GAGNON ENGINEERING, INC.
Structural Consultants

Evaluation of Existing Access Road Bridges & Culvert

for

Proposed Redington Wind Farm Project

in

Redington Township
Franklin Coounty, Maine

Prepared for

Endless Energy Corporation
Yarmouth, Maine

Date: April 04, 2005 (Rev 0)

Purpose. The purpose of this study was to identify, to the extent practical, deficiencies that exist in the Bridges and Culverts located along the access roads and subject to loadings (Equipment and other) associated with, the proposed Redington Wind Farm. This report also suggests, in general terms, remedial measures where deficiencies exist.

Loadings. For the purposes of this study, a hypothetical (Analysis) Transport Vehicle was used. Axle configurations and spacings of this hypothetical Transport Vehicle is shown in Figure 1. Its total weight is 300,000 pounds. More importantly, it consists of two clusters of multiple 40,000 pound axles; one cluster has four axles and the other has three axles. There is also a front axle weighing 20,000 pounds. The Analysis Vehicle is between eight and ten feet wide. Hypothetical Transport Vehicle Axle locations are shown on the Profile view for each Bridge.

Transport Assumptions. It was assumed that the Transport Vehicle will be centered, within two feet, on the Bridge or Culvert traveling at speeds under 10 MPH. The hypothetical Transport Vehicle, including assumed off-center wondering is illustrated on the Section view for each Bridge.

Background. Existing Bridges and Culverts were inspected by Roger Gagnon (GEI) and Bill Conner (EEC) December 4, 2004. Bridge Spans and overall Widths were measured. Stringer (Longitudinal Beam) material (Steel or Timber), sizes, layout & spacing, and Timber Deck member sizes and spacings were measured. Abutment configuration and Type (Timber or other) was noted and photographed.

Inspections and measurements were limited by snow (& ice) cover, stream flow, safe access, and day-light. Deterioration, rust in steel, rot in timbers, and damage was not assessed. Details of Abutment construction was generally hidden and could not be inspected & measured, or subsequently evaluated.

Decks. All Decks consist of transverse (cross traffic) timbers with longitudinal (with traffic) timber plank runners, positioned more or less under the wheels on both sides. As a rule, the Timber Deck cannot safely carry Truck (or Trailer) Wheel Loads. Wheel must, practically, be over one or more Stringers in order for the Deck Timbers not be to overstressed. Figure 2 entitled Deck Support at Wheel Loads, illustrates the maximum offset from the outside edge of a Wheel and the edge of the nearest Stringer (Beam); a distance equal to the depth of the Deck Timbers.

Stringer Stresses. Table 1 summarizes Stringer Stresses for all of the Bridges. Stringers are longitudinal (direction of traffic) main support beams. Loads & centering, analysis criteria, allowable stresses, and assumptions are noted below Table 1.

Inter-Stringer Bridging. In order for the Stringers to Work together and provide mutual support, they must be inter-connected by cross (traffic) structural elements herein called Inter-Stringer Bridging Beams. As a rule, most of the Bridges being evaluated do not have any inter-stringer bridging. In addition, since Timber Decks have limited capacity to laterally (transversely) brace Stringers for stability and against lateral forces (e.g. Wind), longer (over 30 feet) spans should have Lateral Bracing (Framing Plan Diagonals). Figure 3 illustrates Inter-Stringer Bridging and Lateral Bracing (Concept).

Individual Bridge Descriptions, Deficiencies, and Recommendations. Refer to attached engineering sketches, Appendix A, which summarize bridge Span & Width, Framing Plan, Profile, and Section. Hypothetical Transport Vehicle axles were also superimposed on these sketches to illustrate Wheel load location, including transverse wondering (off-center).

Bridge #1.

Description. Bridge #1 spans 21 feet and is, nominally, 12 feet wide curb to curb. The Bridge is a skewed (not square) crossing. It is founded on Timber Abutments approximately five feet high below the Stringers. There are four sets of back-to-back Steel Channel Stringers; also, there are Timber Logs between the Channel sets. The Deck consists of 4 x 8 transverse Timbers, and 4 inch Timber Runners.

