

PIPELINE SAFETY ADVISORY BOARD



DEQ Director
Heidi Grether

MAE Executive Director
Valerie Brader

Agenda

December 11, 2017
9:00 AM – 3:30 PM (EST)

Causeway Bay Lansing Hotel and Conference Center
Ballroom F - J
6820 South Cedar Street
Lansing, Michigan 48911

9:00 – 9:10 AM	Welcome and Introductions
9:10 AM – 12:00 PM	Public Participation
12:00 – 12:05 PM	Meeting Minutes: September 18, 2017 (<i>Attachment A</i>)
12:05 – 12:10 PM	Correspondence Received <ul style="list-style-type: none">• Members (<i>Attachment B</i>)• Non-Members (<i>Attachment C</i>)
12:10 – 12:20 PM	Old Business <ul style="list-style-type: none">• Pipeline Mapping• Data Mapping• Independent Alternatives Analysis• Letter to Secretary of Transportation
12:20 – 1:50 PM	Break for Lunch
1:50 – 2:10 PM	Line 5 Coating Presentation
2:10 – 2:50 PM	Independent Risk Analysis Update (<i>Attachment D</i>)
2:50 – 3:15 PM	Enbridge Agreement Update (<i>Attachment E</i>)
3:15 – 3:30 PM	Organizational Items <ul style="list-style-type: none">• 2018 Meeting Schedule and Agenda Items (<i>Attachment F</i>)• Next Proposed Meeting – March 12, 2017<ul style="list-style-type: none">○ Time: 9:00 AM - 3:30 PM (EST)○ Location: TBD
3:30 PM	Adjourn



MINUTES

MICHIGAN PIPELINE SAFETY ADVISORY BOARD

Causeway Bay Lansing Hotel and Conference Center
Ballroom F - J
6820 South Cedar Street
Lansing, Michigan 48911

September 18, 2017
9:00 a.m. – 3:30 p.m.

Present: Valerie Brader, Co-Chair, Michigan Agency for Energy (MAE)
Heidi Grether, Co-Chair, Department of Environmental Quality (DEQ)
Keith Creagh, Department of Natural Resources
Craig Hupp, Public Member
Capt. Chris Kelenske, (*Designee for Col. Kriste Kibbey Etue*), Michigan State Police
Shawn Lyon, Marathon Petroleum
Homer Mandoka, Nottawaseppi Huron Band of the Potawatomi
Jennifer McKay, Tip of the Mitt
Guy Meadows, Michigan Technological University
Laura Moody (*Designee for Attorney General Bill Schuette*), Department of Attorney General (DAG)
Jerome Popiel, United State Coast Guard
Brad Shamlu, Enbridge Energy Company
Chris Shepler, Shepler's Mackinac Island Ferry Service
Michael Shriberg, National Wildlife Federation
Sally Talberg, Michigan Public Service Commission (MPSC)

Absent: Jeffrey Pillon, National Association of State Energy Officials

Others: Matt Goddard, DEQ
Robert Reichel, DAG
Matthew Schneider, DAG
Brian Sheldon, MAE
Holly Simons, DEQ
Travis Warner, MPSC

I. CALL TO ORDER

Valerie Brader, Executive Director, Michigan Agency for Energy (MAE), called the meeting to order at 9:05 a.m.

II. WELCOME AND INTRODUCTIONS

Co-Chair Brader welcomed everyone and reminded the Board that Holly Simons, elected by the Board to be Secretary, will take the minutes for today's meeting.

III. PUBLIC PARTICIPATION

- Deb Hansen, Concerned Citizens of Cheboygan and Emmet County, shared verbal comments.

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- Michelle Deatrick, Washtenaw County Board of Commissioners, shared verbal comments.
- Jaynan Montague shared verbal comments.
- Leonard Page, Straits Area Concerned Citizens for Peace, Justice, and the Environment (SACCPJE), shared verbal comments.
- Anna Fisher shared verbal comments.
- Anne Woiwode shared verbal comments.
- John Machowicz, Citizens Against ET Rover Pipeline, shared verbal comments.
- Linda Rogers, SACCPJE, shared verbal comments.
- Sherry Nelson, SACCPJE, shared verbal comments.
- Dale Giddings, SACCPJE and Straits Area Audubon Society, shared verbal comments.
- Vince Lumetta, SACCPJE, shared verbal comments.
- Leo Forster shared verbal comments.
- Beth Wallace shared verbal comments.
- Matthew Borke shared verbal comments.
- Cathy Motycka shared verbal comments.
- Sean McBrearty, Oil and Water Don't Mix, shared verbal comments.
- Tommy Tackett shared verbal comments.
- Deb Hansen, Concerned Citizens of Cheboygan and Emmet County, shared verbal comments.
- Leo Forster shared verbal comments.
- Michelle Deatrick, Washtenaw County Board of Commissioners, shared verbal comments.
- Leonard Page, Straits Area Concerned Citizens for Peace, Justice, and the Environment (SACCPJE), shared verbal comments.
- Ryan LoRee shared verbal comments.

IV. BREAK

Co-chair Brader requested any additional members of the public acknowledge their desire to provide comment. Hearing none, the board adjourned for a break at 10:10 a.m. and reconvened at 10:26 a.m.

V. RECOGNITION OF SECRETARY

Co-Chair Brader requested a motion to amend the agenda.

Co-Chair Grether moved, seconded by Keith Creagh, to amend the agenda to recognize the Board Secretary. The vote was taken on the motion. The motion carried unanimously.

