Study Plan, 18CFR Section 5.9b
Submitted for the Wilder Project, FERC 1892-026
By The Town of Lyme, New Hampshire

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and

By the City of Lebanon, New Hampshire

City Manager
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and by an abutter to the Wilder Dam impoundment

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Dated February 26, 2013

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Goals and Objectives:

The goal of the proposed study is to obtain data concerning piping erosion at the shoreline of the Wilder Dam impoundment and to ascertain whether erosion may be reduced by changes in water level management practices by the dam operator. The study will

1. Identify the effects of the size and rate of river level changes on water transport into soils surrounding the impoundment.
2. Study sites will include known highly erodible soils as well as less easily eroded soils.
3. Study sites will also include locations where bank stabilization using various methods has been performed.
4. Identify sites where piping erosion occurs and estimate the amount of siltation from such sites.
5. Place river level and flow gauges at selected study sites above Wilder Dam.
6. Record and collect measurements of flow and river levels at these gauges and Wilder Dam.
7. Produce a model for the management of water levels and rate of water level change that will reduce erosion.
8. Allow the effectiveness of bank stabilization methods to be tested

The strategy is to examine the rate and size of water level changes in the reservoir to ascertain whether these variables produce significant changes in the amount or rate of water loading of erodible soils. This information would enable management of river levels that reduce siltation without necessarily compromising the operator's goal to achieve a satisfactory return on its investment.

The study Objective is to gather data on erosive activity and river flows that will assist the operators of the Wilder Dam and FERC in developing a management plan that minimizes erosion. Reducing erosion, in turn, meets several objectives of public importance:

1. improvement of water quality in the reservoir and downstream
2. improvement in the scenic and recreational value of the river
3. preservation of valuable agricultural land – a resource for migrating birds and wildlife
4. reduction in the siltation in the reservoir with resulting loss of storage capacity and dam lifespan
5. increased protection for private and governmental shoreline structures and/or infrastructure

Relevant Resource Management Goals

5.9(b)(2) Not relevant

5.9(b)(3) Sections 4(c) and 10(a) of the FPA require the Commission to give equal consideration to all uses of the waterway on which the project is located. When reviewing a proposed action the Commission must consider the environmental, recreational, fish and wildlife, and other non-developmental values of the project as well as power and developmental values.

Public Interest Considerations

All of the objectives listed in the Study Objective section on page 3, points 1-5, comprise issues that are in the public interest and which the Commission must consider in addition to power generation and development.

Existing Information and Need for Additional Information

Members of the public speaking at the Scoping Meeting in West Lebanon on January 28thth, 2013 presented anecdotal evidence of erosion their properties abutting the Wilder impoundment. They claimed that the rate of erosion had increased recently, and corresponded to the changes in management of the project following assumption of operations by TransCanada. A popular belief amongst those commenting on this subject is that when water levels are raised, water flows into the soil in the river bank, and when the water levels fall this water flows out of the bank, and carries with it soil particles such that, over time, the bank is undercut by this process.

This is certainly not the first time that concerns about erosion related to this project have been raised. At the time of the last license renewal for the project, the issue was the subject of a study performed by the Army Corps of Engineers the results of which are reported in a synopsis in the PAD prepared for the current license renewal. (Simons, D.B., Andrews, J.W., Li, R.M., and Alawady, M.A. 1979. Connecticut River Streambank Erosion Study Massachusetts, New Hampshire, and Vermont. Prepared for USACE, New England Division.

I quote the synopsis of the Simons, et al. study that appears in the Pre Application Document (PAD):

"The Wilder impoundment was evaluated in this study, which discussed the various processes that occur along the Connecticut River. The study emphasized two categories of forces that affect the shoreline: (1) those forces that act on or near the surface of the

water associated with pool fluctuations; related piping; groundwater; wind waves; boat waves; ice; lack of, or removal of, vegetation;

The forces that act at or near the surface of the water generally cause the bank to gradually adjust by developing a bench or berm area wide enough to dissipate the forces causing erosion, increasing upper bank stability as the adjustment occurs. The report includes an estimate that the extent of erosion landward would in most cases be limited to an average of about 10 to 15 feet in a large river (such as the Connecticut River). After the bench is formed, growth of aquatic vegetation usually takes place, further increasing the stability and curtailing further significant upper bank erosion."