Deck. Wheels can be positioned between Stringers and Transverse Deck Timbers are overstressed. Runners are not wide enough to directly support wondering Wheel Loads.

Stringers. The Stringers are over-stressed by approximately 11 percent (Table 1). There is no effective Inter-stringer Bridging at or near mid-span. The Abutment Bearings are Steel Plates, which are acceptable if the underlying timber is sound.

Abutments. The Abutments are nominally adequate provided (as discussed above) they are in good condition and stable.

Recommendations.

> Stringers. Add a fifth stringer of equivalent strength at the center (mid-width) of the Bridge. Re-position the existing stringers so that they, together with the new stringer are no farther than three feet apart, center to center. Add mid-span Inter-stringer Bridging (Figure 3).
>
> Stringer Bearings. Inspect Stringer Bearings at the Abutments. Repair and/or Reinforce them as required.
>
> Deck. Replace the existing Deck with heavier transverse timbers. As a minimum, use 6 inch deep by 8 inch wide Timbers spaced no more at 12 inches apart (center to center). Install new Running Planks (shoulder-to-shoulder) to provide a continuous 12 foot width of Runners. Replace rotten Timbers and Runners.
>
> Abutments. Inspect for Rot & Damage, and evaluate stability. Repair and/or Reinforce as required.

Bridge #2.

Description. Bridge #2 spans 50 feet and is (nominally) 14 feet wide, curb to curb. Super-structure is supported on Timber Abutments. There are only two Steel Stringers, both 36 inches deep, centered and spaced approximately seven feet apart, center to center. The Deck consists of 6 x 8 Transverse Timbers, and 4 inch thick Timber Runners.

Deck. Wheels can be positioned between, and outside of, Stringers and Transverse Timbers are overstressed; moreover, Transverse Timbers are grossly over-stressed when Wheel loads are outside of the Stringers. Runners are not wide enough to directly support wondering Wheel Loads

Stringers. The Stringers are over-stressed by approximately 11 percent (Table 1). The two stringers, as-arranged, are inherently unstable. There is no effective Inter-stringer Bridging at or near mid-span. There is no Lateral Bracing system. The Abutment Bearings are Steel Plates, which are acceptable if founded on sound timber.

Abutments. The Abutments are nominally adequate provided (as discussed above) they are stable and in good condition.

Recommendations (Bridge #2).

Stringers. A third Stringer of comparable strength to the existing stringers needs to be installed at the center of the Bridge; the existing stringers need to be spaced farther apart (approximately 4.5 ft) in order to improve stability and provide effective, support under wheel loads as discussed above. Add mid-span inter-stringer Bridging Beams and Lateral Bracing (diagonals) as illustrated in Figure 3.

Stringer Bearings. Inspect Stringer Bearings. Repair and/or Reinforce as required.

Deck. Replace the existing Deck with heavier transverse timbers. As a minimum, use 8 inch deep by 6 inch wide Timbers spaced no more at 12 inches apart (center to center). Install new Running Planks (shoulder-to-shoulder) to provide a continuous 12 foot width of Runners. Replace rotten Timbers and Runners.

Abutments. Inspect for Rot and Damage, evaluate stability. Repair and/or Reinforce as required.

Bridge #3.

Description. Bridge #3 spans 43 feet and is (nominally) 14 feet wide, curb to curb. It is founded on Timber Abutments. There are five Steel Stringers, all 14 inches deep, centered and arranged approximately three feet apart. The Deck consists of 6 x 8 transverse Timbers, and 4 inch thick Timber Runners.

Deck. Wheels can be positioned between Stringers and, consequently, (as discussed above) Transverse Timbers are overstressed. Runners are not wide enough to directly support wondering Wheel Loads

Stringers. The Stringers are over-stressed by approximately 50 percent, and there is no effective Inter-Stringer Bridging at or near mid-span, and there is no Lateral Bracing system.

