Connecticut River
Conservancy

Clean water. Healthy habitat. Thriving communities.

15 Bank Row, Greenfield, MA 01301
413.772.2020 · www.ctriver.org

May 15, 2017

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

Re: Wilder Dam Project No. 1892
Bellows Falls Project No. 1855
Vernon Dam Project No. 1904
Connecticut River Conservancy Comments on Great River Hydro, LLC Study Reports filed by March 15, 2017; Request for Study Modification to Require Compliance with the RSP.

Dear Secretary Bose,

The Connecticut River Watershed Council, Inc. (CRWC), now doing business as the Connecticut River Conservancy (CRC), 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 TransCanada by March 15, 2017. CRC attended the study report meeting held on March 30, 2017. In April, the licenses for the TransCanada facilities were transferred to a new owner, Great River Hydro, LLC. Below are our comments. CRC again hired Princeton Hydro to conduct a peer review of the revised ILP Study 2 and Study 3 Riverbank Transect and Riverbank Erosion Studies, and their review is attached to this comment letter.

Revised ILP Study 2 and Study 3: Riverbank Transect and Riverbank Erosion Studies dated 2/4/2017

Comments based on peer review

CRC hired consulting engineering firm Princeton Hydro (http://www.princetonhydro.com/) to conduct a peer review of this revised study report. Based on the peer review, CRC continues to believe that Studies 2-3 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; (2) did not follow several recommendations from FERC's Determination on Requests for Study Modifications and New Studies dated November 29, 2016 ("FERC Determination"), (3) failed to rely on generally accepted scientific methods; and/or (4) otherwise reached conclusions that the science, data or evidence do not support. The revised study report fails to comply with the RSP and/or the FERC determination in the following ways:

- The FERC determination stated that TransCanada would use HEC-RAS modeling in combination with logistic regression statistical analysis at the 21 detailed monitoring sites. Great River

Hydro's revised study report did not include a logistical regression analysis on the 21 detailed monitoring sites. Moreover, stakeholders were not provided with any sheer stress data, nor information how it might have been generated. This runs counter to what TransCanada said they would do in their response to comment document dated October 31, 2016, responding to comment #3: "Shear stress analysis (a function of velocity) will be presented in a manner similar to WSE fluctuations."

- Princeton Hydro's peer review identifies a number of problems with the regression analysis. One, as identified in Appendix E, is that the regression analysis assumes observations are independent variables. Some of the results of the statistical analysis led to counter-intuitive results or inconclusive results, and the value of the analysis is therefore questionable.
- The FERC determination recommends that the revised report should include additional information that describes how the hydraulic gradients were calculated and the resulting potential for riverbank erosion. The discussion should include any discussion of observation of groundwater seeps or groundwater elevation data collected during the studies. No groundwater data, and thereby no hydraulic gradient data for the streambank were collected or analyzed.
- The FERC determination recommended that the revised study report contain a detailed, qualitative discussion of the potential effects of ongoing erosion on other resources, with the discussion including comparative maps and site-specific observations. Few maps or qualitative assessments were included in the revised report.

To remedy these shortcomings, CRC summarizes some of Princeton Hydro's recommendations below:

- Great River Hydro should conduct a sheer-stress and velocity analysis using the one-dimensional HEC-RAS model to identify the likely causes of erosion at the 21 erosion monitoring sites. Great River Hydro should provide input and output data, as well as the HEC-RAS model itself, to facilitate review by stakeholders.
- The input data used for the regression analysis should be evaluated for spatial autocorrelation and dependencies as recommended in Princeton Hydro's attached peer review. If significant, an alternative statistical test should be completed. Regression analysis should be completed on the data set related to the 21 transects.
- Great River Hydro should collect groundwater elevation data and observations of groundwater seeps or seepage-related erosion at the 21 monitored transects. Great River Hydro should analyze that data to determine how <u>operational water surface elevation (WSE) fluctuations</u> potentially affect streambank stability.
- Great River Hydro should include additional mapping as stated in the peer review, and further assessment of potential impacts of ongoing bank erosion and release of fine sediments to the river channel to cobblestone tiger beetle habitat, water quality impacts related to sight-feeding and respiration of fish, aquatic habitat and substrate, spawning of riverine fishes, and freshwater mussels.

<u>Additional CRC comments</u>

1. There were numerous problems associated with the regression analysis, explained in the following comments.

    a. We do not understand why TransCanada chose to perform regression analysis on the 124-mile dataset of bank characteristics when the FERC determination and Princeton Hydro's first peer review recommended regression analysis on the 21 detailed study sites. Even TransCanada acknowledged weaknesses with this dataset in October in response to comment #53: "This does not discount that certain areas may be particularly sensitive to changes, but the data set collected along 250 mi of bank is not refined enough to characterize all of the potential driving forces and resisting forces acting on the bank at any particular point."

    b. The study report stresses repeatedly how important sediment characteristics are (see quotes included in the peer review letter on page 6). Yet sediment characteristics weren't included in the regression analysis at all, because the data set given to the statistician didn't include that information. It is part of the 21 study sites, and again we are unclear why the regression analysis wasn't performed on the data set associated with the 21 sites.

    c. The regression analysis used sheer stresses for two cases only: Case 1 at "low flow," which was described as the high end of project operational flows. Case 2 was "high flow" or the approximate 10-year recurrence interval flows. CRC is unclear what flows were used for each case at each project. At Wilder, for example, Table 6.1-1 footnote "a" states that the maximum Wilder station discharge with all three units operating is approximately 11,700 cfs. However, Table 5.8-1 displayed velocities at the 13 impoundment sites using 10,000 and 16,000 cfs. CRC is not sure what flows were used in the regression analysis and how this compares to the velocities used in the table shown in the report. We also point out that it appears that no velocities or sheer stresses looked at operational flows other than the highest operational flow. The range of flows under project operations was not assessed.

    d. In our comment letter dated September 30, 2016, CRWC had recommended that TransCanada should re-evaluate the existing data with regard to factors such as land use on the impacts of water level fluctuations on erosion. TransCanada's response #36 stated, "We note that the Study 2 study plan was related to the 21 monitoring sites only, not to the entire river within the study area, which was the topic of Study 3. While the report for both studies was consolidated, the goals and objectives for each study differed. Effort was made to determine the relative importance of various factors through the use of the erosion ratio. A determination of groundwater levels and careful mapping of all land uses along the river were beyond the scope of the study." Nevertheless, Appendix E indicates that forest vegetation contributes only a small amount in explaining erosion deviance. We are once again confused why TransCanada did not use the data set for the 21 study sites in its logistic regression analysis, because these sites had a more detailed analysis of land use and riparian cover.