Co-Chair Grether presented Board Secretary, Holly Simons, with a Recognition Coin of Teamwork for her work with the Board and pipeline-related projects.

VI. JUNE 12, 2017 MEETING MINUTES

Having reviewed the minutes from the June 12, 2017 meeting, Co-Chair Brader asked for comments. Hearing none, she requested a motion to approve.

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Shawn Lyon moved, seconded by Guy Meadows, that the minutes from the June 12, 2017 meeting be approved. The vote was taken on the motion. The motion carried unanimously.

VII. ORGANIZATIONAL ITEMS

1. *Next Meeting*

The next regular meeting is scheduled for December 11, 2017 in a location yet to be determined. The State will announce the meeting location in the coming months.

2. *Proposed 2018 Meeting Dates*

Co-Chair Brader highlighted the proposed meeting dates for the next year. She informed the Board the proposed dates do not need to be adopted at this meeting, however, to let Holly know of any scheduling conflicts prior to the December meeting.

VIII. CORRESPONDENCE RECEIVED

Correspondence received on behalf of the Board since its last meeting was shared with the Board in the pre-meeting packet, including:

Board Members

- Michael Shriberg, National Wildlife Federation
- Jeffrey Pillon, National Association of State Energy Officials

Non-Board Members

- Deb Hansen, Concerned Citizens of Cheboygan and Emmet County
- Anabel Dwyer, SACCPJE
- Joanne Cromley, SACCPJE
- Linda Rogers, SACCPJE
- Bobie Crongeyer, SACCPJE
- Dale Giddings, SACCPJE
- Roger Gauthier, SACCPJE
- David Dwyer, SACCPJE
- Vincent Lumetta, SACCPJE
- William Gittlen, Traverse City
- Kathy Bricker, Mackinac Straits Raptor Watch
- June Thaden, Traverse City
- Stephen Brede, Petoskey
- Andrew DeGraw, Kalamazoo
- Elizabeth Kirkwood, For Love of Water (FLOW)
- David Petrove, Norther Michigan Environmental Action Council (NMEAC)
- Carol Shuckra, Traverse City
- Jerry Ness, Rapid River
- Robert Kaszabowski, Millersburg
- Cody Halverson, Gully Minnesota

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- Carl Stenberg, Bark River
- Adam Shirverski, Bark River
- Justin Gangl, Ishpeming
- Robert Blowierz
- Jesse Salazar
- Ben Snow
- Louis Tark
- Kyle White
- Brett Somerfield
- Steven Wolfgang
- Henry Cota
- Matthew Starberg
- Sergio Ayala
- Myles Lange
- Nigel Palmiter
- Matt O'Dell
- Kai Gram
- Dan Cullings
- Jay Penfield
- Jerry Luenburg
- Cory Halbern
- Darren Andrews
- Christopher Gendron
- Richard DeMerge
- Matthew Founder
- Gary Zunkel
- Matt McDonald
- Brian Vowell
- Ryan Freeman
- John Briton
- Kevin Shroden
- Kevia Werner
- Lichan Zhang
- Mike Paradise
- Chris Baker
- Kory Johnson
- Blake Olson
- Jim Schott
- Jon Carlson
- Duane Englund
- Aaron Ryba
- Brody Carlson
- Matthew Stuaer
- Justin Hoffmann
- Andrew Adams
- Mark Elliott

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- Scott Paquette
- Gerry Milford
- Grant Gustafson
- Scott Carlson
- Steve Mussatti
- Luke Peterson
- Scott Billines
- Leroy King
- Joe Fisher
- Scott Lange
- Eric Greenman
- Ben Eyer
- David Jacobson
- Brandon Cerka
- Trish McClelland
- Justin Tromberg
- Jason Bekkala
- Michelle Ryan
- Daniel Mattlys
- Druin Haugen
- Jim Kindler
- TJ Shaver
- Jimmy Prothmo
- Will Turner
- Matt Bagley
- Carl Hunter
- Richard Ness
- Trina Salvisberg
- Jordan Green
- Jeff Wolford
- David Stuard
- Michael Paradise, Jr.
- Richard Smith
- Tom LaCross
- Tom Sasalla
- Josh Fink
- Bryon Johnson
- Zach Barrett, Pipeline and Hazardous Materials Safety Administration (PHMSA)
- Jeff Cook
- Jennie Hoffman
- Friends of the Jordan River Watershed
- Linda Hammond
- Anne Zukowski
- Murtaza Nek, Bike the Line
- Dr. Amarjit Bakshi

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- Stephen Heilman
- Dana Getsinger
- Diane Hallinen
- Mark McMackin
- Leonard Page
- John Ulrich
- Greg Reisig
- Mary Jackson
- James Stover
- Charles Foley
- Diane Hallinen
- John Carroll
- Everett Lee
- Janice Wheelock
- P. Geisler
- Jim Olson, FLOW
- Donna Bogle
- Jill Dunham
- Daniel Fisher
- Jerilynn Hamstra
- Tim Tobin
- Margaret Pierson
- Ross Tius, UA Local 663
- Joel Ackerman
- Patrick Anderson, Anderson Economic Group
- Rita Mitchell, Ann Arbor
- Ed Timm
- Jamie Falik
- Laura Judge, Holland

IX. INDEPENDENT RISK ANALYSIS DISCUSSION

Guy Meadows provided background information and a presentation. Discussion took place.

Co-Chair Grether moved, seconded by Craig Hupp, that the Board recommend that the state enter into a contact with the state universities, led by Northern Michigan University, to undertake the Independent Risk Analysis. The vote was taken on the motion. The motion carried unanimously.