The Abutment Bearings are Steel Plates, which are acceptable if founded on sound timber.

Abutments. The Abutments are nominally adequate provided they are stable and in good condition.

Recommendations.

Stringers. Existing Stringers need to be reinforced, by welded flange cover plates; or by installing two additional, like-sized, stringers to increase stringer capacity at least 50 percent. If new stringers are added, existing stringers should be re-arranged so that the seven stringers are spaced approximately two feet apart, center-to-center. Add mid-span Inter-Stringer Bridging (beams) and Lateral Bracing (diagonals) as illustrated in Figure 3.

Stringer Bearings. Inspect Stringer Bearings. Repair and/or Reinforce as required.

Deck. The existing Deck may be re-installed if, temporarily, it can be removed without damaging it. Alternately, a new like-sized Timber Deck may be installed. Install new Running Planks (shoulder-to-shoulder) to provide a continuous 12 foot width of Runners. Replace rotten Timbers and Runners.

Abutments. Inspect for Rot and Damage, evaluate stability. Repair and/or Reinforce as required.

Bridge #5.

Description. Bridge #5 spans 36 feet and is (nominally) 14 feet wide, curb to curb. It is founded on Timber Abutments. There are five Steel Stringers, all 14 inches deep, centered and arranged approximately three feet apart. The Deck consists of 6 x 8 Transverse Timbers, and 4 inch thick Timber Runners.

Deck. Wheels can be positioned between, and outside of, Stringers and, consequently, (as discussed above) Transverse Timbers are overstressed. Runners are not wide enough to directly support wondering Wheel Loads.

Stringers. The Stringers are over-stressed by approximately 34 percent, and there is no effective Inter-Stringer Bridging at or near mid-span; there is no Lateral Bracing system.

The Abutment Bearings are Steel Plates, which are acceptable if founded on sound timber.

Abutments. The Abutments are nominally adequate provided (as discussed above) they are stable and in good condition.

Recommendations.

> Stringers. Existing Stringers need to be reinforced, by welded flange cover plates; or by adding two like-sized stringers to increase Stringer Capacity at least 34 percent. If new stringers are added, existing stringers should be re-arranged so that the seven stringers are spaced approximately two feet apart, center-to-center. Add mid-span Inter-Stringer Bridging (beams) and Lateral Bracing (diagonals), as illustrated in Figure 3.
>
> Stringer Bearings. Inspect Stringer Bearings. Repair and/or Reinforce as required.
>
> Deck. The existing Deck may be re-installed if, temporarily, it can be removed without damaging it. Alternately, a new like-sized Timber Deck may be installed. Install new Running Planks (shoulder-to-shoulder) to provide a continuous 12 foot width of Runners. Replace rotten Timbers and Runners.
>
> Abutments. Inspect for Rot and Damage, evaluate stability. Repair and/or Reinforce as required.

Bridge #6.

Description. Bridge #6 spans 50 feet and is (nominally) 14 feet wide, curb to curb. It is founded on Timber Abutments. There are six Steel Stringers, all 24 inches deep, centered and arranged approximately three feet apart. The Deck consists of 6 x 8 Transverse Timbers, and 4 inch thick Timber Runners.

Deck. Runners are not wide enough to directly support wondering Wheel Loads

Stringers. The Stringers are not over-stressed; however, there is no effective Inter-Stringer Bridging at or near mid-span, and there is no Lateral Bracing system.

The Abutment Bearings are Steel Plates, which are acceptable if founded on sound timber.

Abutments. The Abutments are nominally adequate provided (as discussed above) they are stable and in good condition.

Recommendations (Bridge #6).

Stringers. Add mid-span Inter-Stringer Bridging (beams) and Lateral Bracing (diagonals) as illustrated in Figure 3.

Stringer Bearings. Inspect Stringer Bearings. Repair and/or Reinforce as required.

Deck. Install new Running Planks (shoulder-to-shoulder) to provide a continuous 12 foot width of Runners. Replace rotten Timbers and Runners.

Abutments. Inspect for Rot and Damage, evaluate stability. Repair and/or Reinforce as required.

