layers based on the materials listed in the list boxes (sand, silt, clay etc.). If the user does this they need to be aware that both the *Fs* value and the erosion amounts will be approximations, since there is considerable uncertainty and variability in the values selected for each material type. With regards to *Fs*, users are advised to use a safety margin when classifying banks as stable. Typical margins might be 1.3 or 1.5, depending on how critical the bank is.

To use the model, begin with **Input Geometry** and proceed through the **Bank Material** and **Bank Vegetation and Protection** sheets. The order you use the components is user-selectable. However, if you choose to use the **Toe Erosion** component, you will be routed to **Toe Model Output** to calculate the amount of bank toe erosion. If you choose to use the Bank Stability component, you will be routed to **Bank Model Output** to calculate Fs. The calculated bank failure profile may be viewed in **Bank Model Output**. If you have chosen to insert a tension crack, each time you make a change to any of the values in **Bank Material**, **Bank Vegetation and Protection** or **Bank Model Output**, you must rerun the Bank Geometry macro on **Input Geometry**. Results can be transferred back into the model for further iterations using the **Export New Profile into Model** buttons. If you choose to do this, **Option A** is automatically selected.

Bank geometry may be inputted in two ways. First, **Option A** allows measured slope values to be entered to give high resolution compound slopes. Note that a maximum of 23 points may now be inputted by the user. However, the minimum is 5 (floodplain point, bank top, top of bank toe, bottom of bank toe, channel bed). Input of these points is mandatory. The user must also tick a box indicating which point corresponds to the top of the bank toe. Between these values, the model will interpolate additional points and populate the geometry. A maximum of 17 points may be used to describe the geometry of the bank and a maximum of 6 points may be used to describe the geometry of the bank toe. Alternatively, **Option B** generates a bank profile based upon a given bank angle, bank height, bank toe angle and bank toe length. If **Option B** is selected the bank automatically scales so that the top bank width is 1m wider than the failure block.
The user has two options for specifying the position of the failure plane emergence elevation and the failure plane angle:

Enter the failure plane angle in the relevant cell (E46 for **Option A** or G28 for **Option B**) and, if using **Option A**, enter the failure plane emergence elevation in cell E44 (if **Option B** is selected, the failure plane emergence elevation is set at the top of the toe).

Do not enter an angle (or shear emergence elevation if using **Option A**) and the model will search for the failure plane emergence elevation and angle that produces the minimum factor of safety.

The resulting bank profile may be viewed in **Toe Model Output** or **Bank Model Output**.

Modeling Tips and Frequently Asked Questions

The validity of model output is subject to two major constraints;

a) the model is a simplification of a complex natural system, and that simplification must be appropriate to the field situation in order for the results to be meaningful

b) the output is only as good as the input data

The bank stability component assumes that river banks fail as either wedges with planar shear surfaces, as wedges with tension cracks, or as cantilever shear-failures (see **Tech Background** for more information). While it will give an indication of the relative stability of banks subject to other failure mechanisms, the precise value of *Fs* will not be correct. Additionally, the toe erosion component assumes that flow is competent to erode and transport material from the bank face, toe and bed. i.e. antecedent sediment loads are either minimal or can be ignored. It also assumes that bank, bed and toe materials are eroded at a rate controlled by excess-shear stress and that critical shear stresses for each material type remain constant; hiding effects are ignored.

The parameter data (soil strength, cohesion due to vegetation, erodibility etc.) provided with this model are subject to natural variability and uncertainty. Where the 'right' answer is needed (i.e. an accurate *Fs* or erosion amount rather than a relative ranking of banks) the user will need to collect their own data.

Figure 3 – "Model use and FAQ' explains scenarios for which the Bank Stability Model is most appropriate, talks briefly about bank geometry, layers and vegetation and provides a history of model revisions.

2. Input Geometry

Any model output is only as reliable as input data; therefore the next few sheets within the model are key to model output. The 'Input Geometry' sheet has two main options (Figure 4): A in which a detailed survey is provided by the user; and B in which a bank height and angle are used as input values and a generalized bank profile generated by the model. Reach slope of at least 6-20 channel widths is also inputted into this sheet and a reach length provided by the user. The slope value is used in the hydraulic erosion sub-model.

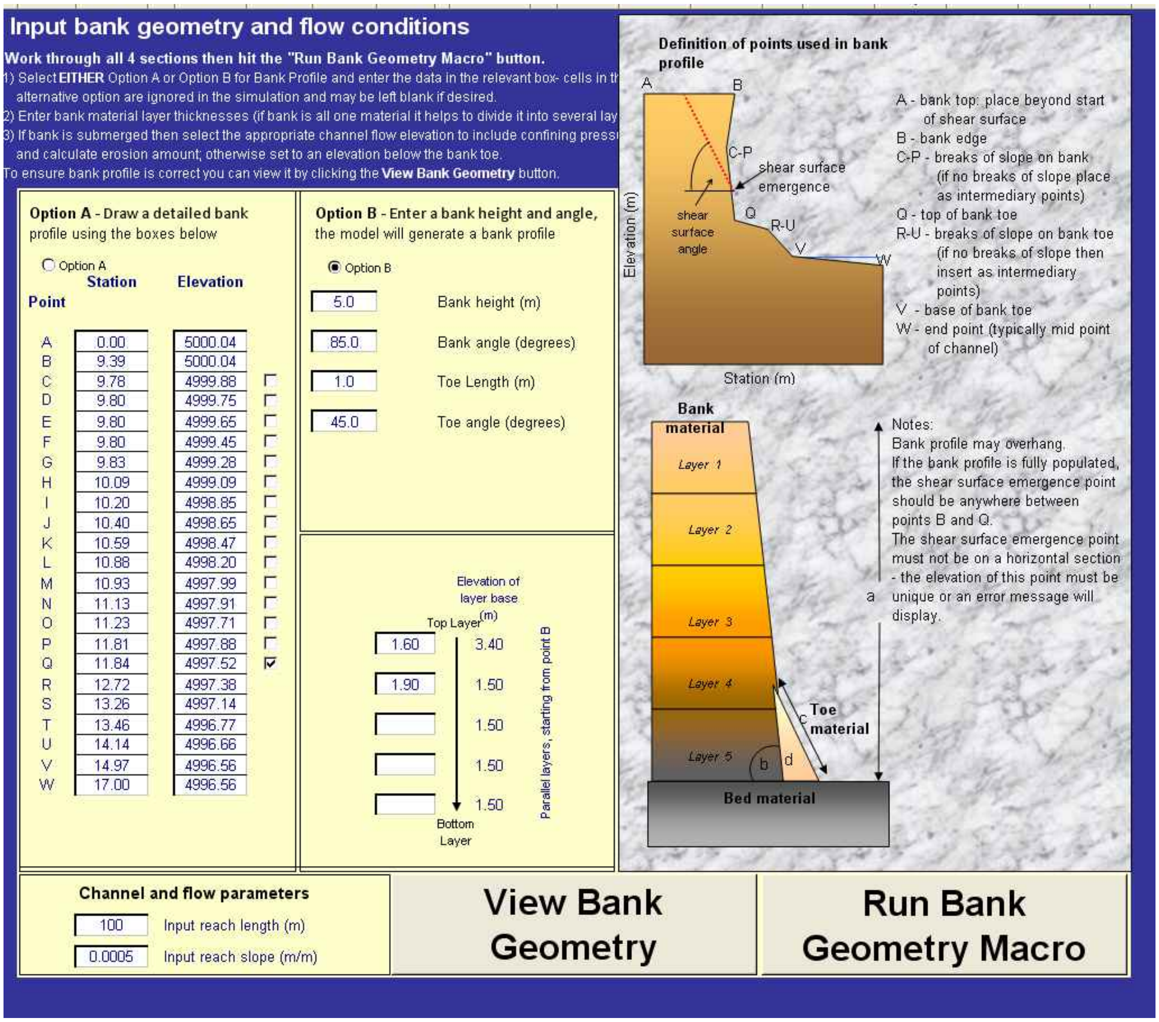


Figure 4 – Screen shot of the 'Input Geometry' sheet where bank geometry, layer depth and flow parameters are input.

Option A – Draw a detailed bank

Some key points to remember when inputting a detailed bank geometry:

- The bank is read from left to right; therefore right banks will need to be reversed before entering the bank profile.
- The second point, point B, should always be the bank top edge.

- Point Q will always end up being the top of the bank toe.
- It is recommended that the first and last points create flat lines at the beginning and end of the bank profile and that the flat line at the base of the bank represents channel thalweg (Figure 5).
- In the instance of a small bank toe, make sure that there are not a condensed conglomeration of bank toe points. The model divides flow into segments from the center point. Very small segments created by points very close together, will cause flow to be maximized over a small bank area, artificially increasing shear stress locally on the bank.
- Make sure all other points are evenly spread between the bank toe top and the bank edge point.

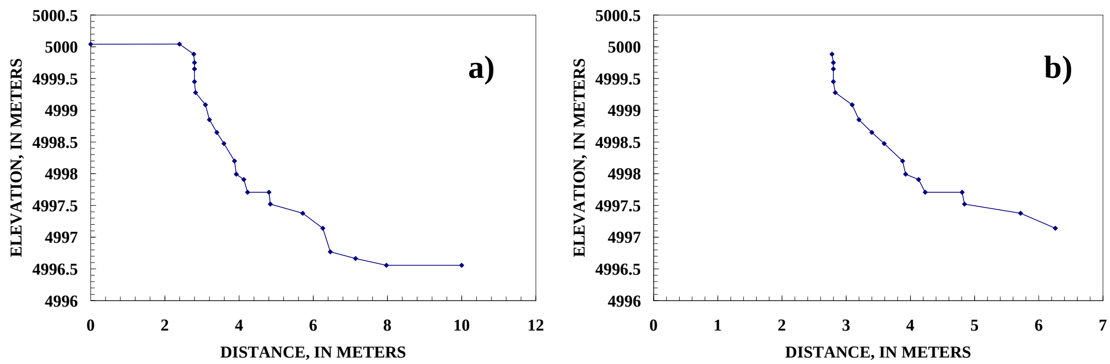


Figure 5 – An example of both good (a) and bad (b) input bank profiles. a) has a flat top and bottom, with the lowest point extending out to the channel thalweg. b) has no flat bank top, no bed point and the bank profile does not extend to the channel thalweg.

Input the initial bank profile, insert a check mark into the appropriate cell for top of bank toe and click 'Run Bank Geometry Macro'. You will automatically be taken to the Bank Material sheet, but it is important to go back and 'View Bank Geometry'. Should you need to change the bank coordinates, paste data into a new Excel book, make adjustments, and paste back into the model.

Option B – Enter a bank height and angle

This option should be used where a detailed bank profile is unavailable or hypothetical scenarios are being run. Bank height and angle, along with toe length and angle are input in order for the model to generate a simplified bank profile. Continue as before by viewing the bank profile and then pressing the run bank geometry macro, once the rest of the page has been completed.

Bank Layer Thickness

Enter the thickness of up to five layers is input, starting from point B. Elevation of layer base is given and should be checked to ensure that the lowest layer elevation is below or equal to the lowest elevation in the bank profile. Not all layers need be used, however if one layer is several meters thick, it is often a good idea to split it up into two layers containing the same data.

3. Bank Material

Once you press the "Run Bank Geometry" button you will be redirected to the "Bank Material" worksheet. The bank material types for each layer can either be selected from the drop down boxes at the top of the sheet, which contain default values for different material types, or "Own data" can be selected and *in situ* measured geotechnical and hydraulic properties can be input (Figure 6). Drop down box options for assumed values are as follows: boulders, cobbles, gravel, coarse angular sand, fine angular sand, coarse rounded sand, fine rounded sand, erodible silt, moderate silt, resistant silt, erodible soft clay, moderate soft clay, resistant soft clay, erodible stiff clay, moderate stiff clay and resistant stiff clay. References for values used for these material types are given in the 'Bank Material' sheet.

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Coarse rounded s	Own data	Gravel	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data			Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	36.0	0.0	18.0	15.0	-	7.439E-05	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	27.0	0.0	18.0	15.0	-	1.130E-06	4.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	30.0	3.0	18.0	15.0	-	5.064E-06	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	25.0	10.0	18.0	15.0	-	9.473E-07	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	20.0	15.0	18.0	15.0	-	1.708E-06	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.9	10.2	17.8	22.0		9.473E-07	1.5812	1.4158	3.32	0.594
	Own data layer 2											
9	Own data layer 3		22.0	0.8	17.8	20.0		9.473E-07	1.5812	1.4158	2.87	0.669
	Own data layer 4											
	Own data layer 5											
	Own data Bank Toe				18.2						1.50	1.144

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (k) ?	
Input non-cohesive particle diameter (mm)		Input critical shear stress τ_c (Pa)	
Critical Shear Stress τ_c (Pa)		Erodibility Coefficient (cm^3/Ns)	

Data Sources:
Bank Model data sources.
Fredlund DG, Rahardjo H. 1993. *Soil Mechanics of Unsaturated Soils*, John Wiley & Sons, Inc., New York

Figure 6 – Bank material properties can be selected from drop down boxes with assigned values for a range of material types such as boulders, moderate silt, coarse rounded sand etc or *in situ* field measurements can be input as 'own data'.

If 'Own data' is selected from the drop down boxes, all cells for that layer must be filled in, except for Chemical concentration. Groundwater Model Input Data values are chosen from the table above, representing the most appropriate material type or friction angle. If critical shear stress is known but not the erodibility coefficient, one can be generated by the model using a relation created by Simon *et al*. (2010). The critical shear stress of a non-cohesive particle can also be generated using the median particle diameter. If vegetation is present on the bank face or toe critical shear stress can be increased an order of magnitude to account for the added resistance of the roots (Bankhead *et al.*, 2011). The layers represented with bank material data here, must equal the number of layers listed in the Input Geometry sheet.

<u>4. Grain Size Distribution</u>

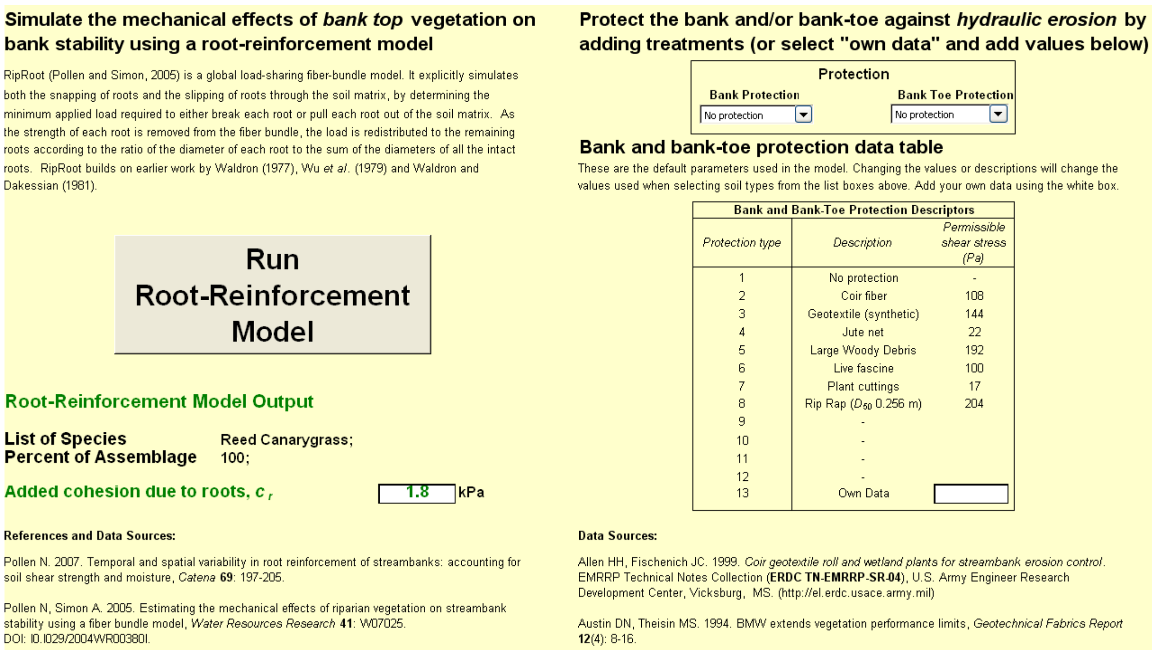
A grain size distribution must be entered for each layer where ‘own data’ was selected and every cell must be filled out (Figure 7). A grain size distribution must be added for each layer listed in the “Bank Material” worksheet. This particle size data is used within the model to calculate sediment loadings by size class for hydraulic and geotechnical erosion at each time step.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
	Size (mm)	**<0.002**	**<0.025**	**<0.063**	**<0.088**	**<0.125**	**<0.178**	**<0.25**	**<0.354**	**<0.5**	**<1.41**	**<2.0**	**<4.0**	**<8.0**	**<16.0**	**<32.0**	**<64.0**	**>65**
	Phi	**9**	**5.5**	**4**	**3.5**	**3**	**2.5**	**2**	**1.5**	**1**	**-0.5**	**-1**	**-2**	**-3**	**-4**	**-5**	**-6**	
	Description	**Clay**	**Fine,Medium & Coarse Silt**	**Coarse & Very Coarse Silt**	**Very Fine Sand**	**Very Fine Sand**	**Fine Sand**	**Fine Sand**	**Medium Sand**	**Medium Sand**	**Coarse & Very CoarseSand**	**Very Coarse Sand**	**Very Fine Gravel**	**Fine Gravel**	**Medium Gravel**	**Coarse Gravel**	**Very Coarse Gravel**	**Boulders**
LAYER	**1**	3.09	8.36	11.20	13.37	17.20	22.60	31.82	40.65	47.11	70.49	76.37	80.17	83.95	86.40	90.54	100.00	100.00
	2	3.06	8.62	17.73	22.73	34.03	52.22	71.75	90.41	97.29	99.87	99.87	100.00	100.00	100.00	100.00	100.00	100.00
	3	2.00	6.27	27.43	35.99	47.08	56.07	64.47	70.46	75.11	81.29	83.25	91.87	96.41	100.00	100.00	100.00	100.00
	4	1.44	5.44	13.12	17.33	23.11	27.76	30.86	32.65	34.07	36.87	39.76	39.76	40.96	45.78	62.65	86.14	100.00
	5																	
	Toe	1.44	5.44	13.12	17.33	23.11	27.76	30.86	32.65	34.07	36.87	39.76	39.76	40.96	45.78	62.65	86.14	100.00

Figure 7 – Grain size distribution in entered for every layer where user data has been entered in the Bank Material sheet.