X. PUBLIC PARTICIPATION

Co-Chair Brader acknowledged additional members of the public who desired to provide comment.

- Roger Gauthier, SACCPJE, shared verbal comments.
- Brandon Denler, Spartan Sierra Club, shared verbal comments.
- Jaynan Montague shared verbal comments.
- Cathy Motycka shared verbal comments.

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- Vince Lumetta, SACCPJE, shared verbal comments.
- Deb Hansen, Concerned Citizens of Cheboygan and Emmet County, shared verbal comments.

Co-chair Brader requested any additional members of the public acknowledge their desire to provide comment. Hearing none, the board continued with the agenda.

XI. STATE UPDATE – INDEPENDENT ALTERNATIVES ANALYSIS

Matt Goddard provided an update. Discussion took place.

XII. PUBLIC PARTICIPATION

Co-Chair Brader acknowledged an additional member of the public who desired to provide comment.

- Chris Wahmhoff shared verbal comments.

XIII. BREAK FOR LUNCH

Co-chair Brader requested any additional members of the public acknowledge their desire to provide comment. Hearing none, the board adjourned for lunch at 12:04 p.m. and reconvened at 1:35 p.m.

XIV. STATE UPDATE – LINE 5 COATING ISSUE

Co-Chair Brader provided an update.

XV. PIPELINE MAPPING – STATE RESOLUTION TO PH SMA

Bob Reichel provided an update. Discussion took place.

Guy Meadows moved, seconded by Jennifer McKay, that the board send the recommendation letter to the U.S. Secretary of Transportation. The vote was taken on the motion. The motion carried unanimously.

XVI. PIPELINE SAFETY BEST PRACTICES AND SITING SUBCOMMITTEE

Travis Warner provided an update. Discussion took place.

XVII. ADJOURN

Co-Chair Grether called the meeting to adjourn at 2:02 p.m.

NEXT MEETING

Monday, December 11, 2017
Location: TBA



Bradley F. Shamla
Vice President, U.S. Operations
Liquids Pipelines

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Enbridge (U.S.), Inc.
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September 18, 2017

Honorable Bill Schuette
Attorney General
State of Michigan
Department of Attorney General
G. Mennen Williams Building, 7th Floor
525 W. Ottawa Street
Lansing, Michigan 48909

Ms. C. Heidi Grether
Director
Michigan Department of Environmental Quality
Constitution Hall
525 West Allegan Street
Lansing, MI 48933

Mr. Keith Creagh
Director
Michigan Department of Natural Resources
Executive Division
525 West Allegan Street
Lansing, MI 48933

Re: Line 5 Dual Pipelines at the Straits of Mackinac – Enbridge Response to Request Letter dated September 1, 2017 – Requested Action 3

Dear Attorney General Schuette, Director Grether and Director Creagh:

This letter responds to Requested Action 3 that is specified in your letter dated September 1, 2017 ("September 1 Letter"). Please find enclosed a copy of Enbridge's "Coating Repairs Work Plan," including appendices, which identifies the methods and procedures that Enbridge will use to repair specified areas of coating on the Line 5 Dual Pipelines.

The enclosed version of the Work Plan was submitted to the US Environmental Protection Agency ("EPA") for review and approval on September 13, 2017, in accordance with the requirements of the Consent Decree entered in *United States v. Enbridge Energy, et al.*, 1:16-cv-914. The EPA approved the enclosed Work Plan on September 14, 2017. EPA's approval

The Honorable Bill Schuette, Director Grether and Director Creagh
September 18, 2017
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letter (copy enclosed) indicates that the Agency does not approve the use of Method 2 – as described in the Work Plan – because Enbridge has not yet demonstrated the effectiveness of that repair method to EPA's satisfaction. Enbridge intends to discuss Method 2 further with EPA in the next several days in the hope that it will be approved, but will not use Method 2 as part of the coating repairs unless and until both EPA and the State have approved that method.

Please note that the attached Work Plan identifies three (3) additional locations on the Dual Pipelines where Enbridge intends to undertake repairs. Those additional locations, at which there are potential coating gaps, were identified subsequent to the submission of Enbridge's September 8, 2017 response to Requested Action 1, but prior to the preparation of the attached Work Plan. Additional information concerning these three locations is included in the Work Plan on pages 3-4 and Appendix A.

EPA's approval of the Work Plan requires that it be implemented immediately. We also recognize that, as stated in your September 1 letter, the State would like Enbridge to complete repairs as soon as possible and, in any event, within the same construction season in which the coating gaps are identified. Given the lateness of this construction season, Enbridge accordingly intends to begin the repair work as soon as possible. We, of course, look forward to your approval of the attached Work Plan, as well as to answering any questions you might have.

Sincerely,

ENBRIDGE ENERGY, LIMITED PARTNERSHIP
By Enbridge Pipelines (Lakehead) L.L.C.
Its General Partner



Bradley F. Shamla
Vice President, U.S. Operations

cc: Valerie Brader, Executive Director, Michigan Agency for Energy

Enclosure



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

September 14, 2017

REPLY TO THE ATTENTION OF

VIA EMAIL AND UPS

Lisa D. Wilson
Associate General Counsel
Enbridge
26 East Superior Street, Suite 309
Duluth, MN 55802

Re: Enbridge Line 5 Coating Repairs Work Plan (Version 2.0)

Dear Ms. Wilson:

On September 13, 2017, the U.S. Environmental Protection Agency ("EPA") received Version 3 of Enbridge's Line 5 Coating Repairs Work Plan ("Work Plan"). Enbridge submitted the Work Plan after identifying gaps in the exterior coating of the Dual Pipelines of Line 5 that cross the Straits of Mackinac. Enbridge identified the coating gaps during implementation of the Biota Investigation Work Plan, as required pursuant to Paragraph 69 of the Consent Decree for *U.S. v. Enbridge Energy, Limited Partnership, et al.*, (Civil Action No: 1:16-cv-914) ("Consent Decree"). The Independent Third Party, retained by Enbridge pursuant to the Consent Decree, has reviewed the Work Plan and provided comments to EPA and Enbridge.