It should be noted that this study mentions "pool fluctuations and related piping," and the reader might conclude that this process as well as others, will be responsive to the riverbank remodeling process. In summary, the authors of this study offer an optimistic view that when the bank remodeling process is complete that erosive forces will be dissipated and a more or less steady state will then prevail.

The remarks by numerous property owners concerning ongoing erosion of their properties at the time of the Scoping Meeting on January 28th, 2012, is evidence that the sequential changes described in the Simons study have not occurred or, if they have, have not operated to control erosion. Although Simons mentions pool fluctuations and piping, the same process the property owners contend is responsible for erosion of their land, pool fluctuations and piping fails to appear as a significant cause of erosion in the PAD.

Piping: Since the above study was performed the issue of "piping" has received a great deal of attention by geomorphologists and hydraulic engineers, because of the risks that erosive piping confers on earth-filled dams and levees. In situations where hydrostatic pressure is exerted one a side of the dam or levee and the soils used in the construction of the structure do not offer a uniform and effective barrier to water penetration, avenues of permeable soils left within it, transmit flow to the low pressure side. This flow carries away soil particles at the low pressure end of the affected strata often leading to a tube-shaped cavity propagated inward from the low pressure side, and referred to as a "pipe." Erosion continues back up the path of water flow (backward piping) until the process reaches the high pressure face of the barrier, often with catastrophic results for the structure.

The same process operates in river banks, though usually with less dramatic outcomes. Fluctuations in river levels may cause permeable soils to accumulate water during high water and when the river level falls, the water trapped in the permeable soil exits carrying soil with it. The formation of tunnels or caves, sometimes of considerable size, with subsequent collapse of overlying strata, at times many feet from the bank, to produce a "sink hole" is one result of this process. At other times the process affects soils closer to the river bank and causes collapse of a portion of the bank into the river.

The term, "sapping" often used in conjuction with descriptions of piping, refers to the erosion caused by groundwater from sources such as springs in a river bank that carry soil away with resultant undermining the bank.

The 1992 report prepared by D.J. Hagerty from the Civil Engineering Department of the University of Louisville for the U.S. Army Corps of Engineers (ACE), (Identification of Piping and Sapping Erosion of Streambanks (Contract Report HL-92-1) is a definitive examination of this phenomenon. It employs observational methods to identify piping and to separate it from other types of erosive activity. It also addresses methods for prevention and mitigation of such erosion.

In a 1991 article in the the Journal of Hydraulic Engineering, Hagerty used knowledge derived from work leading to the above report to comment upon the subject more generally. (Hagerty, D. (1991) "Piping/Sapping Erosion. I: Basic Considerations." J. Hydraul. Eng. 117(8), 991-1008.

I quote a portion of the abstract from this article: *"This mechanism is widespread in occurrence and is very significant to bank and shore stability, but is* ***rarely*** *recognized.* [emphasis mine]. *The mechanism is complex and acts in concert with other processes of bank and shore erosion and deposition. Operation of those other mechanisms often masks the processes and products of the piping/sapping mechanism. Furthermore,* ***failures caused by this mechanism may occur during periods of stream inactivity long after storm and/or flood events have ended****.* [emphasis mine]

In anticipation of the reapplication for the relicense TransCanada commissioned a new study of erosion sites currently present on the Wilder impoundment by Kleinschmidt (Kleinschmidt Associates, Inc. 2012. Technical Report – Phase 1A Archeological Reconnaissance Survey, Wilder Hydroelectric Project (FERC No. 1892). Windsor and Orange Counties, Vermont and Grafton County, New Hampshire. Pawtucket, Rhode Island, July 2012.