5. Bank Vegetation and Protection

The ‘Bank Vegetation and Protection’ sheet allows the incorporation of mechanical and hydraulic resistance through root reinforcement and or a range of bank and bank toe protection methods (Figure 8). Bank and toe protection options include Coir fiber, Geotextile, Jute net, Large Woody Debris, Live fascine, Plant cuttings, Rip Rap and are given by a drop down box.


Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species Reed Canarygrass;
Percent of Assemblage 100;

Added cohesion due to roots, c_r 1.8 kPa

References and Data Sources:

Pollen N. 2007. Temporal and spatial variability in root reinforcement of streambanks: accounting for soil shear strength and moisture, *Catena* **69**: 197-205.

Pollen N, Simon A. 2005. Estimating the mechanical effects of riparian vegetation on streambank stability using a fiber bundle model, *Water Resources Research* **41**: W07025. DOI: I0.I029/2004WR00380I.

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection
Bank Protection: No protection
Bank Toe Protection: No protection

Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors		
Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	

Data Sources:

Allen HH, Fischenich JC. 1999. *Coir geotextile roll and wetland plants for streambank erosion control*. EMRRP Technical Notes Collection (**ERDC TN-EMRRP-SR-04**), U.S. Army Engineer Research Development Center, Vicksburg, MS. (http://el.erdc.usace.army.mil)

Austin DN, Theisin MS. 1994. BMW extends vegetation performance limits, *Geotechnical Fabrics Report* **12**(4): 8-16.

Figure 8 – The ‘Bank Vegetation and Protection’ sheet allows the incorporation of mechanical and hydraulic resistance through root reinforcement and or a range of bank and bank toe protection methods.

In order to run the Root-Reinforcement Model some knowledge of site vegetation is required. Once the ‘Run Root-Reinforcement Model’ is clicked a box appears asking for the maximum rooting depth (Figure 9). This is often considered to be 1 m in riparian environments. It should be noted that this is from top bank (point B in the ‘Input Geometry’ sheet), therefore if you have vegetation growing on the bankface 1 m below the banktop with roots extending down 1 m, the maximum rooting depth entered here should be 2 m.

The next box is the RipRoot Model where the user is prompted to select a species of vegetation from the drop down box (Figure 10). Species options include: Bare soil, Alder, Ash (Oregon), Birch (River), Blackberry (Himalayan), Canarygrass (Reed), Cottonwood, Gamma Grass (Eastern), Meadow (Dry), Meadow (Wet), Olive (Russian), Pine (Lodgepole, Longleaf), Ryegrass (Perennial), Spirea (Douglas), Sweetgum (American), Switch Grass (Alamo), Sycamore (Eastern), Tasmarisk, Willow (Black, Geyer’s, Lemmon’s, or Sandbar). There is also the option to enter ‘Own Tensile Strength Parameters’.

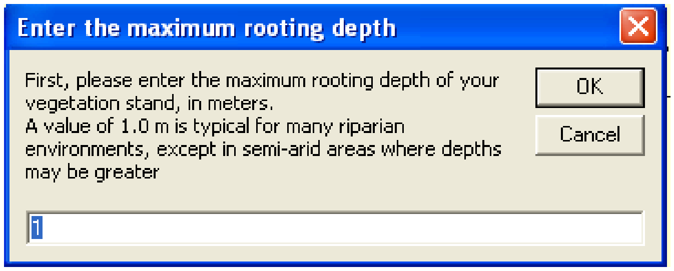


Figure 9 – When running the Root-Reinforcement Model the first box prompts the user for maximum rooting depth of vegetation.

Once a species has been chosen the user must provide either the plant age and percent contributing to assemblage, or the number of roots (by diameter class, in mm), if such information is known. For example there might be 20 % 10 year old Oregon Ash, 5 % 50 year old Oregon Ash, 45 % Himalayan Blackberry and 30 % Reed Canarygrass. Each time a species, age and percentage is added to the assemblage, the user should 'Click to add another species' until after the last species when they 'Click when you are finished entering assemblage data'. At which point a box pops up confirming the assemblage entered and providing the added cohesion by vegetation. This value is automatically added to the critical shear stress provided in the 'Bank Material' sheet when the model is run. It is important to note that this value is partly dependent on bank material type so if the information changes for a given bank material layer, the Root-Reinforcement Model should be re-run. Should the user have tensile strength parameters, a root tensile strength power regression and number of roots per diameter class can be entered into the RipRoot Model having chosen the 'Own Tensile Strength Parameters' from the drop down box.

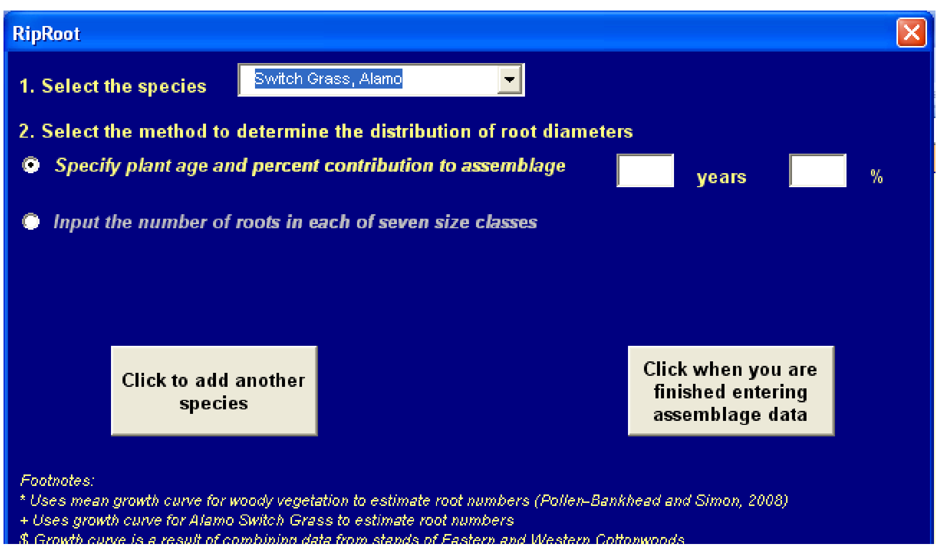


Figure 10 – RipRoot Model to estimate the added resistance of vegetation root networks to the bank.

6. Run Model

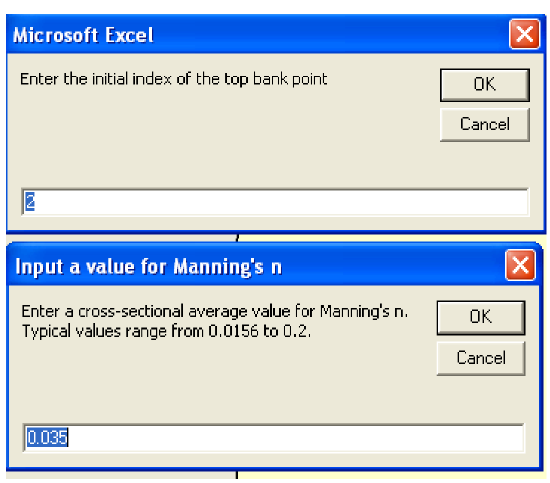
In order to run the model, flow data with a date and time stamp must be entered into the 'Calculations' sheet under the appropriate columns (Row 66 columns A and B respectively). Stage must be in meters and appropriate to the elevations in the bank profile.

It is useful to check that maximum flow does not exceed the bank top, and that the minimum flow is above the minimum elevation of the input geometry profile. Due to the way in which flows are cut into segments to each node in the bank profile from the center of the flow, it is also important that long periods of very small flows do not occur (0.1 – 5 cm range), as this can cause flow to be concentrated in these very small areas artificially increasing localized shear stresses. Should this be the case, the minimum elevation of the bank profile may have to be decreased to increase those small flows.

It is also useful to annotate the top of the stage column with the Manning's n that this given flow represents, for future reference.

One last thing to consider is that 'effective stress acting on each grain' can be switched on or off and that in cases where large amounts of erosion occur, changing the cross-sectional profile and thus flow stage in relation to the profile, the stage can be recomputed at a given time interval (in years).

Once all input data has been checked and the flow data has been entered, the model is ready to be run by clicking the 'Run Model!' button. The user will be prompted to "Enter the initial index of the top bank point" with the default value as 2. Since Point B is always top of bank, this value should always be 2. The user is then prompted to provide a Manning's value, with a default value of 0.035. Remember that different Manning's n values require different stage data depending on Normal Depth calculations.



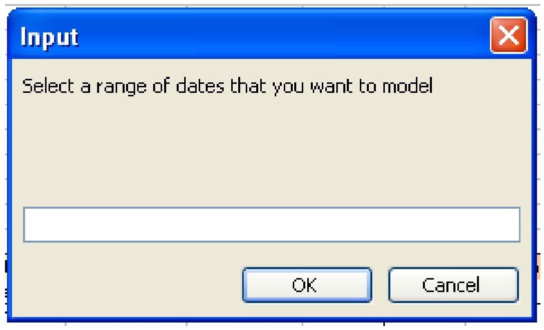


Figure 11 – Once all data has been checked and flow data input, the model is ready to be run. The user is prompted to input the top bank point, the Manning's n to be used and select dates to be run.

Model run time varies greatly, and can depend on things such as computer processing power, how many runs are computing at once, how much erosion is being calculated by the model, length of the flow period and time step.

7. Model Output

Once the model has finished running the numerical results are output to the "Calculations" worksheet. Here the factor of safety, average and maximum boundary shearstresses, volumes of geotechnical and hydraulic erosion, and masses of sediment eroded from each particle size class are output for each time step. On a separate worksheet the before and after bank profiles are plotted. Additionally output graphs are plotted automatically to show:

1) Factor of safety over time
2) Average boundary shear stress over time
3) Maximum boundary shear stress over time
4) Flow stage over time
5) Geotechnical erosion at each time step
6) Hydraulic erosion at each time step
7) Total erosion at each time step
8) Cumulative total erosion over the modeled time period

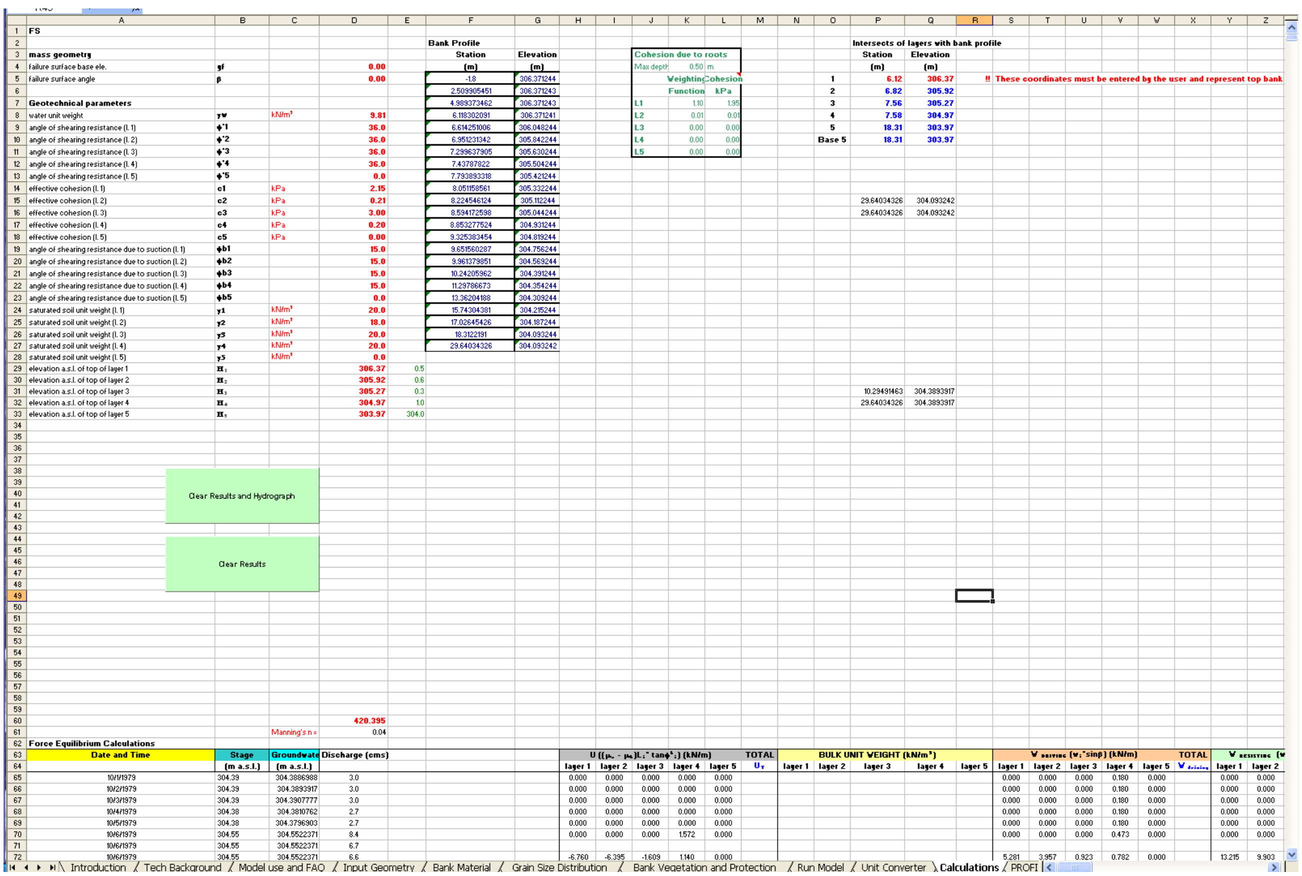


Figure 12 – Once the model has finished running the numerical data are output to the "Calculations" worksheet and graphs of several variables are automatically output to separate worksheets, including before and after bank profiles.

Below is a flow chart summarizing the way the hydraulic and geotechnical algorithms interact once the "Run Model" button has been pressed. (

Figure 13).

