BEFORE THE
PUBLIC SERVICE COMMISSION

Application of Highland Wind Farm, LLC,
for a Certificate of Public Convenience and Necessity
to construct a 102.5 MW Wind Electric Generation Facility **Docket No.: 2535-CE-100**
and Associated Electric Facilities, to be Located in
the Towns of Forest and Cylon, St. Croix County, Wisconsin

EXPERT STATEMENT OF RICHARD JAMES

Richard James INCE, states as follows:

1. I am an acoustical engineer by profession. My resume showing my qualifications is attached to this Expert Statement as Exhibit A.

2. I have 45 years of experience in analysis and measurement of sound and in relating sound measurements to how people respond to sound. In the course of my career I have conducted numerous studies on wind turbine noise and have reviewed and analyzed the studies done by others.

3. I have been accepted as an acoustician with expertise in noise measurement and the impact of noise, including wind turbine noise, on people in the US and in Canada, as shown in my attached qualifications. (Exhibit A). I have also been accepted as an expert before the Wisconsin PSC in prior Glacier Hills and Highland Wind hearings.

4. I prepared the attached letter, Exhibit B, to the Public Service Commission of Wisconsin in March, 2015, concerning my review and analysis of literature regarding the impact of wind turbine noise, both audible and inaudible infrasound, no human health. The subject of the letter was the: "*Scientific Basis for Limiting Exposure to Infra Sound Produced by Utility Scale Modern Upwind Wind Turbines*." The letter provides the results of on-site research I have done on this subject at the Shirley Wind Farm in Brown County Wisconsin.

5. The letter was hand-delivered to Commissioner Nowak during a meeting in March 2015 with Mrs. Barbara Vanden Boogart, Brown County Concerned Citizens for Responsible Wind Energy (BCCRWE).

6. I have completed a review of the recently published paper titled: "Exposure to wind turbine noise: Perceptual responses and reported health effects," by Dr. David Michaud, et al reporting on the results of the Community Noise and Health Study (CNHS) for Health

Canada (HC). This paper was published in the March 2016 issue of the Journal of the Acoustical Society of America (JASA). A copy of the paper is attached as Exhibit C.

7. The HC CNHS paper presents the findings from the study's data and concludes: "The observed increase in annoyance tended to occur when WTN levels exceeded 35 dB and were undiminished between 40 and 46 dB. Beyond annoyance, <u>the current study does not support an association between exposures to WTN up to 46 dB and the evaluated health-related endpoints.</u>" Emphasis added.
8. I also prepared the attached graph, Exhibit D. This graph compares the incidence of three common health symptoms, dizziness, migraines, and tinnitus included in the HC CNHS for which the incidence in the general population is well established.
9. The graph shows the incidence of these symptoms in the general population as dashed lines that are constant for all of the sound level categories in the HC CNHS paper's "Table V. Sample profile of health conditions."
10. The HC CNHS findings for the incidence of these symptoms in the test population were used to calculate trend lines for each of the sound level categories in Table V. These trends are seen in Exhibit D as solid lines, sloping upward, from left to right, as the sound levels of wind turbine noise increase from the 25-30 dBA to the 40-46 dBA test subject groups.
11. Exhibit D demonstrates that the conclusions presented in the HC CNHS JASA paper (see Statement No: 7 above) are not supported by the data presented in the same paper. There is a clear increase in the incidence of the subject adverse health effects as the sound level outside the test subjects' homes increase.
12. Exhibit D also demonstrates that the incidence of these adverse health effects reported in the HC CNHS paper exceeds the incidence in the general population derived from other studies by a significant margin. Even for the lowest exposure group (25-30 dBA) the incidence of migraines and tinnitus are double what would be expected in the general population. This trend continues up through the highest exposure group (40-46 dBA).
13. Migraines, tinnitus, and dizziness are symptoms that are commonly reported by people living near utility scale wind turbines, including those near the Shirley Wind project in Brown County, Wisconsin. The PSC heard ample evidence of these complaints during earlier hearings on the Highland Wind application. The HC CNHS paper provides support for these complaints, in spite of the conclusions by the researchers who claim they found no evidence to support concerns about adverse health effects below 46 dBA.

14. The observation is made that the incidence of three health effects, migraines, dizziness, and tinnitus shown by the HC CHNS is significantly higher for people in the wind energy utility host communities than for the general population, even those at distances of 2 to 5 kilometers (1.25 to 3.1 miles) at modeled sound levels of 30 dBA and lower, related to living near utility scale wind turbines. This observation should be given weight by the PSC and its staff as new evidence showing that the Highland Wind project poses a strong risk of adverse health effects for people who will be living in the Town of Forest host community.
15. Exhibit D also includes the general incidence for an aggregate health indicator, "health worse vs. last year" (dashed red line at 10%) and the incidence reported by the HC CNHS paper seen as the solid red line sloping upwards from left to right reaching 16% for the 40-46 dBA group. Independent review of the "health worse vs. last year" data from Table V of the HC paper does not support the CNHS researchers' conclusion in the JASA paper (see Statement 7). Instead, it shows increasing health concerns the closer the wind turbines are located near homes.
16. The data depicted in Exhibit D demonstrates that wind turbine noise does adversely impact human health.
17. This discussion of the attached Exhibit D graph indicates the study design and/or analysis was deeply flawed. Until this is resolved, the entire HC CNHS study's conclusions and findings about no evidence of adverse health effects below 46 dBA should be disregarded. It does show wind turbine sound emissions do adversely impact people in the host community even at levels below those many jurisdictions have accepted as being protective of public health.
18. This graph and an explanation that expands on what is stated above is being prepared for submittal to the JASA, Editor.

Dated this 15 day of April, 2016.

Richard R. James

Richard James, INCE
E-Coustic Solutions, LLC

Exhibits:

Exhibit A-RJames Qualifications, Testimony, and Publications.pdf
Exhibit B-15-03-16 RJames Letter to PSC Commissioners re ILFN and AHE.pdf
Exhibit C-JASA March 2016, Michaud et al, Exposure to wind turbine noise, Perceptual responses and reported health effects.pdf
Exhibit D-Graph of HC Study JASA paper Table V health conditions against accepted incidence in general population.pdf

Bio Materials for: Richard R. James, INCE

Mr. James is the Owner and Principal Consultant for E-Coustic Solutions, LLC, of Okemos, Michigan. He has been a practicing acoustical engineer for over 40 years. He started his career as an acoustical engineer working for the Chevrolet Division of General Motors Corporation in the early 1970s. His clients include many large manufacturing firms, such as, General Motors, Ford, Goodyear Tire & Rubber, and others who have manufacturing facilities community noise and worker noise exposure. In addition, he has worked for many small companies and private individuals. He has been actively involved with the Institute of Noise Control Engineers (INCE) since it's formation in the early 1970's and is currently a Member Emeritus.

His academic credentials include a degree in Mechanical Engineering (BME) from General Motors Institute, Flint Michigan (now Kettering Institute). He has been an adjunct Instructor to the Speech and Communication Science Department at Michigan State University from 1985 to 2013 and a adjunct Professor for the Department of Communication Disorders at Central Michigan University from 2012 through 2017. In addition, Mr. James served on the Applied Physics Advisory Board of Kettering Institute from 1997 to 2007.

Specific to wind turbine noise, he has worked for clients in over 60 different communities.

He has provided written and oral testimony in approximately 30 of those cases. He has also authored or co-authored four papers covering wind turbine noise topics including:

- Criteria for wind turbine projects necessary to protect public health (2008),
- Demonstrating that wind turbine sound immissions are predominantly comprised of infra and low frequency sound (2011), and
- A peer reviewed historical review of other types of low frequency noise sources with similar sound emission characteristics, such as large HVAC systems (fans) which caused noise induced Sick Building Syndrome and other noise sources that have known adverse health effects on people exposed to their sound. (2012).

He has been qualified as an expert in acoustics for hearings and court proceedings in several countries. Examples of recent qualifications are:

Jurisdiction	Before	Qualified as:	
Ontario, CA (January 2014)	Ministry of Environment (MOE) and Environmental Review Tribunal (ERT)	Qualified to provide evidence on matters related to acoustics and noise control engineering and wind turbines	
Alberta, CA (Dec. 2013)	Alberta Utilities Commission (AUC)	an acoustical engineer and acoustician with expertise in the field of sound including noise, low frequency noise, sounds emitted from industrial wind turbines and human response to noise.	
Michigan, US	Michigan Circuit Court	1. acoustician with expertise in measurement of wind turbine noise and its effects on people. (Dec. 2013) 2. acoustician qualified to opine that the plaintiff's symptoms were caused by the defendant's wind turbines. After special Daubert Hearing (Dec. 2013)	

BIOGRAPHICAL SKETCH

NAME	POSITION TITLE	BIRTHDATE
Richard R. James	Principal Consultant, E-Coustic Solutions, LLC (2006-)	3/3/48

ACADEMIC CREDENTIALS

INSTITUTION	DEGREE/POSITION	YEAR	FIELD
General Motors Institute, Flint, MI	B. Mech. Eng.	1966-1971	Noise Control Engineering
Michigan State University, East Lansing, MI	Adjunct Instructor	1985-2013	Acoustics and Effects of Noise on People
Central Michigan University, Mount Pleasant, MI	Adjunct Professor	2012-2017	Wind Turbine Noise and its Impact on People

RESEARCH AND PROFESSIONAL EXPERIENCE:

Richard R. James has been actively involved in the field of noise control since 1969, participating in and supervising research and engineering projects related to control of occupational and community noise in industry. In addition to his technical responsibilities as principal consultant, he has developed noise control engineering and management programs for the automotive, tire manufacturing, and appliance industries. Has performed extensive acoustical testing and development work in a variety of complex environmental noise problems utilizing both classical and computer simulation techniques. In 1975 he co-directed (with Robert R. Anderson) the development of SOUNDTM, an interactive acoustical modeling computer software package based on the methods that would be later codified in ISO 9613-2 for pre and post-build noise control design and engineering studies of in-plant and community noise. The software was used on projects with General Motors, Ford Motor Company, The Goodyear Tire & Rubber Co., and a number of other companies for noise control engineering decision making during pre-build design of new facilities and complaint resolution at existing facilities. The SOUNDTM computer model was used by Mr. James in numerous community noise projects involving new and existing manufacturing facilities to address questions of land-use compatibility and the effect of noise controls on industrial facility noise emissions. He is also the developer of ONE*dB(tm) software. He was also a co-developer (along with James H. Pyne, Staff Engineer GM AES) of the Organization Structured Sampling method and the Job Function Sound Exposure Profiling Procedure which in combination form the basis for a comprehensive employee risk assessment and sound exposure monitoring process suitable for use by employers affected by OSHA and other governmental standards for occupational sound exposure. Principal in charge of JAA's partnership with UAW, NIOSH, Ford, and Hawkwa on the HearSaf 2000tm software development CRADA partnership for world-class hearing loss prevention tools.

1966-1970 Co-operative student: General Motors Institute and Chevrolet Flint Metal Fabricating Plant.

1970-1971 GMI thesis titled: "Sound Power Level Analysis, Procedure and Applications". This thesis presented a method for modeling the effects of noise controls in a stamping plant. This method was the basis for SOUNDTM.

1970-1972 Noise Control Engineer-Chevrolet Flint Metal Fabricating Plant. Responsible for developing and implementing a Noise Control and Hearing Conservation Program for the Flint Metal Fabricating Plant. Member of the GM Flint Noise Control Committee which drafted the first standards for community noise, GM's Uniform Sound Survey Procedure, "Buy Quiet" purchasing specification, and guidelines for implement-ing a Hearing Conservation Program.

1972-1983 Principal Consultant, Total Environmental Systems, Inc.; Lansing, MI. Together with Robert R. Anderson formed a consulting firm specializing in community and industrial noise control.

1973-1974 Consultant to the American Metal Stamping Association and member firms for in-plant and community noise.

1973 Published: "Computer Analysis and Graphic Display of Sound Pressure Level Data For Large Scale Industrial Noise Studies", Proceedings of Noise-Con '73, Washington, D.C.. This was the first paper on use of sound level contour 'maps' to represent sound levels from computer predictions and noise studies.

Nov. 1973 Published: "Isograms Show Sound Level Distribution in Industrial Noise Studies", Sound & Vibration Magazine

1975 Published: "Computer Assisted Acoustical Engineering Techniques", Noise-Expo 1975, Atlanta, GA which advanced the use of computer models and other computer-based tools for acoustical engineers.