Bridge #7.

Description. Bridge #7 spans approximately 15 feet and is (nominally) 14 feet wide, curb to curb. It is founded on Timber Abutments. The Bridge is low with barely five feet of clearance under the Stringers. There are nine Timber Stringers, all 10 by 10 inch, centered and variably spaced between 20 inches and 24 inches, center to center. The Deck consists of 6 x 8 Transverse Timbers, and 4 inch thick Timber Runners (multiple planks).

Deck. Runners are not wide enough to directly support wondering Wheel Loads

Stringers. The Stringers are grossly over-stressed, by nearly 100 percent, and there is no effective Inter-Stringer Bridging at or near mid-span.

Details of Stringer (Abutment) Bearings are unknown.

Abutments. The Abutments are nominally adequate provided (as discussed above) they are stable and in good condition.

Recommendations.

Stringers. Existing Stringers need to be reinforced at least 100 percent. Given the Bridge's relatively short Span, existing Timber Runners should be removed and Pre-cast Concrete Runners, at least 14 feet long and otherwise as illustrated in Figure 4, should be installed directly over the existing Transverse Timbers. Appropriate shimming, blocking, and stiffening should be installed as required between the Pre-Cast Concrete Runners and the Abutment Bearings to provide adequate load-paths for Transport Vehicle loads. Approach Roads will need to be re-graded to transition from existing to the higher grades at the ends of the Pre-cast Concrete Runners.

Stringer Bearings. Inspect Stringer Bearings. Repair and/or Reinforce as required.

Deck. Existing Transverse Timbers Deck may be salvaged except that severely rotted elements should be replaced.

Abutments. Inspect for Rot and Damage, evaluate stability. Repair and/or Reinforce as required.

Timber Box Culverts. Timber Box Culverts, designated #2-5, #6-7a, and #6-7b, based on their locations on the access road(s) with respect to Bridges. For example, Box Culvert #6-7b is the second of two Box Culverts located between Bridge #6 and Bridge #7.

Description. The Timber Box Culverts all feature four inch thick Transverse Timbers (planks), installed shoulder-to-shoulder on Timber Stringers which are spaced approximately 12 inches on center The Stringers bear on Timber Abutments. The extent of rot in any of the timber members was not assessed.

Analysis-Stringers. The Stringers in Box Culvert #6-7b are, nominally, overstressed in both Bending and Shear. Stringers in Box Culverts #5-6 and #6-7a are, nominally, not overstressed; however, they must be in good condition (i.e. not rotted) in order not to be over-stressed.

Analysis-Transverse Timbers. Transverse Timbers are not, nominally, over-stressed; however, rotted and/or damaged Transverse Timbers result in Stringer over-load and Stringer over-stress.

Recommendations, Box Culverts.

> Box Culvert #6-7b. Install Pre-cast Concrete Runners (Figure 4), at least 14 feet long over the existing Bridge to reinforce existing Stringers and assume the major portion of Transport Vehicle Wheel Loads. This will require re-grading approach roads, transitioning and raising road grades to the height of the Pre-Cast Concrete Runners over several feet.
>
> Box Culverts #5-6 and #6-7a. If, upon close inspection, the Timber elements, particularly Transverse Timbers or Stringers are found to have measurable Rot, then Pre-cast Concrete Runners (Figure 4) should be installed as described for Box Culvert #6-7b, above. Alternately, the Rotted and/or Damaged Timbers, including Abutment Timbers, may be replaced in-kind, with sound, good-condition Timbers.

Circular Culverts. Culverts designated Culvert #4, Culvert #5, and Culvert #10 are generally circular in section, and made of Steel Plate or Corrugated (ribbed) Steel Plate. Typically there was less than two feet of earth cover over the tops of the Culverts, and little distribution of Transport Vehicle Wheel Loads could be assumed in the determination of culvert stresses. The level of deterioration (corrosion) and damage was not assessed.

Analysis. The Culverts were all, nominally, over-stressed under Transport Vehicle Wheel Loads.