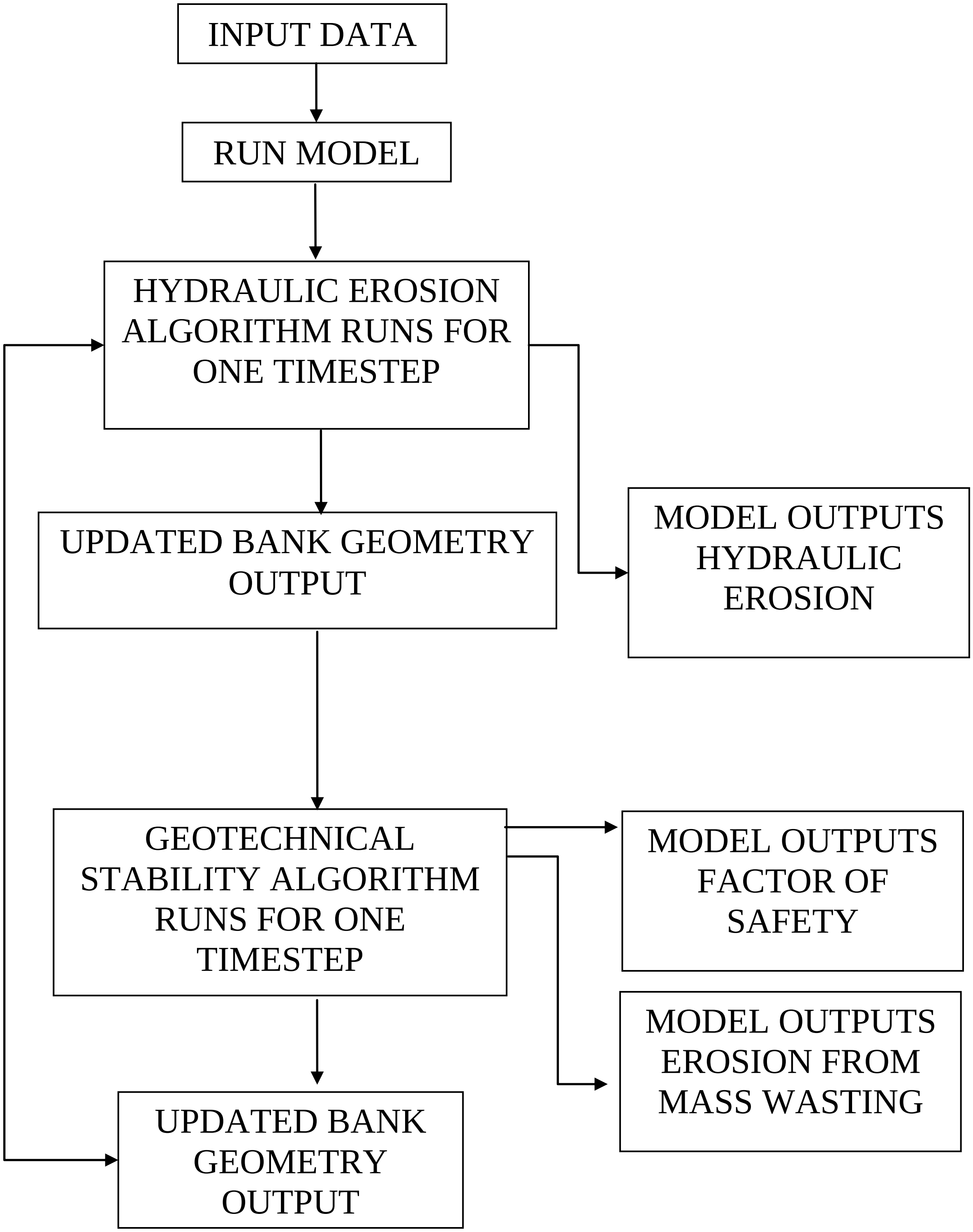


Figure 13 – Flow chart illustrating the Bank Stability inner workings to output Factor of Safety and erosion from both hydraulic and mass failure processes.

8. Model Tips And Tricks

Input data quality control

1. Input geometry. Check the position of the top bank node (bear in mind that with levees, this may not be node 2). Check the position of the top toe node. There should be a maximum of 6 points channelward of the top toe node. Compare the elevation of the base of the lowest layer against the minimum elevation in the bank profile.
2. Bank material. Check that all the required data has been entered for all the layers and the toe (be especially careful that you have entered a unit weight for the toe). If the entered values or description matches that for boulders, cobbles, gravel or sands, select that material type from the drop down box. This will ensure that the correction to account for the portion of the total boundary shear stress acting upon the grains comprising the boundary is performed correctly.

How to assess the appropriateness of the inputted erodibility coefficient

As shown in equation 4, the rate of erosion, ε, of cohesive materials can be predicted by:

$$\varepsilon = k(\tau_o - \tau_c) \qquad \text{(for } \tau_o > \tau_c\text{)}$$
$$\varepsilon = 0 \qquad \text{(for } \tau_o \leq \tau_c\text{)}$$

-4

where ε = erosion rate (m s^{-1}), k = erodibility coefficient ($m^3N^{-1}s^{-1}$) representing the volume of material eroded per unit force and per unit time, τ_o = bed shear stress (Pa), and τ_c = critical shear stress (Pa).

Now, let's try a thought experiment. If k has a value of 10.0 $cm^3N^{-1}s^{-1}$, that's the same as 10 µm $Pa^{-1}s^{-1}$. In other words, if $\tau_o - \tau_c$ = 1.0 Pa, we get 10 µm of erosion per second, or 3.6 cm per hour, or 86.4 cm per day. If $\tau_o - \tau_c$ = 10.0 Pa, we get 0.1 mm of erosion per second, or 36 cm per hour, or 8.64 m per day! For the observed bank materials, is that reasonable? Conversely, if k has a value of 1.0 $cm^3N^{-1}s^{-1}$, that's the same as 1 µm $Pa^{-1}s^{-1}$. In other words, if $\tau_o - \tau_c$ = 1.0 Pa, we get 1 µm of erosion per second, or 3.6 mm per hour, or 8.64 cm per day. If $\tau_o - \tau_c$ = 10.0 Pa, we get 100 µm of erosion per second, or 3.6 cm per hour, or 86.4 cm per day. For the observed bank materials, is that reasonable?

3. Grain size distribution. Make sure that grain size information has been added for all the layers and the toe. As a last resort, add a value of 100 for the >65 mm class (this cell should always be 100).

Result quality control

Plot the initial geometry and then use the data on the Time series sheet to add a plot of the final geometry. Look at the profile. Are there multiple cusps (this generally means that either the applied stress is too high (in this case, the user can add grain roughness or increase the channel roughness value if it has already been included), the critical shear stress is too low (is there an *a priori*/ defensible reason for increasing it? Is there vegetation on the bank face?) or the erodibility coefficient is too high)? How much bank top retreat has occurred? Anything more than about 1 m per year is probably excessive and therefore an attempt should be made to either increase the shear strength (increase cohesion and/or friction angle or reduce unit weight) or adjust the applied stress, critical shear stress and/or erodibility coefficient.

General Limitations

The model can simulate the most common types of bank failures that typically occur along alluvial channels. Once failure is simulated, the failed material is assumed to enter the flow. The model does not simulate rotational failures that generally occur in very high banks of homogeneous, fine-grained materials characterized by low bank angles. Although potentially damaging with regards to the amount of land loss, these failures are not common along alluvial streams. Bank undercutting by seepage erosion is similarly not included in the version described herein. Finally, the hydrologic effects of riparian vegetation, including interception, evapotranspiration and the accelerated delivery of water along roots and macro pores cannot be simulated at this time.

Attachment 18. FRCOG Comments on Pre-Application (PAD) and Study Requests

March 1, 2013

Franklin Regional
Council of Governments

March 1, 2013

Honorable Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project No. 2485-063
Turners Falls Project No. 1889-081
Comments on the Preliminary Application Document, Scoping Document 1, and Study Requests

Dear Secretary Bose:

The Franklin Regional Council of Governments (FRCOG) is the regional planning agency for Franklin County, Massachusetts. Two committees of the FRCOG, the Connecticut River Streambank Erosion Committee (CRSEC) and the Franklin Regional Planning Board (FRPB), have worked closely with the owner/operator of the Northfield Mountain and Turners Falls Projects for almost 20 years to develop and implement bank stabilization projects that address problems of significant streambank erosion occurring in the Turners Falls Pool on the Connecticut River (the Pool). This cooperative effort set aside differences over erosion causes and focused instead on working together to identify and achieve solutions that protect prime farmland, structures, and other natural resources.

Since the new licenses for these projects will be valid for 30 to 50 years, stakeholders have a "once in a lifetime" opportunity to participate in the process to identify, evaluate and mitigate the environmental impacts of these projects. We believe that it is vital for the residents and municipalities of Franklin County to be actively represented and engaged in the relicensing effort to ensure that the health and vitality of the river is sustained; to protect the region's treasured prime farmland, riparian and aquatic habitat for rare and endangered species; and to make sure that recreational areas and facilities are maintained. We hope that FERC will hold the owner of the hydroelectric projects to high standards and expectations.

We have been and continue to be concerned with the frequent and significant water level fluctuations associated with the operation of the Northfield Mountain Pumped Storage and Turners Falls projects, which result in streambank erosion and impacts to water quality, threatened and endangered species, fisheries, wetlands, and riparian and littoral habitat. In particular, we believe that the Northfield

Mountain Pumped Storage project and its operational use of the Connecticut River have been a long-term "experiment" that has resulted in significant adverse environmental impacts. We now have an opportunity to seriously consider the benefits of taking the river "off-line" and creating a closed-loop lower reservoir that would address most of the environmental impacts and specific resource concerns raised by Federal and state agencies and stakeholders.

Our regional economy benefits from the number and variety of recreational resources associated with the projects. We appreciate the applicant's efforts to maintain and enhance the projects' recreational opportunities over the years. We encourage the applicant to continue their stewardship and consider working with the local towns and regional groups to expand and enhance the recreational opportunities, which in turn will help to strengthen and grow the Franklin County economy. Tourism is important to the economy of Franklin County, which is one of the poorest counties in the state.

Representatives of the FRCOG attended the public scoping meetings held by FERC on January 30th and 31st in Turners Falls, Massachusetts. We understand from these meetings that it is FERC's intention to collectively review and consider the cumulative impacts of the five hydroelectric projects on the Connecticut River up for relicensing. The FRCOG strongly endorses this holistic and cumulative approach because we believe the river and these projects should be evaluated as a single, hydrologically-interconnected system. We recommend that the Vermont Yankee Atomic Power Station and water withdrawals also be evaluated in this review. It is imperative that FERC and the mandatory conditioning agencies have the information they need to better understand the individual and cumulative environmental impacts of all these projects and to balance power generation with environmental protection of the river.

The FRCOG believes that the magnitude of river alteration caused by these five projects and the complexity of issues involved, and the controversy of the best approaches to maintain power generation while not decimating aquatic communities and other natural resources, fully warrants an Environmental Impact Statement (EIS) under NEPA. We endorse FERC's approach to developing a single EIS for the five Connecticut River hydroelectric facilities to evaluate their individual and cumulative impacts on the river ecosystem. Now is the best opportunity in the near and long term to look at all these facilities holistically. We are committed to working with FERC and other stakeholders to implementing an Integrated Licensing Process for these projects that will positively affect the Connecticut River and its resources for present and future generations.

We recently received notification that FirstLight filed a Hydraulic Modeling Assessment of the Turners Falls Impoundment, Turners Falls Hydroelectric Project (No. 1889) and Northfield Mountain Pumped Storage Project (No. 2485) with FERC. FirstLight states in the report that "[t]he findings contained herein demonstrate that the TF Impoundment does not backwater to the base of the Vernon Dam and that the upstream influence of the TF Project is located approximately 9,000 feet downstream of Vernon

Dam, or just below Stebbins Island. The findings also show that hydraulic control of the river shifts from the TF Dam to the Gorge at a flow of approximately 30,000 cfs. Accordingly, FL intends to propose a geographic scope for its relicensing studies limited to the zone of impact of the TF Project. In addition FL will propose modifying both the width and upstream geographic extent of the Project Boundary as part of its relicensing proposal." Since the report was made available on February 22, 2013, we did not have adequate time to review the report and provide our comments as part of this letter. We respectfully request that we be given at least 90 days to provide FERC with our comments.

We appreciate the opportunity to submit our comments on the Preliminary Application Document (PAD), Scoping Document 1, and Study Requests for the projects. For ease of reference, our comments on the PAD and Scoping Document 1 are organized by the major sections in each document. The Study Requests that we are submitting to FERC are detailed in the Appendix to this letter.

Preliminary Application Document (PAD)

The purpose of the Preliminary Application Document (PAD) is to provide information on the existing environment, existing data, and studies relevant to the existing environment, and any known or potential effects of the Turners Falls Project and the Northfield Mountain Project on natural, recreational, cultural, aesthetic and socio-economic resources. The information in the PAD also helps stakeholders identify scoping issues and study needs for the FERC's National Environmental Policy Act (NEPA) document.

Section 3.4 Other Turners Falls Project and Northfield Mountain Project Information

3.4.1 Current License Requirements

We are concerned that the list of "key license requirements" for the two projects did not include Article 19 for the Turners Falls Dam (P-1889) and Article 20 for the Northfield Mountain Pumped Storage Project (P-2485). Given the amount of money the applicant has spent to address the severe and ongoing erosion in the Turners Falls Pool, we believe that the section on "key license requirements" should include Articles 19 and 20. Article 19 states, "[i]n the construction, maintenance, or operation of the project, the Licensee shall be responsible for, and shall take reasonable measures to prevent, soil erosion on lands adjacent to streams or other waters, stream sedimentation, and any form of water or air pollution. The Commission, upon request or upon its own motion, may order the Licensee to take such measures as the Commission finds to be necessary for these purposes, after notice and opportunity for hearing." Article 20 contains similar language, "[t]he Licensee shall be responsible for and shall minimize soil erosion and siltation on lands adjacent to the stream resulting from construction and operation of the project. The Commission upon request, or upon its own motion, may order the Licensee to construct and maintain such preventive works to accomplish this purpose and to revegetate exposed soil surface as the Commission may find to necessary after notice and opportunity for hearing."

The PAD does reference the 1999 Erosion Control Plan (ECP), which was developed by Simons & Associates (S&A) for the previous Licensee to address riverbank erosion in the Turners Falls impoundment. The ECP was developed in response to concerns over riverbank erosion and pursuant to Articles 19 and 20 of the FERC licenses for the Turners Falls Dam and Northfield Mountain Pumped Storage projects. The ECP was approved by FERC and includes a list of 20 riverbank segments where erosion was most severe. These sites were identified as priority sites to be considered for stabilization. Management measures for erosion control in the ECP included: restoration of eroded riverbank segments, preventative maintenance to minimize or prevent future erosion, and maintenance and monitoring of the restored sites. The ECP has been and is currently being implemented in cooperation with the Connecticut River Streambank Erosion Committee (CRSEC), of which the Licensee is a member. This ad hoc committee provides an established forum for the Licensee to coordinate with resource agencies and local landowners on erosion control projects and issues. One provision in the ECP requires the Licensee to periodically repeat the classification and prioritization process at 3- to 5-year intervals (Full River Reconnaissances) during the remaining term of the current FERC license.

3.4.3 <u>Proposed Modifications</u>
The applicant listed the following proposed project modifications in the PAD:

- Upgrading Station No. 1 with new or rehabilitated turbines.
- Closing Station No. 1 and adding a turbine generator at Cabot of similar hydraulic capacity to that at Station No. 1.
- Utilizing the full hydraulic capacity of the Cabot turbines including currently unused capacity.
- Utilizing more storage in the Northfield Mountain Project's upper reservoir.
- Increasing the unit and station capacity at the Northfield Mountain Project.

We are concerned that no specific information about these proposed modifications was included in the PAD. We request that FERC require the applicant to provide information to the public on the need and justification for these proposed modifications as soon as possible. Also, we request that any studies undertaken by the applicant to evaluate environmental impacts of the projects include the environmental impacts of the above proposed modifications to the project facilities and operations. We urge that these analyses be done early in the relicensing process so they can be fully understood and evaluated by all interested parties.