1976 Expert Witness for GMC at OSHA Hearings in Washington D.C. regarding changes to the "feasible control" and cost-benefit elements of the OSHA Noise Standard. Feasibility of controls and cost-benefit were studied for the GMC, Fisher Body Stamping Plant, Kalamazoo MI.

1977-1980 Principal Consultant to GMC for the use of SOUND(tm) computer simulation techniques for analysis of design, layout, and acoustical treatment options for interior and exterior noise from a new generation of assembly plants. This study started with the GMAD Oklahoma City Assembly Plant. Results of the study were used to refine noise control design options for the Shreveport, Lake Orion, Bowling Green plants and many others.

1979-1983	Conducted an audit and follow-up for all Goodyear Tire & Rubber Company's European and U.K. facilities for community and in-plant noise.
1981-1985	Section Coordinator/Speaker, Michigan Department Of Public Health, "Health in the Work Place" Conference.
1981	Published: "A Practical Method for Cost-Benefit Analysis of Power Press Noise Control Options", Noise-Expo 1981, Chicago, Illinois
1981	Principal Investigator: Phase III of Organization Resources Counselors (ORC), Washington D.C., Power Press Task Force Study of Mechanical Press Working Operations. Resulted in publishing: "User's Guide for Noise Emission Event Analysis and Control", August 1981
1981-1991	Consultant to General Motors Corporation and Central Foundry Division, Danville Illinois in community noise citation initiated by Illinois EPA for cupola noise emissions. Resulted in a petition to the IEPA to change state-wide community noise standards to account for community response to noise by determining compliance using a one hour $_{Leq}$ instead of a single not-to-exceed limit.
1983	Published: "Noise Emission Event Analysis-An Overview", Noise-Con 1983, Cambridge, MA
1983-2006	Principal Consultant, James, Anderson & Associates, Inc.; Lansing, MI. (JAA), Together with Robert R. Anderson formed a consulting firm specializing in Hearing Conservation, Noise Control Engineering, and Program Management.
1983-2006	Retained by GM Advanced Engineering Staff to assist in the design and management of GM's on-going community noise and in-plant noise programs.
1984-1985	Co-developed the 1985 GM Uniform Plant Sound Survey Procedure and Guidelines with James H. Pyne, Staff Engineer, GM AES.
1985-2013	Adjunct instructor in Michigan State University's Department of Communicative Sciences and Disorders from 1985-2013
1986-1987	Principal Consultant to Chrysler Motors Corporation, Plant Engineering and Environmental Planning Staff. Conducted Noise Control Engineering Audits of all manufacturing and research facilities to identify feasible engineering controls and development of a formal Noise Control Program.
1988-2006	Co-Instructor, General Motors Corporation Sound Survey Procedure (Course 0369)
1990	Developed One*dB$^{(tm)}$, JAA's Occupational Noise Exposure Database manager to support Organizational structured sampling strategy and Job Function Profile (work-task) approach for sound exposure assessment.
1990-1991	Co-developed the 1991 GM Uniform Plant Sound Survey Procedure and Guidelines with James H. Pyne, Staff Engineer, GM AES. Customized One*dB$^{(tm)}$ software to support GM's program.
1990-2006	Principal Consultant to Ford Motor Company to investigate and design documentation and computer data management systems for Hearing Conservation and Noise Control Engineering Programs. This included bi-annual audits of all facilities.
1993-2006	GM and Ford retain James and JAA as First-Tier Partners for all non-product related noise control services.
1993	Invited paper: "An Organization Structured Sound Exposure Risk Assessment Sampling Strategy" at the 1993 AIHCE
1993	Invited paper: "An Organization Structured Sound Exposure Risk Assessment Database" at the Conference on Occupational Exposure Databases, McLean, VA sponsored by ACGIH
1994-2001	Instructor for AIHA Professional Development Course, "Occupational Noise Exposure Assessment"
1996	Task Based Survey Procedure (used in One*dB$^{(tm)}$) codified as part of ANSI S12.19 Occ. Noise Measurement
1995-2001	Coordinate JAA's role in HearSaf 2000^{tm} CRADA with NIOSH, UAW, Ford, and HAWKWA
1997-2007	Board Member, Applied Physics Advisory Board, Kettering Institute, Flint, Michigan
2002-2006	Member American National Standards Institute (ANSI) Accredited Standards Committee S12, Noise
2006	Closed James, Anderson and Associates, Inc. (JAA) and founded E-Coustic Solutions (E-CS)
2006-Present	Consultant to local communities and citizen's groups on proper siting of Industrial Wind Turbines. This includes presentations to local governmental bodies, assistance in writing noise standards, and formal testimony at zoning board hearings and litigation.
2008	Paper on "Simple guidelines for siting wind turbines to prevent health risks" for INCE Noise-Con 2008, coauthored with George Kamperman, INCE Bd. Cert. Emeritus, Kamperman Associates.

2008	Expanded manuscript supporting Noise-Con 2008 paper titled: “The “How To” Guide To Siting Wind Turbines To Prevent Health Risks From Sound”
2009	"Guidelines for Selecting Wind Turbine Sites," Kamperman and James, Published in the September 2009 issue of Sound and Vibration.
2010	Punch, J., James, R., Pabst, D., "Wind Turbine Noise, What Audiologists should know," Audiology Today, July-August 2010
2011	Jerry L. Punch, Jill L. Elfenbein, and Richard R. James, "Targeting Hearing Health Messages for Users of Personal Listening Devices," Am J Audiol 0: 1059-0889_2011_10-0039v1
2011	Bray, W., HEAD Acoustics, James, R., "Dynamic measurements of wind turbine acoustic signals, employing sound quality engineering methods considering the time and frequency sensitivities of human perception," invited paper for Noise-Con 2011, Portland OR
2012	James, R., "Wind Turbine Infra and Low Frequency Sound: Warning Signs that were not Heard," April 2012, Bulletin of Science, Technology and Society
2012	Appointed to position as Adjunct Professor in the Department of Communication Disorders at Central Michigan University.

Professional Affiliations/Memberships/Appointments

Research Fellow - Metrosonics, Inc.		American Industrial Hygiene Association (through 2006)
National Hearing Conservation Association (through 2006)		Institute of Noise Control Engineers (Full Member)
American National Standards Institute (ANSI) S12 Working Group (through 2006)		Founder and Board Member of the Society for Wind Vigilance, Inc.
Adjunct Professor, CMU 2012-2017		Adjunct Instructor, MSU 1985-2013

Summary of Court and Administrative Agency Cases
for Richard R. James, $_{\text{INCE}}$ Since 2006
Dec. 1, 2015[1]

Jurisdiction	Date	Case No.	Topic
Chatham Ontario, Kent Breeze Wind	February-11	Hearing before Ontario Environmental Board of Review: Case No: 10-121/10-122	Hearing on whether project complies with Ontario regulations to protect health under the Green Energy Act.
Town of Albany, VT	February-11	Hearing before Public Services Commission, Docket No. 7628	Hearing before PUC on application for permit by Green Mountain Power Corp. for Kingdom Mountain Wind, LLC.
State of Maine	July 7, 2011	Hearing before the Maine Board of Environmental Protection	Hearing before the BEP on a Petition for Rule Change for Maine's Chapter 375 Noise Regulations to add specific Rules for wind turbine noise.
State of Michigan Circuit Court of Leelanau county	Nov. 8-10, 2011	Michigan Circuit Court, Leelanau County. Case No: 11-8456-CZ	Complaint of Nuisance Noise and other effects of a 100kW Residential class wind turbine
Illinois, Bureau County, Friesland Farms, LLC, Pierson, Plaintiff, v. Big Sky Wind, LLC)	Dec. 30, 2011 (filed testimony) Feb. 1, 2012 Deposed	US District Court, Central District of Illinois, Peoria. Case No. 10-01232	Complaint of noise annoyance and adverse health effects. Case to be heard in early 2013.
Escanaba Twp. (Gladstone MI) vs. Wells Lions Race Track	March 2012 field study and June 2012 report to town attorney	Township enforcement actions	Complaint of noise annoyance related to ice racing race track adjoining residentially zoned property.
Vermonters for a Clean Environment vs. U.S.D.A. Forest Service,	July 23, 2012 filed testimony for Appeal of Decision	US District Court, District of Vermont Civil Action No. 1:12-cv-73	USFWS Failed to properly consider impact of Deerfield Wind Project on Aiken Wilderness Area in its Decision to Approve said project.
Intervenors opposing Application for Certification: Pursuant to RSA 162-H of ANTRIM WIND ENERGY, LLC	PFT and oral testimony presented Aug. 23, 2012. Additional oral testimony on Nov. 29, 2012.	State of New Hampshire Site Evaluation Committee. Docket No. 2012-01	Application for Certification: Pursuant to RSA 162-H of ANTRIM WIND ENERGY, LLC. Testimony on behalf of North Branch Residents Intervenors Group, Abutting Property Owners Intervenors Group, and Katharine Elizabeth Sullivan. Case to be heard Oct. 2012.
Union Neighbors United, Intervenors opposing Application of Champaign Wind LLC before Ohio Power Siting Board	PFT and oral testimony presented Nov. 2012	State of Ohio, Power Siting Board Case No: 12-0160-EL-BGN	Testimony on behalf of Union Neighbors United in opposition to 2nd Phase of Buckeye Wind project. Champaign County, Ohio.
Private lawsuit by Wiltzer family against Stoney Creek Wind Project, McBain, Michigan	Affidavits and other documents	Lawsuit pending	Testimony on behalf of family who has vacated their home as a result of a 2.5 MW wind turbine being operated at 1350 feet from their home.
Private Lawsuit by Zawadzki family vs. Noble Bliss Wind Park and Town of Eagle, New York	Affidavits, noise studies and other related testimony.	Before the State of New York, Supreme Court, Wyoming County, NY, Index No. 43260/10	Testimony on behalf of family who allege that the subject wind utility causes sleep interference and other adverse effects from operation of wind turbines located approximately 1500 feet from home.
MOE Public Hearing for St. Columban Wind Project,	Critical review of Noise Impact Assessment conducted by Zephyr North for St. Columban Wind.	Ontario EBR Registry Number 011-7629, Ministry Reference Number: 6602-8V9P97	Written testimony on behalf of residents living in or near the foot print of the St. Columban project, Huron County, Ontario, Canada
Wisconsin, Public Service Commission, Hearing on Application of Highland Wind Farm, Towns of Forest and Cylon, Wisconsin.	Supplemental Direct Testimony and additional statements to WPSC. Oral testimony pending on January 17, 2013.	WPSC Docket No. 2353-CE-100	Testimony on behalf of Forest Voice on advanced analysis methods and findings from use of those methods to analyze the calibrated audio files collected by the PSC selected Team at homes of affected families in Shirley Wind Project, Glenmore, Wisconsin.
Michigan 28th Circuit Court: Wiltzer vs. Heritage Sustainable Energy, LLC	July 7, 2013 through April 3, 2014	Case No. 12 8205 CZ	Deposition by Heritage July 7, 2013 Daubert Hearing: Oct. 24, 2013 and Dec. 5, 2013 2nd Deposition: April 3, 2014

Summary of Court and Administrative Agency Cases for Richard R. James, INCE Since 2006
Dec. 1, 2015[1]