Kleinschmidt's shoreline surveys in 2010 found "*moderate to severe erosion along sections of the shoreline upstream of Wilder Dam…."* and attributed this to *"rapid decline of stream inflow following a prolonged or sustained high inflow period where bank-full flows combined with surface runoff flow result in high saturation of low cohesion bank material."* The report continues with an examination of farming practices and comments on how agricultural practice has culminated in the lack of adequate vegetated buffer in 77 of 100 erosion sites studied.

As a result of the studies by Simons and Kleinschmidt TransCanada states in Section 3.4.6 of the PAD that it "*knows of no information suggesting that the Project or its operations are solely responsible for any adverse effects on geological or soil resources in the vicinity of the project. As indicated in section 3.4.5, Project operations associated with impoundment fluctuations play a minor role in shoreline erosion, with flood flows from major storms playing a significant role. Other causes of erosion, including agricultural practices, piping, groundwater, wind waves, boat waves, ice and lack of or removal of vegetation also play roles in ongoing erosion effects on geological and soil resources."*

Neither of the two studies reported in the PAD attempt to quantify the erosion due to piping. Kleinschmidt's statement that the major cause of erosion, "*rapid decline of* *stream inflow following a prolonged or sustained high inflow period…"* describes the essential characteristics of a piping situation without reporting on the ground or bank observations that could confirm the operation of this mechanism in the erosive events. Nor did either of the two studies described in the PAD attempt to ascertain whether impoundment fluctuations caused by the Project result in piping erosion. TransCanada did not recruit a person with extensive experience in the recognition of piping erosion for the conduct of the studies despite hosting a situation in which the piping mechanism of erosion is most likely to be operative and in situations in which experts in the discipline describe it as being most likely to be overlooked. For this reason the **statements in section 3.4.6 of the PAD should be disregarded in the relicensing process**, because the applicant's studies were not designed or conducted in a manner capable of ascertaining whether piping erosion was resulting from reservoir fluctuations.

Further, there is an extensive literature concerning mechanisms for mitigating piping erosion. Some of these are laboratory based, for instance Fox, GA, Ma Librada Chu-Agor,M,and Wilson,GV; SSSAJ 71 No6 p1822-1830, 2007 and Tomlinson,SS, and Vaid YP; Canadian Geochemical Jr. 37(1); 1-13,2000 while the NSF has awarded a grant for investigation of groundwater contributions to the piping process to support research at the Oklahoma State University and the USDA-ARS National Sedimentation Laboratory in Oxford Mississippi. (Fox G, Wilson GV; Resource 19 (2) 15, 2012). These investigators are using methods that could be applied in the case of the Wilder impoundment.

Other methods of mitigation are field based (summarized in Hagerty, referenced above). Essentially, successful mitigation includes establishment of a barrier to water infiltration in the subject area coupled with appropriate steps to maintain that barrier intact. **While maintenance of stream-side vegetated buffer zones is desirable for many reasons, such zones do not prevent piping in highly erodible soils such as are found in farmland surrounding the Wilder impoundment.** For example, substantial erosion in a mature **natural** area referred to as "Pine Park" in Hanover was reported by a member of the public at the Scoping Meeting held January 28thth and 23 of the 100 examples of erosion reported by Kleinschmidt (above) occurred in non-agricultural sites. **Nor does formation of a berm of collapsed bank material necessarily prevent subsequent water infiltration of porous soils and continuance of the piping erosion mechanism.**

Examples of Damage to Infrastructure by Erosion:

River Road North:

In 2011 a large section of the bank adjacent to the western side of River Road in Lyme, just south of the North Thetford road, collapsed into the Wilder impoundment. Because of this, 1200 feeet of River Road had to be reconstructed. This road passes through Lyme and other New Hampshire river towns and was the route to Canada in colonial times. Very little rerouting has occurred, and for the most part, the road follows the same path as it did more than 250 years ago. The section of road that had to be reconstructed passes between the river and houses built around the time of the signing of the Declaration of

Independence. Until 2011, the road was able to defy the record floods and ice jams to which it was subjected.

Figure 1. Collapse of a portion of Wilder impoundment bank in spring of 2011 necessitating reconstruction of 1200 feet of River Road south of its intersection with the North Thetford Road in Lyme , New Hampshire.