Section 4 Description of Existing Environment and Resource Impacts

4.2.4 <u>Reservoir Shoreline and Streambanks</u>
Although, as the applicant states, numerous studies have been conducted since 1979 to study erosion of streambanks along the Connecticut River, we caution that there has been a considerable amount of controversy over the findings and conclusions of several of the reports listed in this section. We are

concerned that the summary of the 1979 U.S. Army Corps of Engineers' (USACE) study provided in the PAD doesn't reference specific findings related to the Turners Falls Pool but instead includes general summary statements that are not informative or specific to this reach of the river. For example, we have excerpted general and specific findings in the 1979 USACE study, which are informative and specific to the Turners Falls Pool and should have been included in the PAD. These findings are listed below and include:

- *In the Executive Summary – "Note that forces exerted on the bank of a channel by the flowing water can be increased as much as 60 percent by such factors as flood stage variations, pool fluctuations, boat and wind waves, etc. Evaluation of forces causing bank erosion verifies the relative importance of causative factors. In descending order of importance they are: shear stress (velocity), pool fluctuations, boat waves, gravitational forces, seepage forces, natural stage variations, wind waves, ice, flood variations, and freeze-thaw."*
- *On page 21 of the report it states that the "Turners Falls Dam was raised by 5.5 feet in 1971 as a part of the Northfield Mountain Project. Prior to that time it operated similarly to the three upstream dams. Conditions have dramatically changed since completion of this project. Soils that were rarely wet are subject to frequent inundation. Pool fluctuations and variations in discharges and velocities have increased. In fact, the entire hydraulics of the system has changed."*
- *On page 51 – "Sediment and cross*-sectional data *are the two most important data gaps preventing a quantitative analysis of the Connecticut River."*
- *On pages 118-120 – "The impacts of hydropower deve*lopment *on bank stability in Turners Falls Pool have been and continue to be more severe than for the other pools. The increase in pool level, the larger pool fluctuations and flow reversals caused by the present hydropower operation all contribute to the documented bank instabilities in this part of the study reach. In analyzing the causes of bank erosion in Turners Falls Pool it is suggested that the erosion analysis presented in Table 2 and subsequent tables should be utilized. From this analysis coupled with consideration of adverse hydraulic conditions related to power generation it is concluded that:*

    1. *The maximum tractive forces that can be exerted on the banks of the river will occur during periods of moderate and major floods. Hence, power generation has not altered this condition.*
    2. *The flow reversals, turbulence and changes in river stage caused by present power generation methods have increased the tractive force sufficiently to induce bank erosion in those locations where the bank alignment and bank material causes the rate to be vulnerable to these forces.*
    3. *The increase in pool fluctuations on bank stability in Turners Falls Pool is a very significant factor. Pool fluctuations on the order of 5 feet are at least twice as destructive*

to banks or pool fluctuations of about 1-3 feet as experienced in the other hydropower pools.

4. *To stabilize the eroding banks in Turners Falls Pool will require special attention.*

In summary, if upper bank erosion is to be controlled it will be necessary to implement some measure of upper bank protection capable of withstanding the forces to which it will be subjected; also the means to provide lower bank protection to prevent failure of upper bank protection must be considered, and the cost of such bank stabilization treatments is large. Conversely, if upper bank protection is not provided where such erosion is in progress, erosion will continue until a stable terrace or bench is formed. It is estimated that upper bank erosion will slow down and in many cases stabilize within a 5-10 year period unless conditions for further upper bank erosion are set up by lower bank erosion. Furthermore, in the Turners Falls Pool upper bank erosion may extend landward on the order of 20-25 feet at vulnerable sites before some semblance of upper bank stability is achieved."

Our concerns with the methodology and findings and conclusions of the 2008 Full River Reconnaissance are well documented in our correspondence to FirstLight and FERC, yet have not been included in the PAD. We reiterate our concerns here that accurate data and a reproducible methodology are needed for documenting the type and stage of erosion in the pool and evaluating whether the pace of erosion control work is keeping up with the rate of erosion. We request that the relicensing record reflect our continuing objections to the findings of the 2008 FRR, and specifically, our objections to including statements in the PAD that reference the 2008 FRR, and all of the text on page 4-12 of the section *4.2.4.2 Shoreline and Streambank Characterization.*

4.2.4.3 <u>Geomorphic Studies</u>

We are pleased to see a reference to the 2007 Fluvial Geomorphology Study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT prepared for FirstLight by Field Geology Services. We endorsed FirstLight's decision to undertake this study and enthusiastically supported its findings and encouraged FirstLight to implement the study's recommendations. We are disappointed to find the PAD does not accurately present the important findings and recommendations of this study that are specific to the Turners Falls Pool. Instead, the PAD includes a brief, generalized discussion of erosion.

In particular, the Executive Summary of the Field study is compelling and should have been included in the PAD. Dr. John Field also offered detailed recommendations for future work in the Turners Falls pool, which, if implemented, could provide for: a) an improved understanding of the causes of erosion; b) more accurate monitoring of erosion; and c) more successful bank stabilization efforts. Following are excerpts from the Executive Summary of the report that could have been used to inform the readers of the PAD:

"Four types of bank erosion are present in the Turners Falls Pool and occur together through time at any given location. Undercutting and notching at the base of the banks results in topples and slides as the stability of the upper bank is compromised. The slide and topple blocks are disassociated into flows and deliver loose sediment to the base of the bank. This loose sediment can be carried away from the bank by water currents generated by flood flows, boat waves, pool fluctuations, groundwater seeps, and overland flow. Where sediment is moved directly offshore, beaches can form that may promote the stabilization of the bank if the accumulated sediment is not removed or beach face inundated by flood flows. The monitoring of several cross sections since 1990 shows that bank recession rates are on the order of 1.0 ft/yr, but as much as 9.0 ft of erosion has occurred in a single year (i.e., Kendall Site). The average erosion rate of 1.0 ft/yr is corroborated by the measurement of bank recession adjacent to fixed bank points along sections of river armored with rock.

The raising of the Turners Falls Dam in 1970 destabilized previously stable portions of the bank by increasing the pore pressure in bank sediments higher up the bank. An increase in pool fluctuations with the opening of the Northfield Mountain Pumped Storage Project in 1972 and an increase in boat waves accompanying greater recreational use of the Turners Falls Pool could have played a role in the increase in erosion documented by mapping in 1978 and 1990. The lack of a riparian buffer in a few localities makes the banks more susceptible to erosion due to a lack of roots to bind the soil together and an increase in runoff over the bank that can cause gullying. An increase in overall bank stability between 1990 and 2001, as documented by erosion maps, may be related to the development of beaches observed throughout much of the Turners Falls Pool.

Comparisons of erosion maps from different years must account for variations in mapping season, mapping methods, and mapping personnel. Comparisons of two different erosion maps completed in 1990 reveal several discrepancies in the location and amount of erosion. The minor increases in erosion between 2001 and 2004 are less than the discrepancies between the 1990 maps. Consequently, policy decisions based on the erosion mapping data should be carefully reviewed, because apparent differences in erosion from year to year may simply be an artifact of the mapping process. Currently 20 percent of the bank length has been protected with rock armor. As bank stabilization efforts proceed, new approaches should be considered, because the continued reliance on armoring at the base of the bank with rock, in both riprap and bioengineering projects, could lead to increased erosion elsewhere. While the development of beaches is an indication of increasing bank stability, erosion is likely to persist as natural flood flows rework beach deposits and inundate the beach face.

However, promoting the development and preservation of beaches through the addition of large woody debris could improve bank stability by buttressing the banks against erosion and by further *trapping fine sediment on the beaches. Given the complexity of issues surrounding erosion in the Turners Falls Pool the results of this study should be considered preliminary in nature. Many areas of additional study are necessary including surveys of erosion using a systematic and explicit method for mapping the types of erosion present in order to eliminate artifacts in the mapping process. Experimentation with large woody debris placements on beach faces should also begin to determine their value in improving bank stability. Only with a thorough understanding of the character and causes of erosion can effective and sustainable bank stabilization efforts be implemented throughout the Turners Falls Pool."*

The final report listed in section 4.2.4.3 is the 2012 Riverbank Erosion Comparison along the Connecticut River prepared for FirstLight by Simons & Associates (S&A). We strenuously object to the findings and conclusions stated in this report and repeated in the PAD. Unlike the USACE reports and the Field Geology Services report, the S&A report does not include a documented methodology, the analysis lacks a robust data set, and the analysis itself is qualitative and subjective.

We specifically object to the conclusion that the Turners Falls Impoundment is in better condition than all other reaches of the river studied. This conclusion is drawn solely from an analysis of a few erosion sites in the Holyoke, Turners Falls, Vernon and Bellows Falls impoundments, documented photographically in 1998 and again in 2008, the results of the 2008 FRR, and the findings of a fluvial geomorphic study that focused on the free-flowing reach of the Connecticut River farther upstream of these four impoundments (Field Geology Services, 2005). The S&A report notes that erosion was continuing in all but one of the 23 sites evaluated in the Holyoke, Vernon, and Bellow Falls impoundments. In contrast, the report claims that in the Turners Falls impoundment, most of the eroded sites were either stabilized, in the process of stabilization through erosion control measures, or experiencing some degree of natural stabilization. We note that this conclusion is based on the results of the 2008 Full River Reconnaissance, which we dispute. The 2012 S&A report goes on to state that the segment of the river with the greatest extent of eroding riverbanks is the free-flowing reach of the Connecticut River farther upstream of these four impoundments. However, we are not convinced that such a direct comparison can be made based on the paucity of data in the S&A report and dissimilar methodologies used between the S&A report and the 2005 Field Geology Services report.

4.3.1.4 <u>Water Withdrawals</u>

We are concerned that this section did not include information about FirstLight's requirement that irrigation withdrawals obtain a permit from FirstLight. We request information about the fee structure, permit language and time-frame, need for requiring the permits, and the legal authority under which FirstLight is requiring these permits. The PAD states that for the Four Star Farms' withdrawal, "[c]ompared to the Connecticut River flow at this location, this withdrawal volume is negligible. We would anticipate that this is the case for the remaining four irrigation withdrawals in this reach of the river. Uninterrupted access to irrigation water is critical to the economic viability of these farms. The need for and legality of the permits required by FirstLight is not clear. Further, the climate of uncertainty created by the need for the farmers to obtain a permit from a private corporation to use a public resource, when this permit can be at any time and for any reason revoked, is a burden that interferes with the economic viability of these farms.

Section 5 Preliminary Issues and Studies List

5.1 Issues Pertaining to the Identified Resources

We would like to add the following issues:

5.1.2 Water Resources - Effects on water quantity, particularly the availability of water to the downstream reach of the river, below the Turners Falls dam, known as the bypass channel.

5.1.3 Water Quality – Effects of the projects' operations on the levels of turbidity, total suspended solids, and nutrients in the water. Effect of project operations on water quality, which results in the river being listed as impaired by the MA DEP (Category 5 – Waters Requiring a TMDL). The entire length of the river within the projects' boundary is listed for the following impairments.

- Segment MA34-01 (3.5 miles) for "other flow regime alternations" and "alteration in stream-side or littoral vegetative covers"
- Segment MA34-02 (10.9 miles) for "alteration in stream-side or littoral vegetative covers"
- Segment MA34-03 (3 miles) for total suspended solids, "low flow alterations" and "other flow regime alternations"
- Segment 34-04 (34.4 miles) for *E.coli* bacteria
- Barton Cove is listed as impaired for non-native aquatic plants (Eurasian water milfoil).

5.2 Potential Studies or Information Gathering

5.2.1 Geology and Soils. In the PAD, the applicant states that information from previous studies will be used to assess the effects of the project operations on streambank erosion. At the Scoping Meeting, the applicant updated the list of proposed studies for this resource category to include the following:

- 2013 Full River Reconnaissance (FRR) study and development of a QAPP for the Turners Falls Impoundment.
- Hydrologic, Hydraulic and Geomorphic Analysis of Erosion in Turners Falls Impoundment.
- Analysis of Erosion in Vicinity of Route 10 Bridge Spanning the Connecticut River (completed 2012).

- Riverbank Erosion Comparison along the Connecticut River (completed 2012).

First, for the reasons articulated above and in previous correspondence with FERC, we are concerned with the applicant's plan to use information from the earlier Full River Reconnaissance (FRR) studies (2001, 2004 and 2008) and the Riverbank Erosion Comparison along the Connecticut River (2012) report. We are currently working with the applicant to develop a suitable Quality Assurance Project Plan (QAPP) and appropriate methodology for the 2013 FRR. At this point, an outline for the proposed Hydrologic, Hydraulic and Geomorphic Analysis of Erosion in the Turners Falls Impoundment has not been shared with us so we aren't able to provide specific comments other than our hope that the findings and recommendations for further study found in the 2007 Field Geology Services report are reflected in the proposed study.

5.2.3 Water Quality. Add the following to the *Study Objectives* section:

- Collect data on the levels of turbidity, total suspended solids, and nutrients in the water.
- Collect data on the effect of project operations that result in the river being listed as impaired by the MA DEP (Category 5 – Waters Requiring a TMDL) for the following impairments:
  - "other flow regime alternations"
  - "alteration in stream-side or littoral vegetative covers"
  - total suspended solids
  - "low flow alterations"
  - *E.coli* bacteria
  - non-native aquatic plants (Eurasian water milfoil).

Scoping Document 1

We have several comments to offer on the Scoping Document 1 issued on December 2012 by FERC. Our comments are arranged by the sections in the document.

3.5 Alternatives to the Proposed Action

On page 8 of the Scoping Document, the text reads that "[i]n accordance with NEPA, the environmental analysis will consider the following alternatives, at a minimum: (1) the no-action alternative, (2) the applicant's proposed action, and (3) alternatives to the proposed action." We strongly urge the FERC staff to consider a closed-loop alternative for the lower reservoir serving the pumped storage project and request that the applicant complete a feasibility study of this alternative to the proposed action.

4.0 Scope of Cumulative Effects and Site-Specific Resource Issues

We concur with the list of resources listed in Scoping Document 1 that could be cumulatively affected by the proposed operation and maintenance of the five hydroelectric projects on the Connecticut River. The Connecticut River is a public resource that is used as fuel for these hydroelectric projects, which not only generate electricity for public use (at a cost) but generate profits for the projects' owners. This is the public's first opportunity to evaluate environmental data and operational information and to suggest modifications to the way the projects operate, both individually and collectively, to avoid or mitigate the environmental impacts. We respectfully request that all project resource issues be analyzed for both cumulative and individual project effects. The geographical scope of the cumulative impacts analysis should include the main stem of the Connecticut River from the Wilder Project downstream to the Holyoke Dam.

4.3 FirstLight's Turners Falls and Northfield Mountain Pumped Storage Project Resource Issues

Our comments on this section are the same as the comments we provided on the PAD, above, for Section 5 Preliminary Issues and Studies List, 5.1 Issues Pertaining to the Identified Resources. Rather than repeating our comments here, we request that our comments on the PAD be noted as comments on Section 4.3.1 Geology and Soil Resources and 4.3.2 Water Resources of the Scoping Document 1.

6.0 Request for Information and Studies

We are aware of at least 18 Study Requests that have been drafted by Federal and state resource agencies, with the assistance of various NGOs and other stakeholders for the Turners Falls and Northfield Mountain Pumped Storage projects. The sheer number of requests indicates how little we know about the environmental impacts these projects have had and will have in the future. Further, we believe that the wide range and severity of the environmental impacts provides additional support for a closed-loop alternative to using the Connecticut River as the lower reservoir for the Northfield Mountain project. We support these Study Requests and encourage FERC to require the applicant to undertake these studies. FRCOG staff reviewed and provided comments during the drafting of these study requests. FRCOG endorses and submits the following study requests as its own in support of the resource agencies and a complete relicensing process.

1. Study of shoreline erosion caused by Northfield Mountain Pump Storage (NMPS) operations.
2. Study of feasibility for converting Northfield Mountain Pump Storage (NMPS) station to a closed-loop or partially closed-loop system.
3. Study of Northfield Mountain/Turners Falls Operations Impact on Sedimentation and Sediment Transport.
4. Water Quality Study.