EPA approves this Work Plan with the following conditions:

1. EPA is not approving the use of Method 2 (described in the Work Plan) at this time because Enbridge has not yet demonstrated the effectiveness of that Method. Enbridge may not use Method 2 unless EPA provides prior written approval; and
2. within 30 days of Enbridge's completion of the activities required by the Work Plan, Enbridge shall submit to EPA a Final Report, summarizing its activities and identifying and justifying any deviations from the procedures in the Work Plan; and
3. Enbridge shall implement the Work Plan in accordance with all federal, state, and local regulations and laws, including any permitting requirements.

Enbridge shall implement this Work Plan immediately upon receipt of this approval.

Approval of this Work Plan does not release Enbridge from its obligation to fully comply with Paragraph 69(c) of the Consent Decree. Paragraph 69(c) requires that, no later than 60 days after

the completion of the biota investigation, Enbridge shall submit a final report to EPA, describing the findings of the investigation. In the event that the investigation finds that biota have impaired, or threaten to impair, the Dual Pipelines, Enbridge shall supplement its final report with a proposed work plan and schedule to address such impairments.

Approval of the Work Plan also does not indicate that EPA accepts Enbridge's confidentiality claims attached to the Work Plan. As described in Paragraph 155 of the Consent Decree, EPA will evaluate any claims of confidentiality pursuant to 40 C.F.R. Part 2.

Sincerely,

A handwritten signature in black ink, appearing to read 'Jo - El-Zein', followed by a horizontal line.

Jason H. El-Zein, Chief
Emergency Response Branch 1

cc: Matthew Thompson, Enbridge
Joanne Coprez, Enbridge
Carrie Mymko, Enbridge
William Hassler, Steptoe
Jay Eickholt, MDEQ
Jerry Popiel, USCG
Allan Beshore, PHMSA
Margaret Guerriero, EPA
J. Matthew Moore, EPA
Karen Peaceman, EPA
Ellen Riley, EPA
Matthew Mankowski, EPA

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Coating Repairs Work Plan Line 5 Dual Pipelines

United States v. Enbridge Energy et al Case 1:16 –cv-914

Consent Decree	VII. Injunctive Measures, E. Measures To Prevent Spills In The Straits Of Mackinac, Paragraph 69c., Biota Investigation		
Version	3.0	Version date	September 13, 2017



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Introduction

Paragraph 69 of the Consent Decree entered in Case 1:16-cv-00914 (ECF No. 14, 05/23/17) requires the Enbridge defendants (collectively referred to as "Enbridge") to create and complete a Biota Investigation Work Plan ("BI Work Plan") on the Dual Pipelines that cross the Straits of Mackinac. On or about August 14, 2017, Enbridge initiated the field activities of the BI Work Plan at the Straits and as of September 13, 2017 the BI Work Plan field work has been completed.

Through the BI Work Plan activities there have been several locations identified as areas with bare or potentially bare metal.

Per Paragraph 69c, Enbridge is required to submit a final report to the EPA within 60 days of completion of the BI Work Plan investigation. In particular, in the event that evidence is developed that zebra mussels and other biota have impaired, or threaten to impair, the Dual Pipelines Enbridge shall supplement the final report with a proposed work plan to address such impairments. Enbridge however, is currently unaware of any evidence linking zebra mussels or other biota to the coating repairs identified above.

Enbridge is submitting this Coating Repairs Work Plan ("CR Work Plan") in advance of the final BI Work Plan Report with the intent of receiving EPA approval for implementing coating repairs in time to allow Enbridge to complete the work in 2017.

Objective

The objective of the CR Work Plan is to ensure that all repairs are completed safely and in accordance with the Enbridge's coating procedure and in compliance with federal regulations.

Background

On June 13, 2017 the EPA approved Enbridge's BI Work Plan. This plan included detailed steps to complete biota sampling at various locations along the Dual Pipelines. The BI Work Plan also highlighted 18 areas of interest that would be investigated by divers as per the BI Work Plan definition (partial) included below:

Area(s) of Interest: An Area of Interest is a part of the pipeline where, based on visual inspection, (i) the normal (local) Biota is unexpectedly absent or (ii) there is evidence of possible coating damage (e.g., Dislodged Coating and/or potential Holiday).

In addition to the 18 Areas of Interest, three (3) Additional Sites were identified by the Enbridge marine contractor as being appropriate to investigate further. These Additional Sites were identified on Figures 2 and 3 of the BI Work Plan.

Coating Repair Scope Of Work And Schedule

The following locations have been identified as areas with bare or potentially bare metal:

<ul style="list-style-type: none"> Additional Site #1 (EAS-1): One area proposed for coating repair (bare metal). Additional Site #2 (EAS-2): One area proposed for coating repair (potential bare metal). Additional Site #3 (WAS-1): Four areas proposed for coating repair (bare metal). 	Known at the time for inclusion in CR Work Plan - Version 1.0
<ul style="list-style-type: none"> East Additional Sites (August Supplement): Three areas proposed for coating repair (bare metal) (North and South). Please refer to coating inspection reports titled EAS-3 and EAS-4. 	Known at the time for inclusion in CR Work Plan - Version 2.0
<ul style="list-style-type: none"> Area of Interest #1 (EAOI-1): Three areas proposed for coating repair (potential 	Known at the time for inclusion

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Method 1 is more likely to be chosen when the repair is located on the side of the pipe and the repair area is larger and runs axially along the pipe. Method 2 is more likely to be chosen in situations where dive time is limited, the repair area is smaller, and the repair is located on top of the pipe.