2. Use of the Erosion Ratio

Princeton Hydro's peer reviews have noted potential biases in the use of the erosion ratio and that it is not generally accepted scientific practice. TransCanada in their 10/31/2016 responses to comments noted in several places that the erosion ratio was used in the 2007 fluvial geomorphology study of the Turners Falls impoundment and that this study was accepted by FERC and no stakeholders objected to its use at that time. CRC, as one of the stakeholders involved in reviewing the 2007 Field study, would like to point out that the 2007 study was conducted in response to a FERC order dated June 28, 2005 that the owner Northeast Generation Company (called Northeast) "...submit a plan of action by which Northeast will be able to show a reduction in the rate of erosion of the shoreline of the Turners Falls Pool by the next scheduled river reconnaissance." Instead of submitting a plan, the owner of Northfield Mountain Pumped Storage Project (P-2485) hired Field Geology Services to conduct the fluvial geomorphology study. The study produced some useful observations and recommendations, and stakeholders were generally pleased with the quality of the work (but displeased that the study never resulted in the required "plan"). The erosion ratio was included in a single column in a single table, and had no bearing on the overall purpose of the report. Therefore, the lack of comments should not be inferred as an agreement with the methodology of that single column—reviewers paid no attention to it, and focused comments on other elements of the study.

3. Operation Trends

CRWC's comment letter dated September 29, 2016, recommended that TransCanada "revise the report to add data supporting their claim that 'normal project operations have changed little in several decades' that appears in the last paragraph in the report." In TransCanada's Response to Comments document dated October 31, 2016, the response to comment #37, TransCanada stated, "The revised report will provide additional information to support our claim that operations have changed little in several decades." Section 6.3 Historic Trends in Project Operations has been added in this revised study report. In this section, TransCanada provided exceedance curves for impoundment elevations at midnight for 3 sample 10-year operating periods at the three dams. This section actually indicates that project operations have changed, and provides explanations for these changes.

Of interest is that the 50% exceedance of Wilder impoundment elevation at midnight has increased by 6 inches in the recent decade compared to previous decades. This corresponds with landowner concerns that the river is being held at higher elevations than in the past, submerging beaches that had been exposed in the past. As we have learned with other projects on the Connecticut River, such as the Turners Falls impoundment, changes in the daily "average" water level can destabilize repaired banks.

CRC would like to add that exceedance curves for midnight readings do not capture the full scope of "normal operation of the station generation and impoundment storage." There is more to project operations than a midnight elevation of the impoundment. In particular, in the past decade, we have seen deregulation of the electric industry, sales of hydropower assets to international companies and investment firms, and retirement of some of the larger coal and nuclear power plants in the region. The changing energy market *could* result in more hydropower peaking and therefore higher sub-daily fluctuations of impoundments or multiple peaks per day. The report contains no information on trends in operations leading to sub-daily changes, and TransCanada states on page 133 (also stated at the

March 30 meeting) that to provide this information would be a time-consuming process converting paper logs sheets to electronic data.