Jurisdiction	Date	Case No.	Topic
Paulus vs. Citicorp, Bank data processing center backup diesel generator noise	Deposition: Dec. 18, 2013 Declarations and assistance with motions	Case No. 2:12-cv-856	Deposition by Citibank on Dec. 18, 2013 Judge's response to motions for summary judgment and Daubert Hearing on James' qualifications for noise related to combustion engine noise and human response.
Dixon et. al v. Director, MOE and Middlesex- Lambton Wind Action Group Inc. et. al. v. Director, MOE	Sept. 26, 2013	Case Nos. 13-084-13- 087 and Case. Nos. 13- 088-13-089	Hearing on Application under Ontario Renewable Energy Act for St. Columban Wind project approval.
Cooper vs. Comer, Onandaga Race Track, Leslie, MI	Noise Study: Oct. 12, 2013 Hearing: Mar. 17, 2014, June 22, and Aug. 24, 2015	File No: 13-1193-ND	Noise study of drag strip events and hearing with audio visual demonstration of noise at three test sites.
Drennan v. Director, Ministry of the Environment	Oct. 21, 2013	Case Nos. 13-097/13- 098	Hearing on Application under Ontario Renewable Energy Act for Kings Bridge 2 Wind Project approval.
Michigan, 28th Circuit Court for County of Missaugee. Wiltzer vs. Heritage Sustainable Energy. Daubert Hearing	Oct. 24, 2013 and Dec. 5, 2013	Case No. 12 8205 CZ	Deposition: July 22, 2013 Daubert Hearing: Dec. 5, 2013 2nd Deposition: April 3, 2014
Alberta, CA, Alberta Utility Commission, Bull Creek Wind	Nov. 18, 2013-Dec.	Proceeding ID No. 1955	Testimony on behalf of Killarney Lake Group regarding deficiencies in Application for Bull Creek Wind and other reasons the application should be rejected.
Koeplin v. Director, Ministry of the Environment (ARMOW)	January 8, 2014	Case: 13-124/13-125	Hearing on Application under Ontario Renewable Energy Act for ARMOW Wind Project approval.
Rueter v. Osceola Windpower, LLC Iowa District Court/Osceola County	Deposition: original date of Aug. 21, 2014 postponed at defendant's request. To be rescheduled	EQCV0018304	Noise Nuisance lawsuit against wind energy utility
Cham Shan Temple v. Director, Ontario Ministry of Environment (MOE)	Dec. 19, 2014 via Skype	ERT File: 13-140/13-141/13-142.	Hearing on impact of Sumac project wind turbines on Buddhist pilgrimage meditation practices.
Dingeldein v. Director, Ontario Ministry of Environment and Climate Change (MOECC)	May 6, 2015 at Grey Highlands Zero Power ERT	ERT File:15-011	Hearing on impact of Grey Highland Zero Power Project.
Fohr v. Director, Ontario Ministry of Environment and Climate Change (MOECC)		ERT File: 15-026	Hearing on Impact of Grey Highland Clean Energy Project. Oral testimony not given due to problems with teleconference equipment.
Daniel Brian Williams v. Invenergy LLC, et al.	Trial date not set.	Case No. 2:13-cv-01391- AC US District Court, District of Oregon	Written Testimony and Deposition.
Intervenors v. Walnut Ridge Wind LLC (BHE Renewables)	July 23, 2105 and August 12, 2105	BCZBA-WRW Bureau County, IL, USA	Oral and written testimony before Bureau County Zoning Board of Appeals regarding Walnut Ridge Wind Project.
Alliance to Protect Prince Edward County (APPEC) et al v. Director, MOECC	Nov. 19, 2015	ERT Case Nos. 15-068/15-069	Oral and written testimony before Ontario Environmental Review Tribunal regarding appeal of permit
Walker et al v. Kingfisher Wind, LLC,et al	TBD	Case No. 14-cv-914-D	US District Court, Western District of Oklahoma
Falmouth v Falmouth (Anderson) and (Ohkagawa)	TBD	Docket no. BACV2013-00281-A	Suit filed against Falmouth, MA regarding actions or inactions of Zoning Board of Appeals

[1] This list is not intended as a definitive list of all work. It lists the primary cases where testimony was provided. It may also have incomplete or inaccurate information as a result of rescheduling or other changes.

E-Coustic Solutions

Noise Control ● Sound Measurement ● Consultation
Community ● Industrial ● Residential ● Office ● Classroom ● HIPPA Oral Privacy
P.O Box 1129, Okemos, MI, 48805
rickjames@e-coustic.com Fax: (866) 461-4103

Richard R. James
Principal
Tel: 517-507-5067

List of Recent Publications

Sept. 28, 2015

2008 Paper on "Simple guidelines for siting wind turbines to prevent health risks" for INCE Noise-Con 2008, co-authored with George Kamperman, Kamperman Associates.

2008 Expanded manuscript supporting Noise-Con 2008 paper titled: "The "How To" Guide To Siting Wind Turbines To Prevent Health Risks From Sound"

2009 "Guidelines for Selecting Wind Turbine Sites," Kamperman and James, Published in the September 2009 issue of Sound and Vibration.

2010 Punch, J., James, R., Pabst, D., "Wind Turbine Noise, What Audiologists should know," Audiology Today, July-August 2010

2011 Jerry L. Punch, Jill L. Elfenbein, and Richard R. James , "Targeting Hearing Health Messages for Users of Personal Listening Devices," Am J Audiol 0: 1059-0889_2011_10-0039v1

2011 Bray, W., HEAD Acoustics, James, R., "Dynamic measurements of wind turbine acoustic signals, employing sound quality engineering methods considering the time and frequency sensitivities of human perception," invited paper for Noise-Con 2011, Portland OR

2012 James, R., "Wind Turbine Infra and Low Frequency Sound: Warning Signs that were not Heard," April 2012, Bulletin of Science, Technology and Society, http://bsts.sagepub.com, DOI:10.1177/0270467611421845

E-Coustic Solutions

NOISE CONTROL ● SOUND MEASUREMENT ● CONSULTATION
COMMUNITY ● INDUSTRIAL ● RESIDENTIAL ● OFFICE ● CLASSROOM ● HIPPA ORAL PRIVACY
P.O BOX 1129, OKEMOS, MI, 48805
RICKJAMES@E-COUSTIC.COM FAX: (866) 461-4103

RICHARD R. JAMES
PRINCIPAL
TEL: 517-507-5067

March 16, 2015

Public Service Commission
Ellen Nowak, Chairperson
Phil Montgomery, Commissioner
Mike Huebsch, Commissioner

Subject: Scientific Basis For Limiting Exposure to Infrasound Produced by Utility Scale Modern Upwind Wind Turbines

Dear Commissioners Nowak, Montgomery and Huebsch:

I am an acoustician with over 45 years of experience in the analysis and measurement of sound and in relating those measurements to how people respond to it. I have testified in both the Glacier Hills and Highland Wind hearings before the PSC in Wisconsin and at similar hearings in most of the states in the Midwest and Northeast, plus Ontario and Alberta. I have been qualified as an expert in acoustics, noise measurement and impact of noise on people in lawsuits involving utility scale wind turbines.

For the past five years I have been working with some of the members of the Shirley community and the Brown County Board of Health to better understand why some families have experienced adverse health effects sufficient to cause them to have vacated their homes. The most recent aspect of this work involved a series of multi-day measurements in homes situated both close to and distant from the Shirley Wind Project's wind turbines using a micro barometer as the acoustic sensor. This instrument is sensitive to acoustic energy down to frequencies far below 1 Hz. It is well suited for measuring the infrasonic tones in the frequency range of 0-10 Hz that are characteristic of wind turbine operation.

The measurements showed that at distances from wind turbines comparable to the distances of the vacated homes (1200 feet to over one mile) the acoustic energy of the tones produced by the wind turbines averaged 50 dB or higher, often over 60 dB and with some periods having levels that were above 70 dB. What was also observed is that the average levels were a result of very short duration pulses with levels 10 to 20 dB above the average. Thus, the average levels are a result of short pulses with low energy between them, and not steady tones. It is the pulsitivity of the tones that makes the sound emissions especially problematic. Acousticians have known since the 1960's that slowly rotating machines produce infrasound tones, and that when the sounds have pulsations they cause symptoms of the type reported near wind turbine utilities. Tests inside homes at increasing distances away from the Shirley Wind wind turbines showed that even at distances over 4 miles the characteristic tones measured closer to the wind turbines were still clearly evident even at lower sound pressure levels and at times almost at sound pressure levels comparable to those found in the vacated homes.

The results of this work was presented to the Brown County Board of Health at a hearing in October 2014 along with oral and written testimony from many of the people who had experienced adverse health effects during periods of wind turbines operation. Based on the evidence provided in that hearing, and the evidence that the Board of Health had collected since the complaints first started to occur, the Board declared the wind project to be a Human Health Hazard.

The work I did with the community members is not the only study that has been conducted at these homes. In December of 2012 the homes were tested by a team of acousticians at the request of the PSC in the Highland Wind hearing. That study concluded that infrasound emitted by the operation of the Shirley Wind wind turbines was present inside the homes and that the adverse health effects reported in the complaints of the families was linked to that infrasound. Dr. Paul Schomer was one of the acousticians involved in that test and the Highland hearing before the PSC. I was also involved in setting up the test protocol and conducting analysis because I was the acoustician working with the homeowners.

Similar to the studies conducted at Shirley Wind in Brown County, other acousticians have been conducting studies using comparable instrumentation and analysis techniques. A study conducted in 2014 by an Australian acoustician, Steve Cooper, working for Pacific Hydro, at its Cape Bridgewater wind project in Australia was broader than what was done in Shirley because the utility operator cooperated with the acoustician in sharing operational data and setting up special test conditions. This was a very well funded study, reported to have a budget of $180,000 $AU and one that spanned months of testing. This study was released in February of 2015 and has been reviewed by a number of independent acousticians, including Dr. Paul Schomer, Director of the Acoustical Society of America Standards Committee. Dr. Schomer was also involved in the 2012 Shirley Wind study for the Wisconsin PSC and has testified at the Highland hearing. Dr. Schomer's review of the Cooper study gave it his full support, as have the reviews conducted by other independent acousticians.

I have conducted a review of the findings of the Cooper Cape Bridgewater study and have confirmed that it supports the findings of the studies conducted at Shirley Wind. As a reference point, the Cape Bridgewater study ranks the severity of the infrasound for each test home and test period by summing the energy of the wind turbine tones and harmonics in the infrasonic frequency range. This sum is called the Wind Turbine Signature (WTS). While the studies of the Shirley wind turbine infrasound did not use that term, the concept of summing the energy of the tones was similar in both. There were some differences in how the energy was analyzed. However, I have worked with Mr. Cooper to compare his study findings to mine. The result is that a test showing a 51 dB tone on a Shirley Wind micro barometer test is equivalent to 61 dB using Mr. Cooper's method for Cape Bridgewater. The Cooper study ranked the intensity of the sensations reported by his test subjects on a scale of 1 to 5. The highest sensation level, Sensation Level 5, corresponds to his 61 dB results and my 51 dB readings. In Shirley Wind sound pressure levels of the WTS of 51 and higher are associated with severe levels of sensation and adverse health effects leading to families leaving their homes. In the Australian study, Sensation Level 5 was associated with strong sensations that could lead to one abandoning a home. In fact, in Cooper's study, three of the test homes have been vacated since the end of his field study last summer. The tones found in the homes close to the Shirley Wind towers are at or above the Sensation 5 threshold both by my measurements and the testimony of the home owners.

These studies are confirming what was reported in studies conducted in the 1980's by the Department of Energy and NASA. Those studies demonstrated the mechanisms that are producing the infrasonic tones (WTS) and related them to human response. They concluded that locating large utility scale wind turbines of the type and size now being installed and operated by wind energy utilities would lead to complaints of the type that are now reported. While the wind industry claims that these studies are no longer relevant, recent interviews with some of those researchers show they consider the findings of their work in the 1980's to still apply. The studies conducted in Shirley Wind and Cape Bridgewater applied many of the same measurement and analysis methods used in these early studies. Thus, there is a long history of research showing that what was found in the new studies was well understood by acousticians in the 1980's and 90's.

To conclude I wish to use a quote from Dr. Schomer's letter describing his peer review of the Cooper Cape Bridgewater study. He states:

> "Some may ask, this is only 6 people, why is it so important? The answer is that up until now windfarm operators have said there are no known cause and effect relations between windfarm emissions and the response of people living in the vicinity of the windfarm other than those

> related to visual and/or audible stimuli, and these lead to some flicker which is treated, and "some annoyance with noise." <u>This study proves that there are other pathways that affect some people,</u> at least 6. <u>The windfarm operator simply cannot say there are no known effects and no known people affected.</u> One person affected is a lot more than none; the existence of just one cause-and-effect pathway is a lot more than none. It only takes one example to prove that a broad assertion is not true, and that is the case here. <u>Windfarms will be in the position where they must say: "We may affect some people."</u> <u>And regulators charged with protecting the health and welfare of the citizenry will not be able to say they know of no adverse effect</u>s. **Rather, if they choose to support the windfarm, they will do so knowing that they may not be protecting the health and welfare of all the citizenry**."
>
> (Emphasis added) Quote by: Dr. Paul Schomer, Stand**a**rds Director, Acoustical Society of America Feb. 10, 2015, Peer Review of Cooper Cape Bridgewater Wind Farm Study.

Based on the above, it is reasonable to conclude that the adverse health effects reported by members of the Shirley community are linked to the operation of the Shirley Wind project wind turbines. While there may still be debate about the precise mechanism that causes these sounds to induce the symptoms; it is clear from this study, the Cape Bridgewater Study in Australia, and others conducted in different parts of the world by other acousticians, that acoustic energy emitted by the operation of modern utility scale wind turbines is at the root of the adverse health effects.