Figure 2 River Road north adjacent to bank collapse. Note pattern of cracks in blacktop and compare with those in photo 3, below, in area of slumping River Road South.

The engineering report prepared by HTE Northeast, Inc. states that the cause of the bank collapse was long-term erosion and undermining due to flow action, and existence of water in the riverbank soils. Piping was not a named cause although the statements concerning water in the riverbank soils is consistent with that mechanism. The report also states, **"The frequent raising and lowering of the water level by downstream dam management (Wilder Dam), over time, is a contributing factor."**

In order to repair the road, it was moved east because of the excessive cost of reconstructing it in situ. The farmland to the east of the road was the subject of a conservation easement. Because of the protection of farmland conferred by the easement, it was necessary to take the land by eminent domain. Following this, the road was rebuilt according to an engineering plan that fails to mention piping and may not have used impervious material to mitigate erosive piping in the future. The total cost of the project was $685,308 of which the Town paid $398,061. The remaining $287,247 was paid by a grant from the U.S. Department of Agriculture (NRCS). Because of regulatory and financing requirements related to the repair, the road was closed to travel for nearly 2 years.

River Road South:

River Road a quarter mile south of the East Thetford Bridge ascends to a bench that runs along farm and woodland to the east. On the west a steep bank descends to the river below. In this section 120 feet of the western half of this road has settled, with a more pronounced dip of 30 feet as shown in figure 3 below.

Figure 3. River Road, Lyme, looking south about a quarter mile south of the East Thetford bridge. The string is on the road at each end of the slump which is 7 inches below the string in the center. Note the cracking of the blacktop on the west side of the road due to the slump and compare it with the cracking seen in the photo taken at the site of the collapse near the North Thetford road in figure 2

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Figure 4. River road south looking west. Wilder impoundment in background. Slump in road is 7 inches.

Additional observations on River Road: Immediately north of the section shown in Figure 1 and 2, another several hundred feet of River road is threatened by erosion and is subject to collapse. **A survey of the rest of the road by the Lyme Roads Committee documents additional segments constituting about a mile in total that are in danger.**

Conclusions: Erosion due to piping may be difficult to detect in situations where there are other causes of erosion at work. It is more common than generally recognized and can result in bank collapse and sink hole appearance long after high water has receded. Such erosion may be recognized later when it occurs under paved roads than in farm fields where observations are easier. Piping may be anticipated when porous soils are exposed to fluctuating water levels as encountered in dam impoundments. Erosion due to piping is clearly present in agricultural land surrounding the Wilder impoundment and this piping may also have been an important factor in damage to River Road in Lyme. Members of the public commenting at the Scoping meeting on Monday, January 28th, 2013 stated their belief that erosion had increased subsequent to the assumption of dam management by TransCanada. It should be determined whether this is true and if so, how important water level fluctuations in the Wilder Impoundment are to the piping erosion events mentioned above.

Project Nexus

Connection between the project and its potential effect on the applicable resource.

The application for renewal of the Wilder Dam license intersects with an assortment of resources, including clean water, preservation of riverine habitat, aquatic recreation, and public safety among others.

The applicant recognizes this, and presents in the PAD the results of two studies that address the subject of erosion in the Wilder Dam project area. These two studies have led the applicant to conclude that Project activities have a minimal impact on the above listed resources. (See section 3.4.6 of the PAD and cited above.) It is up to FERC to decide whether the studies the applicant has already performed allow TransCanada to reach the conclusions that are offered in section 3.4.6 of the PAD without further evidence to back those conclusions. **The Existing Information section, above, provides abundant evidence that TransCanada cannot conclude that the dam operation has no significant effect on erosive activity.**

How the information from this study would be used to develop license requirements:

The study will test the hypothesis that the rate and amount of impoundment water level changes correlate with the amount of piping erosion. The study will also determine whether piping erosion is an important component of overall erosion in the Project. If the hypothesis is proved true and if piping constitutes a significant portion of the erosion taking place, then the license could set rate and amount of change limits in the Wilder impoundment that would reduce erosive damage. In addition, the license could require the Applicant to mitigate such erosion, especially with respect to damage to infrastructure and agriculture.

