Comments by O. Ross McIntyre M.D.
Wilder Hydroelectric Project (FERC Project No 1892-026) Study Number 1
Historical Riverbank Position and Erosion – Study Report TransCanada Hydro Northeast Inc. in connection with Federal Energy Regulatory Commission Relicensing of the Wilder Project.

Comments on Study Number 1 by O. Ross McIntyre, M.D. the owner of land abutting the project in Lyme, NH.

I have reviewed the above cited study report, Historical Riverbank Study and Erosion, and attended the March 17, 2016 presentation by John Fields of the study findings at the Wilder Project Conference Room and offer the following comments.

O. Ross McIntyre's Summary Conclusions

The executive summary of the report is misleading. It fails to mention a number of caveats concerning the methodology of Study 1 that John Field offered while presenting the findings on March 17, 2016. When read by those who did not hear his presentation it could leave the impression that Study 1 provides reliable evidence that erosion "has remained steady or deceased over time at the majority of the sites studied." Although the subsequent sentence states that "further analysis as part of Study 3…..is needed to confirm this trend and to ascertain potential project-effects" **the wording suggests that there is a trend to confirm when it is equally possible that there is no trend to confirm.**

Two years prior to the West Lebanon, NH scoping meeting for the relicensing of Wilder Dam on January 28thth, 2013, a portion of River Road in Lyme, an historic road that had been located next to the river bank for 250 years, fell into the Wilder impoundment. One might think that this event would be noted in any history-based study of erosion related to the dam relicensing, but it was not. Erosion has recently closed another section of River Road in Lyme and threatens to do so at two additional sites. It will cost about $2 million for the first two repairs. The Report of Erosion Study 1, issued on March 1, 2016, reveals that three of the four areas of road affected are located in stretches of river-bank judged to be "still stable" in 1978. This, alone, would demand that the status of erosion in the project area should be presented to the public in carefully measured terms.

If the above damage is due to operation of the Wilder Project, Lyme wishes to be reimbursed for the repairs and for mitigation of the erosive mechanism. It is natural that TransCanada is reluctant to fund and perform studies that could suggest that this kind of damage results from operation of its dam. This must be kept in mind when one reads the reports of studies by TransCanada. . **It is the responsibility of FERC to ensure that the erosion studies carried out are able to discover, and quantify dam operation related erosion, if any. To date, the studies have not been designed and carried out in a manner that could discover the extent of piping erosion, the most likely mechanism whereby dam operation could cause erosion.** Even the language used by the staff to describe photos of river-bank erosion contains semantic bias. Erosion that has resulted in an overhanging bank is described as "undercut" a word that suggests removal of material by flowing river water. Overhanging material on a river-bank can be caused equally well by piping erosion or by stream action. A look at a photo of the overhang cannot

distinguish the cause. I was encouraged when I suggested to John Field, who conducted the study, that he might use the term "overhanging" rather than "undercutting" that he agreed to change his description of such photos.

Discussion of Study Limitations: The caveats that Field mentioned are several. Different observers were responsible for the data collected in each of the study periods. Methodologies were not standardized throughout the study period and in some cases they are not adequately documented. **To this I would add that there is no evidence of statistician input into the design of any of the historical studies and no statistical evaluation of the summary data presented in this report.**