Enbridge is currently working with the coating manufacturer to investigate the suitability of using Method 2 with a pre-cast sleeve in place of the Stricture Bandings ("Modified Method 2"). Enbridge will approach the EPA for approval of Modified Method 2 if the investigation shows the approach is effective. The table below shows the coating repair locations and the currently proposed coating repair method.

Location	Identification	Coating Repair Method
Additional Site #1	EAS-1	Method 1
Additional Site #2	EAS-2	Method 1
Additional Site #3	WAS-1	Method 1
East Additional Site (August Supplement)	EAS-3	Method 1
	EAS-4	Method 1 or Modified Method 2 - if deemed acceptable through testing and subsequently approved by the EPA
Area of Interest #1	EAOI-1	Method 1
Area of Interest #5	EAOI-5	Method 1
Area of Interest #7	EAOI-7	Method 1

It is anticipated that permit(s) for lake floor excavation will be required for EAS-4 unless Modified Method 2 is acceptable and approved. Enbridge will provide the state of Michigan with the plan detailing the materials, methods, and procedures it will use to repair the coating areas.

The product data sheets for the BIO-DUR 563 epoxy filler and the X-100 UW epoxy are included in Appendix C. In addition, Appendix D includes a letter from the Manufacturer confirming that the materials comply with 49CFR195.559 and highlighting underwater installations that have been performed using their products since 1989.

Based on the full scale application and testing at SES, Enbridge has also developed a procedure for the application of the coating repair to the Dual Pipelines. The Enbridge procedure "Application Of Underwater Repair Coatings For Line 5 Straits" – Version 2.0 is found in Appendix E. The procedure was developed in consultation with PRTI.

The cure time for the coating system will be verified using a field trial to confirm the SES testing results that are incorporated into the coating procedure. A pipe sample will be prepared and coated concurrently with the coating repairs at WAS-1. This site represents the deepest water depth (201 feet) and therefore the location with the most challenging environment for successful coating repair. The sample will be allowed to cure at depth and retrieved to the barge after 7 days of cure. While on the barge, Shore D measurements will be completed to confirm a value of 60 or greater. Should the field trial not confirm a Shore D measurement of 60 or greater Enbridge will inform the EPA and the Independent Third Party to discuss next steps relative to the CR Work Plan.

REDACTED SUBMITTAL - PUBLIC COPY**Reporting**

Per Paragraph 69c. Enbridge is required to submit a final report to the EPA within 60 days of completion of the BI Work Plan investigation. In particular, in the event that evidence is developed that zebra mussels and other biota have impaired, or threaten to impair, the Dual Pipelines Enbridge shall supplement the final report with a proposed work plan to address such impairments. Enbridge however, is currently unaware of any evidence linking zebra mussels or other biota to the coating repairs identified above.

In addition to the above mentioned report, Enbridge will submit a report to the EPA within 30 days of completion of the CR Work Plan. This report will include a summary of the work completed, any CR Work Plan deviations with justification, and other pertinent information.

REDACTED SUBMITTAL - PUBLIC COPY**External Pipeline Inspection Form for L5 Straits of Mackinac****General Information**

Date:	08/15/2017	Contractor:	Ballard Marine Co
AFE / W.O.#:	20008990	Company Rep / Inspector:	REDACTED
Segment:	EAS-1	Water Depth (ft):	R
Longitude:	REDACTED	Latitude:	REDACTED

External Pipe Coating Inspection Results

General Area	<input checked="" type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	48.84 (46'x 1.74')
Holiday 1	<input type="checkbox"/> Disturbed Area <input checked="" type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	0.01 (3.0"x0.5")
	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	
	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	
	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	
Corrosion present:	<input type="checkbox"/> YES	<input checked="" type="checkbox"/> NO	Biota present:	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO
Dislodged coating observed on the lake floor: <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO			Lake floor location wrt pipe:	N/A (pipe is suspended)

Comments/Issues/Discussion

EAS-1 within span of E-72. Total span is 46' long, within the areas of 10:00 and 2:00.

South End Lat: REDACTED long REDACTED
 North End Lat: REDACTED long REDACTED

Center Line listed in general information above.

One (1) feature with DFT measurements below the minimum resolvable thickness of gauge was found. The Polatrak CP gun was used to confirm the existence of bare metal:

Holiday 1 presented average CP reading of -1680mV CSE (holiday confirmed). Holiday found in coating at coordinates Lat: REDACTED Long: REDACTED

No external corrosion was detected by dive team.

Contractor Signature

REDACTED

Enbridge Representative/ Inspector Signature

REDACTED SUBMITTAL - PUBLIC COPY**External Pipeline Inspection Form for L5 Straits of Mackinac****Cathodic Protection and Coating Measurements (if Holiday is found) -
Holiday 1**

CP Reading #1 (mV)		-1676 -1683	CP Reading #2 (mV)		-1674 -1681	CP Reading #3 (mV)		-1690 -1674
Temperature (°F)	NR	DFT at Holiday (mil)	≤ 25	DFT Adjacent to Holiday (mil)			96, 94, 95	

*For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.*



Date:	8/15/17	Frame(HH:MM:SS)	13:02:03	Date:	8/15/17	Frame(HH:MM:SS)	13:05:42
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REDACTED SUBMITTAL - PUBLIC COPY**External Pipeline Inspection Form for L5 Straits of Mackinac****Visual Inspection (General Coating Condition)**

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.