We find that the adverse health effects are not limited just to homes close to the wind turbines (e.g at the distances to homes found in projects like Highland Wind), but extend outward to distances of over four miles from the nearest wind turbine. As the distance to the wind turbines decreases, the frequency and severity of the sensations experienced and reported as adverse health effects increases. In the Cape Bridgewater study, it was concluded that the radius of impact is approximately 7 km (4.3 miles). This corresponds well to the findings at Shirley.

In conclusion, I offer my opinion that until more is known about this aspect of wind turbine sound emissions and adverse health effects that utility scale wind projects should have precautionary buffer zones of two or more miles with some provisions for those people who will still be affected at these greater distances to relocate away from the utility. For those people living in or near existing wind projects that have been experiencing the adverse effects of these acoustic emissions this could be considered an emergency situation. For those people living in communities where wind energy projects are planned and the developer is only considering the effects of audible sounds it is also of extreme importance that the PSC act to protect them from similar adverse effects.

I am available to discuss this in more detail or to provide additional information expanding on my statements.

Sincerely,
E-Coustic Solutions

Richard R. James

Richard R. James, INCE

Exposure to wind turbine noise: Perceptual responses and reported health effects

David S. Michaud,[a)] Katya Feder, Stephen E. Keith, and Sonia A. Voicescu
Health Canada, Environmental and Radiation Health Sciences Directorate, Consumer and Clinical Radiation Protection Bureau, 775 Brookfield Road, Ottawa, Ontario K1A 1C1, Canada

Leonora Marro, John Than, and Mireille Guay
Health Canada, Population Studies Division, Biostatistics Section, 200 Eglantine Driveway, Tunney's Pasture, Ottawa, Ontario, Canada

Allison Denning
Health Canada, Environmental Health Program, Health Programs Branch, Regions and Programs Bureau, 1505 Barrington Street, Halifax, Nova Scotia, Canada

D'Arcy McGuire and Tara Bower
Health Canada, Environmental and Radiation Health Sciences Directorate, Office of Science Policy, Liaison and Coordination, 269 Laurier Avenue West, Ottawa, Ontario, Canada

Eric Lavigne
Health Canada, Air Health Science Division, 269 Laurier Avenue West, Ottawa, Ontario, Canada

Brian J. Murray
Department of Medicine, Division of Neurology, Sunnybrook Health Sciences Center, University of Toronto, Toronto, Ontario, Canada

Shelly K. Weiss
Department of Pediatrics, Division of Neurology, Hospital for Sick Children, University of Toronto, 555 University Avenue, Toronto, Ontario, Canada

Frits van den Berg
The Amsterdam Public Health Service (GGD Amsterdam), Environmental Health Department, Nieuwe Achtergracht 100, Amsterdam, The Netherlands

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Health Canada, in collaboration with Statistics Canada, and other external experts, conducted the Community Noise and Health Study to better understand the impacts of wind turbine noise (WTN) on health and well-being. A cross-sectional epidemiological study was carried out between May and September 2013 in southwestern Ontario and Prince Edward Island on 1238 randomly selected participants (606 males, 632 females) aged 18–79 years, living between 0.25 and 11.22 km from operational wind turbines. Calculated outdoor WTN levels at the dwelling reached 46 dBA. Response rate was 78.9% and did not significantly differ across sample strata. Self-reported health effects (e.g., migraines, tinnitus, dizziness, etc.), sleep disturbance, sleep disorders, quality of life, and perceived stress were not related to WTN levels. Visual and auditory perception of wind turbines as reported by respondents increased significantly with increasing WTN levels as did high annoyance toward several wind turbine features, including the following: noise, blinking lights, shadow flicker, visual impacts, and vibrations. Concern for physical safety and closing bedroom windows to reduce WTN during sleep also increased with increasing WTN levels. Other sample characteristics are discussed in relation to WTN levels. Beyond annoyance, results do not support an association between exposure to WTN up to 46 dBA and the evaluated health-related endpoints.

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[SF] Pages: 1443–1454

I. INTRODUCTION

Jurisdiction for the regulation of noise is shared across many levels of government in Canada. As the federal department of health, Health Canada's mandate with respect to wind power includes providing science-based advice, upon request, to federal departments, provinces, territories and other stakeholders regarding the potential impacts of wind turbine noise (WTN) on community health and well-being. Provinces and territories, through the legislation they have enacted, make decisions in relation to areas including installation, placement, sound levels, and mitigation measures for wind turbines. In July 2012, Health Canada announced its

[a)]Electronic mail: david.michaud@canada.ca

intention to undertake a large scale epidemiological study in collaboration with Statistics Canada entitled Community Noise and Health Study (CNHS). Statistics Canada is the federal government department responsible for producing statistics relevant to Canadians.

In comparison to the scientific literature that exists for other sources of environmental noise, there are few original peer-reviewed field studies that have investigated the community response to modern wind turbines. The studies that have been conducted to date differ substantially in terms of their design and evaluated endpoints (Krogh *et al.*, 2011; Mroczek *et al.*, 2012; Mroczek *et al.*, 2015; Nissenbaum *et al.*, 2012; Pawlaczyk-Łuszczyńska *et al.*, 2014; Pedersen and Persson Waye, 2004, 2007; Pedersen *et al.*, 2009; Shepherd *et al.*, 2011; Tachibana *et al.*, 2012; Tachibana *et al.*, 2014; Kuwano *et al.*, 2014). Common features among these studies include reliance upon self-reported endpoints, modeled WTN exposure and/or proximity to wind turbines as the explanatory variable for the observed community response.

There are numerous health symptoms attributed to WTN exposure including, but not limited to, cardiovascular effects, vertigo, tinnitus, anxiety, depression, migraines, sleep disturbance, and annoyance. Health effects and exposure to WTN have been subjected to several reviews and the general consensus to emerge to date is that the most robust evidence is for an association between exposure to WTN and community annoyance with inconsistent support observed for subjective sleep disturbance (Bakker *et al.*, 2012; Council of Canadian Academies, 2015; Knopper *et al.*, 2014; MassDEP MDPH, 2012; McCunney *et al.*, 2014; Merlin *et al.*, 2014; Pedersen, 2011).

The current analysis provides an account of the sample demographics, response rates, and observed prevalence rates for the various self-reported measures as a function of the outdoor WTN levels calculated in the CNHS.

II. METHOD

A. Sample design

Factors considered in the determination of the study sample size, including statistical power, have been described by Michaud *et al.* (2013), Michaud *et al.* (2016b), and Feder *et al.* (2015). The target population consisted of adults, aged 18 to 79 years, living in communities within approximately 10 km of a wind turbine in southwestern Ontario (ON) and Prince Edward Island (PEI). Selected areas in both provinces were characterized by flat lands with rural/semi-rural type environments. Prior to field work, a list of addresses (i.e., potential dwellings) was developed by Statistics Canada. The list consists mostly of dwellings, but it can include industrial facilities, churches, demolished/vacant dwellings, etc. (i.e., non-dwellings), that would be classified as out-of-scope for the purposes of the CNHS. The ON and PEI sampling areas included 315 and 84 wind turbines, respectively. Wind turbine electrical power output ranged between 660 kW to 3 MW (average 2.0 ± 0.4 MW). All turbines were modern design with 3 pitch controlled rotor blades (~80 m diameter) upwind of the tower, and predominantly 80 m hub heights. This study was approved by the Health Canada and Public Health Agency of Canada Research Ethics Board (Protocols #2012–0065 and #2012–0072).

B. Wind turbine sound pressure levels at dwellings

A detailed description of the approach applied to sound pressure level modeling [including background nighttime sound pressure (BNTS) levels] is presented separately (Keith *et al.*, 2016b). Briefly, sound pressure levels were estimated at each dwelling using both ISO (1993) and ISO (1996) as incorporated in the commercial software CadnaA version 4.4 (Datakustik, 2014). The calculations were based on manufacturers' octave band sound power spectra at 10 m height, 8 m/s wind speed for favorable propagation conditions (Keith *et al.*, 2016a). As described in detail by Keith *et al.* (2016b), BNTS levels were calculated following provincial noise regulations for Alberta, Canada (Alberta Utilities Commission, 2013). With this approach BNTS levels can range between 35 dBA to 51 dBA. The possibility that BNTS levels due to highway road traffic noise exposure may exceed the level estimated by Alberta regulations was considered. Where the upper limits of this approach were exceeded (i.e., 51 dB), nighttime levels were derived using the US Traffic Noise Model (United States Department of Transportation, 1998) module in the CadnaA software.

Low frequency noise was estimated in the CNHS by calculating outdoor C-weighted sound pressure levels at all dwellings. There was no additional gain by analysing the data using C-weighted levels because the statistical correlation between C-weighted and A-weighted levels was very high (i.e., $r = 0.81$–0.97) (Keith *et al.*, 2016a).

C. Data collection

1. Questionnaire content and collection

The final questionnaire, available on the Statistics Canada website (Statistics Canada, 2014) and in the supplementary materials,[1] consisted of basic socio-demographics, modules on community noise and annoyance, health effects, lifestyle behaviors and prevalent chronic illnesses. In addition to these modules, validated psychometric scales were incorporated, without modification, to assess perceived stress (Cohen *et al.*, 1983), quality of life (WHOQOL Group, 1998; Skevington *et al.*, 2004) and sleep disturbance (Buysse *et al.*, 1989).

Questionnaire data were collected through in-person home interviews by 16 Statistics Canada trained interviewers between May and September 2013. The study was introduced as the "Community Noise and Health Study" as a means of masking the true intent of the study, which was to investigate the association between health and WTN exposure. All identified dwellings within ~600 m from a wind turbine were selected. Between 600 m and 11.22 km, dwellings were randomly selected. Once a roster of adults (between the ages of 18 and 79 years) living in the dwelling was compiled, one individual from each household was randomly invited to participate. No substitutions were permitted under any circumstances. Participants were not compensated for their participation.

2. Long-term high annoyance

To evaluate the prevalence of annoyance, participants were initially asked to spontaneously identify sources of noise they hear originating from outdoors while they are either inside or outside their home. The interviewer grouped the responses as road traffic, aircraft, railway/trains, wind turbine, and "*other*." Follow-up questions were designed to confirm the initial response where the participant may not have spontaneously identified wind turbines, rail, road and aircraft as one of the audible sources. For each audible noise source participants were asked to respond to the following question from ISO/TS (2003a): "*Thinking about the last year or so, when you are at home, how much does noise from [SOURCE] bother, disturb or annoy you?*" Response categories included the following: "*not at all*," "*slightly*," "*moderately*," "*very*," or "*extremely*." Participants who reported they did not hear a particular source of noise, were classified into a "*do not hear*" group and retained in analysis (to ensure that the correct sample size was accounted for in the modeling). The analysis of annoyance was performed after collapsing the response categories into two groups (i.e., "*highly annoyed*" and "*not highly annoyed*"). As per ISO/TS (2003a), participants reporting to be either "*very*" or "*extremely*" annoyed were treated as "*highly annoyed*" in the analysis. The "*not highly annoyed*" group was composed of participants from the remaining response categories in addition to those who did not hear wind turbines. Similarly, an analysis of the percentage highly subjectively sleep disturbed, highly noise sensitive, and highly concerned about physical safety from having wind turbines in the area was carried out applying the same classification approach used for annoyance.

The use of filter questions and an assessment of annoyance using only an adjectival scale are approaches not recommended by ISO/TS (2003a). The procedures followed in the current study were chosen to minimize the possibility of participant confusion (i.e., by asking how annoyed they are toward the noise from a source that may not be audible). Although there is value in confirming the response on the adjectival scale with a numerical scale, this approach would have added length to the questionnaire, or led to the removal of other questions. Collectively, the deviations from ISO/TS (2003a) conformed to the recommendations by Statistics Canada and to the approach adopted in a large-scale study conducted by Pedersen *et al.* (2009).

D. Statistical methodology

The analysis for categorical outcomes closely follows the description outlined in Michaud *et al.* (2013), which provides a summary of the pre-data collection study design and objectives, as well as the proposed data analysis. Final wind turbine distance and WTN categories were defined as follows: distance categories in km {$\leq$0.550; (0.550–1]; (1–2]; (2–5]; and >5}, WTN exposure categories in dBA {<25; [25–30); [30–35); [35–40); and [40–46]}. The top category included 46 dB as only six cases were observed at $\geq$45 dBA. All models were adjusted for provincial differences. Province was initially assessed as an effect modifier. When the interaction between WTN and province was significant, separate models were reported for each province. This included reporting separate chi-square tests of independence or logistic regression models for each province. When the interaction was not statistically significant, province was treated as a confounder in the model. This included using the Cochran-Mantel-Haenszel (CMH) chi-square tests for contingency tables (which adjusts for confounders), as well as adjusting the logistic regression models for the confounder of province.