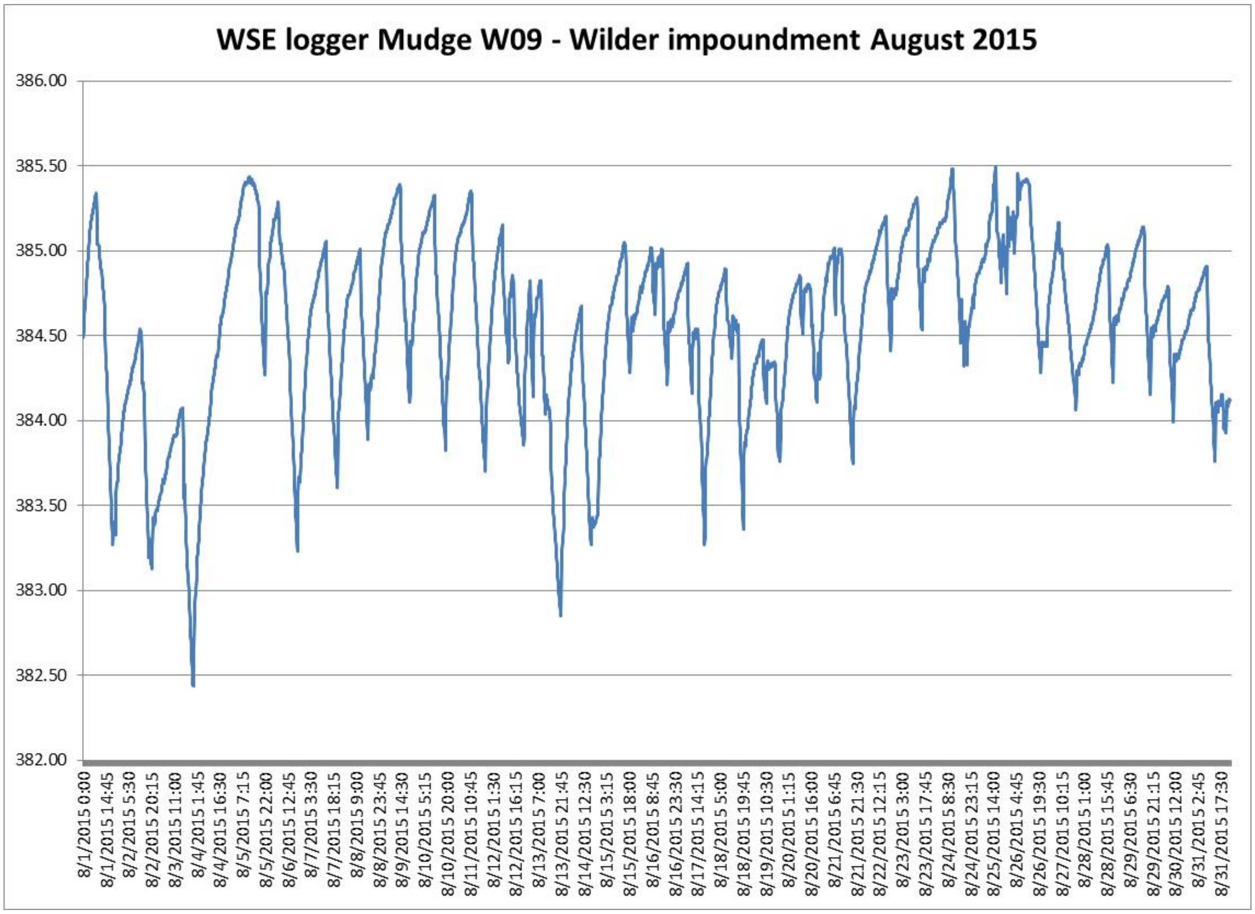
4. WSE Fluctuations

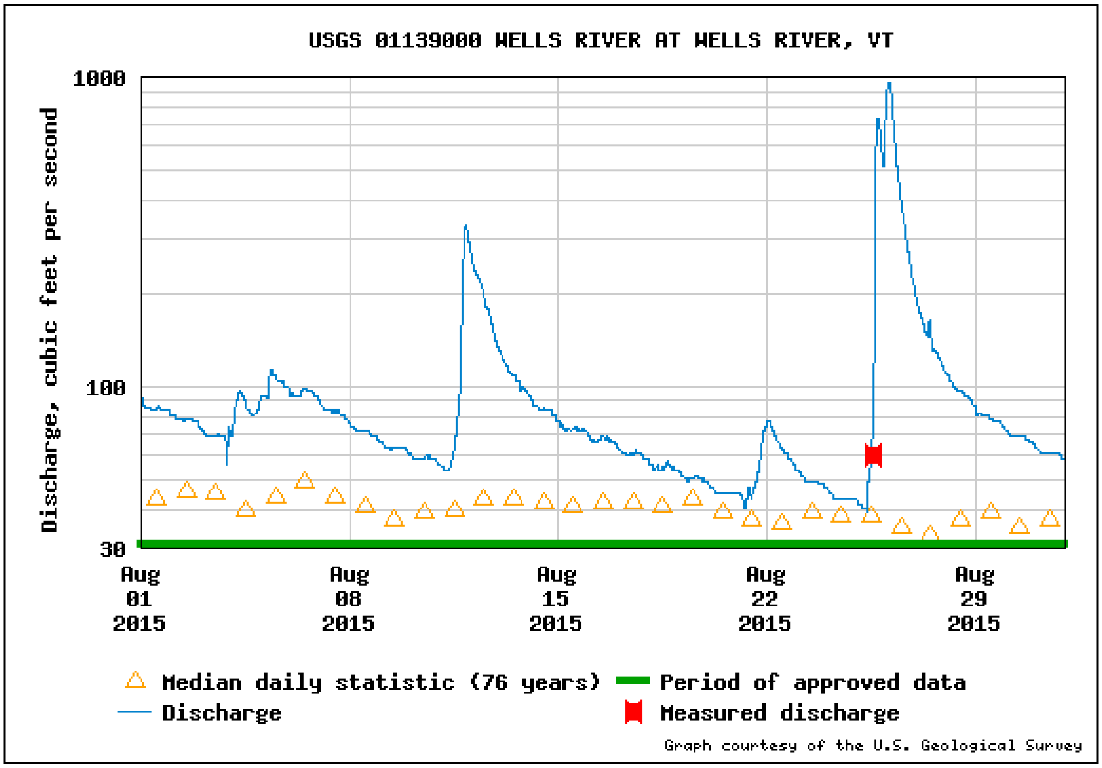
Appendix A contained river stage profiles for the 21 transects, showing the median WSE fluctuation zone compared to the river bank profile. Table 4 in Appendix E shows the bins of the median fluctuation ranges. It is notable that though the report often states how project operations result in a fairly narrow fluctuation range, data in Table 4 of Appendix E show that the riverbank lengths associated with median fluctuations of between 4 and 7 ft add up to 193,803 ft or 36.7 miles of bank.

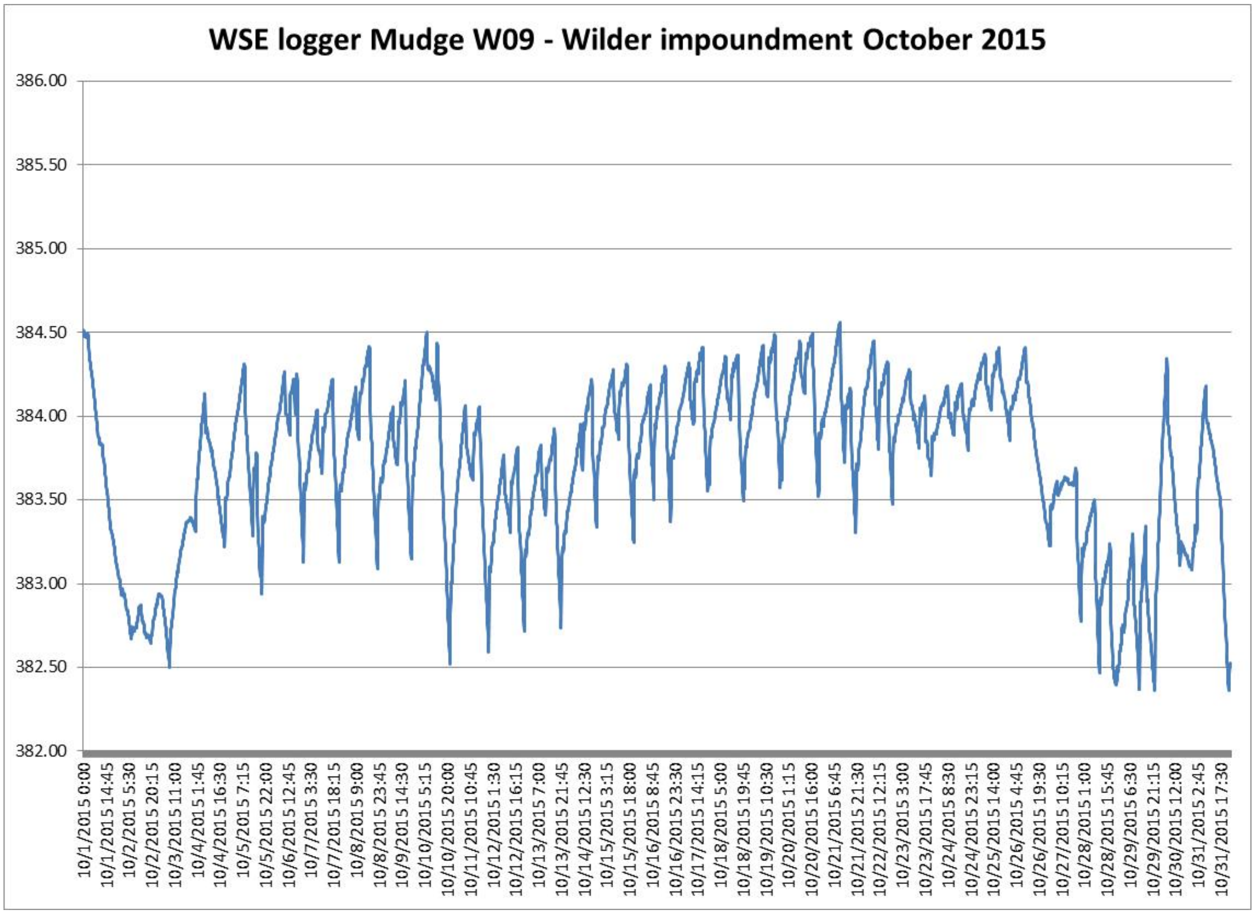
TransCanada provided logger data to stakeholders, which helps us understand the nature of river fluctuations better than exceedance curves or shaded bands on a bank. The graphs below have been made using the WSE logger data provided by TransCanada that were installed for Study 2 and 3, using one site for example purposes. The graphs show how water levels at the Wilder impoundment transect site, Mudge W09, varied in August and October 2015. In August, the river elevations varied between 383 and 385.5 ft, whereas in October, the river elevations never exceeded 384.5 ft, with two peaks per day being common. It also appears that midnight is a time when the river levels are steeply rising, as the impoundments are being re-filled to get ready for the next day's generation period. Below each graph shows the USGS gage for the corresponding month at the Wells River, VT site, approximately 50 miles upstream of the Wilder Dam but downstream of the next upstream dam (Ryegate Dam).