8/24/2017 2:11:12 PM
EAS-2

Thickness: No Data
H: REDACT
D: REDACT
Temp: 61.2 °F



8/24/2017 2:38:33 PM
EAS-2

Thickness: No Data
H: REDACT
D: REDACT
Temp: 61.9 °F



Date: 8/24/17

Frame(HH:MM:SS)

14:11:12

Date: 8/24/17

Frame(HH:MM:SS)

14:38:33

Coating Gauge Information

Manufacturer:	Elcometer Inspection Equip	Product:	211 Coating Thickness Gauge
Last Calibrated:	08/09/2017	Next Calibration Due:	08/09/2018
Gauge verified prior to use:	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO		

Coating Thickness Inspection Data

Thickness Measure (mil)	Area of Interest	Undisturbed Area (< 2 in.)	Undisturbed Area (> 5 ft.)
North End #1	135	130	115
#2	140	130	115
#3	110	140	120
South End #4	117	119	125
#5	130	94	130
#6	70	150	135
Average Thickness	117	127	121

Additional Coating Thickness Inspection Data (A/R)

REDACTED SUBMITTAL - PUBLIC COPY**External Pipeline Inspection Form for L5 Straits of Mackinac****General Information**

Date:	08/29/2017	Contractor:	Ballard Marine Co
AFE / W.O.#:	20008990	Company Rep / Inspector:	REDACTED
Segment:	EAS-3	Water Depth (ft):	RE
Longitude:	REDACTED	Latitude:	REDACTED

External Pipe Coating Inspection Results

Coating Condition	<input type="checkbox"/> Disturbed Area <input checked="" type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	0.93 (8"x1.4")
	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	
	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	
	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	
	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	
Corrosion present:	<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO	Biota present:	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	
Dislodged coating observed on the lake floor:	<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO	Lake floor location wrt pipe:	Pipe suspended	

Comments/Issues/Discussion

East Additional Site #3 (South of E-22).

DFT measurements at the feature are below the minimum resolvable thickness of gauge.
The Polatrak CP gun was used to confirm the existence of bare metal:

Holiday 1 presented average CP reading of -848mV CSE (holiday confirmed).

No external corrosion was detected by dive team.

REDACTED

Contractor Signature

Enbridge Representative/ Inspector Signature

REDACTED SUBMITTAL - PUBLIC COPY**External Pipeline Inspection Form for L5 Straits of Mackinac****Cathodic Protection and Coating Measurements (if Holiday is found) - Holiday 1**

CP Reading #1 (mV)	-852 -886	CP Reading #2 (mV)	-804 -842	CP Reading #3 (mV)	-834 -875
Temperature (°F)	44	DFT at Holiday (mil)	≤ 25	DFT Adjacent to Holiday (mil)	80, 80, 125

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.

8/29/2017 10:35:09 AM



H: REDACT
D: ED
Temp: 51.0 °F

8/29/2017 10:35:44 AM



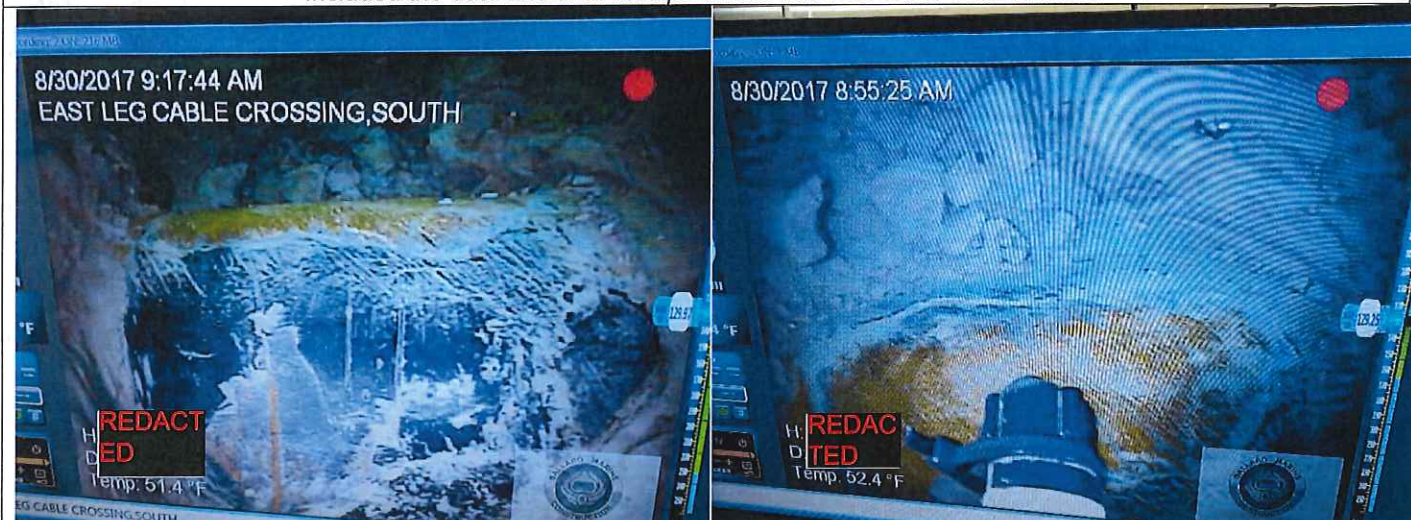
H: REDACT
D: ED
Temp: 51.0 °F

Date: 8/29/17 Frame(HH:MM:SS) 10:35:09

Date: 8/29/17 Frame(HH:MM:SS) 10:35:44

REDACTED SUBMITTAL - PUBLIC COPY**External Pipeline Inspection Form for L5 Straits of Mackinac****Visual Inspection (General Coating Condition, Holidays 1 and 2)**

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.