Proposed Methodology

Introduction: Currently, the most used method for the investigation of piping erosion is that of observational field studies by those with a large amount of experience in making these observations. Because the results are provided in a descriptive rather than quantitative sense, they can be challenged, but only successfully by those with quantitative data. As will be seen below, the observational studies have the advantage of the least cost, but lack the persuasive value of numeric data. At the other end of the methodologic spectrum are quantitative tests that could yield reasonably accurate measurements of unit losses due to erosion. Perhaps the most sophisticated of these is based upon isotope dilution techniques using residual tracer radionuclides deposited as a result of atmospheric bomb testing, coupled with soil sampling, soil mapping, water sample collections, and extensive instantaneous measurements of flow and level in the Wilder impoundment. This latter approach would require a major investment of human and material resources and have a higher cost. We have chosen to describe a methodology of intermediate complexity and cost that will yield some quantitative data and will assure feasibility for the purpose of this study request. **Nevertheless, any study of piping required by FERC should first pass muster with consultants chosen from**

those referenced in the background section of this study proposal.

Hypotheses to be tested: 1.The rate and/or amount of water level changes in the Wilder impoundment correlate with the amount of piping erosion. 2.Piping erosion is an important component of overall erosion in the Project.

Study Design:

1. Appointment of expert panel: several experts in the field of piping erosion should participate in a site review of the geomorphology of the Wilder impoundment, soil maps, erosion locations, local resources, and operations of the Wilder Dam. This panel will specify the study sites, study calendar, type and number of gauges required, type and number of core samples required, and recommend methods to document erosion at soil pipe exits.
2. Overview of measurements to be made: At selected sites of known elevation on the impoundment, water levels and flow rates will be measured and recorded continuously. On shore, test bores will be made in a grid according to recommendations by the expert panel. Soil sample segments will be collected at various depths from the surface level to 380 feet above sea level, the lowest operating level of Wilder Dam. Cores will be obtained when the impoundment is at various water levels and times in relation to water level changes as recommended by the expert panel.
3. Data Recording: The study will yield a large data-base and the outcome of the study will depend on the accuracy and completeness of the data collected. Prior to activation of the study, the data collection methodology as well as statistical methods should be reviewed and approved by the expert panel.
4. Handling of cores: The recommendations of the expert panel will be followed concerning the handling and protection of the cores for measurement. In general, the water content at various levels and distance from the impoundment bank will be determined. The standard for this measurement will be the original weight minus the weight after oven drying to a constant weight. The experts may recommend surrogates for this cumbersome method. The budget for the project could be reduced if photographs of slump testing using an inverted cone method correlated well with the standard. Further studies may be recommended by the expert panel to characterize the properties in each soil core .
5. Bank observations: The bank face in the study areas will be evaluated and documented using methods suggested by the expert panel for evidence of outflow of water and/or silt. Insertion of dye markers into test bores showing high amounts of water may be used to identify lateral connections to the bank face.
6. Correlations with the hydraulic “history” of the impoundment/soil interface: Before data collection begins certain assumptions must be stated so that the required number of samples and observations collected can be ascertained. Some of these are given here: A. At a rise to a given high water level, porous soils at that water level will become wetter. This process will propagate inward from the impoundment/soil boundary. B. This process will be slower or non-existant in relatively impervious soils such as clay. C. When impoundment water levels drop,

dewatering of porous soils will occur. D. Such dewatering will be visible at the surface of the bank once flooded by the now receding water. E. The longer the high water level is maintained the further inward water infiltration will occur. F. The more rapid the water level in the impoundment falls the more rapidly the previously watered area will dewater. G. The more rapidly the soil is dewatered the more evidence there will be of erosion at the bank. H. These predicted changes will occur in soils tested within the strata subject to varying water levels resulting from normal operations of the Wilder Dam.