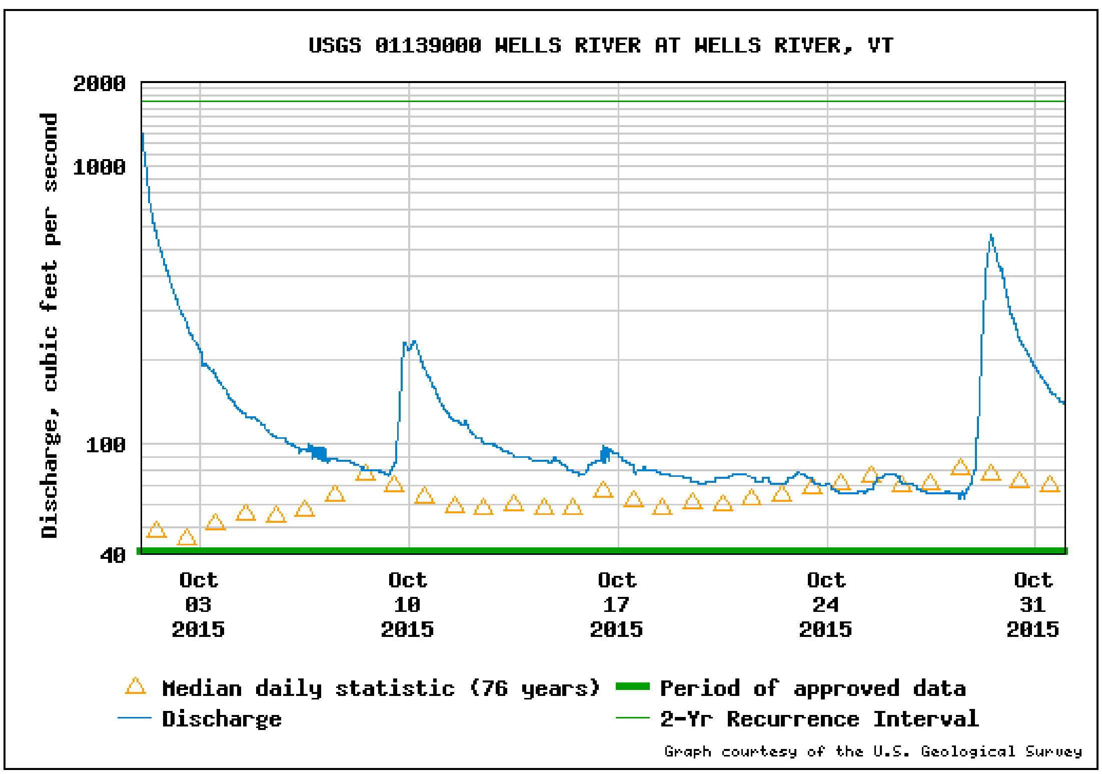
<u>CRC recommendation</u>

The TransCanada RSP for Study 2 stated that, "Relationships observed between changing water levels and the timing of bank erosion will help establish whether water-level fluctuations, described in terms of magnitude, periodicity and duration, and increased shear stresses resulting from project operations are correlated with erosion in project-affected areas." Overall, Great River Hydro has provided information indicating that high flow events are the dominant cause of erosion along the banks of the Connecticut River impacted by the operation of Wilder, Bellows Falls, and Vernon Dams. However, project operational effects have mostly gone unassessed. If you examine the graphs provided below, CRC maintains that the operation of the dams cause river fluctuations that are far from that of a natural river. The study report has looked at the magnitude of water level fluctuations, but not the periodicity and duration of water level fluctuations, and sheer stresses from project operations have only been looked at for the upper end. Sub-daily fluctuations will undoubtedly have some effect on bank stability, and it may not be entirely due to changes in sheer stress. Our understanding of the degree of influence of these fluctuations has not been appreciably advanced by this study. CRC requests that these studies be modified pursuant to 18 C.F.R. § 5.15(a) and (d) (1) to fully address these comments. In lieu of fixing the problems with the study, we may also need to just proceed with a gap in understanding. To the extent possible we will recommend operational changes to reduce river fluctuations, and in lieu of that we will be recommending elements of a plan to mitigate the impact of project operations.


WSE logger Mudge W09 - Wilder impoundment August 2015
386.00
385.50
385.00
384.50
384.00
383.50
383.00
382.50
382.00


USGS 01139000 WELLS RIVER AT WELLS RIVER, VT
Discharge, cubic feet per second
1000
100
30
Aug 01 2015
Aug 08 2015
Aug 15 2015
Aug 22 2015
Aug 29 2015
Median daily statistic (76 years)
Period of approved data
Discharge
Measured discharge
Graph courtesy of the U.S. Geological Survey


WSE logger Mudge W09 - Wilder impoundment October 2015
386.00
385.50
385.00
384.50
384.00
383.50
383.00
382.50
382.00
10/1/2015 0:00
10/1/2015 14:45
10/2/2015 5:30
10/2/2015 20:15
10/3/2015 11:00
10/4/2015 1:45
10/4/2015 16:30
10/5/2015 7:15
10/5/2015 22:00
10/6/2015 12:45
10/7/2015 3:30
10/7/2015 18:15
10/8/2015 9:00
10/8/2015 23:45
10/9/2015 14:30
10/10/2015 5:15
10/10/2015 20:00
10/11/2015 10:45
10/12/2015 1:30
10/12/2015 16:15
10/13/2015 7:00
10/13/2015 21:45
10/14/2015 12:30
10/15/2015 3:15
10/15/2015 18:00
10/16/2015 8:45
10/16/2015 23:30
10/17/2015 14:15
10/18/2015 5:00
10/18/2015 19:45
10/19/2015 10:30
10/20/2015 1:15
10/20/2015 16:00
10/21/2015 6:45
10/21/2015 21:30
10/22/2015 12:15
10/23/2015 3:00
10/23/2015 17:45
10/24/2015 8:30
10/24/2015 23:15
10/25/2015 14:00
10/26/2015 4:45
10/26/2015 19:30
10/27/2015 10:15
10/28/2015 1:00
10/28/2015 15:45
10/29/2015 6:30
10/29/2015 21:15
10/30/2015 12:00
10/31/2015 2:45
10/31/2015 17:30


USGS 01139000 WELLS RIVER AT WELLS RIVER, VT
Discharge, cubic feet per second
2000
1000
100
40
Oct 03 2015
Oct 10 2015
Oct 17 2015
Oct 24 2015
Oct 31 2015
Median daily statistic (76 years)
Discharge
Period of approved data
2-Yr Recurrence Interval
Graph courtesy of the U.S. Geological Survey

ILP Study 25: Dragonfly and Damselfly Inventory and Assessment

The study uses 30 minutes for assessing project impacts on dragonfly eclosure, based on a literature review. Using an eclosure period of 30 minutes seems to be too short a time span. The FirstLight dragonfly study used a critical duration of 2 hours in their risk assessment. CRC recommends Great River Hydro consider using a longer eclosure period to be consistent with the FirstLight report.

The study used logger data to assess impacts from water elevation increases during the 30-minute eclosure period. The logger data were collected every 15 minutes and the hydraulic model data is hourly. Showing an accurate river elevation rate of change for 30 minutes would be difficult with the available data. Again, CRC recommends that Great River hydro use a longer eclosure period, such as 1-2 hours.