Date:	8/30/17	Frame(HH:MM:SS)	09:17:44	Date:	8/30/17	Frame(HH:MM:SS)	08:55:25
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Coating Gauge Information

Manufacturer:	Elcometer Inspection Equip	Product:	211 Coating Thickness Gauge
Last Calibrated:	08/09/2017	Next Calibration Due:	08/09/2018
Gauge verified prior to use:	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO		

Coating Thickness Inspection Data

Thickness Measure (mil)	Area of Interest	Undisturbed Area (< 2 in.)	Undisturbed Area (> 5 ft.)
North End #1	≤25	N/R (see note, below)	N/R
#2	≤25	N/R	N/R
#3	≤25	N/R	N/R
South End #4	≤25	N/R	N/R
#5	≤25	N/R	N/R
#6	≤25	N/R	N/R
Average Thickness			

Additional Coating Thickness Inspection Data (A/R)

Note: coating thickness in undisturbed areas around the cable rub could not be obtained due to the presence of silt and soil (lake bed). The pipe is below the level of the lake bed. See Holiday 1 and Holiday 2 'DFT thicknesses adjacent to the Holidays' for representative coating thickness in the area.

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Date:	08/25/2017	Contractor:	Ballard Marine Co
AFE / W.O.#:	20008990	Company Rep / Inspector:	REDACTED
Segment:	WAS-1	Water Depth (ft):	RE
Longitude:	REDACTED	Latitude:	REDACTED

External Pipe Coating Inspection Results

General Area	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input checked="" type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	20.8 (13' x 1.6')
Holiday 1	<input type="checkbox"/> Disturbed Area <input checked="" type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	0.06 (9" x 1")
Holiday 2	<input type="checkbox"/> Disturbed Area <input checked="" type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	0.24 (1'2" x 2.5")
Holiday 3	<input type="checkbox"/> Disturbed Area <input checked="" type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	0.07 (1'7" x 1/2")
Holiday 4	<input type="checkbox"/> Disturbed Area <input checked="" type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating	Size of anomaly (ft ²):	0.01 (1'3" x 1/8")
Corrosion present:	<input type="checkbox"/> YES	<input checked="" type="checkbox"/> NO	Biota present:	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO
Dislodged coating observed on the lake floor: <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO			Lake floor location wrt pipe:	N/A (pipe is suspended)

Comments/Issues/Discussion

WAS-1 within span of W-68A. Four (4) features with DFT measurements below the minimum resolvable thickness of gauge were found. The Polatrak CP gun was used to confirm the existence of bare metal at the following features:

Holiday 1 presented average CP reading of -1312mV CSE (holiday confirmed).
 Holiday 2 presented average CP reading of -1312mV CSE (holiday confirmed).
 Holiday 3 presented average CP reading of -1365mV CSE (holiday confirmed).
 Holiday 4 presented average CP reading of -1408mV CSE (holiday confirmed).

No external corrosion was detected by dive team. A white deposit was found at the holiday area.

Contractor Signature

REDACTED

Signature

REDACTED SUBMITTAL - PUBLIC COPY**External Pipeline Inspection Form for L5 Straits of Mackinac****Cathodic Protection and Coating Measurements (if Holiday is found) - Holiday 1**

CP Reading #1 (mV)	-1300 -1362	CP Reading #2 (mV)	-1277 -1336	CP Reading #3 (mV)	-1277 -1322
Temperature (°F)	43	DFT at Holiday (mil)	≤ 25	DFT Adjacent to Holiday (mil)	90, 93, 110

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.

8/25/2017 9:15:30 AM
WAS-1

Thickness: No Data
H: REDACT
D: ED
Temp: 50.0 °F



8/25/2017 10:14:42 AM
WAS-1

Thickness: No Data
H: REDACT
D: ED
Temp: 51.6 °F



Date: 8/25/17 Frame(HH:MM:SS) 09:15:30

Date: 8/25/17 Frame(HH:MM:SS) 10:14:42

Cathodic Protection and Coating Measurements (if Holiday is found) - Holiday 2

CP Reading #1 (mV)	-1274 -1328	CP Reading #2 (mV)	-1283 -1237	CP Reading #3 (mV)	-1375 -1372
Temperature (°F)	43	DFT at Holiday (mil)	≤ 25	DFT Adjacent to Holiday (mil)	79, 94, 100

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.