7. Before data collection begins the expert panel should agree on what level of statistical significance should be used for the various correlations sought above and others that may be relevant.
8. The study results will be in the form of correlations or lack thereof that support or deny the hypotheses stated.
9. Modeling from this data will enable estimates of the total amount of wetted area and volume subject to erosion at various water levels in the impoundment as a result of the rise and fall of the impoundment. This coupled with local observations of silt flow from piping will provide a measure of how significant the piping mechanism is to the erosion in the Project area.

Level of Effort and Cost:

As mentioned in the Study Methodology Section above, the cost of the project will depend upon the final study design. Three methods of gathering the data of progressively increasing cost were described yielding small, intermediate and large amounts of quantitative data concerning erosion. The intermediate level of study has been chosen for the purposes of cost estimation in this section of the study plan.

1. Expert panel: Three members travel, per diem and consulting fee for five days. Meet with Hydrologist and Statistician. Four days will be required to identify, map, and examine existing and possible future piping erosion sites for layout of drill core locations. One day will be required at end of data analysis period to determine results and present conclusions from the study. Travel $6000, Per diem $3000, Consulting fee: $12,000 Total $21,000
2. Field Hydrologist: meets with Expert Panel and Statistician, marks drill sites, supervises drill crew, places gauges for measurement of stream flow and depth, maintains instruments, downloads digital output from gauges and correlates with timing of drill core procurement. 80 hours. $8,000 plus instrument cost $2,000 Total $10,000
3. Statistician: Meets with Expert Panel and Hydrologist. Determines number of cores per site on basis of pilot data and record of impoundment fluctuations in order to acquire needed number of observations to deliver a valid study. Analyzes results from lab using statistical package agreed upon by Expert Panel. Supervises data manager. Consulting fee 40 hours. Total $ 4,000
4. Field Technician/data manager: Receives core from drill operators, places in pre labeled container, and delivers to lab for measurement of water content. Tabulates

data from lab. Total 120 hours $6,000
5. Truck mounted drilling rig and crew 15 days at $1900 per day plus one time positioning and setup fee $500. Total $28, 500
6. Laboratory expenses: Drying oven, weighing samples, storage for future examination, reimbursement of travel to lab: Total $7,000
7. Supplies for site and laboratory: sample containers and handling $1000. Misc. flagging, stakes etc. $500. Total $1,500
8. Boat/motor rental: $100/day 10 days Total $1,000
9. Contingency: Unsuitable weather, equipment failure, lack of impoundment level fluctuations necessary for study could result in unexpected delays in data acquisition or need to retain drill crew longer than expected $15,000

Total estimated cost: $94,000

Notes on budget:

1.This estimate does not include indirect costs for project if the study contractor is a university. If the contractor is a consulting firm, the contractor may demand a “cost plus” arrangement. It is assumed that the study would be mounted as a result of an RFP.

2. If a descriptive study lacking much quantitative data was deemed acceptable it could be accomplished by the Expert Panel for an additional 5 days plus the costs of preparing the report, boat rental and other incidental costs or about $30,000.

3. If highly quantitative information on erosion, based upon isotope dilution methodology, was viewed as desirable it is estimated that it could be obtained for an additional $100,000 or a total of about $193,500.

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Simon L. Carr
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February 21, 2013

FERC
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

The Town of Lyme would like to support and be considered a co-signer with O. Ross McIntyre for the proposal of study concerning the Wilder Dam.

Sincerely,

Simon L. Carr, Chair
Selectmen, Town of Lyme NH

Charles J. Smith

Project 1892

City of Lebanon

51 North Park Street
Lebanon, New Hampshire 03766

February 25, 2013

FERC,
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington D.C. 20426

Re: FERC Project 1892-026 – Wilder Dam Relicensing

The City of Lebanon, New Hampshire would like to support and be considered a co-signer with O. Ross McIntyre and the Town of Lyme, New Hampshire for the study proposal submitted to FERC concerning the Wilder Dam Relicensing.

Sincerely,

Gregory D. Lewis

City Manager

City Manager's Office (603) 448-4220 Fax (603) 448-4891