It seems that to assess project effects, the study should look at the height of water surface elevation (WSE) change over the critical time period (30 minutes in this study, but CRC would prefer 1-2 hours) and compare that with the typical distance above water that eclosure takes place. Despite the habitat elevations and hourly WSE's in figures in the report, we could not find information that would help us understand the amount of change in a 30-min, 1-hour, or 2-hour period. For example, on page 20 it states that, "The mean vertical distance from the water surface at which eclosing *Stylurus spiniceps* were observed was 12 inches (range of 8-16 inches)." What is the likelihood in the study areas that the water level would rise by 12 inches in the span of 30 minutes, 1 hour, or 2 hours?

We appreciate the opportunity to provide comments on the studies submitted by March 15, 2017. I can be reached at adonlon@ctriver.org or (413) 772-2020 x.205.

Sincerely,

Andrea F. Donlon
River Steward

ATTACHMENT: Princeton Hydro peer review dated May 15, 2017

Princeton Hydro

Scientists, Engineers & Environmental Planners Designing Innovative Solutions for Water, Wetland and Soil Resource Management

May 15, 2017

MEMORANDUM

To: Andrea Donlon, CRC

From: Laura Wildman, P.E., Princeton Hydro, LLC
Paul Woodworth, Fluvial Geomorphologist, Princeton Hydro, LLC

Re: FERC Re-Licensing Process for Great River Hydro, LLC
Peer-Review of ILP Study 2 and Study 3
Riverbank Transect and Riverbank Erosion Studies
Final Study Report, dated February 4, 2017

FERC Numbers:
Project No. 1892-026 – New Hampshire/Vermont
Project No. 1892-045 – New Hampshire/Vermont
Project No. 1892-073 – New Hampshire/Vermont
Great River Hydro, LLC

The Connecticut River Conservancy (CRC) (formerly Connecticut River Watershed Council) is a stakeholder and participant in the re-licensing process of the Federal Energy Regulatory Commission (FERC) for the three hydropower facilities owned by Great River Hydro, LLC (formerly TransCanada Hydro Northeast Inc.) on the Connecticut River, Wilder Dam, Bellows Falls Dam, and Vernon Dam. Princeton Hydro (PH) was retained by CRC to complete a peer review of technical erosion studies, specifically the Integrated Licensing Process (ILP) Study 2 and Study 3: Riverbank Transect and Riverbank Erosion Studies, revised by TransCanada on February 4, 2017. This memorandum is a critical review of the revised ILP Study 2 and Study 3 and aims to address the following questions as defined in 18 CFR § 5.15 Conduct of studies (d) Criteria for modification of approved study, the RSP, and FERC's November 29, 2016 Determination on Requests for Study Modifications and New Studies – Wilder, Bellows Falls, and Vernon Hydroelectric Projects:

- Is the revised report now in compliance with the Revised Study Plan (RSP) dated 8/14/2013 and FERC's study plan determination dated November 29, 2016 on the study report from August?
- Were the new analyses conducted in a way that is generally accepted scientific practice?
- Are the results and conclusions valid?

COMPLIANCE WITH THE 8/14/2013 RSP AND FERC'S 11/29/16 DETERMINATION

FERC's Determination on Requests for Study Modifications and New Studies, dated November 29,2016, ("FERC's Determination") requested additional information regarding modeling (shear-stress and velocity analysis, as well as logistic regression analysis of bank instability), assessment of hydraulic gradient between water surface elevations and groundwater, and effects of shoreline erosion on other resources. The format of our response uses the section headings from FERC's 11/29/16 Determination, including: 1) *River 2D Modeling,* 2) *Hydraulic Gradient between Water Surface Elevations and Groundwater*, and 3) *Effects of Shoreline Erosion on Other Resource*, to discuss critical omissions such as a shear-stress velocity analysis, hydraulic gradient data, and an adequate analysis of other resources, respectively, as well as the inconclusive nature of TransCanada's logistic regression statistical analysis. Excerpts from FERC's Determination on Requests for Study Modifications and New Studies, Nov. 29, 2016 have been included at the beginning of each section below, followed by our peer review comments and recommendations. We conclude our document with short sections on Accepted Scientific Practice, and the Validity of Results and Conclusions, followed by a brief Summary section.

1. River 2D Modeling

Based on TransCanada's promise in response to comments dated October 31, 2016, to "**conduct shear-stress and velocity analyses** using the one-dimensional Hydrologic Engineering Center's River Analysis System (HEC-RAS) model in the revised report for studies 2 and 3…to identify the likely causes of erosion at the 21 erosion monitoring sites…", FERC recommended the following in its Determination:

"Using **HEC-RAS modeling in combination with logistic regression statistical analysis** may be adequate **to identify and describe the likely causes of erosion** at the 21 monitoring sites. When TransCanada files its revised study report in January 2017, we will review the results, including the proposed HEC-RAS modeling and regression analysis, and as appropriate, **consider the need for additional analysis**, including use of the River2D model. Based on the information available at this time, we expect that the revised report will be adequate for staff's analysis and to develop any necessary license requirements (section 5.9(b)(5)). Therefore, we do not recommend requiring TransCanada to conduct any River2D modeling at this time."

Peer Review Comments Regarding Compliance with FERC Determination

Shear-stress and Velocity Analysis

No shear-stress and velocity analysis, using the HEC-RAS model to identify the likely causes of erosion at the 21 erosion monitoring sites, was included in the revised Study 2 and 3. The revised study again refers to the original Study 4 – Hydraulic Modeling Report dated March 1, 2016, which was not recently revised. There is no mention of a HEC-RAS model in the revised Study 2 and 3, and no results listed shear stress throughout the study reach, although it is presumed this data was used as input for the logistic regression analysis. Study 4 – Hydraulic Modeling Report also does not include the tabular output data from the one-dimensional HEC-RAS model, which would list velocity and shear stress by model cross section, nor does it include any of the standard water surface profiles or cross-sectional modeling data, such that Princeton Hydro could review the validity of this modeling.

The revised Study 2 and 3 does list velocity data for a limited number of flows, with no associated shear stress data, in Table 5.8-1 on page 123, Section 5.8, and in Tables 6.1-1 and 6.1-2. The velocity data and analysis in Section 6.1 focuses only on a single element of the cycle of erosion, the potential for sediment entrainment at the toe of the stream bank. The velocity data and discussion in Section 5.9 (Table 5.8-1) focuses only on the change in velocities during periodic operational drawdowns, in preparation for anticipated high flows (as described in page 120 of the report). The data presented in Table 5.8-1 actually show that velocities *increase* between 36% and 400% during these periodic operational drawdowns, resulting in velocities significantly in excess of the threshold velocity for sediment entrainment later discussed in Section 6.1. The data presented in Table 5.8-1 therefore suggests that periodic operation drawdowns, in preparation for high flows, could regularly mobilize sediment at the toe of the streambank at 9 of the 13 monitored impoundment cross sections. However, the revised Study 2 and 3 then attempts to discount the significance of this finding by running a scenario where only WSE fluctuates and flow remains constant even though they state that, "such a scenario does not actually occur" (page 122). Again, no shear stress was included in the velocity data included in Section 5.8.