The amount of effort spent in carrying out this study should not be minimized. The hand digitizing of erosion data from 1958 and comparison with similar data from the Corps of Engineers collected in 1978 clearly was a large task. This work is compromised by the omission of detailed information concerning the criteria used to allocate sections of river bank into the four categories used in the display. The presentation of this data on the topographical maps covering the three projects in Appendix A, uses colored lines that I estimate cover a breadth of 5-10 feet on the ground and for this reason are useful in this context only when changes exceed this amount. The changes seen in aerial photographs taken of the 11 sites chosen for detailed analysis of erosion are far more helpful in documenting the extent of erosive activity over time in these few and limited sites. (Appendix C.) The collection of hundreds of photographs that can be used to follow erosion sites sequentially also represents a major effort. (Appendix B) The study selected sites that could be relocated for follow-up photos, but often conditions at the time of later photos has changed dramatically. This is particularly true for "naked" banks in the original photos (open fields or banks that had been clear cut) and later photos showing heavy forest replacement. On forested banks, the use of the center of trees to delineate the edge of the riverbank was used in compiling the digital map from aerial photos. Although this method has been used in other studies referenced in the report, I question whether a systematic error occurs in when tree-center is used to define the top of an eroding bank because trees in such locations often lean outwards toward the river. Other photos of banks covered with heavy brush or overhanging trees should not be considered a "match" as should underexposed photos in which detail is not seen. As might be expected, some pairs include a photo taken from a position on land and a photo taken from the water. These also can yield comparisons of doubtful value.

Causes of Erosion: On the base of the photographic record and other data from the study, erosion at various sites was allocated by cause. A small percentage of the total (data presented at the conference but not included in the report) was found to be **piping erosion**. The written report does not describe the criteria used for making this distinction and how these sites were selected.

Members of the public speaking at the Scoping Meeting for the Wilder Relicensing Application in West Lebanon on January 28thth, 2013 presented anecdotal evidence of erosion of 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 left with an overhang.

Piping: The public, above, was describing a type of erosion called "piping." This mechanism of erosion 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 on a side of the dam or levee and the soils used in the construction of the structure does 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.

Piping erosion also occurs in stream and river banks. 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.

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.

In concluding this definitive work on piping erosion, Hargerty offers the following:

"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]

Inadequacy of prior Wilder studies to ascertain the type of erosion most likely to result from dam operation: 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.

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 performed on the Wilder impoundment 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 Wilder PAD attempt to ascertain whether impoundment fluctuations caused by the Project result in piping erosion.

Because information was lacking, this reviewer and with the support of the Town of Lyme and the City of Lebanon submitted to FERC a proposed study that could have provided information concerning piping in soils bordering the Wilder impoundment. This line of investigation was not chosen for pursuit in the Relicensing process.

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.

Why is it important to ascertain how much of the erosion seen is due to piping and the Wilder project operation?

1. Because there is an extensive literature concerning mechanisms for mitigating piping erosion when it is found. 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.

2. Because 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.**

3. And because significant erosion has resulted in major damage to roads in the Town of Lyme, NH and according to news and meeting reports in other towns as well. Appendix A of the Study Report offers topographic maps of River Road in Lyme.

The first is a section of River Road south of the North Thetford Road that collapsed in 2011 and was closed for 2 years before it could be moved and reconstructed at a cost of $680,000 This section of road is shown in green (Still stabile) in Appendix A (1978) of the study report.

The second is a 500 foot section of River Road that showed subsidence in 2013 and was found in imminent danger of collapse and closed in 2015. Replacement estimates are in the $1,000,000 plus range. This section of river bank is shown in green (Still stable) in Appendix A (1978) of the study report

Two other portions of River Road show subsidence in 2016 and are under watch for possible closure: one is in an area shown in red in Appendix A (1978) (Destabilized), the other is shown in green in Appendix A (Still stable) of the study

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 two sections of road that will have to be reconstructed pass along the river and historic 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 without collapse. The recent events suggest acceleration of a process

detrimental to its continued existence.

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."**

Figure 3. Dog-leg on River Road, Lyme, NH. by-passes land lost to erosion.

In order to repair the road, it was moved east with a resulting "dog-leg" 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 4. 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

Figure 5. River road south looking west. Wilder impoundment in background. Slump in road is 7 inches.

Two years later the road was closed because of further subsidence and the risk of sudden catastrophic slippage that could result in a plunge into 40 feet of water. The resulting closure with estimated costs to a town of less than 2000 persons of more than a $1 million. It has also created a continuing financial hardship to residents, farmers, and others, including emergency services, who must use long detours around the blocked road segment

Fig. 6. Barrier closes River Road segment with threat of catastrophic slippage.

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.