The questionnaire assessed participant's long-term ($\sim$1 year) annoyance to WTN in general (i.e., location not specified), and specifically with respect to location (outdoors, indoors), time of day (morning, afternoon, evening, nighttime) and season (spring, summer, fall, winter). In addition, participants' long-term annoyance in general, to road, aircraft and rail noise was assessed. These evaluations of annoyance are considered to be clustered because they are derived from the same individuals (i.e., they are repeated measures). Therefore, in order to compare the prevalence of annoyance as a function of location, time of day, season, or noise source, generalized estimating equations for repeated measures were used to account for the clustered responses (Liang and Zeger, 1986; Stokes *et al.*, 2000).

Statistical analysis was performed using SAS version 9.2 (SAS Institute Inc., 2014). A 5% statistical significance level is implemented throughout unless otherwise stated. In addition, Bonferroni corrections are made to account for all pairwise comparisons to ensure that the overall type I (false positive) error rate is less than 0.05. In cases where cell frequencies were small (i.e., <5) in the contingency tables or logistic regression models, exact tests were used as described in Agresti (2002) and Stokes *et al.* (2000).

III. RESULTS

A. Wind turbine sound pressure levels at dwellings

Modeled sound pressure levels, and the field measurements used to support the models are presented in detail by Keith *et al.* (2016a,b). Calculated outdoor sound pressure levels at the dwellings reached levels as high as 46 dB. Unless otherwise stated, all decibel references are A-weighted. Calculations are likely to yield typical worst case long-term (1 years) average WTN levels (Keith *et al.*, 2016b).

B. Response rate

Of the 2004 addresses (i.e., potential dwellings) on the sample roster, 434 dwellings were coded as out-of-scope by Statistics Canada during data collection (Table I). This was consistent with previous surveys conducted in rural areas in Canada (Statistics Canada, 2008). In the current study, 26.7% and 20.4% of addresses were deemed out-of-scope in PEI and ON, respectively. No significant difference in the distribution of out-of-scope locations by distance to the nearest wind turbine was observed in PEI ($\chi^2 = 3.19$, $p = 0.5263$). In ON, a higher proportion of out-of-scope addresses was observed in the closest distance group ($\leq$0.55 km) compared to other distance groups ($p < 0.05$, in all cases). After adjusting for province, there was a

TABLE I. Locations coded out-of-scope.

	Distance to nearest wind turbine (km)						
	≤0.55	(0.55–1]	(1–2]	(2–5]	>5	Overall	CMH *p*-value[a]
Range of WTN (dB)	37.4–46.1	31.8–43.6	26.3–40.4	14.6–30.9	0–18.2		
Total potential dwellings	143	887	781	95	98	2004	
ON	76	718	669	60	80	1603	
PEI	67	169	112	35	18	401	
Total number of potential dwellings out-of-scope n(%)[b]	48 (33.6)	158 (17.8)	189 (24.2)	19 (20.0)	20 (20.4)	434 (21.7)	0.9755
ON	29 (38.2)	109 (15.2)	166 (24.8)	9 (15.0)	14 (17.5)	327 (20.4)	<0.0001[c]
PEI	19 (28.4)	49 (29.0)	23 (20.5)	10 (28.6)	6 (33.3)	107 (26.7)	0.5263[c]
Code A	28 (19.6)	23 (2.6)	18 (2.3)	5 (5.3)	8 (8.2)	82 (4.1)	0.0068
Code B	12 (8.4)	54 (6.1)	55 (7.0)	5 (5.3)	6 (6.1)	132 (6.6)	0.8299
Code C	2 (1.4)	36 (4.1)	61 (7.8)	7 (7.4)	1 (1.0)	107 (5.3)	
Code D	4 (2.8)	35 (3.9)	50 (6.4)	2 (2.1)	5 (5.1)	96 (4.8)	
Code E	0 (0.0)	7 (0.8)	4 (0.5)	0 (0.0)	0 (0.0)	11 (0.6)	
Code F	2(1.4)	3(0.3)	1(0.1)	0(0.0)	0(0.0)	6(0.3)	

[a]The Cochran Mantel-Haenszel chi-square test is used to adjust for province, *p*-values <0.05 are considered to be statistically significant.

[b]Total number of potential dwellings out of scope (given as a percentage of total potential dwellings) is broken down by province, as well it is equal to the sum of Code A-F. The percentages of dwellings that are coded as out-of-scope are based on the total number of potential dwellings in the area. Code A—address was a business/duplicate/other (17%), address listed in error (83%). Code B—an inhabitable dwelling unoccupied at the time of the survey, newly constructed dwelling not yet inhabited, a vacant trailer in a commercial trailer park. Code C—summer cottage, ski chalet, or hunting camps. Code D—all participants in the dwelling were >79 years of age. Code E—under construction, institution, or unavailable to participate. Code F—demolished for unknown reasons.

[c]Chi-square test of independence.

significant association between distance groups and the proportion of locations assigned a *Code A* ($p = 0.0068$) (Table I). A post-collection screening of interviewer notes by Statistics Canada has confirmed that of the total number of *Code A* locations, the vast majority (i.e., 83%) were locations listed in error. In rural areas, there is more uncertainty in developing the address list frame and this can contribute to a higher prevalence of addresses listed in error within 0.55 km of a wind turbine where the population density is lower compared to areas at greater setbacks.[2]

The remaining 1570 addresses were considered to be valid dwellings, from which 1238 residents agreed to participate in the study (606 males, 632 females). This resulted in a final response rate of 78.9%, which was not statistically different between ON and PEI or by proximity to wind turbines (Table II).

C. Sample characteristics

Table III outlines demographic information for study populations in each 5 dB WTN category. The prevalence of employment was the only variable that appeared to consistently increase within increasing WTN levels. Household income and education were unrelated to WTN levels. There was no obvious pattern to the changes observed in the other variables that were found to be statistically related to WTN level categories (i.e., age, type of dwelling, property ownership and facade type).

D. Perception of community noise and related variables as a function of WTN level

The prevalence of reporting to be very or extremely (i.e., highly) noise sensitive was statistically similar across all WTN categories ($p = 0.8175$). As expected and as shown in Fig. 1, visibility and audibility of wind turbines increased with increasing WTN levels.

The overall audibility of other noise sources is shown in Table IV. Not shown in Table IV is how often the noise source was spontaneously reported as opposed to being identified following a prompt by the interviewer (see Sec. II).

TABLE II. Sample response rate.

	Distance to nearest wind turbine (km)						
	≤0.55	(0.55–1]	(1–2]	(2–5]	>5	Overall	*p*-value
Final number of potential participants[a]	95	729	592	76	78	1570	
ON	47	609	503	51	66	1276	
PEI	48	120	89	25	12	294	
Participants n (%)	71 (74.7)	583 (80.0)	463 (78.2)	58 (76.3)	63 (80.8)	1238 (78.9)	0.9971[b]
ON	34 (72.3)	488 (80.1)	396 (78.7)	42 (82.4)	51 (77.3)	1011 (79.2)	0.7009[c]
PEI	37 (77.1)	95 (79.2)	67 (75.3)	16 (64.0)	12 (100.0)	227 (77.2)	0.1666[c]

[a]Potential participants from locations established to be valid dwellings (equal to the difference between “Total potential dwellings” and “total number of potential dwellings out-of-scope”; see Table I) used in the derivation of participation rates.

[b]The CMH chi-square test is used to adjust for province, *p*-values <0.05 are considered to be statistically significant.

[c]Chi-square test of independence.

TABLE III. Sample characteristics.

Variable	WTN (dB) <25	[25–30)	[30–35)	[35–40)	[40–46]	Overall	CMH *p*-value[a]
n	84[b]	95[b]	304[b]	521[b]	234[b]	1238[b]	
Range of closest turbine (km)	2.32–11.22	1.29–4.47	0.73–2.69	0.44–1.56	0.25–1.05		
Range of BNTS (dB)	35–51	35–51	35–56	35–57	35–61		
BNTS (dB) mean (SD)	43.88(3.43)	44.68 (2.91)	45.21 (3.60)	43.29 (4.11)	41.43 (4.21)		
ON	44.98 (2.88)	44.86 (2.78)	45.54 (3.31)	44.06 (3.86)	42.70 (4.25)		<0.0001[c]
PEI	41.13 (3.18)	43.00 (3.67)	43.81 (4.38)	38.44 (1.59)	38.05 (1.00)		<0.0001[c]
Sex *n* (% male)	37 (44.0)	48 (50.5)	150 (49.3)	251 (48.2)	120 (51.3)	606 (49.0)	0.4554
Age mean (SE)	49.75 (1.78)	56.38 (1.37)	52.25 (0.93)	51.26 (0.68)	50.28 (1.03)	51.61 (0.44)	0.0243[d]
Marital status *n* (%)							0.2844
Married/Common-law	54 (64.3)	69 (73.4)	199 (65.7)	367 (70.6)	159 (67.9)	848 (68.7)	
Widowed/Separated/Divorced	16 (19.0)	18 (19.1)	61 (20.1)	85 (16.3)	35 (15.0)	215 (17.4)	
Single, never been married	14 (16.7)	7 (7.4)	43 (14.2)	68 (13.1)	40 (17.1)	172 (13.9)	
Employed *n* (%)	43 (51.8)	47 (49.5)	161 (53.0)	323 (62.0)	148 (63.2)	722 (58.4)	0.0012
Level of education *n* (%)							0.7221
≤High school	45 (53.6)	52 (54.7)	167 (55.1)	280 (53.7)	134 (57.3)	678 (54.8)	
Trade/Certificate/College	34 (40.5)	37 (38.9)	110 (36.3)	203 (39.0)	85 (36.3)	469 (37.9)	
University	5 (6.0)	6 (6.3)	26 (8.6)	38 (7.3)	15 (6.4)	90 (7.3)	
Income (×$1000) *n* (%)							0.8031
<60	39 (51.3)	40 (54.8)	138 (52.5)	214 (49.1)	100 (49.3)	531 (50.5)	
60-100	18 (23.7)	17 (23.3)	72 (27.4)	134 (30.7)	59 (29.1)	300 (28.5)	
≥100	19 (25.0)	16 (21.9)	53 (20.2)	88 (20.2)	44 (21.7)	220 (20.9)	
Detached dwelling *n* (%)[e]	59 (70.2)	84 (88.4)	267 (87.8)	506 (97.1)	216 (92.3)	1132 (91.4)	
ON[e]	46 (76.7)	77 (89.5)	228 (93.1)	437 (97.1)	154 (90.6)	942 (93.2)	<0.0001[f]
PEI[e]	13 (54.2)	7 (77.8)	39 (66.1)	69 (97.2)	62 (96.9)	190 (83.7)	<0.0001[f]
Property ownership *n* (%)	60 (71.4)	85 (89.5)	250 (82.2)	466 (89.4)	215 (91.9)	1076 (86.9)	
ON	45 (75.0)	78 (90.7)	215 (87.8)	399 (88.7)	157 (92.4)	894 (88.4)	0.0085[f]
PEI	15 (62.5)	7 (77.8)	35 (59.3)	67 (94.4)	58 (90.6)	182 (80.2)	<0.0001[f]
Facade type *n* (%)							0.0137
Fully bricked	20 (23.8)	30 (31.6)	85 (28.0)	138 (26.5)	67 (28.6)	340 (27.5)	
Partially bricked	24 (28.6)	29 (30.5)	62 (20.4)	88 (16.9)	15 (6.4)	218 (17.6)	
No brick/other	40 (47.6)	36 (37.9)	157 (51.6)	295 (56.6)	152 (65.0)	680 (54.9)	

[a]The Cochran Mantel-Haenszel chi-square test is used to adjust for province unless otherwise indicated, *p*-values <0.05 are considered to be statistically significant.
[b]Totals may differ due to missing data.
[c]Analysis of variance (ANOVA) model.
[d]Non-parametric two-way ANOVA model adjusted for province.
[e]Non-detached dwellings included semi/duplex/apartment.
[f]Chi-square test of independence.