The discussions included in section 5.9 and 6.1, do not "identify the likely causes of erosion at the 21 erosion monitoring sites" as was indicated in TransCanada's response to the requested study modifications, and as was stated in the FERC Determination dated November 29, 2016.

It is not possible for Princeton Hydro, FERC, or any of the stakeholders to review the one-dimensional flow analysis, referred to in Study 4, the presumed source for the velocity data listed in Study 2 and 3, without standard output tables, profiles, and model cross sections. HEC-RAS model reviews are typically completed by opening the actual model and reviewing both the input and output data, since reviewing just output data assumes that the model was set up and run accurately.

Princeton Hydro Recommendation: We recommend that TransCanada conduct the shear-stress and velocity analyses using the one-dimensional Hydrologic Engineering Center's River Analysis System (HEC-RAS) model to identify the likely causes of erosion at the 21 erosion monitoring sites, and provide all of the needed input and output data, as well as the HEC-RAS model itself, such that a review of the modeling and analysis is possible.

Logistic Regression Analysis of Bank Instability

A Logistic Regression Analysis was performed in partial response to requests by Princeton Hydro and FERC; however, we find the selected analytical test to be inappropriate, the results in conflict with the known causative physical forces of bank erosion, and the results to be invalid. The analysis focuses solely on the data set that categorizes all banks within the study area into one of six classes of stability or instability. The analysis does not include the data set derived from the review of aerial photographs at 0.5-mile increments, nor the data set related to the 21 transects, as was recommended in the FERC Determination dated November 29, 2016 or in Princeton Hydro's Recommendation #9 on page 13, in the memo entitled FERC Re-Licensing Process for TransCanada Hydro Northeast Inc., dated September 30, 2016. According to Appendix E of Study 2 and 3, the input data provided to the statistician who conducted the logistic regression analysis were two comma delimited text files corresponding to the left and right river banks, which included shear stress data at high normal operational flows and the 10-yr recurrence interval flood flow averaged across the full width of the channel. This input data was not included in Appendix E, and again no tabular data relating to shear stress by location was reported, including at the 21 monitored cross sections.

Shear stress computations generated from one-dimensional modeled flow, which is averaged across the full width of the channel, yields single values for shear stress at a cross-section and do not generate results that differentiate between the outside and inside banks of the channel. Without explanation of the source and type of the shear stress data utilized in the analysis, the results associated with shear stress are difficult to interpret and may be invalid.

The analysis reduces the six classes of stability into two binary categories (stable or unstable). This initial step in the process could skew the analysis if, as explained in the September 30, 2016 Princeton Hydro memo (page 12), the bank category of "armored" is represented as "stable." Armored banks were previously unstable to such a degree to necessitate engineering intervention. Thus, their characteristics, WSE fluctuation, height, shear stress, etc. are all conditions that should be attributed to "instability".

The analysis concludes that there are no single strong predictors of bank instability; and, that bank height, shear stress (at the lower flow), and WSE fluctuation were the top three, albeit low (up to 3.5% deviance explained in the single predictor model, and 7.4% deviance explained in the multiple predictors model) predictors of bank instability. Statistical analyses are useful when they can account for much higher (e.g. greater than 50%) explanatory power. Regression analysis assumes observations are independent variables; however, as explained on page E-2 of Appendix E, the observations in this data set are not independent. Princeton Hydro had pointed out the potential for spatial autocorrelation in this dataset in the September 30, 2016 memo, and thus had suggested "more rigorous spatial statistical methods should be employed." The fact that the data is subject to spatial autocorrelation may be the cause of the poor predictive power of the analysis and brings into question the validity of comparing the results of shear stress, bank height, WSE fluctuation, etc.

The analysis produces a strongly counter-intuitive finding that there are no unstable banks at the highest shear stresses, and that bank instability does not increase with bank height, shear stress, and WSE fluctuation. A basic understanding of the physical forces and the cycle of erosion would clearly support the notion that bank instability would increase with one or all of those factors – this conclusion to the contrary is highly suspect and raises serious doubts about the validity of the input data, the statistical method employed, and its interpretation. For example, the use of cross-section-averaged shear stress from a one-dimensional model that is then extrapolated many thousands of feet from a modeled cross-section may be of insufficient resolution to provide meaningful quantitative connection to bank stability.

A statistical analysis of the dataset of the 21-transects, which was not completed, could incorporate the presence of bank materials and stratification, which are acknowledged as factors that contribute to bank instability relative to WSE fluctuation (discussed in section 2 below). While a much smaller dataset, the 21 transects are likely sufficiently separated so as to reduce or avoid problems with spatial autocorrelation.

Importantly, the revised study emphasizes how the shear stresses at high flows are the primary driver of the cycle of erosion as they are the only flows sufficient to remove soil from the bank toe (however, their data on Figure 6.1-1. page 131 does not support that statement). Assuming that the results can be compared relative to each other (despite the inherent problems with this statistical test related to the nature of the dataset), this analysis finds high flow shear stress to have less effect than WSE fluctuation and bank height. This suggests that WSE fluctuation has nearly equivalent importance on determining the probability of erosion as high flows, contrary to assertions made throughout the revised study report. Furthermore, the results of the analysis indicate that WSE fluctuation is one of the top three factors that determine bank stability, an admission that project operations are in fact a significant factor in causing bank instability.

Princeton Hydro Recommendation: We request that the input data, or the regression residuals, be evaluated for spatial autocorrelation using Moran's I or a similar spatial index to determine the degree of spatial autocorrelation and spatial dependencies, and if significant, we request an alternative statistical test or at a minimum, further discussion about the utility and validity of the results despite the current test's limitations. Further, we recommend additional statistical analyses on the data set derived from aerial photographs at 0.5-mile increments, and on the data set related to the 21 transects as was recommended in the FERC Determination dated November 29, 2016.

2. Hydraulic Gradient between Water Surface Elevations and Groundwater

The FERC Determination stated, "It is unclear how or if TransCanada determined the hydraulic gradient between impoundment water surface elevations and groundwater elevations along the shoreline (i.e., the report for studies 2 and 3 does not include any groundwater elevation data). Therefore, Commission staff recommends that the revised report that will be filed in January 2017 include additional information that **describes how the hydraulic gradients were calculated and the resulting potential for riverbank erosion** (e.g., naturally occurring seepage and project-related seepage). The discussion should **include any observations of groundwater seeps or seepage-related erosion** at the 21 erosion monitoring sites **and any groundwater elevation data** that was collected during the studies."

<u>Peer Review Comments Regarding Compliance with FERC Determination</u>

The revised Study does not describe how the hydraulic gradients were calculated and the resulting potential for riverbank erosion, nor does it include observations of groundwater seeps or seepage-related erosion at the 21 erosion monitoring sites and any groundwater elevation data.

As previously stated in our September 30th, 2016 peer review of the original Study 2 and 3 and as per our current review of the revised Study 2 and 3, no ground water data, and thereby no hydraulic gradient data for the streambank, was collected or analyzed for the review of how operational WSE fluctuations potentially effect streambank stability. The revised Study 2 and 3 states that "even small WSE fluctuations could still contribute to bank instabilities" (page 138), but then discounts this potential without any data; basing their assumption on the magnitude of the assumed hydraulic gradient (discounting 25% of the reaches with higher fluctuations) and what they refer to as the short duration of the fluctuations, which occur on a daily basis.