Recommendation. Install Pre-cast Concrete Runners (Figure 4) on grade, centered span-wise on the Culverts, and at least 13 feet long. Appropriately designed, the Pre-cast Concrete Runners will effectively assume most of the Transport Vehicle Wheel Loads. Approach roads will need to be re-graded, transitioning and raising adjacent road grades over several feet to meet the height of the Pre-Cast Runners.

Portable Bridge Concept. (See Figure 5)

The temporary use of a Portable Bridge should be investigated as a viable, cost-effective alternative to installing significant and expensive reinforcements to the longer bridges. Conceptually, this Portable Bridge would be approximately 40 feet long by 12 feet wide. It would weigh approximately 15 tons, feature a low-profile deck and approach ramps (separate or hinged).

The Portable Bridge would travel on its own removable axles; the front axle would turn so that the Bridge could be towed, cart-like, behind a truck. The tow truck would have a small crane capable of lifting one end of the Portable Bridge to remove and install travel axles, and set up the Bridge.

The Portable Bridge would be designed to safely support all Transport Vehicle Loads along its length. It would set directly on top of an existing Bridge, including Bridges over 40 feet long. The Portable Bridge would by-pass existing Bridge deficiencies, or effectively reinforce existing bridge to reduce stresses to acceptable levels.

Closure. As noted above, inspections and measurements were limited by snow (& ice) cover, stream flow, safe access, and day-light. Deterioration, rust in steel, rot in timbers, and damage was not assessed. Details of Abutment construction were generally hidden and could not be inspected & measured, or subsequently evaluated.

Prior to detailing remedial measures, close inspection of conditions and details of existing construction will need to be performed. Even then, some deficiencies will remain hidden and can, practically, only be exposed during construction. Consequently, contingency funding will need to be held in reserve to address unknown conditions.

Recommendations made in this report are Concept Recommendations, only. They are general and not detailed; and are not sufficient to serve as Construction Documents. Dimensions of existing Bridges and Culverts are for illustration only, are not exact, need to be verified prior to ordering materials or fabricating components.

Detailed Engineering, which is beyond the scope of this study, will be required to develop adequate, for-construction Plans, Materials, and Specifications for the successful implementation of recommendations.

TABLE 1.
Bridge Stringer Stresses

Br ID	Span feet	ID Stringers No. Size	% total load	Stress Fb,ksi	Allow Fb,ksi	% Over
#1	21.0	4 - Dbl C15x33.9s	0.40	29.9	27.0	11.1
#2	50.0	2 – W36x160	0.78	31.4	27.0	16.3
#3	43.0	5 – HP 14x102	0.33	40.5	27.0	50.0
#5	36.0	5 – HP 14x89	0.33	36.4	27.0	34.8
#6	50.0	6 – W24x94	0.27	27.0	27.0	OK
#7	15.0	9 - 10x10 Timber	0.17	3.14	1.60	196.

Notes:

1. Refer to Existing Bridge Profiles & Sections, and Analysis Truck Configuration for Details

2. Bridge Load is Truck with four 40k (40,000 lb) Axles at 4.50 feet on center, Truck is assumed to be centered on the Bridge within two feet. (2 ft max offset from centered), and traveling at slow / low impact speeds. (See Figure 1)

3. Analysis assumes that all stringers are inter-connected by adequate Inter-Stringer Bridging located at or near mid-span.

4. All Stringers are Steel Beams, except that Bridge #7 Stringers are 10x10 Timbers.

5. Allowable Stresses (Fb)

   Steel: 1.25 x 0.6 Fy, where Fy = 36.0 ksi

   Timber: 1.33 x Fb, where Fb = 1.20 ksi

Appendix A

Existing Bridges & Culverts

Appendix B

Figures

Figure 1 - Transport Vehicle

Figure 2 – Deck Support at Wheel Loads

Figure 3 – Inter-Stringer Bridging & Lateral Bracing

Figure 4 – Pre-Cast Concrete Runners

Figure 5 – Portable Bridge Concept