5. Impacts of Water Level Fluctuations on Aquatic Vegetation Including Invasive Species and their Associated Habitats in the Project Impoundment.
6. Model River Flows and Water Levels Upstream and Downstream from the Turners Falls Project Dam Generating Stations and Integration of Project Modeling with Upstream and Downstream Project Operations.
7. Develop A Comprehensive And Predictive Model Of The Electrical Generation System Consisting Of Five Generation Projects Along The Connecticut River To Study The Impact and Feasibility Of Various Changes In Operations On Environmental Resources

Detailed discussion of these Study Requests is included as an appendix to this letter. It should be noted that no fishery study requests are included. While FRCOG supports those requests as relevant and important to understanding the impact of the hydroelectric projects on the Connecticut River, fisheries are outside of its purview. We encourage FERC to accept the study recommendations of the Federal and state fishery agencies.

We appreciate the opportunity to provide comments on the PAD, Scoping Document 1 and the Study Requests. We look forward to continuing our active engagement in the relicensing of the Connecticut River hydroelectric projects.

Sincerely,

Bill Perlman, Vice-Chair
FRCOG Executive Committee

Jerry Lund, Chair
Franklin Regional Planning Board Executive Committee

Tom Miner, Chair
Connecticut River Streambank Erosion Committee

cc: Franklin County Legislative Delegation
US Fish & Wildlife Service
Massachusetts Department of Environmental Protection
Massachusetts Department of Conservation and Recreation
Congressman James McGovern
Town of Gill, MA
Town of Northfield, MA
Town of Montague, MA
Franklin Conservation District
Connecticut River Watershed Council
Nathan L'Etoile, Four Star Farms
John Howard, FirstLight Power

Attachment: Appendix 1 – Franklin Regional Council of Governments' Study Requests

Appendix 1
Franklin Regional Council of Governments' Study Requests

Study Request 1 - Study of Shoreline Erosion Caused by Northfield Mountain Pumped Storage (NMPS) Operations

Development of the current configuration of the Northfield Mountain Pumped Storage project included raising the dam height at Turners Falls by 5.9 feet in 1970 in preparation for NMPS operations. Operations began in 1972; since then all project operations have operated under this raised dam environment. The additional 5.9 foot in elevation changed the elevation of the Turners Falls impoundment, which extends some 20 miles upstream. The increase in river elevation also resulted in motorized boat traffic becoming more popular and makes the use of larger boats more possible. The presence of motorized recreational boats increases wake energy that can accelerate bank erosion rates.

The operation of NMPS causes alterations to the river as a direct feature of plant functionality. The alterations include: 1) daily fluctuating pond levels which at times in some places can exceed six feet (the license allows fluctuations up to 9 feet measured at an undisclosed location near and upstream of the Turners Falls dam); 2) altered flow and velocity profiles of river; 3) reversal of river flow direction; and 4) changes to the downstream hydrograph. Elevation data for the river in Appendix E of the PAD indicate that stage changes of 2 to 3 feet during the summer of 2012 were not uncommon.

Raising the level of the river can saturate bank soils. These same soils can quickly become dewatered when the river is lowered by the NMPS pumping cycle. Repeated saturation and dewatering of banks can lead to bank instability which in turn can lead to bank failure and eroded material entering the river. See Field (2007)[1] for an extended discussion on bank erosion and failure mechanics. Elevated levels of turbidity and suspended solids in the water column can diminish spawning, rearing and migratory habitat for fish. When too much fine grain material is deposited on channel bed substrates, particularly those substrates used for spawning, spawning success of resident and migratory fish is compromised, potentially reducing recruitment and carrying capacity.

Goals and Objectives

The goals of this study request would be to determine the environmental effects of the presence and operation of the licensed facilities on river bank stability, shoreline habitat, agricultural farmland, wetland resources, bed substrate, and water quality in the Turners Falls impoundment. We recognize that data from other studies will be made available and we think that the data from these other studies could be used to help meet the objectives of this study request.

Objectives of the study include the following:

1. Calculate the total volume of eroded material, calculate resulting nutrient loading of eroded material, and document and describe the three dimensional changes to the bank, including lateral bank recession, changes to bank slope, and the presence and subsequent inundation of pre-

[1] Field Geology Services. (2007). *Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT*. Prepared for Northfield Mountain Pumped Storage Project. Farmington, ME: Field Geology Services.

project beaches and shoreline since the Turners Falls Dam was raised and the Northfield Mountain Pumped Storage facility came on-line.

2. Document and describe the changes to banks upstream and downstream of riverbank restoration projects, including bank recession.
3. Identify the changes that have occurred to bed substrate as a result of fine grain material being eroded from the banks and being deposited on the channel bed.

Relevant Resource Management Goals and Public Interest Considerations

Our management goal is to ensure high quality habitat for migratory diadromous fish. Shortnose sturgeon, American shad and American eel all require suitable spawning, rearing, migratory and foraging habitat. Eroding banks and subsequent increases in turbidity and deposition of fine grained material onto bed substrates in the Turners Falls impoundment, the bypass reach and downstream of the Turners Falls project reduces the quality of habitat for these species. Elevated levels of suspended sediment are associated with a diminution in water quality which also affects the quality of habitat for native, rare and endangered fish and other aquatic and riparian species.

In addition to habitat effects, soil erosion contributes to nutrient loading. In 2001, the U.S. EPA approved New York and Connecticut's Long Island Sound (LIS) dissolved oxygen TMDL. As a result, the New England Interstate Water Pollution Control Commission (NEIWPCC) established the Connecticut River Workgroup and the Connecticut River Nitrogen Project. This project is a cooperative effort involving staff from NEIWPCC, the states of Connecticut, Massachusetts, New Hampshire, and Vermont, and EPA's Region 1 and Long Island Sound (LIS) offices. All are working together to develop scientifically-defensible nitrogen load allocations, as well as an implementation strategy, for the Connecticut River Basin in Massachusetts, New Hampshire, and Vermont that are consistent with TMDL allocations established for LIS. Since its inception, the Connecticut River Workgroup has participated in a number of projects to better understand nitrogen loading, transport, and reductions in erosion.

Public Interest Considerations if Requester is not a Resource Agency.

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Existing Information and Need for Additional Information

The PAD makes reference to several studies in section 4.2.4 including the Erosion Control Plan (Simons & Associates, 1999), previous Full River Reconnaissance studies (1998, 2001 – maps but no report generated, 2004, and 2008), Field Geology Services' 2007 fluvial geomorphic investigation of the Turners Fall impoundment, and 2012 investigations by Simons & Associates.

Field Geology Services' 2007 investigation provided several good recommendations for future work in section 9.3 of its report which, if implemented, could provide for: a) an improved understanding of the causes of erosion; b) more accurate monitoring of erosion; and c) more successful bank stabilization efforts. This document is a good point of reference. The Simons & Associates' (2012) documents are qualitative and based on several unstated assumptions that may not be valid. Full River Reconnaissance efforts have been undertaken using varying methodologies, making for difficult comparisons from one report to the other.

We believe that these existing studies do have data that can be useful if certain new analyses are undertaken. These analyses of existing data would help fill in our gaps of understanding of bank erosion in the Turners Fall impoundment. We are also asking for the collection of additional field data. With the existing and additional information, it should be possible to better display what changes have occurred to streambanks over time. Current Geographic Information System (GIS) software allows for various types of data to be assembled into a map and into a database such that change over time analysis can be conducted fairly easily. The change over time analysis is a critical analysis that is needed, and was already started under Field (2007).

Photos that have been taken at or near the same location but at different times exist. For example, the last three Full River Reconnaissance efforts have included continuous videotaping of the river banks with locational information. With these data, "snapshots" of the bank at various locations could be extracted and compared over time. Field (2007) photo locations could be re-shot as well. This existing information should be presented such that it is easy to discern where the photo was taken and what changes have occurred over time. A comparison of the bank every 100 ft could be compared over the years.

Historic aerial photography for the Turners Fall impoundment should be gathered and analyzed. Examples of good photographic datasets include the Field 2007 appendices and 1929 aerials. The location of the shoreline over time should be noted such that it is easy to discern where bank retreat has been most severe and where the river has been relatively stable since the earliest aerial photograph was taken.

Very little turbidity data for the Turners Falls impoundment, the bypass reach or stretches of the Connecticut River downstream of the Turners Fall project exist. Thus far, implementation of the *Northfield Mountain Pumped Storage Project Sediment Management Plan* (revised February 15, 2012) has yielded few results, and many technological difficulties (see *2012 Sediment Management Plan – 2012 Summary of Annual Monitoring* dated November 30, 2012). Suspended sediment monitoring equipment is installed at the Route 10 Bridge upstream of the project and inside the powerhouse, theoretically taking readings representative of pumping and discharging through the turbines. An analysis of how turbidity might change relative to rapidly changing impoundment levels would be very useful information.

Nexus to Project Operations and Effects

The construction of the NMPS project was contingent upon the Turners Falls project raising the dam crest elevation by 5.9 feet. The NMPS project operations rely on the Turners Falls impoundment as the source of water to be pumped up and then discharged back into the river through turbines. The importance of this river reach to the NMPS operation is made clear by FirstLight's reference to this portion of the river as the "lower reservoir." Daily pumping and discharging changes the ponded elevation of the Connecticut River which in turn leads to bank material that repeatedly becomes saturated and then dewatered. Weakened bank material can then become eroded and the fine grain material from the banks can enter the water column and be transported in suspension in the river and eventually settle onto bed material. The raising of the Turners Falls impoundment also made recreational boating more popular, including the introduction of large, high-horsepower powerboats that were not previously present. Because of the fluctuating water levels, boat wakes impact the shoreline to a much greater extent than would occur if levels were more constant, thus exacerbating both the effects of the wakes and the fluctuating levels. For these reasons, erosion caused or contributed by NMPS project operation can negatively affect spawning, rearing and migratory habitat for rare and endangered species, including the endangered shortnose sturgeon. The requested study will help inform the mandatory conditioning agencies and stakeholders when contemplating mitigation measures and or operational modifications.

Proposed Methodology

1. This study should determine the net soil loss in cubic yards between 1970 and the present; a density estimate of the eroded material should also be provided. Provide an analysis of where the greatest loss has occurred, location of proximity to the tailrace, soil type, riparian land use, and vegetative cover in that area. Calculate nutrient loadings (nitrogen and phosphorus compounds) to the river system based on soil loss.
2. Obtain copies of the original survey plans for the project, and complete a new survey using the same landmarks used previously. The Field (2007) report states on page 11 that the original survey plans of the river are still retained by Ainsworth and Associates, Inc. of Greenfield MA. Use pre-operation aerial photos and current aerial photos to complete a 10-foot topographic map of the section of river between Turners Falls Dam and Vernon Dam and the 200-foot buffer regulated under the Massachusetts Rivers Protection Act. The Field (2007) report on page 11 states that Eastern Topographics, Inc. determined that sufficient information is known about the 1961 aerial photos (e.g., height of airplane) to create a 10-foot topographic map of that time period, and that 1961 aerial photos could be accurately overlaid with recent aerial photos. Field (2007) states that this analysis would enable a more reliable determination of small-scale shifts in channel position and changes in bank height that may have resulted from the erosion of a low bench that previously existed along portions of the river. Among other things, create a single map showing areas of erosion and deposition, and also overlay the Field report's hydraulic modeling analysis of the river channel.
3. With respect to the January 22, 2013 submittal from FirstLight to FERC regarding its long term monitoring transects in the Turners Fall impoundment, we ask that any data errors (as discussed

in Field, 2007) and problems that have occurred over the years at each site be mentioned. We also ask that an analysis for each cross section extending to the top of the bank and including a portion of the floodplain be provided.

4. Take the information presented in Figure 4.2.3-1 "Soils in the vicinity of Turners Falls and Northfield Mountain projects" in the PAD and convert from 63 categories to just a few that are defined in a key that will allow readers to understand which soils are easily erodible, which aren't, and where there is bedrock along the banks.
5. Complete detailed surficial mapping (topographic map or LIDAR) to identify the various geomorphic surfaces, height of benches/terraces above the river level, and types of sediments underlying the surfaces. This will allow one to determine how erosion varies with geomorphic conditions. One could then normalize the amount of erosion to a specific type of bank material/geomorphic surface/terrace.
6. Another information request covers the range of daily water level fluctuations. In this study request, we ask for an analysis on the degree to which boat wakes increase that fluctuation range. The task would be to observe boat wakes under a range of boat sizes and flow rates on the river. We recommend implementation of the 2007 Field report recommendation that states, "A more thorough study of boat waves is merited to better document how many boats use the Turners Falls Pool, how fast they travel, the type and size of waves they produce, and their impact on shoreline erosion."

A component of this study request is not necessarily for new data, but for existing data to be presented in a more clear, coherent and comprehensive manner. All existing photographs of banks that have been collected either by FirstLight, on behalf of FirstLight or on behalf of the FRCOG Connecticut River Streambank Erosion Committee should be geo-referenced in such a way that it is easy to discern where the photograph was taken and the date should be easily discernible as well. These photos should be presented in a manner that makes it easy to visualize how a particular section of bank has changed over time. Providing geographic context for photographic data of river banks and making these photos comparable over time should be standard practice. The 2007 Field report contains the following recommendation on page 47: "An attempt should be made to overlay the 1961 aerial photographs with a current flight and to create a topographic map from the 1961 flight. The feasibility of this effort has been confirmed by Eastern Topographics, Inc. This effort will identify the previous extent of the low bench and identify areas of the most significant bank recession the past 45 years." Given that this statement was written in 2007, we request that that the analysis is extended to current conditions.

Given the complexity of this study request and the expertise necessary to implement it, we request that we and the mandatory conditioning agencies be involved with the selection of the hired consultant.

Level of Effort and Cost

The level of effort to compile existing information and to make the data available in a map and searching for existing bed substrate material data should not take more than a few days. The level of effort for the bed sampling work will vary based upon how much existing historic information exists. Much of the effort of this study request is essentially office work that compiles and better presents existing data. While an estimate on the amount of field time required, including a current flight for aerial photography (LIDAR) or a topographic map survey, is difficult to make, we estimate that up to two weeks of field work could be required and that some of the data collection could be done while other field studies are occurring.

Study Request 2 – Study the Impact of Operations of the Northfield Mountain Pumped Storage Project and Turners Falls Dam on Sedimentation and Sediment Transport in the Connecticut River

Goals and Objectives

The goal of this study request is to provide hydraulic and sediment transport modeling of both the intake and discharge conditions (current and proposed) at the Northfield Mountain Pumped Storage Project. The results of the study should provide information sufficient to enable mandatory conditioning agencies and stakeholders to understand current and proposed effects on water level fluctuations and relate them to potential increase in sedimentation to the Connecticut River. Mandatory conditioning agencies and stakeholders should be able to identify techniques that could be used to mitigate the effects of project operations or other mitigation techniques that could be developed to reduce riverbank erosion within the impoundment. In addition, an assessment of means to minimize the sediment load passing through the Turners Falls Canal during and after maintenance drawdowns should be conducted.

The specific objectives of this study are as follows:

1. Assess hydraulic and sediment dynamics in the Connecticut River from Vernon Dam to Turners Falls Dam, the upper reservoir at Northfield Mountain, and downstream of the Turners Falls Dam.
2. Identify management measures to minimize erosion and sedimentation.
3. Determine areas of sediment deposition and beach formation in the Project Area and 1 km downstream of Cabot Station and describe habitat features of these areas, recreational uses and effects on invasive species, if any. Habitat areas include but are not limited to coves (e.g. Barton Cove), back channels, islands, wetland habitats, shorelines, shoals, deep water areas and channels.
4. Identify management measures to mitigate for substrate (habitat) impacts and recreational impacts in sediment-starved areas below the dam and sediment accumulation areas upstream of the dam.

Relevant Resource Management Goals and Public Interest Considerations

The resource management goal is to ensure that the Connecticut River, which is designated as a Class B river for its entire length in Massachusetts, meets its designated uses of habitat for fish, other aquatic life and wildlife, and for primary and secondary contact recreation. Class B waters must also have consistently good aesthetic value and meet minimum criteria for numerous water quality indicators to achieve compliance with the standards set forth in the regulations. The other resource management goal is to protect prime farmland soils, which are eroding, and riparian habitat. Eco-based tourism and agricultural operations are important to the economy of Franklin County so maintaining the water quality of the river and protecting scenic landscapes and productive farmland along the river from erosion are important.