The following four excerpts taken from the revised Study 2 and 3, further highlight the importance of assessing the hydraulic gradient between impoundment water surface elevations and groundwater elevations along the shoreline, based on site specific groundwater field data for the 21 monitored sites.

> Page 138 : "While even small WSE fluctuations could still contribute to bank instability, the texture and stratigraphy of bank sediments are also important controls on the hydraulic gradient and associated seepage forces (Fox et al., 2010) such that the stability of two adjacent banks with slight differences in bank composition could be very different despite experiencing identical WSE fluctuations, thereby complicating efforts in discerning whether bank instability is the result of project-induced WSE fluctuations."

> Page 124: "The character of sediments in the study area creates banks with limited resistance to erosion. The bank sediments at the monitoring sites, representative of the study area as a whole, are nearly ubiquitously comprised of fine-grained and unconsolidated floodplain or glaciogenic sediments that are particularly prone to erosion (see Appendix A stratigraphic columns). Frequently observed inter-beds of permeable sand and less permeable silt can further reduce the resisting force of floodplain sediments by creating horizontal surfaces along which groundwater can preferentially move, potentially increasing seepage forces acting on the bank."

> Page 132: "When the water surface in an impoundment is increased when a dam is raised, the previously dry bank sediments inundated by the rising water becomes saturated, the pore pressures increase, and the resisting forces of the bank material decrease. Together with the added weight of the water in the bank sediment (causing an increase in the driving forces), the reduced strength of the bank material creates an unstable situation that leads to bank failure (Brunsden and Kesel, 1973; Lawson, 1985)."

> Page 165: "…although such operations could contribute to erosion by creating seepage forces associated with daily fluctuations."

This last excerpt was taken from Section 6.6, Study Conclusions, and clearly highlights the need to assess seepage forces associated with daily operational fluctuations.

In addition to assessing the hydraulic gradient associated with daily operational WSE fluctuations, it is also critical to assess the potential for streambank instabilities caused by periodic operational drawdowns in preparation for high flow events. The revised Study 2 and 3 does not include a discussion of the potential for seepage forces and bank instabilities during periodic operational drawdowns, which occur over longer durations than the daily WSE fluctuations. Although it does bring up stability concerns relating to periodic operational drawdowns, when it states on page 120 that, "As a result of lowering WSE at the dams, a convexity in the longitudinal profile develops in the impoundments, most pronounced at the lower end (Figure 5.8-1 on page 121 – this is the second figure labeled 5.8-1 in the report), that could potentially engender a channel response as a stable river profile typically has a concave-up profile in contrast to the observed convexity." This same discussion shows that velocities during periodic operational drawdowns exceed the threshold velocity for sediment entrainment at 70% of the 13 erosion impoundment monitoring sites, and as such periodic drawdowns to precipitate movement of accumulated sediment away from the tow of the streambanks, similarly to high flow events and a handful of the higher operational flow events at the 21 monitored cross sections.

Princeton Hydro Recommendation: We recommend that Great River Hydro collect groundwater elevation data and observations of groundwater seeps or seepage-related erosion at the 21 monitored transects and, as requested, analyze that data to determine how operational WSE fluctuations potentially effect streambank stability. This analysis is needed since, as stated in Study 2 and 3 on page 138, "even small WSE fluctuations could still contribute to bank instabilities." Great River Hydro should calculate the hydraulic gradients specific to the full range of operational WSE fluctuations including both normal operational WSE fluctuations and periodic operational drawdowns, inclusive of durations for both current operational practices. The analysis should incorporate the data already collected by TransCanada at the 21 transects relating to the layering of sediments within the banks and the stratification of permeable and less permeable zones. The studies should describe how the hydraulic gradients were calculated and the resulting potential for riverbank erosion (e.g., naturally occurring seepage and project-related seepage). The discussion should include data, observations, analysis, and discussion for potential riverbank erosion and all 21 erosion monitoring sites. Without this data the validity of the conclusions of Study 2 and 3 remain in question.

3. Effects of Shoreline Erosion on Other Resource

The FERC Determination stated, "An objective of study 3 (see the fourth bullet on page 27 of the approved RSP) was to 'identify the effects of shoreline erosion on other resources (e.g., riparian areas and shoreline wetlands, rare plant and animal populations, water quality, and aquatic and terrestrial wildlife habitat).' TransCanada proposed to conduct this analysis partly by using "maps showing the location of different bank conditions and features along the river […] to investigate whether bank erosion has the potential to affect other resources.' The report for studies 2 and 3 provides a limited analysis of other resources and suggests that other studies (i.e., studies 6, 8, 14, 15, 24, 25, 27, and 30) determined erosion is 'unlikely to have measureable negative effects on those resources.' The report for studies 2 and 3 does not include any maps comparing areas with documented erosion to the maps created for other studies.

…the discussion of existing information should be expanded to provide a more detailed description of the effects of ongoing erosion within the project boundary on other resources. Therefore, we recommend that the revised study report that will be filed in January 2017 include a **detailed qualitative discussion of the potential effects of ongoing erosion** within the project areas **on riparian areas and shoreline wetlands, rare plant and animal populations, water quality, aquatic habitat, and terrestrial habitat**. Where possible, this discussion should include **comparative maps and site-specific observations**. "

Peer Review Comment Regarding Compliance with FERC Determination

Our comments on how the effects of shoreline erosion were assessed regarding other resources are addressed as follows:

3.1. Cultural and Historic Resources

No maps are provided. Six of seven sites were recommended for listing in the National Historic Register and protection. A qualitative assessment of the potential effects of ongoing erosion on these cultural and historic sites is not provided.

3.2. Recreation Facilities

67 public access sites are identified, 7 sites were linked to erosion concerns. No mapping is provided. TransCanada manages impacts from erosion, scour, and sedimentation at FERC Project recreation sites through as-needed maintenance. A qualitative assessment of the potential effects of ongoing erosion on these recreation sites is not provided.

3.3. Wetlands

Only three example maps are provided. Statistics were presented that show that wetlands are more prevalent at stable banks and in the dam impoundments than the riverine reaches. The discussion raises the question whether the wetlands promote bank stability or whether stable banks promote wetlands. A qualitative assessment of the potential effects of ongoing erosion on wetlands is not provided.

3.4. Rare Plants

Jesup's Milk Vetch

- Four known sites; no mapping is provided. Ongoing bank erosion is not likely to adversely impact Jesup's Milk Vetch as it inhabits bedrock outcrop crevices.

Northeastern Bulrush

- Not located in field surveys. Ongoing bank erosion is not likely to adversely impact NB as it inhabits beaver dams and habitats beyond the impoundment.

Other Rare Plants

- No mapping is provided. Other rare plants were 2x more commonly found at stable banks (65 out of 96 at stable sites, 23 out of 96 at unstable sites). One species is an erosion specialist and benefits from eroded sites. Ongoing bank erosion may adversely impact other rare plants.