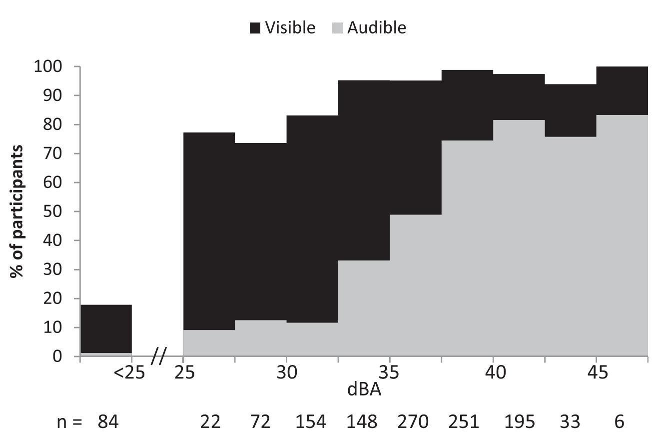

FIG. 1. Proportion of participants as a function of calculated outdoor A-weighted WTN levels. The figure plots the proportion of participants that reported wind turbines were visible from anywhere on their property or audible from inside or outside their homes from the total number of participants with valid responses living in each WTN level category.

Among the participants who reported hearing each specific noise source, the prevalence of spontaneously reporting road traffic, wind turbines, rail and aircraft was 84%, 71%, 66%, and 30%, respectively. A total of 102 participants (8.2%) indicated that there were no audible noise sources around their home. These participants lived in areas where the average WTN levels were 32.4 dB [standard deviation (SD) = 8.3] and the mean distance to the nearest turbine was 1.7 km (SD = 2.0) (data not shown).

Table IV also provides the observed prevalence rates for high (i.e., very or extreme) annoyance toward wind turbine features. The results suggest that there was a tendency for the prevalence of annoyance to increase with increasing WTN levels, with the rise in annoyance becoming evident when WTN levels exceeded 35 dB. The pattern was slightly different for visual annoyance among participants drawn from the ON sample, where there was a noticeable rise in annoyance among participants living in areas where WTN

TABLE IV. Perception of community noise and related variables.

Variable	Wind Turbine Noise (dB) <25	[25–30)	[30–35)	[35–40)	[40–46]	Overall	CMH *p*-value[a]
n	84[b]	95[b]	304[b]	521[b]	234[b]	1238[b]	
Sensitivity to noise[c]	14 (16.7)	14 (14.7)	35 (11.6)	77 (14.8)	35 (15.1)	175 (14.2)	0.8175
Audible perception of transportation noise sources *n* (%)							
Road traffic	62 (73.8)	60 (63.2)	259 (85.2)	443 (85.0)	192 (82.1)	1016 (82.1)	0.0013
Aircraft	43 (51.2)	33 (34.7)	146 (48.0)	263 (50.5)	124 (53.0)	609 (49.2)	
Aircraft (ON)	32 (53.3)	31 (36.0)	120 (49.0)	220 (48.9)	82 (48.2)	485 (48.0)	0.2114[d]
Aircraft (PEI)	11 (45.8)	2 (22.2)	26 (44.1)	43 (60.6)	42 (65.6)	124 (54.6)	0.0214[d]
Rail[e]	30 (50.0)	27 (31.4)	73 (29.8)	90 (20.0)	7 (4.1)	227 (22.5)	<0.0001[d]
Perception of wind turbines *n* (%)							
See wind turbines	15 (17.9)	70 (74.5)	269 (89.1)	505 (96.9)	227 (97.0)	1086 (87.9)	<0.0001
Hear wind turbines	1 (1.2)	11 (11.6)	67 (22.0)	319 (61.2)	189 (80.8)	587 (47.4)	<0.0001
Number of years hearing the WT *n* (%)							<0.0001
Do not hear	83 (98.8)	84 (88.4)	237 (78.0)	202 (39.0)	45 (19.3)	651 (52.8)	
<1 year	1 (1.2)	2 (2.1)	15 (4.9)	31 (6.0)	12 (5.2)	61 (4.9)	
≥1 year	0 (0.0)	9 (9.5)	52 (17.1)	285 (55.0)	176 (75.5)	522 (42.3)	
Notice vibrations/rattles indoors during WTN operations	0 (0.0)	3 (3.2)	8 (2.6)	28 (5.4)	19 (8.2)	58 (4.7)	0.0004
Highly concerned about physical safety	1 (1.2)	3 (3.2)	5 (1.6)	46 (8.9)	22 (9.6)	77 (6.3)	<0.0001
Formal complaint[f]	2 (2.4)	2 (2.1)	3 (1.0)	22 (4.2)	6 (2.6)	35 (2.8)	0.2578
Reporting a high (very or extreme) level of annoyance to wind turbine features, *n* (%)							
Noise	0 (0.0)	2 (2.1)	3 (1.0)	52 (10.0)	32 (13.7)	89 (7.2)	<0.0001
Visual	2 (2.4)	15 (16.0)	17 (5.6)	81 (15.5)	44 (18.9)	159 (12.9)	
Visual (ON)	2 (3.3)	15 (17.6)	17 (7.0)	76 (16.9)	36 (21.2)	146 (14.5)	<0.0001[d]
Visual (PEI)	0 (0.0)	0 (0.0)	0 (0.0)	5 (7.0)	8 (12.7)	13 (5.8)	0.0268[d]
Blinking lights	2 (2.4)	8 (8.5)	17 (5.6)	61 (11.7)	34 (14.6)	122 (9.9)	<0.0001
Shadow flicker	0 (0.0)	3 (3.2)	6 (2.0)	51 (9.8)	36 (15.5)	96 (7.8)	<0.0001
Vibrations/rattles	0 (0.0)	1 (1.1)	2 (0.7)	9 (1.7)	7 (3.0)	19 (1.5)	0.0198
Reporting a high (very or extreme) level of WTN annoyance by time of day, *n* (%)							
Morning	0 (0.0)	0 (0.0)	1 (0.3)	28 (5.4)	10 (4.3)	39 (3.2)	
Afternoon	0 (0.0)	0 (0.0)	1 (0.3)	26 (5.0)	14 (6.1)	41 (3.3)	
Evening	0 (0.0)	1 (1.1)	2 (0.7)	48 (9.2)	26 (11.3)	77 (6.3)	
Nighttime	0 (0.0)	1 (1.1)	2 (0.7)	48 (9.2)	26 (11.3)	77 (6.3)	
Reporting a high (very or extreme) level of WTN annoyance by season, *n* (%)							
Spring	0 (0.0)	1 (1.1)	1 (0.3)	45 (8.6)	22 (9.6)	69 (5.6)	
Fall	0 (0.0)	1 (1.1)	2 (0.7)	42 (8.1)	22 (9.6)	67 (5.5)	
Summer	0 (0.0)	2 (2.1)	4 (1.3)	50 (9.6)	31 (13.7)	87 (7.1)	
Winter	0 (0.0)	1 (1.1)	1 (0.3)	38 (7.3)	21 (9.2)	61 (5.0)	
Closing bedroom window to block outside noise during sleep *n* (%)							
	26 (31.3)	30 (31.6)	87 (28.7)	178 (34.3)	68 (29.2)	389 (31.6)	0.8106
Source identified as cause for closing window[g] *n* (%)							
Road traffic	15 (18.1)	13 (13.7)	47 (15.5)	77 (14.8)	24 (10.3)	176 (14.3)	0.1161
Rail	6 (10.2)	1 (1.2)	7 (2.9)	10 (2.2)	0 (0.0)	24 (2.4)	0.0013
Wind turbines	0 (0.0)	2 (2.1)	6 (2.0)	79 (15.2)	50 (21.6)	137 (11.1)	<0.0001
Other	12 (14.5)	20 (21.1)	54 (17.8)	65 (12.5)	14 (6.0)	165 (13.4)	0.0002
Perceived benefit from having wind turbines in the area *n* (%)							
Personal	3 (3.9)	2 (2.2)	11 (4.0)	47 (9.2)	47 (20.3)	110 (9.3)	
ON	0 (0.0)	1 (1.2)	6 (2.7)	44 (10.0)	36 (21.4)	87 (9.0)	<0.0001[d]
PEI	3 (15.8)	1 (11.1)	5 (9.8)	3 (4.3)	11 (17.2)	23 (10.8)	0.1700[d]
Community	20 (29.0)	14 (20.9)	62 (36.0)	136 (35.1)	79 (40.7)	311 (35.0)	0.0135

[a]The Cochran Mantel-Haenszel chi-square test is used to adjust for provinces unless otherwise indicated, *p*-values <0.05 are considered to be statistically significant.
[b]Columns may not add to total due to missing data.
[c]Sensitivity to noise reflects the prevalence of participants that reported to be either very or extremely (i.e., highly) noise sensitive in general.
[d]Chi-square test of independence.
[e]Nobody reported hearing rail noise in PEI as there is no rail activity in PEI, therefore the percent is given as a percentage of ON participants only.
[f]Refers to anyone in the participant's household ever lodging a formal complaint (including signing a petition) regarding noise from wind turbines.
[g]Reasons for closing bedroom windows due to aircraft noise was suppressed due to low cell counts (i.e., n <5 overall).

levels were between [25 and 30) dB. The prevalence of *household* complaints concerning wind turbines, which could include signing a petition regarding noise from wind turbines, was 2.8% overall and unrelated to WTN levels ($p = 0.2578$). However, complaints were found to be greater among the PEI sample ($13/224 = 5.8\%$), compared to ON ($22/1010 = 2.2\%$) ($p = 0.0050$).

Other notable observations from Table IV include the finding that the number of participants who self-reported to personally benefit in any way (e.g., rent, payments or indirect benefits such as community improvements) from having turbines in their area, was not equally distributed among provinces. In ON, reporting such benefits was significantly related to WTN categories ($p < 0.0001$) and there was a gradual increase from the lowest WTN category (<25 dB: 0.0%) to the loudest WTN category ([40–46] dB: 21.4%), whereas in PEI benefits were statistically evenly distributed across the sample ($p = 0.1700$).

Closing bedroom windows to block outside noise during sleep was equally prevalent across all WTN categories ($p = 0.8106$); however, identifying WTs as the reason for closing the window was found to be related to WTN levels ($p < 0.0001$). In the two loudest categories, [35–40) dB and [40–46] dB, 15.2% and 21.6% of participants identified WTN as the reason for closing bedroom windows, respectively, compared to ≤2.1% in the other WTN categories (Table IV).

Figure 2 plots the fitted percentage highly annoyed by WTN category overall and for ON and PEI separately. WTN annoyance was observed to significantly increase when WTN levels exceeded ≥35 dB compared with lower exposure categories ($p < 0.009$, in all cases). Overall, observed prevalences of noise annoyance increased from less than 2.1% in the three lowest WTN level categories to 10% in areas where WTN levels were between [35 and 40) dB and 13.7% between [40 and 46] dB. Additionally, annoyance was observed to be significantly higher in the ON sample compared to the PEI sample. Across all WTN categories, the odds of being highly annoyed by WTN were 3.29 times greater in ON compared to PEI [95% confidence interval (CI), 1.47–8.68, $p = 0.0015$]; however, the difference was most pronounced above 35 dB.

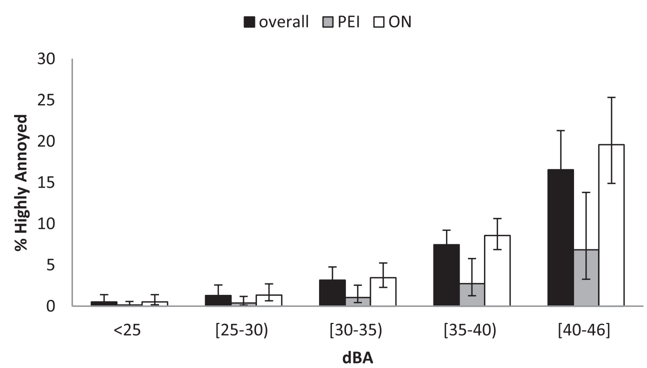

FIG. 2. Prevalence of high annoyance with wind turbine noise overall and by province as a function of calculated outdoor wind turbine noise levels. This illustrates the percentage of participants that reported to be either very or extremely (i.e., highly) bothered, disturbed or annoyed by WTN while at home over the last year. At home refers to either inside or outside the dwelling. Results are shown for participants from southwestern ON, PEI, and as an overall average. Fitted data are plotted along with their 95% confidence intervals. Results are shown as a function of calculated outdoor A-weighted WTN levels at the dwelling (dBA). WTN annoyance was observed to significantly increase when WTN levels exceeded ≥35 dB compared with lower exposure categories ($p < 0.009$, in all cases). Additionally, annoyance was observed to be significantly higher in the southwestern ON sample compared to the PEI sample ($p = 0.0015$), regardless of WTN level.