Public Interest Considerations if Requester is not a Resource Agency

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Existing Information and Need for Additional Information

The PAD provides a summary of the work that has been done to characterize streambank conditions of the Turners Falls Impoundment, to understand the causes of erosion, and to identify the most appropriate approaches for bank stabilization. There has been no work undertaken to gather and assess the data that this study request would provide. Implementation of the *Northfield Mountain Pumped Storage Project Sediment Management Plan* (revised February 15, 2012) was begun in 2011 and is scheduled to end in 2014. This is a limited study related to sediment problems in the upper reservoir, not the entire river.

Nexus to Project Operations and Effects

The Turners Falls and Northfield Mountain Pumped Storage projects operate in a peaking mode, with allowable impoundment fluctuations of up to 9 feet, with the intent to continue these fluctuations. It is proposed to evaluate increasing the volume of flow from the Northfield Mountain Pumped Storage Project through increased use of the upper reservoir, which is expected to result in additional water level fluctuations. Upstream hydroelectric facilities also operate in a peaking mode of operation. Periodically, the upper reservoir at Northfield Mountain and the power canal at the Turners Falls dam need to be dewatered for maintenance purposes. Historically, both procedures have resulted in the discharge of large quantities of sediment. Sediment from shoreline erosion and riverbank failure is one of the major contributors that negatively affect water quality and habitat by increasing the turbidity and sedimentation, and smothering aquatic habitat. Repetitive water level fluctuations and flow alterations caused by hydroelectric peaking operations are known to be a major contributor to shoreline erosion.

The Proposed Massachusetts Year 2012 Integrated List of Waters shows two river segments, from the VT/NH state line to the Turners Falls dam (MA34-01 & MA34-02) impaired and considered a "Water Requiring a TMDL" due to "Other flow regime alterations", "Alteration in stream-side or littoral vegetative covers" and "PCB in Fish Tissue". In addition, the segment below the Turners Falls dam to the confluence with the Deerfield River (MA34-03) is impaired by these causes as well as total suspended solids.

Proposed Methodology

We concur with the proposed methodology developed by the MA Department of Environmental Protection, which is consistent with accepted practices:

<u>Assess hydraulic and sediment dynamics</u>

1. FirstLight should continue implementing the Northfield Mountain Pumped Storage Project Sedimentation Management Plan over the full range of river flows and pumping/generating cycles. An unfulfilled task in the Plan is to develop a correlation over the full range of flow conditions between the overall suspended sediment transport through the entire cross section of the river compared to the continuous sampling at the single fixed location. Environmental Protection Agency approval of a Quality Assurance Project Plan is required for valid data acquisition.
2. Provide data on the daily water level fluctuation changes for the past five years from stations listed in the PAD, and estimate fluctuations within Turners Pool assuming proposed operations and hydraulic conditions.
3. Identify the most appropriate techniques for bank stabilization given the existing and proposed hydraulic conditions.

<u>Determine areas of sediment deposition in the Project Area</u>

1. Field (2007) conducted a bathymetric study as part of his report. Use previous bathymetric data, if available (Field 2007 recommends putting additional effort into finding a bathymetric survey from 1913 that was partially shown in Reid 1990), and current bathymetric information to look at areas of sediment accumulation. Determine areas of sediment deposition in the Project Area and 1 km downstream of Cabot Station and describe habitat features of these areas. Habitat areas include but are not limited to coves (e.g., Barton Cove), back channels, islands, wetland habitats, shorelines, shoals, deep water areas and channels.
2. Identify recreational uses and impacts in areas known to be impacted by accumulated sediment, such as Barton Cove.
3. Identify invasive species (plant or animal) present in the reaches and determine if erosion and sedimentation in any way contributes to the establishment and/or proliferation of these species.
   a. Investigate the formation of beaches using remote sensing, LIDAR at low pool levels or some other mapping technique to understand the processes of beach deposition the distribution of beaches in the pool, the impact of beach deposition on habitat and species, and how can this be related to the operation of NMPS.
   b. Evaluate management strategies to address the release of accumulated sediment through the Northfield Mountain Pumped Storage Project works during upper reservoir drawdown or dewatering activities. FirstLight should specifically evaluate the feasibility of the installation of a physical barrier across the bottom of the intake channel of the upper reservoir that is designed to prevent the migration of sediment during future drawdowns of the upper reservoir
4. Evaluate management strategies to minimize flow fluctuations within Turners Pool including coordination with upstream users.

5. Evaluate management strategies to minimize sediment released through spillway gates and the log sluice located near the bottom of the forebay adjacent to the Cabot Powerhouse during canal dewatering activities.
6. Identify a prioritized list of locations for bank stabilization projects in the Project Area.
7. Develop a map of land owned by FirstLight within 200 feet of the Connecticut River with an overlay of land use and vegetation cover. Provide land use options aimed at reducing bank erosion.

<u>Management measures to change sediment flow below and above the dam.</u>

1. Any historic information of existing bed substrate material in the Turners Falls impoundment, bypass reach or downstream of the project should be collected and assembled. To the extent possible, the location of each sample should be made available on a map. The request for new data would stem from being able to make any valid comparison to changes in bed substrate at a given location, assuming that historic data exists.
2. Identify measures that could be taken to mitigate impacts to recreational use, habitat, or invasive species from sedimentation.
3. Identify measures that could be taken to change or mitigate sediment starved reaches below the Turners Falls dam.

Level of Effort and Cost

Many erosion studies have already been conducted and the cost of expanding the scope of some should be reasonable. A Full River Reconnaissance under the *Erosion Control Plan for the Turners Falls Pool of the Connecticut River* (Simons & Associates, Inc. dated June 15, 1999) is scheduled for 2013 and could accomplish many of the objectives listed above.

Study Request 3 - Study the Feasibility of Converting the Northfield Mountain Pumped Storage (NMPS) Facility to a Closed-loop or Partially Closed-loop System

Building and operating the Northfield Mountain Pumped Storage project required the Turners Falls Dam be raised 5.9 feet. The Turners Falls impoundment of the Connecticut River acts as the lower reservoir and is subject to large sub-daily fluctuations in water level. The collateral environmental consequences of using the Connecticut River during the pumping and generation cycles for the last 40 years are not fully understood, but have likely contributed to extensive erosion of streambanks, downstream sedimentation, entrainment of large numbers of resident and migratory fishes, and destruction of important spawning and nursery habitat, both within the Turners Falls Pool and downstream. Intrinsic consequences include radical fluctuations in the hydrograph at a sub-daily level, which also negatively impact recreation, habitat, and likely disrupts key life history stages of resident and migratory fishes, benthic invertebrates, and macrophytes. The vast majority of proposed new pumped storage projects currently being considered by FERC are closed-loop because of a growing consensus that open-cycle pumped storage causes unacceptable environmental damage.

Resource agencies have identified restoration of a more natural hydrograph to the Connecticut River as a key management goal, and view the current relicensing process for five projects on the Connecticut River mainstem as an opportunity to achieve this. Converting to closed-loop or partial closed-loop would allow the restoration of ecological flows to the Connecticut River, and provide much greater flexibility in operational guidance for both NMPS and the other hydropower stations on the Connecticut River. It will also eliminate or partially eliminate many of the environmental concerns expressed by Federal and state agencies and other stakeholders, which are outlined in the numerous study requests and comment letters that FERC will receive on the NMPS project and the other four hydropower projects.

Goals and Objectives

The goal of this study request is to provide resource managers, stakeholders, and the licensee with an analysis of possible options for converting the plant to a close-loop or partially closed-loop system.

The objectives of this study request would be to determine:

1. Candidate locations for placement of a lower reservoir.
2. Costs and logistics of construction and modification of the current facility to convert to a closed-loop or partially closed-loop system.
3. Projected savings associated with eliminating need for ongoing mitigation measures, both for stabilizing river banks as well as likely modification to operations that the facility that will be required to implement in order to protect habitat and native fauna.
4. Other ancillary costs or savings, such as eliminating requested studies, operational changes, or mitigation measures.

Relevant Resource Management Goals and Public Interest Considerations

The resource management goal is to ensure high quality habitat for migratory diadromous fish. Shortnose sturgeon, American shad, blueback herring, and American eel all require suitable spawning, rearing, migratory and foraging habitat. Eroding banks and subsequent increases in turbidity and deposition of fine grained material onto bed substrates in the Turners Falls impoundment, the bypass reach and downstream of the Turners Falls project reduces the quality of habitat for these species. Elevated levels of suspended sediment are associated with a diminution in water quality that also affects the quality of habitat encountered by endangered species. Entrainment into the facility could be lethal to any of these fish. Juvenile and larval stages of resident and migratory species, including rare, threatened, and endangered species of vertebrates and invertebrates are particularly vulnerable to entrainment. This damage is aggravated by the repeated cycling of the facility—unlike standard hydro, where organisms are likely only exposed to passage events a single time and may bypass the system safely, NMPS continuously recycles river water, and therefore increases the risk of exposure to entrainment and death.

Public Interest Considerations if Requester is not a Resource Agency

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Existing Information and Need for Additional Information

Data on environmental effects of NMPS and facilities that use fresh or salt water for generation and/or cooling are widely available and consistently indicated that these types of hydroelectric facilities damage native and migratory fauna. Once plentiful populations of blueback herring have been entirely eliminated from this portion of the Connecticut River. Populations of American eel are in steep decline throughout this reach, and American shad that initially used fish passage facilities downstream of NMPS have experienced dramatic reductions above Turners Falls Dam.

Section 4.4.6 of the PAD (page 4-146) discusses entrainment at Northfield Mountain of migratory fish species. Previous studies estimated 28.6% of Atlantic salmon entrained, which was reduced to 6.7% after the installation of a guide net only during upstream passage season. LMS Engineers estimated in 1993 that the facility impacted 0 to 12.4% of adult American shad passing the water intake. No studies have looked at impacts to resident fish or other migratory fish or other times of the year, but several study requests address this information gap.

Other facilities in the region (Brayton Point Power Station, a coal plant in Mt. Hope Bay) have been required by EPA to switch from open- to closed cycle at very significant cost because of the extensive damage done to fragile habitats by open-cycle pumping.

Streambank erosion has been a major concern since NMPS began operation in 1972. Section 4.2.4 of the PAD summarizes the extensive work that has been done to study and mitigate erosion along the river banks. Significant loss of agricultural land has resulted from unnatural river fluctuations and increased boat wakes from a raised impoundment, and in some cases poor mitigation efforts like helicopter removal of trees along the banks. Since 1996, the licensee has reportedly spent $750,000 - $1,000,000 annually on erosion control measures. In some cases, these projects will need to be re-done in the future. Converting the plant to closed-loop operation could provide significant cost savings over the life of the upcoming license, eliminating erosion control projects, proposed studies related to use of the Connecticut River as a lower reservoir, and any mitigation or operational changes to protect fisheries and other natural resources that may be contemplated as a result of relicensing.

Nexus to Project Operations and Effects

In conjunction with other study requests, parties to the relicensing process will be reviewing data and considering operation and facility conditions that will best achieve the balance between natural resource protection, property and infrastructure protection, and power generation. Making the plant closed-loop or partially closed-loop is one important consideration to the scenario and would eliminate any operation changes that might result from concerns about fishery resources, water quality effects, and farmland losses.

Proposed Methodology

1. Collate existing geological and hydrologic information for areas surrounding Northfield Mountain, including preliminary design plans for suitable facilities able to accommodate the existing and proposed discharge. These plans should include any and all possible locations, including modifications to infrastructure near the current outfall, and any other locations that could accommodate the necessary volume of water.
2. Provide an engineering analysis of structural modifications necessary to accommodate a full or partial lower reservoir in an alternate nearby location.
3. Provide information on whether and how a smaller lower reservoir, with ties to the Connecticut River, would act as a buffer to river level fluctuations and change the hydrologic pattern of flow on the Connecticut River in the Turners Falls pool (fluctuations), the water quality effects, and decrease the possibility of entrainment.
4. Provide an analysis on water losses from evaporation and leakage and how much make-up water would be needed during normal operations by season or month.
5. Identify and make available any similar studies conducted during the planning phase of the existing facility in the 1960's or any other time.
6. Provide a cost estimate of each option considered and evaluated.
7. Provide an itemized cost estimate of how taking the river off-line (not using it as the lower reservoir) would affect other costs, such as eliminating the erosion control program, any ancillary changes to generation at Turners Falls Dam and NMPS, and fish protection measures.
8. Provide a summary of available information on the costs of converting existing open-loop pumped storage systems to a closed-loop system and a description of the environmental benefits of other closed-loop pumped storage facilities.

These methods are consistent with accepted practice for weighing costs and benefits of environmental impacts.

Level of Effort and Cost

The level of effort to compile existing information and to make the data available in a map should be low. Development of contingency scenarios would be low. The majority of the effort of this study request is essentially office work, with some engineering and design work required to scope likely costs of various scenarios.

Study Request 4 - Water Quality Monitoring in the Turners Falls Impoundment and Downstream of the Turners Falls Project

Goals and Objectives

Determine the current water quality of the Connecticut River within the Turners Falls impoundment. The results of the study should provide information sufficient to enable mandatory conditioning agency staff to understand water quality conditions at the project. The study plan for the water quality monitoring should be developed in consultation with the U.S. Fish and Wildlife Service (USFWS) and the Massachusetts Department of Environmental Protection (MA DEP).

The specific objectives of this study are as follows:

1. Characterize water quality in the Turners Falls impoundment, bypass reach, canal and below the confluence of the bypass reach and canal discharge.
2. Evaluate the potential effects of project operation on water quality parameters such as temperature, dissolved oxygen, total suspended sediment and turbidity in conjunction with various other water uses.
3. Determine the level of contamination in sediment impeded by Turners Falls dam.
4. Collect continuous temperature, dissolved oxygen, total suspended sediment and turbidity data during the summer period and under various hydropower operating conditions at the Northfield Mountain Project.

Relevant Resource Management Goals and Public Interest Considerations

The resource management goal is to ensure that the Connecticut River, which is designated as a Class B river for its entire length in Massachusetts, meets its designated uses of habitat for fish, other aquatic life and wildlife, and for primary and secondary contact recreation. Class B waters must also have consistently good aesthetic value and meet minimum criteria for numerous water quality indicators to achieve compliance with the standards set forth in the regulations. The other resource management goal is to protect prime farmland soils, which are eroding, and riparian habitat. Eco-based tourism is important to the economy of Franklin County so maintaining the water quality of the river for boaters and kayakers is important, too.

Public Interest Considerations if Requester is not a Resource Agency.

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Existing Information and Need for Additional Information

The PAD provides a summary of existing water quality data. While a number of monitoring efforts have taken place and include sample sites within the project boundary, none of those studies was designed to comprehensively investigate whether all relevant project areas currently meet Class B standards: The Massachusetts DEP's Connecticut River watershed assessment monitoring occurred in 2003, it had only two stations located within the project area (both upstream of the Turners Falls dam) and only collected five to six samples from late April to early October. The Connecticut River Watershed Council's volunteer monitoring program only had one sample site within the project area (at Barton's Cove in the Turners Falls impoundment) and while those data are more recent, only three samples were collected in 2007 and only six samples in 2008 (over the course of three to four months each year). The U.S. Geological Survey's long-term water quality monitoring station located downstream of the Cabot Station tailrace only collects information roughly once per month (and no dissolved oxygen data are provided).

No directed, site-specific surveys have been conducted to determine whether waters within the Project area meet state standards. This information gap needs to be filled so that resource agencies can evaluate properly the potential impact of project operations on water quality.

Nexus to Project Operations and Effects

The project creates a 20-mile-long impoundment where there would naturally be a free-flowing river. It currently operates in a peaking mode, with allowable river fluctuations of up to 9 feet, with proposals to continue with river fluctuations. Portions of the impoundment are nearly 100 feet-deep. There is a 2.7 mile-long reach of river bypassed by the Turners Falls power canal with only a nominal seasonal release required (equal to 0.05 cfsm). The below-project flow requirement is equal to 0.20 cfm (1,433 cfs). Water quality is directly affected by the operating mode of a hydropower project. Impoundments can stratify, resulting in a near-hypoxic hympolimnion. If the project intake draws off of these deep waters then it could cause low dissolved oxygen levels downstream from the project discharge.