3.5. Rare Animals

Cobblestone Tiger Beetle

- No mapping is provided. Cobblestone Tiger Beetle (CTB) was found at 7 of 14 study sites, 5 of which were stable. Erosion is an important process for maintaining CTB habitat; however, the discussion does not acknowledge that bank erosion rarely yields the coarse-grained material that forms CTB habitat. Contrary to the report's findings, ongoing bank erosion does have the potential to adversely impact CBT.

Fowler's Toad

- No mapping is provided. Fowler's Toad habitat is naturally rare in the CT River; FT was located at 1 of 10 study sites that had suitable habitat. The report concludes that periodic scouring and erosion during high flow events would contribute to creating and maintaining FT habitat.

Dragonflies and Damselflies

- Only two example maps are provided. Dragonflies and Damselflies (D/D) were found at 11 of 11 study sites, including 6 Species of Greatest Conservation Need. As species were co-located with stable and unstable sites, the report concludes that ongoing bank erosion is unlikely to adversely impact D/D and may maintain desirable habitat conditions.

3.6. Terrestrial Wildlife

Bank Swallows

- No mapping is provided. Bank Swallows require eroded banks for colony nests.

King Fishers

- No mapping is provided. King Fishers utilize eroded banks for individual nests.

Bald Eagles

- No mapping is provided. While single potential nest trees can be lost due to bank erosion, the report concludes that the greater population is unlikely to be impacted by ongoing bank erosion.

3.7. Aquatic Resources

Water Quality

- Water quality monitoring reported in Study 6 found turbidity to be within state standards. Few recorded peak spikes in turbidity were found to occur in response to high flows resulting from heavy rain events. However, there is no discussion of how ongoing bank erosion is contributing to measure peaks in turbidity. Further, periodic drawdowns in anticipation of high flows also generate high velocities which are likely to generate bank erosion and contribute to turbidity. Discussion is provided on the impacts of turbidity to spawning, although there is no assessment on the impacts to sight-feeding fish or gill respiration, both of which are known to be impacted by turbidity and total suspended solids (TSS).

Aquatic Habitat and Substrate

- Statistics are presented that show that fines are far more prevalent in the impounded reaches (72-84%) and that coarse-grained substrates are far more prevalent in the riverine reaches (65-75%). This stark contrast would seemingly have substantial effects on benthic communities; however, it is not acknowledged.

Fish Spawning

- Three species spawn in slack-water habitat. At least four species practice nest-cleaning behaviors, where they sweep away fine sediments. Six riverine species do not actively clean nests, and indeed multiple nests were found abandoned, for unknown reasons. These riverine species could be adversely affected by ongoing bank erosion, although the report does not clearly state this.

Freshwater Mussels

- Statistics are presented showing the co-location of Freshwater Mussels with stable and unstable banks. However, the report states that surveys were not conducted randomly but rather “purposely avoided areas with highly unstable banks, because, based on surveyor experience, mussels are less likely to be found near those types of banks.” This fact renders the statistics invalid, and reinforces the concern that ongoing bank erosion could adversely effect freshwater mussel species.

Princeton Hydro Recommendation: We recommend that TransCanada include mapping as requested in the FERC Determination dated November 29, 2016 including riparian areas and shoreline wetlands, rare plant and animal populations, water quality, aquatic habitat, and terrestrial habitat. Locational information for stationary state-listed species can be made privileged. More importantly, we recommend further qualitative discussion about the potential impacts that ongoing bank erosion and the release of fine sediments may have on (i) the Cobblestone Tiger Beetle habitat, (ii) water quality impacts related to sight-feeding and respiration of fish, (iii) aquatic habitat and substrate, (iv) spawning of riverine fishes, and (v) freshwater mussels.

ACCEPTED SCIENTIFIC PRACTICE

- **Erosion Ratio**: While a statistical analysis was added to Study 2 and 3, the revised study still utilizes and makes conclusions based on the “erosion ratio.” This approach is not an accepted scientific practice and was not proposed and a method for inclusion in the RSP. No citation or reference is provided for this metric, and the metric is not used, to our knowledge, in the extant fluvial geomorphic scientific literature. We understand through our conversations with CRC, that Field Geology Services used the erosion ratio in a table in their 2007 fluvial geomorphology study of the Turners Falls impoundment of the Connecticut River. The TransCanada study does not demonstrate that the method conforms to generally accepted scientific practice; in fact the revised study states that “the erosion ratio approach for identifying potential causes for erosion has not been widely used” (page 103 Revised Study 2 and 3). Please refer to our previously prepared peer review comments from September 30th, 2016, for a more detailed explanation of the potential biases associated with the erosion ratio.

VALIDITY OF RESULTS AND CONCLUSIONS

Study Conclusion #1: “Flow velocities and shear stresses during normal project operations have been shown to be inadequate, within the impoundment sections and at nearly all locations within the riverine sections, to mobilize sediment accumulating at the base of the banks and are by themselves unable to sustain the cycle of erosion.” (from page 140 of the Revised Study 2 and 3)

Peer Review Comment: The study continually discounts the role that normal project operations may have on erosion, based on their statement that normal project operational flows are not responsible for mobilizing accumulated sediment at the base of the banks, even though their own data (Figure 6.1-1. page 131) demonstrates that operational flows can entrain sediment accumulations at the toe of the slope. While we concur with the study that mobilization of eroded streambank sediment that has deposited at the base of the bank typically occurs during high flows, we do not concur that it therefore follows that WSE fluctuations caused by normal project operation do not play a role in initiating the erosion at the toe of the bank, which is also a critical element in the bank erosion cycle. While the initial toe of bank notching may result in a lower quantity of sediment being mobilized, it does directly contribute to the bank failures that then result in sediment deposits at the toe of the bank, once the bank has failed. The cycle of erosion is only propagated when all of its elements continue to occur. It does not logically follow to place a higher significance on only one element of the cycle, such as mobilization of the sediment depositions at the toe of the bank due to high flow. As the study states, “Not all causal mechanisms need be present at any given site to effect erosion, but where they are present they all work in concert to increase bank instability.” (page 124)

In addition to the above referenced invalid study conclusion we would also refer FERC to our peer review comments and recommendations from our September 30, 2016 peer review for Study Conclusion #4 on page 15 and Study Conclusion #5 on pages 15 and 16.

PEER REVIEW SUMMARY

Princeton Hydro finds the revised Final Study Report, dated February 4, 2017 to be incomplete, inconclusive, and at least partially, invalid. The Final Study Report does not fulfill the obligations put forth in the Revised Study Plan, nor the follow-up requests in the FERC Determination on Requests for Study Modifications and New Studies, dated November 29, 2016. Essential data, related to the hydrologic and hydraulic analyses and subsequent analyses, including detailed stage monitoring and hydraulic modeling output of velocity and shear stress, were never provided for review or analysis. Statistical analysis from that data was compromised by spatial autocorrelation, rendered inconclusive results, contradicted assertions made in the Revised Study Report, and led to interpretations that are counter to the known physical processes that effect bank stability.