In addition to asking participants how annoyed they were toward WTN in general (i.e., without reference to their particular location), other questions were designed to assess annoyance as a function of location (i.e., indoors, outdoors). As shown in Fig. 3, the prevalence of high annoyance was significantly higher outdoors.

The prevalence of annoyance by time of day and season is provided in Table IV. For WTN levels below 30 dB, the prevalence of high annoyance was very low (<1.2%) and similar for all times of day. Starting at 30 dB, the percentage highly annoyed during the evening and nighttime were significantly higher than the morning and afternoon; however this difference was most pronounced at WTN levels ≥35 dB. For WTN levels below 30 dB, the prevalence of high annoyance was very low (<2.2%) and similar for all seasons. At WTN levels ≥35 dB, the prevalence of high annoyance during the summer was higher compared to all other seasons.

Noise annoyance toward road, aircraft and rail noise was also assessed in the questionnaire. It was of interest to determine how annoyance to these sources compared to WTN annoyance. In areas where WTN levels were <35 dB the greatest source of noise annoyance was road traffic. In WTN categories ≥35 dB, annoyance toward WTN exceeded all other sources (p <0.0003, in all cases) (see Fig. 4).

E. Self-reported health conditions and use of medication

Table V shows that subjectively reported sleep disturbance from any source while sleeping at home over the last year, in addition to a multitude of health effects, were found

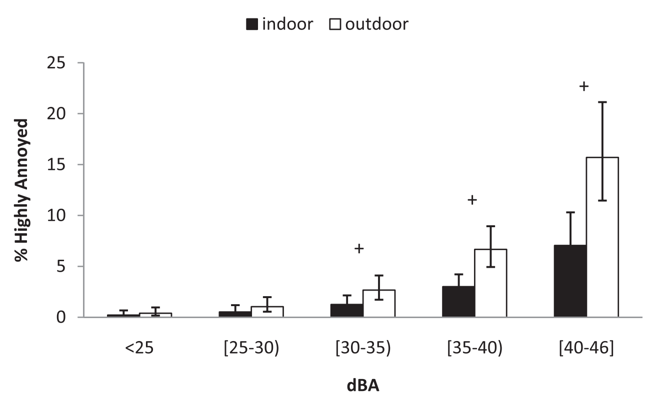

FIG. 3. Prevalence of high annoyance with wind turbine noise by location as a function of calculated outdoor wind turbine noise levels. Participants were asked to think about the last year or so and indicate how bothered, disturbed or annoyed they were by WTN while at home. The percentage of participants reporting to be either very or extremely (i.e., highly) bothered, disturbed or annoyed is shown as a function of calculated outdoor A-weighted WTN levels at the dwelling (dBA). Figure 3 presents the fitted results by location (i.e., indoors and outdoors) along with their 95% confidence intervals. + Indoor significantly different from outdoor ($p < 0.001$).

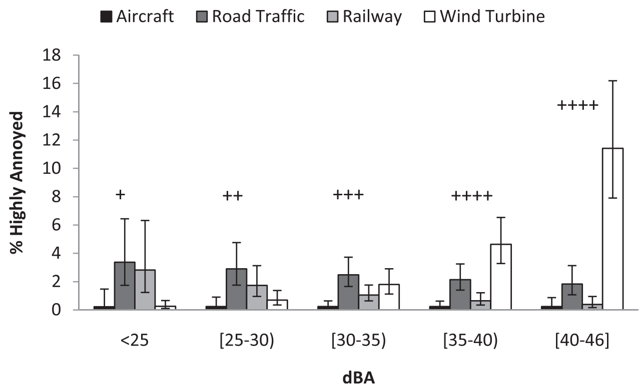

FIG. 4. Prevalence of high annoyance toward different noise sources as a function of calculated outdoor wind turbine noise levels. Illustrates the percentage of participants that reported to be either very or extremely (i.e., highly) bothered, disturbed or annoyed by road traffic, aircraft, rail and wind turbine noise (WTN) while at home over the last year. At home refers to either inside or outside the dwelling. Results represent fitted data along with their 95% confidence intervals and are shown as a function of calculated outdoor A-weighted WTN levels at the dwelling (dBA). $^{+}$WTN significantly different from road traffic and rail noise ($p < 0.001$); $^{++}$WTN significantly different from road traffic ($p < 0.001$); $^{+++}$WTN significantly different from aircraft noise ($p < 0.001$), $^{++++}$WTN significantly different from road traffic, rail, and aircraft noise ($p < 0.0003$).

to be unrelated to WTN levels. Similarly, medication use for high blood pressure, anxiety or depression was also found to be unrelated to WTN levels. Although sleep medication use was significantly related to WTN levels ($p = 0.0083$), the prevalence was *higher* among the two lowest WTN categories {<25 dB and [25–30) dB} (see Table V).

IV. DISCUSSION

The prevalence of self-reporting to be either "*very*" or "*extremely*" (i.e., highly) annoyed with several wind turbine features increased significantly with increasing A-weighted WTN levels. When classified by the prevalence of reported annoyance overall, and in areas where WTN levels exceeded 35 dB, annoyance was highest for visual aspects of wind turbines, followed by blinking lights, shadow flicker, noise and vibrations. Consistent with Pedersen *et al.* (2009), the increase in WTN annoyance was clearly evident when moving from [30–35) dB to [35–40) dB, where the prevalence of WTN annoyance increased from 1% to 10%. This continued to increase to 13.7% for areas where WTN levels were [40–46] dB. The prevalence of WTN annoyance was higher outdoors, during the summer, and during evening and nighttime hours. Pedersen *et al.* (2009) also found that annoyance with WTN was greater outdoors compared to indoors.

Despite a similar pattern of response between the ON and PEI samples, the self-reported WTN annoyance was 3.29 times greater in ON, a difference that was most pronounced at the two highest WTN categories. This difference is in contrast to the prevalence of *household* complaints related to wind turbines. Even though the overall prevalence of such complaints was low (i.e., 2.8%), complaints were more likely in PEI (5.8%) compared to ON (2.2%). The reasons for this difference despite greater reported annoyance in ON are unclear. Research has shown that there are several contingencies that must be met before someone that is highly annoyed will complain (Michaud *et al.*, 2008). Such contingencies include knowing who to complain to, how to file a complaint and holding the belief that the complaint will result in positive change. The fact that the prevalence of complaints regarding wind turbines was unrelated to WTN levels is another indication that complaints do not always correlate well with changes in noise exposure (Fidell *et al.*, 1991). The motives underlying household complaints were not assessed in the present study, but the disparity found with annoyance could also be related to the wording used in the questionnaire. The prevalence of complaints was the one question where the respondent answered on behalf of the entire household.

More participants reported that they were highly annoyed by the visual aspects of wind turbines than by any other feature, even at higher WTN levels. Similar to WTN annoyance, the overall prevalence of annoyance with the visual impact of wind turbines was more than twice as high in the ON sample, and more prevalent across the exposure categories when compared to PEI. In the PEI sample, no participants reported visual annoyance in areas where WTN levels were below 35 dB. This is in contrast to a clear intensification in visual annoyance among the ON sample in areas where WTN levels were [25–30) dB. Exploring the variables that may underscore provincial differences was not within the scope of the current study. The questionnaire was not designed to probe underlying factors that may explain observed provincial differences; however, reported personal benefit from having wind turbines in the area was found to be different between the ON and PEI samples (Table IV).

Shepherd *et al.* (2011) assessed annoyance in response to WTN, but not in a manner that would permit comparisons with the Swedish (Pedersen and Persson Waye, 2004, 2007), Dutch (Janssen *et al.*, 2011; Pedersen *et al.*, 2009) or the current study. Shepherd *et al.* (2011) reported that 59% of participants living within 2 km of a wind turbine installation spontaneously identified wind turbines as an annoying noise source, with a mean annoyance rating of 4.59 (SD, 0.65) when the 5 category adjectival scale was analyzed as a numerical scale from 0 to 5. No exposure-response relationship could be assessed because the authors did not provide an analysis based on precise distance or as a function of WTN levels, which they reported to be between 20 and 50 dB among participants living within 2 km of a wind turbine. This encompasses the entire WTN level range in the CNHS. As such, the only tentative comparison that can be made between the current study and the Shepherd *et al.* (2011) study would be that the observed prevalence of highly annoyed (i.e., "*very*" or "*extremely*") within 2 km of the nearest wind turbine was 7.0%. These data are not shown because the focus of the current study was on WTN levels and an analysis based solely on distance to the nearest turbine does not adequately account for WTN levels at any given dwelling. WTN is a more sensitive measure of exposure level because, in addition to the distance to the turbine, it accounts for topography, presence of large bodies of water, wind turbine characteristics, the layout of the wind farm and the number of wind turbines at any given distance.

TABLE V. Sample profile of health conditions.

	Wind turbine noise (dB)						
Variable *n* (%)	<25	[25–30)	[30–35)	[35–40)	[40–46]	Overall	CMH[a] *p*-value
n	84[b]	95[b]	304[b]	521[b]	234[b]	1238[b]	
Health worse vs last year [c]	17 (20.2)	12 (12.6)	46 (15.1)	90 (17.3)	51 (21.8)	216 (17.5)	0.1724
Migraines	18 (21.4)	24 (25.3)	56 (18.4)	134 (25.8)	57 (24.4)	289 (23.4)	0.2308
Dizziness	19 (22.6)	16 (16.8)	65 (21.4)	114 (21.9)	59 (25.2)	273 (22.1)	0.2575
Tinnitus	21 (25.0)	18 (18.9)	71 (23.4)	129 (24.8)	54 (23.2)	293 (23.7)	0.7352
Chronic pain	20 (23.8)	23 (24.2)	75 (24.8)	118 (22.6)	57 (24.5)	293 (23.7)	0.8999
Asthma	8 (9.5)	12 (12.6)	22 (7.2)	43 (8.3)	16 (6.8)	101 (8.2)	0.2436
Arthritis	23 (27.4)	38 (40.0)	98 (32.2)	175 (33.7)	68 (29.1)	402 (32.5)	0.6397
High blood pressure (BP)	24 (28.6)	36 (37.9)	81 (26.8)	166 (32.0)	65 (27.8)	372 (30.2)	0.7385
Medication for high BP	26 (31.3)	34 (35.8)	84 (27.6)	163 (31.3)	63 (27.0)	370 (29.9)	0.4250
Family history of high BP	44 (52.4)	49 (53.8)	132 (45.5)	254 (50.6)	121 (53.8)	600 (50.3)	0.6015
Chronic bronchitis/emphysema/COPD	3 (3.6)	10 (10.8)	17 (5.6)	27 (5.2)	14 (6.0)	71 (5.7)	0.7676
Diabetes	7 (8.3)	8 (8.4)	33 (10.9)	46 (8.8)	19 (8.2)	113 (9.1)	0.6890
Heart disease	8 (9.5)	7 (7.4)	31 (10.2)	32 (6.1)	17 (7.3)	95 (7.7)	0.2110
Highly sleep disturbed[d]	13 (15.7)	11 (11.6)	41 (13.5)	75 (14.5)	24 (10.3)	164 (13.3)	0.4300
Diagnosed sleep disorder	13 (15.5)	10 (10.5)	27 (8.9)	44 (8.4)	25 (10.7)	119 (9.6)	0.3102
Sleep medication	16 (19.0)	18 (18.9)	39 (12.8)	46 (8.8)	29 (12.4)	148 (12.0)	0.0083
Restless leg syndrome	7 (8.3)	16 (16.8)	37 (12.2)	81 (15.5)	33 (14.1)	174 (14.1)	
Restless leg syndrome (ON)	4 (6.7)	15 (17.4)	27 (11.0)	78 (17.3)	28 (16.5)	152 (15.0)	0.0629[e]
Restless leg syndrome (PEI)	3 (12.5)	1 (11.1)	10 (16.9)	3 (4.2)	5 (7.8)	22 (9.7)	0.1628[e]
Medication anxiety or depression	11 (13.1)	14 (14.7)	35 (11.5)	59 (11.3)	23 (9.8)	142 (11.5)	0.2470
QoL past month[f]							
Poor	9 (10.8)	3 (3.2)	21 (6.9)	29 (5.6)	20 (8.6)	82 (6.6)	0.9814
Good	74 (89.2)	92 (96.8)	283 (93.1)	492 (94.4)	213 (91.4)	1154 (93.4)	
Satisfaction with health[f]							
Dissatisfied	13 (15.5)	13 (13.7)	49 (16.1)	66 (12.7)	36 (15.4)	177 (14.3)	0.7262
Satisfied	71 (84.5)	82 (86.3)	255 (83.9)	455 (87.3)	198 (84.6)	1061 (85.7)	

[a]The Cochran Mantel-Haenszel chi-square test is used to adjust for provinces unless otherwise indicated, *p*-values <0.05 are considered to be statistically significant.
[b]Columns may not add to total due to missing data.
[c]Worse consists of the two ratings: "*Somewhat worse now*" and "*Much worse now*."
[d]High sleep disturbance consists of the two ratings: "*very*" and "*extremely*" sleep disturbed.
[e]Chi-square test of independence.
[f]Quality of Life (QoL) and Satisfaction with Health were assessed with the two stand-alone questions on the WHOQOL-BREF. Reporting "*poor*" overall QoL reflects a response of "*poor*" or "*very poor*," and "*good*" reflects a response of "*neither poor nor good*," "*good*," or "*very good*." Reporting "*dissatisfied*" overall Satisfaction with Health reflects a response of "*very dissatisfied*" or "*dissatisfied*," and "*satisfied*" reflects a response of "*neither satisfied nor dissatisfied*," "*satisfied*," or "*very satisfied*." A detailed presentation of the results related to QoL is presented by Feder *et al*. (2015).