The FRCOG requests that the applicant conduct a water quality survey of the impoundment, bypass reach and tailrace reach in order to determine whether state water quality standards are being met under all currently-licensed operating conditions (i.e., during periods of generation and non-generation). Results of the survey would be used, in conjunction with other studies requested herein, to determine an appropriate below-project flow prescription, bypass reach flow(s), and to recommend an appropriate water level management protocol for the impoundment (e.g., limiting impoundment fluctuations to protect water quality). Operation of upstream hydroelectric projects as well as the Turners Falls Project and Northfield Mountain Project may impact water quality through the use of water for hydropower generation.

Methodology Consistent with Accepted Practice

Turners Falls: Water quality samples should be collected from a minimum of six locations: upstream of the impoundment, at a deep location within the impoundment, in the forebay near the intake, in the bypass reach, in the canal near Cabot Station and downstream of the confluence of the Cabot Station discharge and the bypass reach but upstream of the confluence with the Deerfield River. In order to ensure that data are collected under “worst case” conditions (low flow, high temperature, antecedent of any significant rainfall event), we recommend deploying continuous data loggers at all six locations, with biweekly vertical profiles taken at the deep impoundment location from June 1 through September 30. Results should include date, time of sampling, sunrise time, GPS location, generation status (estimated flow through canal and bypass reach), precipitation data, water temperature, DO concentration and percent saturation.

In addition, impoundment sediment adjacent to the Turners Falls dam should be analyzed for metals and polychlorinated biphenyls (PCBs).

A proposed water quality sampling plan should be submitted to USFWS and MADEP for approval. A section on quality assurance and quality control must be included.

If river flow and temperature conditions are representative of an “average” or “low” water year, then one year of data collection should be sufficient to perform the study. If conditions are not representative (i.e., a “wet” or cool year) then a second year of data collection may be necessary.

Northfield Mountain: The water quality study will include two components: a) continuous dissolved oxygen and temperature monitoring at specific locations in the Northfield Mountain Project area and b) monthly *in-situ* dissolved oxygen, temperature profiles, total suspended solids and turbidity within the Northfield Mountain Upper Reservoir. It is anticipated that the study will be conducted from approximately June 1 through September 30.

Level of Effort and Cost

Cost would depend on the specific methodology chosen. If continuous data loggers are installed at all six locations and biweekly vertical profiles taken at the deep impoundment location from June 1 through September 30 then the estimated cost of the water quality study is approximately $55,000, including at least one full year of data collection. It is expected to take two technicians approximately one day to deploy the loggers, eight days to collect the vertical profiles, one day to remove the loggers, one day to download the data, and five days to write the report.

In the PAD, the applicant proposes to assess the effects of the Turners Falls and NFMPS project operations on dissolved oxygen and temperature by continuously monitoring DO and temperature at locations within the project areas and gathering vertical profiles within the TF impoundment and NFMPS upper reservoir.

Study Request 5 – Quantify the Impacts of Water Level Fluctuations on Riparian and Aquatic Vegetation Including Invasive Species and their Associated Habitats in the Turners Falls Dam Project Impoundment

Conduct a study to quantify the impacts of river level fluctuations due to project operations on riparian, wetland, Emergent Aquatic Vegetation (EAV), Submerged Aquatic Vegetation (SAV), littoral zone and shallow water aquatic habitats in the Turners Falls Dam impoundment.

Goals and Objectives

The goal of this study is to obtain baseline information on riparian, wetland, emergent and submerged aquatic vegetation, and associated shallow water aquatic habitats (subject to operational inundation and exposure to near exposure) known to occur in the project area. Information would be used to determine whether riparian, wetland, EAV and SAV, littoral, and shallow water (e.g., mid river bars and shoals) habitats are impacted by current water level fluctuations permitted under the Turners Falls and Northfield projects' licenses and whether these vegetation types and shallow water habitats can be protected and restored by modifications to project operations or other mitigation measures. This analysis needs to take into account existing and potential future limits on river level fluctuations intended to limit recreation impacts, and the interactions of any changes in river level fluctuation range or frequency and discharge changes under a new licenses of the Turners Falls and upstream projects. This information is needed to determine whether the projects' operation affects plants, habitat, and wildlife in the project area, whether aquatic vegetation and its habitats can be enhanced by modifications to project operations or other mitigative measures, and whether there is any unique or important shoreline or aquatic habitats that should be protected.

The specific objectives of the field study, at a minimum, include:

1. Quantitatively describe and map wetland types within 200 feet of the shoreline, and describe associated wildlife;
2. Delineate, quantitatively describe, and map all wetland types including invasive species and wildlife observed (e.g., bald eagle nesting, water fowl nesting) within 200 feet of the shoreline, and the extent of this habitat if it extends beyond 200 feet; and
3. Quantitatively describe (e.g., substrate composition, vegetation type and abundance) and map shallow water aquatic habitat types subject to project operation inundation and exposure, noting and describing additional areas where water depths at lowest operational range are wetted to a depth less than one foot (flats, near shore areas, gravel bars, with very slight bathymetric change).

A second year of study may be required should river discharge in the first year prove to be atypical (outside of 25-75th percentile of average weekly flow values) during the study period.

The field study should produce a habitat inventory report that includes:

1. The results of the field study in the form of maps and descriptions;

2. An assessment of project effects on wetland, riparian, littoral zone vegetation and shallow water habitats, invasive plant species, and wildlife habitat at the project; and
3. Recommendations for any necessary plant, habitat type, or wildlife, protection and/or invasive species control measures.

Relevant Resource Management Goals and Public Interest Considerations

Protect and restore native riparian, wetland, EAV, SAV, littoral and shallow water habitat (i.e., spawning and or nursery areas for aquatic organisms) in the Turners Falls impoundment.

Public Interest Considerations if Requester is not a Resource Agency

The Franklin Regional Council of Governments (FRCOG) is a regional organization that offers diverse programming, products and services, both on the municipal and regional level, to our 26 member towns. The FRCOG is also the Regional Planning Agency for Franklin County, Massachusetts, which is the most rural county in the state. The FRCOG serves the town governments, municipal boards and committees, businesses, and our citizens. In the early 1990's, the FERC recognized the creation of an ad hoc committee, the Connecticut River Streambank Erosion Committee, convened by the FRCOG and FRPB to bring together the NMPS operator, state and municipal entities, landowners, and NGOs to carry out bioengineering projects to stabilize and repair areas of bank erosion. We advocate on behalf of our communities and the county at the federal, state and regional levels. We work together to advocate for legislative action, social policy, and governmental programming that recognize the unique character and conditions of our rural area.

Existing Information and Need for Additional Information

Existing information in the PAD does not quantify EAV and SAV in this area, or other shallow aquatic habitat types and physical features (e.g., depths, substrates, wood structure) that are the environment for aquatic biota in the project area. The PAD does provide some limited monitoring data for 2012 (2 locations) on water surface elevations that show daily fluctuations, in the upper third of this impoundment, that varied over 4 feet on a daily cycling frequency, with fluctuations generally in the 2 foot range in low flow months for the data provided in the PAD. The current license does permit a greater pool elevation operational fluctuation, up to a 9 foot change in elevation, based on the Turners Falls Dam water elevation. In the PAD it is noted these operational fluctuations under most circumstances at the Turners Falls Dam are within 3.5 feet.

In the PAD it is noted that FirstLight would like to expand its NMPS upper reservoir capacity (by up to 24%). How this may affect project operations and the habitats noted in this request is unknown. It is also noted that water is typically pumped to the upper reservoir in evening and generation back to the river occurs once to twice daily, in daytime hours, based upon power needs and power value. Under current license conditions, and provided that set thresholds for minimum flow and Turners Dam current license elevations are met, the NMPS may operate with no restriction in timing, frequency, or magnitude for pumping or generation. No data were provided on the operation of the NMPS plant over time relative to data on pumping and generation on an hourly basis, only averaged values were provided over monthly periods. It is unclear what the actual timing, frequency and magnitude of these NMPS operations are over the course of a year and how that relates to: aquatic plant species establishment, growth, survival, littoral zone or other shallow water habitat fish spawning periods and their effects on these fishes (reproduction success and subsequent recruitment, e.g., bass and fall fish nests) based on the available and utilized habitat, and how the quantity and quality of these shallow water habitats are affected by project operational manipulation/alteration, as currently permitted or proposed.

The PAD provides lists of plant and wildlife species whose native ranges overlap with the project area, but it does not provide any baseline information on known occurrences of these species in the wetlands, riparian, littoral and shallow water habitats, within or adjacent to, the project area. Plant and wildlife occurring in these habitats may benefit from protection, mitigation, and enhancement (PMEs) measures, given the potential effects of continuing the current semiautomatic peaking operating regime. In addition, a large scale sediment discharge from NMPS resulted in regulatory actions by FERC, the EPA and MADEP in 2010. Continuing and as yet unresolved management plan measures relative to sediment and NMPS project operations are further concerns for shallow water, littoral zone, and wetland habitats.

The Atlantic States Marine Fisheries Commission, Atlantic Coast Diadromous Fish Habitat: A Review of utilization, threats, recommendations for conservation, and research needs (ASMFC 2009)[2], contains a review of habitat information for these species. Recommendations in this report include: maintain water quality and suitable habitat for all life stages of diadromous species in all rivers with populations of diadromous species.

Nexus to Project Operations and Effects

Water level fluctuations due to project operations could likely affect EAV and SAV habitat as well as the quantity and quality of littoral and shallow water habitat. These operational water level fluctuation effects are expected to impact fish species' use of these habitats and may affect spawning fishes reproductive success and subsequent population recruitment including but not limited to American shad, blueback herring, sea lamprey, fall fish, and bluegill, which spawn in mid to late spring through early summer in areas subject to daily or more frequent water level fluctuations.

The current operating mode, as well as the unknowns with the proposed upper reservoir expansion, may affect wetland riparian, littoral and other shallow water habitats and promote the introduction and expansion of invasive plant species through fluctuating water levels. A study that explains the relationship between the proposed mode of operation and the type and quantity of wetland, riparian, littoral, shallow water habitats, and invasive species affected would help inform a decision on the need for protection and/or control of these resources in the license.

Methodology Consistent with Accepted Practice

The PAD currently contains maps portraying general wetland types from the Cabot Station tailrace upstream to the Vernon Dam. In addition, we understand that recent bathymetry exists for the Turners Falls impoundment (Field, 2007). The proposed study should utilize this existing information in conjunction with field surveys designed to describe the characteristics of each mapped wetland, riparian, littoral and shallow water habitat including plant species composition, relative abundance/density, habitat quality, and land use. These surveys should be conducted to describe these habitats at the lowest

[2] Atlantic States Marine Fisheries Commission. 2009. Atlantic coast diadromous fish habitat: A review of utilization, threats, recommendations, for conservation, and research needs. Habitat Management Series #9. Washington, D.C.

water level operational range permitted on a daily operation schedule, under low flow conditions. Information collected should include:

1. Plant species composition, and their relative abundance/density and condition/structure (e.g., seedlings);
2. Structured data, including estimates of average heights and aerial cover of each vegetation layer (specifically denoting invasive species);
3. Aquatic habitat substrate composition, quantity (i.e., percent types and area), wood structure (relative abundance measure applied by area), water depths (inundated, exposed, and water less than one foot);
4. Predominate land use(s) associated with each cover type;
5. Wildlife sightings should be noted;
6. Field-verified wetland, riparian, and littoral and shallow water habitats and invasive species occurrences, should be geo-referenced as polygons and overlain on orthophoto at a suitable scale.

Level of Effort and Cost

In the PAD, First Light identified impacts of the project operations on wetlands, riparian and littoral zone habitat as a potential issue to be addressed in relicensing, and proposed wetland vegetation mapping. However, additional analysis as described above is needed to understand the impacts of the project on these resources and habitats.

A wetlands, riparian, littoral/shallow water, invasive species inventory, of the scope envisioned, would likely require 6-8 months to complete and cost an estimated $40,000 to $50,000.

Study Request 6 - Model River Flows and Water Levels Upstream and Downstream from the Turners Falls Project Dam Generating Stations and Integration of Project Modeling with Upstream and Downstream Project Operations.

Develop a river flow model(s) that is designed to evaluate the hydrologic changes to the river caused by the physical presence and operation of the Turners Falls Hydroelectric Project and the Northfield Mountain Pumped Storage Project and the interrelationships between the operation of all five hydroelectric projects up for relicensing (i.e., P-1889 Turners Falls Hydroelectric Project, P-2485 Northfield Mountain Pumped Storage, P-1904 Vernon Hydroelectric Project, P-1855 Bellows Hydroelectric Project, P-1892 Wilder Hydroelectric Project) and river inflows. The river flow model(s) and analyses should include the following components:

1. A quantitative hydrologic modeling of the hydrologic influences and interactions that exist between the water surface elevations of the Turners Falls Project impoundment and discharges from the Turners Falls Dam and generating facilities and the upstream and downstream hydroelectric projects.

   Data inputs to and outputs from the model(s) should be sorted and analyzed by monthly, weekly, daily and sub-daily increments and include:
   i. Withdrawals from the Turners Falls impoundment by the Northfield Mountain Pumped Storage Project, FERC No. 2485,
   ii. Discharges to the Turners Falls impoundment by the Northfield Mountain Pumped Storage Project,
   iii. Discharges into the Turners Falls impoundment from the Vernon Project, FERC No. 1904 and other sources.
   iv. Existing and potential discharges from the Turners Falls Project generating facilities and spill flows.
   v. Existing and potential water level fluctuation restrictions (maximum and minimum pond levels) of the Turners Falls impoundment and downstream flows from the project
   vi. Existing and potential required minimum flows and/or other operation requirements at each of the four upstream projects.
   vii. Minimum discharge flows ranging between 2,500 and 6,300 cfs in the bypass reach from April 15th through June 22nd to support spawning, rearing, and outmigration of shortnose sturgeon at Rock Dam.

2. Document how the existing and potential outflow characteristics from the four upstream projects affect the operation of the Turners Falls Project including downstream flow releases and Turners Falls impoundment levels.
3. Assess how the operation of the existing Turners Falls Project and upstream projects affect Holyoke Project (P-2004) operations including:
   i. How Turners Falls Project flow fluctuations affect Holyoke impoundment water levels, with emphasis on the influence on the water levels on listed

Puritan tiger beetle habitat at Rainbow Beach in Northampton, MA and assess what changes would be needed in Turners Falls operations to stabilize water levels at Rainbow Beach.

ii. How Turners Falls Project operations affect Holyoke Project discharges and what changes in Turners Falls operations would be needed to reduce fluctuations in the discharges from the Holyoke Project.

iii. To the extent predictable and practical, incorporate the potential effects of climate change on project operations over the course of the license.

Goals and Objectives

The goal of this study request is to determine the extent of alteration of river hydrology caused by operation of the project and the interactions between upstream project operations, Turners Falls operations and downstream operations at the Holyoke Project. The objectives of this study request are as follows:

1. Determine what changes can be made to each of the five project's flow releases and/or water levels restrictions, and how those changes affect downstream resources. For example, for the Turners Falls Project continuous minimum discharge flows in the Turners Falls bypass reach need to be no less than 2,500 cfs during shortnose sturgeon spawning, rearing, and outmigration (April 15th – June 22nd). Incorporating these parameters into the model will inform what changes, if any, need to be made to operations of upstream projects to accommodate such flows.
2. As other specific modifications of the operations of each of the projects are identified based on results of other requested studies, these desired conditions will need to be input into the models to assess how each change affects that project and other project operations and the implications of those changes on other resources and/or the ability to achieve desired operational changes at other projects.

Relevant Resource Management Goals and Public Interest Considerations

The resource management goal and public interest consideration is to provide adequate information to mandatory conditioning agencies to ensure that the mitigation, protection and enhancement measures for the projects are commensurate with project effects and help conserve, protect, and enhance the habitats for fish, wildlife, and plants, including rare and endangered species.

Public Interest Considerations if Requester is not a Resource Agency

The Franklin Regional Council of Governments (FRCOG) is a regional organization that offers diverse programming, products and services, both on the municipal and regional level, to our 26 member towns. The FRCOG is also the Regional Planning Agency for Franklin County, Massachusetts, which is the most rural county in the state. The FRCOG serves the town governments, municipal boards and committees, businesses, and our citizens. In the early 1990's, the FERC recognized the creation of an ad hoc committee, the Connecticut River Streambank Erosion Committee, convened by the FRCOG and FRPB to bring together the NMPS operator, state and municipal entities, landowners, and NGOs to carry out bioengineering projects to stabilize and repair areas of bank erosion. We advocate on behalf of our communities and the county at the federal, state and regional levels. We work together to advocate for legislative action, social policy, and governmental programming that recognize the unique character and conditions of our rural area.

Existing Information and Need for Additional Information

Available information in the PAD does not indicate how project operations have altered downstream hydrology, which may affect resident and migratory fish, macroinvertebrates, rare, threatened, and endangered species, aquatic plants and other biota and natural processes in the Connecticut River from below the Vernon Dam downstream to the Holyoke Dam.

Information in the PAD also does not reflect data analyzed in Kynard et al. 2012, which identifies minimum discharge thresholds for shortnose sturgeon spawning and rearing at the Rock Dam spawning site. Spawning success was observed at Rock Dam when discharge was between 2,500 cfs and 22,000 cfs during the spawning period (April 27–May 22nd) (Kynard et al. 2012, chapter 3). In 1995 at the Cabot spawning area, the greatest level of spawning and spawning success occurred (i.e., 21 late stage females present, 342 ELS captured, spawning period was 17 days) even though no spawning was detected at Rock Dam (Kynard et al. 2012, chapter 3). Discharges in 1995 at Rock Dam had dropped below 2,500 cfs by March 26th (Kynard et al. 2012, chapter 3), showing that even though 1995 saw the largest number of pre-spawning adults, none spawned at Rock Dam. This may indicate the need to have adequate flow well in advanced of spawning. Discharge reductions at the Rock Dam site that occurred during spawning caused females to leave the spawning site and not return even if flow increased to acceptable levels later during the spawning period. Researchers observed that substrate did not change during fluctuating flows and thus cessation of spawning is likely due to velocities falling below the range preferred by females. Given the current flow dynamics at Rock Dam, spawning does not occur most years (Kynard et al. 2012, chapter 3). These data represent the best available scientific information and indicates that the current minimum flow thresholds at the project are not adequate for the protection of endangered shortnose sturgeon. All modeling efforts described above must incorporate the identified minimum flow and temporal parameters.

Nexus to Project Operations and Effects

The Turners Falls Project is currently operated with a seasonally-varying minimum bypass flow (400 cfs from 5/1 through 7/15, then 120 cfs through the winter until river temperature rises to ≥ 7°C) and year-round minimum flow below the projects of 1,433 cfs. The project operates as a daily peaking project, often with large, rapid, daily flow fluctuations between the minimum and project capacity (15,928 cfs) and fluctuations in impoundment elevation (175’ to 186’ MSL). These changes affect biotic habitat and biota upstream and downstream of the project. Project operations and potential changes to operations to mitigate impacts are influenced by inflows and operations of upstream hydroelectric projects and the Northfield Mountain Pumped Storage Project operations. Potential changes in operations of each project could affect the ability to achieve desired operational changes at other projects. Results of river flow analyses will be used to develop flow-related license requirements and/or other mitigation measures.

Methodology Consistent with Accepted Practice

River hydrology statistics and modeling are commonly employed at hydroelectric projects to assess implications of project operations on the river environment.

Level of Effort and Cost

Level of effort and cost of model development are expected to be moderate. To be valuable in developing license conditions, the model(s) will need to be run under various scenarios throughout the relicensing process to assess the implications of changes to the operations of each project on other projects and other resources. Therefore, ongoing consultation and re-running of the model(s) are likely to be needed throughout the relicensing process. The modeling exercise will also require coordination and cooperation between First Light and the upstream licensee to assure that the model inputs and outputs can be accurately related.

We would anticipate that the expected level of effort and anticipated costs will be comparable to that experienced on similar FERC relicensing projects of this size (e.g., Conowingo, FERC No. 405).

Study Request 7 – Develop A Comprehensive And Predictive Model Of The Electrical Generation System Consisting Of Five Generation Projects Along The Connecticut River To Study The Impact and Feasibility Of Various Changes In Operations On Environmental Resources

If the five generation facilities (i.e., P-1889 Turners Falls Hydroelectric Project, P-2485 Northfield Mountain Pumped Storage, P-1904 Vernon Hydroelectric Project, P-1855 Bellows Hydroelectric Project, P-1892 Wilder Hydroelectric Project) were to be viewed as a single system, rather than separate entities, and if those five systems could work in concert with each other, it is possible that many of the environmental concerns could be addressed by choreographing operational parameters.

Developing a tool which could simulate the interactions among all generation entities, and report the condition of a variety of parameters would be of great help in evaluating the feasibility and effectiveness of different scenarios.

1) Inputs would be:
   a) Normal flow and height of the river entering the system around a median point
   b) Start time and duration of discharge into the river from each generation facility and dam within the project area
   c) discharge rate into the river by the stations of each generation facility and dam within the project area
   d) Operation of Northfield Mountain Pumped Storage (P-2485):
      i) Start time and duration of filling
      ii) Intake rate
      iii) Start time and duration of discharge
      iv) Discharge rate
   e) Event to effect lag times, both spatial and temporal
2) Constraints on the system
   a) Maximum and minimum on river heights
   b) Maximum and minimum on discharge rates
   c) Maximum and minimum depth of upper reservoir at P-2485 Pump Storage
3) Other parameters of interest could be overlaid
   a) Demand curves for electricity generation
   b) Cost of electricity
   c) Availability of excess generation capability
   d) Abnormal conditions i.e. Vernon Nuclear off line, spring freshet or other weather related emergencies like floods
4) Outputs of the model would be:
   a) River height at any number of locations
   b) Flow rate at any number of locations
   c) Rate of change of river height and flow
   d) Alarms when limits are exceeded

Goals and Objectives

Determine whether operating the system as a whole under a single set of operation parameters can serve to mitigate the environmental shortcomings of the current method of operation. Specifically, the model will be able to predict whether necessary modifications in timing of releases and rates, can maintain the required stability of river height, minimum and maximum flow while making sure that electrical demand is met and business concerns are taken into consideration. The model will also be able to identify the contribution to fluctuations in output by each facility, thereby determining what kind of modification will have the greatest effect.

Another specific goal would be to help inform the analysis conducted as part of Study Request 3 – Study the Feasibility of Converting the Northfield Mountain Pumped Storage (NMPS) Facility to a Closed-loop or Partially Closed-loop System. If a majority of the environmental concerns can be met by coordinating operating parameters of the installations along the river, the need becomes less. However, if the environmental concerns cannot be met, the need for a closed loop system increases in importance.

Relevant Resource Management Goals and Public Interest Considerations

1. Determine the need and extent of protective and mitigating projects to aid in the protection of the ecology of the system area.
2. Assist FERC and the operational management of the system after the relicensing project is complete. This model will be able to instruct what day by day adjustments need to be made to maintain stability of the system.
3. Long-term changes in conditions based on climate change or changes in operation further upstream can be tracked and adjusted for by modifying the input conditions. Annual measurements of normal flow can be made and the model can easily be adjusted.
4. Catastrophic events can be simulated and preparedness and emergency management plans can be based on outputs of the model.

Public Interest Considerations if Requester is not a Resource Agency

The Franklin Regional Council of Governments (FRCOG) is a regional organization that offers diverse programming, products and services, both on the municipal and regional level, to our 26 member towns. The FRCOG is also the Regional Planning Agency for Franklin County, Massachusetts, which is the most rural county in the state. The FRCOG serves the town governments, municipal boards and committees, businesses, and our citizens. In the early 1990's, the FERC recognized the creation of an ad hoc committee, the Connecticut River Streambank Erosion Committee, convened by the FRCOG and FRPB to bring together the NMPS operator, state and municipal entities, landowners, and NGOs to carry out bioengineering projects to stabilize and repair areas of bank erosion. We advocate on behalf of our communities and the county at the federal, state and regional levels. We work together to advocate for legislative action, social policy, and governmental programming that recognize the unique character and conditions of our rural area.

Existing Information and Need for Additional Information

None of the existing information attempts to coordinate the operations of all five installations as a system. Most of the information available tells of parameters of individual locations and consequences of single events around a single location. There does not seem to be information of larger interactions among various events and time-lines of events are not shown with enough information to draw conclusions on overall effects in the entire project area.

Nexus to Project Operations and Effects

This study and resultant model will show the advantages of coordinated operation of the facilities along the river. This, then, can be accomplished by coordinated license requirements mandating the level of cooperation, communication, and coordination of the system. Initial use of the model will help dictate the license requirements to achieve the most protective and most efficient operation of the system. Ongoing use of the model will help to maintain the protective and efficient practices.

Methodology Consistent with Accepted Practice

Computer modeling is standard practice in many fields. The predictive model analyzing interactions, over time is also used extensively. Many standard templates for this kind of modeling are readily available in the scientific community.

Level of Effort and Cost

The level of effort and cost is expected to be moderate. Virtually all of the input data is available in one place or another. Much of the effort will be in locating and obtaining the data, and making sure that the units used will be compatible.

The model will have to be run numerous times to help analyze multiple scenarios as submitted by other commenters. Input parameters will have to be changed prior to each run to reflect the scenario being tested, and a variety of reports must be produced depending on what variables are of interest.

The project will require the cooperation of FirstLight and TransCanada, the owners of the facilities in the project area.

Attachment 19. CRSEC Comments on 2nd Draft of QAPP

January 25, 2013

Franklin Regional Council of Governments

CONNECTICUT RIVER STREAMBANK EROSION COMMITTEE

January 25, 2013

John S. Howard
Director, FERC Hydro Compliance
FirstLight Power Resources Services, LLC
99 Millers Falls Road
Northfield, MA 01360

Re: COMMENTS ON
Draft Quality Assurance Project Plan for the 2013 Full River Reconnaissance
Turners Falls Impoundment of the Connecticut River

Dear John:

The Connecticut River Streambank Erosion Committee (CRSEC) has been suggesting for several years that the Full River Reconnaissance (FRR) be conducted using methodology described in a Quality Assurance Project Plan (QAPP). We are thus very pleased that FirstLight prepared a draft QAPP for the 2013 FRR and provided it to us for comment.

Several CRSEC members have extensive experience with QAPPs, both in preparation and in review, and have received certified training directly from EPA QA staff. They have reviewed the first two drafts of the QAPP, and helped the Committee prepare the attached comments. Our goal is to help ensure a rigorous project that will provide replicable data on the status of bank erosion in the Turners Falls impoundment that can be a baseline for future FRRs and allow for quantitative analysis of streambank changes over time.

Sincerely,

Tom Miner
Chair, Connecticut River Streambank Erosion Committee

Attachment

Cc: Kimberly D. Bose, Secretary, Federal Energy Regulatory Commission
Kenneth Hogan and Chris Chaney, Federal Energy Regulatory Commission
Robert McCollum, MA Department of Environmental Protection
Charles Momnie, FirstLight

Connecticut River Streambank Erosion Committee's
Comments on the Draft Quality Assurance Project Plan (QAPP) for the
2013 Full River Reconnaissance (FRR) of the Turners Falls Impoundment of the Connecticut River
January 25, 2013

The purpose of a QAPP is to provide a project-specific "blueprint" for obtaining the type and quality of environmental data needed for a specific decision or use. The QAPP document describes how QA/QC procedures are applied to an environmental data collection operation to assure that the results obtained are of the type and quality needed and expected. We do not agree with FirstLight's assertion that the Full River Reconnaissance is the type of project that does not fit well within a QAPP framework, and we expect to see a more complete draft of the QAPP for the FRR that includes the necessary elements and all appendices, etc.

As we noted in our comments on the initial Draft QAPP (email from Tom Miner to Chuck Momnie dated 11/1/12), the EPA has prepared guidance documents on preparing a QAPP[1] (for your reference, we are providing the information again). We have found reference to two hydropower QAPPs that are part of FERC proceedings, and the contents of these have many common elements to EPA QAPPs.[2] These could be used for reference as to QAPP structure and format. Although FERC projects may not be required to follow EPA protocol, we believe that the QAPP for the 2013 FRR should include more elements of the EPA structure, as in the example from the New Hampshire's Department of Environmental Services.[3]

In addition, through a Google search, we found an example of a QAPP for a Geomorphology Survey of Huron Creek in Houghton, MI. One of the elements of this study is a Modified Bank Erosion Hazard Index (BEHI), which is the approach used on previous FRRs conducted in the Turners Falls Pool. This QAPP contains appendices that are Procedural Manuals for each of the field surveys to be conducted, including the Modified BEHI. We've provided the link to the document for your reference.[4] While we are not specifically advocating for a Modified BEHI methodology, the Huron Creek QAPP is a good example of the level of detail that is needed in order to provide the project-specific "blueprint."

The importance and value of a rigorous QAPP is underscored by the statement in the 12/3/12 draft QAPP (section 1.0 Project Description) that it is "for work proposed <u>as part of the FERC re-licensing process</u> (*emphasis added*)." That comports with comments by Ken Hogan, head of the FERC relicensing team, who participated by phone in CRSEC's 12/5/12 meeting. He noted that much of the information to be generated in the FRR is potentially useful for relicensing, and he proposed integrating the upcoming FRR into the study plan for relicensing, i.e., crafting an FRR that could serve both purposes, thereby achieving some efficiency. The CRSEC endorses that approach.

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[1] www.epa.gov/nrmrl/qa/qappreq.html

[2] 2010 FERC Order approving a QAPP as part of 401 WQ compliance. Doesn't have table of contents of QAPP, but lists the key elements of the QAPP:
http://www.chelanpud.org/departments/licensingCompliance/rr_implementation/ResourceDocuments/35664.pdf
2012 QAPP for Enloe Dam (in WA state, FERC No. 12569)) water quality monitoring:
http://www.ecy.wa.gov/programs/wq/ferc/existingcerts/EnloeAppHOperQAPP.pdf

[3] The NH Department of Environmental Services has a useful website with links to EPA QAPP guidance documents, as well as example QAPPs, a QAPP template, and a stream morphology data collection generic QAPP:
http://des.nh.gov/organization/divisions/water/wmb/was/qapp/index.htm

[4] www.geo.mtu.edu/~asmayer/HuronCreek/Appendix/App%20I/Geomorph%20QAPP.pdf.

Connecticut River Streambank Erosion Committee's
Comments on the Draft Quality Assurance Project Plan (QAPP) for the
2013 Full River Reconnaissance (FRR) of the Turners Falls Impoundment of the Connecticut River
January 25, 2013

Currently missing in the draft QAPP is a clear statement of purpose for the FRR. Beyond documenting existing conditions, the FRR needs to establish a basis for comparing changes over time. The inability to make such comparisons has been a major complaint about and failing of past FRRs. By following the EPA QAPP procedures discussed here, the FRR QAPP will establish survey procedures and protocols that will remain consistent and repeatable over time, ensuring data quality controls are in place to provide the basis for long-term observation and conclusions.

A QAPP that follows EPA standards will address or eliminate many concerns that CRSEC identifies in the current draft QAPP. A major concern of the CRSEC regarding the draft QAPP is the subjective nature of the riverbank characterizations presented by Appendix C. Photographs of specific sites are generalized for application to 40 miles of riverbank that experience varied conditions of river flow and dynamics, differing soils, and multiple other factors affecting stability. The characteristics matrix shown in Table 3 cannot be used over time as there are no procedures in place to prevent observer variability from significantly changing results (e.g., what is "upper riverbank slope" vs. "lower riverbank slope?" what is "some" mass wasting vs. "little" vs. "extensive"?).

For Appendix C to be fully useful, we believe it should be modeled on the characterizations presented by the 2007 Fluvial Geomorphology Study prepared for FirstLight by Field Geology Services in which the stages of erosion and erosion type are primarily identified through line-drawing profiles and plan views, and text descriptions.

The EPA QA/R-5 Quality Assurance Project Plan format contains the elements listed below, which would be adapted to reflect the disciplined and consistent collection and analysis of field data rather than sample collection with laboratory analysis. We believe these elements, which are absent or lacking sufficient detail in the second draft of the QAPP presented to the CRSEC at its meeting on December 3, 2012, are critical to the FRR QAPP.

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As you know, the CRSEC had issues with the methodology and conclusions of the 2008 FRR. Our comments in this letter focus entirely on the content and structure of the draft QAPP. We are ready to work with FirstLight on the 2013 methodology for the FRR after the framework of the QAPP has been established.