It was important to assess the extent to which the sample was homogenously distributed, with respect to demographics and community noise exposure. The reason for this is that the validity of the exposure-response relationship is strengthened when the primary distinction across the sample is the exposure of interest; in this case, WTN levels. Demographically, some minor differences were found with respect to age, employment, type of dwelling and dwelling ownership; however, with the possible exception of employment, these factors showed no obvious pattern with WTN levels and none were strong enough to exert an influence on the overall results. At the design stage, there was some concern that selecting participants up to 10 km might result in an unequal exposure to community noise sources other than WTN. This may have an influence on the underlying response to WTN. Limited data availability did not permit the modeling of sound pressure levels from other noise sources as originally intended, however it was possible to model BNTS levels. Although Fields (1993) concluded that background sound levels generally do not influence community annoyance, his review did not include wind turbines as a noise source and in the current study BNTS levels were calculated to be lower in areas where WTN levels were higher. Lower BNTS could contribute to a greater expectation of peace and quiet. Therefore, a limitation in the CNHS may be that the expectation of peace and quiet was not explicitly evaluated. This factor may influence the association between long-term sound levels and annoyance by an equivalent of up to 10 dB (ANSI, 1996; ISO, 2003b). The influence this factor may have had on the exposure-response relationship found specifically between WTN levels and the prevalence of reporting high annoyance with WTN in the CHNS is discussed in Michaud *et al*. (2016a).

In the absence of modeling, the audibility of road traffic, aircraft and rail noise provided a crude indication of exposure to these sources. In general, road traffic noise exposure was heard by the vast majority of the sample (82.1%).

Aircraft noise was uniformly audible in ON by about half the sample; in PEI however, hearing aircraft was more common in the higher WTN exposure categories (i.e., above 35 dB) where between 61% and 66% of the respondents indicated that they could hear aircraft. Future research may benefit from assessing the extent to which audible aircraft noise may have influenced the annoyance with WTN in PEI. Only when WTN levels were [40–46] dB was the audibility of wind turbines comparable to road traffic (i.e., both sources were audible by approximately 81% of participants). For these community noise sources, participants were asked how bothered, disturbed, or annoyed they were while at home over the last year or so. The findings are of interest in light of the source comparisons made by Pedersen *et al.* (2009) and Janssen *et al.* (2011), which placed WTN annoyance above all transportation noise sources when comparing them at equal sound levels. In the current study, the overall annoyance toward WTN (7.2%) was found to be higher in comparison to road (3.8%), aircraft (0.4%), and rail in ON (1.9%). Source comparisons need to be made with caution because the observed source differences in annoyance may result from an *actual* difference in sound pressure levels at the dwellings in this study. Modeling the sound levels from transportation noise sources in the current study would allow a more direct comparison between these sources and WTN annoyance at equivalent sound exposures. Another approach is to assess the relative community tolerance level of WTN with that reported for road and aircraft noise studies. This analysis indicates that there is a lower community tolerance level for WTN when compared to both road and aircraft noise at equivalent sound levels (Michaud *et al.*, 2016a).

The list of symptoms that are claimed to be caused by exposure to WTN is considerable (Chapman, 2013), but there is a lack of robust evidence from epidemiological studies to support these associations (Council of Canadian Academies, 2015; Knopper *et al.*, 2014; MassDEP MDPH, 2012; McCunney *et al.*, 2014; Merlin *et al.*, 2014). The results from the current study did not show any statistically significant increase in the self-reported prevalence of chronic pain, asthma, arthritis, high blood pressure, bronchitis, emphysema, chronic obstructive pulmonary disease (COPD), diabetes, heart disease, migraines/headaches, dizziness, or tinnitus in relation to WTN exposure up to 46 dB. In other words, individuals with these conditions were equally distributed among WTN exposure categories. Similarly, the prevalence of reporting to be highly sleep disturbed (for any reason) and being diagnosed with a sleep disorder were unrelated to WTN exposure. These self-reported findings are consistent with the conclusions reached following an analysis of objectively measured sleep among a subsample of the current study participants (Michaud *et al.*, 2016b). Medication use (for anxiety, depression, or high blood pressure) was unrelated to WTN levels. It is notable that the observed prevalence for many of the aforementioned health effects are remarkably consistent with large-scale national population-based studies (Innes *et al.*, 2011; Kroenke and Price, 1993; Morin *et al.*, 2011; O'Brien *et al.*, 1994; Shargorodsky *et al.*, 2010).

V. CONCLUDING REMARKS

Study findings indicate that annoyance toward all features related to wind turbines, including noise, vibrations, shadow flicker, aircraft warning lights and the visual impact, increased as WTN levels increased. The observed increase in annoyance tended to occur when WTN levels exceeded 35 dB and were undiminished between 40 and 46 dB. Beyond annoyance, the current study does not support an association between exposures to WTN up to 46 dB and the evaluated health-related endpoints. In some cases, there were clear differences between the southwestern ON and PEI participants; however, exploring the basis behind these differences fell outside the study scope and objectives. The CNHS supported the development of a model for community annoyance toward WTN, which identifies some of the factors that may influence this response (Michaud *et al.*, 2016a). At the very least, the observed differences reported between ON and PEI in the current study demonstrates that even at comparable WTN levels, the community response to wind turbines is not necessarily uniform across Canada. Future studies designed to intentionally explore the factors that underscore such differences may be beneficial.

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[1]See supplementary material at http://dx.doi.org/10.1121/1.4942391 for the univariate analysis results.

[2]Locations coded as out-of-scope were originally assigned the following categories: *Demolished for unknown reasons*, *vacant for unknown reasons*, *unoccupied*, *seasonal*, *>79 years of age*, and *other* (Michaud, 2015b; Health Canada, 2014). In an effort to address feedback and provide further clarification, the categories used to define out-of-scope locations were further defined elsewhere (Michaud, 2015a) with additional details provided in the current paper. Specifically, locations that were determined to be "demolished for unknown reasons" are presented separately in Table I as Code F. Locations that were originally defined as "unoccupied for unknown reasons" are now more precisely defined under Code B (i.e., inhabitable dwelling not occupied at time of survey, newly constructed dwelling, or unoccupied trailer in vacant trailer park). Furthermore, it was confirmed that 6 dwellings originally listed under Code B (Michaud, 2015a) were in fact GPS coordinates listed in error and have therefore been reassigned to Code A.

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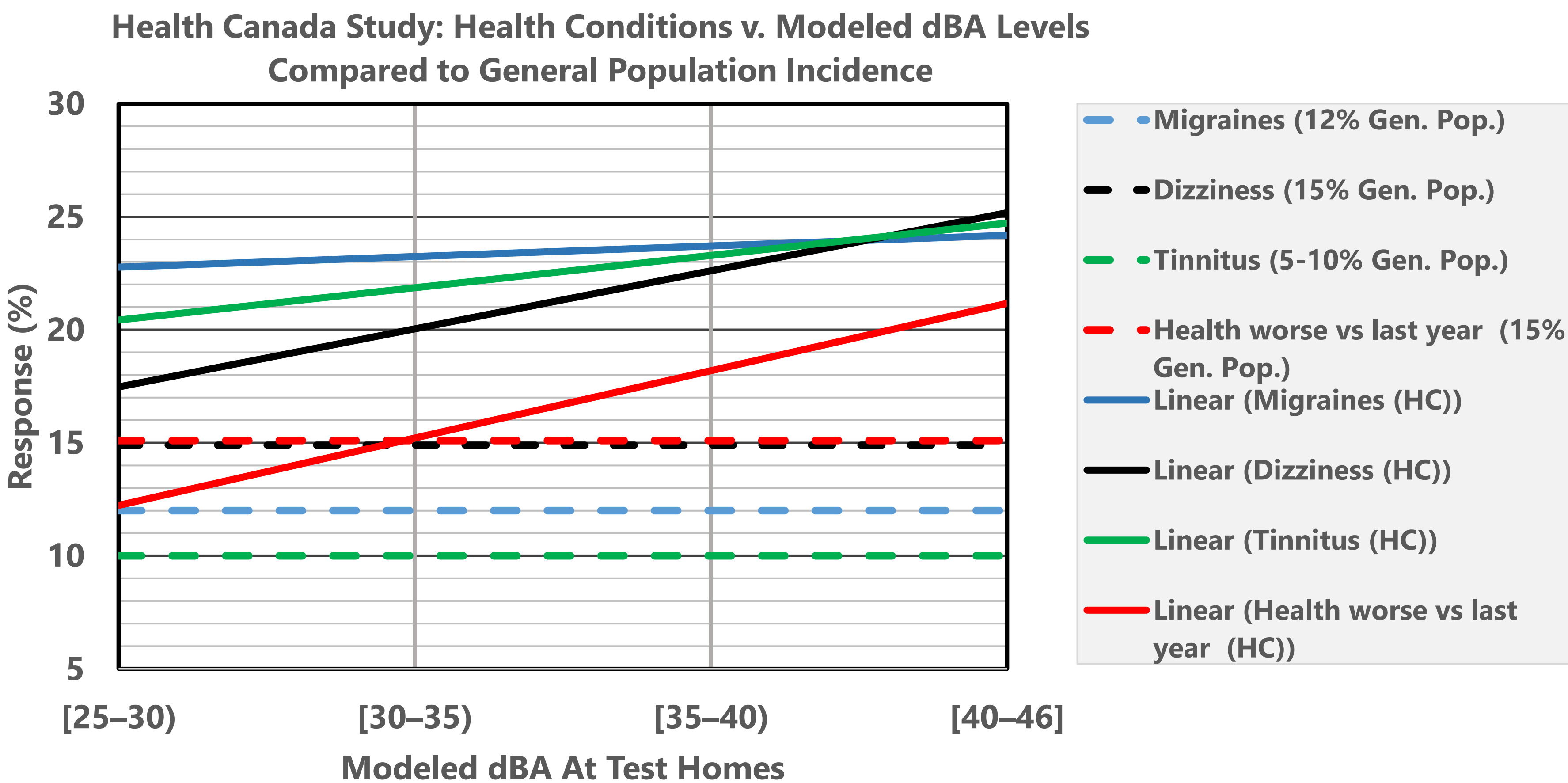

<u>HC Data Source:</u>

"Exposure to wind turbine noise: Perceptual responses and reported heath effects," TABLE V: Sample profile health conditions, Variables"Migraines," "Dizziness," "Tinnitus,"and "Health worse vs last year" versus modeled dBA sound level, D. S. Michaud et al, Health Canada, Journal Acoustical Society of America (JASA) 139 (3), March 2016

<u>General Population Incidence:</u>

Migraines: Migraine Research Foundation
Dizziness: Dizziness-and-Balance.com
Tinnitus: Hearing Health Foundation
Self Reported Health: Canadian Journal Of Public Health, Volume 98, No. 2, P. 154, K. Wilson et al, Table III

By: Richard R. James, INCE, E-Coustic Solutions, LLC, rickjames@e-coustic.com
Robert Rand, INCE, ASA, Rand Acoustics, rrand@randacoustics.com (4/7/2016)