8/25/2017 1:29:51 PM
WAS-1

Thickness: No Data
H: REDACT
D: ED
Temp: 51.4 °F



8/25/2017 1:30:30 PM
WAS-1

Thickness: No Data
H: REDACTE
D: D
Temp: 51.3 °F



Date: 8/25/17 Frame(HH:MM:SS) 13:29:51

Date: 8/25/17 Frame(HH:MM:SS) 13:30:30

REDACTED SUBMITTAL - PUBLIC COPY**External Pipeline Inspection Form for L5 Straits of Mackinac****General Information**

Date:	09/08/17	Contractor:	Ballard Marine Co
AFE / W.O.#:	20008990	Company Rep / Inspector:	REDACTED
Segment:	EAOI-1	Water Depth (ft):	194
Longitude:	REDACTED	Latitude:	REDACTED

External Pipe Coating Inspection Results

Coating Condition	<input checked="" type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating <input type="checkbox"/> Other	Size of anomaly (ft ²):	9.17 (3'4" X 2'9")
Feature 1	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating <input checked="" type="checkbox"/> Other	Size of anomaly (ft ²):	0.01 (1" X 1")
Feature 2	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating <input checked="" type="checkbox"/> Other	Size of anomaly (ft ²):	0.01 (1" X 1.5")
Feature 3	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating <input checked="" type="checkbox"/> Other	Size of anomaly (ft ²):	0.01 (1" X 1")
	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating <input type="checkbox"/> Other	Size of anomaly (ft ²):	
Corrosion present:	<input type="checkbox"/> YES	<input checked="" type="checkbox"/> NO	Biota present:	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO
Dislodged coating observed on the lake floor: <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO			Lake floor location wrt pipe:	6 o'clock (pipe resting on lake bed)

Comments/Issues/Discussion

EAOI-1 E-01B-B is an area of disturbed biota and contains three areas of white deposit within a 6" X 1.5" area on the top of the pipe (12 o'clock).

DFT measurements indicate normal coating thickness through the entire area inspected.

CP measurements taken with the Polatrak CP gun through the white deposit areas deviated slightly from reference 'open water' measurements, but they were not sufficiently electronegative to indicate contact with Line 5 pipe metal.

Contractor Signature

REDACTED

Enbridge Representative/ Inspector Signature

REDACTED SUBMITTAL - PUBLIC COPY**External Pipeline Inspection Form for L5 Straits of Mackinac**
Cathodic Protection and Coating Measurements (if Holiday is found)
 (note: holiday could not be confirmed)

CP Reading #1 (mV) (feature 1)	-234 -281	CP Reading #2 (mV) (feature 2)	-440 -316	CP Reading #3 (mV) (feature 3)	-320 -260
Temperature (°F)	45	DFT at Feature (mil)	N/R	DFT Adjacent to Features (mil) (features 1, 2, and 3 respectively)	130, 145, 140

For all sections of dislodged coating or holidays, provide pictures below.
 Included the date and time stamps associated with video surveillance.

9/8/2017 12:07:06 PM
 E-AOI1,S3,B1



H: REDACT
 D: REDACT
 Temp: 57.9 °F

Date:	09/08/17	Frame(HH:MM:SS)	12:07:06	Date:		Frame(HH:MM:SS)	
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Note: CP readings at this feature were recorded with the probe of Polatrak CP gun pressed firmly into the white substance coating the pipe. These readings were more electronegative than the 'open water' CP readings (-198mV / -170mV), but are not consistent with Line 5 pipe metal contact – indicating that the presence of a resistive coating on the pipe surface.

REDACTED SUBMITTAL - PUBLIC COPY**External Pipeline Inspection Form for L5 Straits of Mackinac****Visual Inspection (General Coating Condition)**

*For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.*

9/6/2017 2:45:12 PM
E-AOI5

H: REDACTED
D: REDACTED
Temp: 58.0 °F



9/6/2017 2:47:47 PM
E-AOI5

H: REDACTED
D: REDACTED
Temp: 58.1 °F



Date: 09/06/17

Frame(HH:MM:SS)

14:45:12

Date: 09/06/17

Frame(HH:MM:SS)

14:47:47

Coating Gauge Information

Manufacturer:	Elcometer Inspection Equip	Product:	211 Coating Thickness Gauge
Last Calibrated:	08/09/2017	Next Calibration Due:	08/09/2018
Gauge verified prior to use:	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO		

Coating Thickness Inspection Data

Thickness Measure (mil)	Area of Interest	Undisturbed Area (< 2 in.)	Undisturbed Area (> 5 ft.)
North End #1	145	72	130
#2	94	115	130
#3	105	100	110
South End #4	130	130	135
#5	110	120	105
#6	105	100	105
Average Thickness	119	106	119

Additional Coating Thickness Inspection Data (A/R)* (see note below)

	16" from South End	34" from South End	52" from South End
West	135	145	145
Top	105	105	120
East	105	125	105

Note: An area of dislodged outer wrap was identified 2.5' from the south end of the AOI. Coating thickness in this area was 100 mil.

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Date:	09/05/17	Contractor:	Ballard Marine Co
AFE / W.O.#:	20008990	Company Rep / Inspector:	REDACTED
Segment:	EAOI-7	Water Depth (ft):	81
Longitude:	REDACTED	Latitude:	REDACTED

External Pipe Coating Inspection Results

Coating Condition	<input checked="" type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating <input type="checkbox"/> Other	Size of anomaly (ft ²):	7.08 (2'5" X 2'10")
Feature 1	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating <input checked="" type="checkbox"/> Other	Size of anomaly (ft ²):	0.04 (3" X 2")
	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating <input type="checkbox"/> Other	Size of anomaly (ft ²):	
	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating <input type="checkbox"/> Other	Size of anomaly (ft ²):	
	<input type="checkbox"/> Disturbed Area <input type="checkbox"/> Holiday	<input type="checkbox"/> Dislodged Coating <input type="checkbox"/> Other	Size of anomaly (ft ²):	
Corrosion present:	<input type="checkbox"/> YES	<input checked="" type="checkbox"/> NO	Biota present:	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO
Dislodged coating observed on the lake floor: <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO			Lake floor location wrt pipe:	N/A (pipe is suspended)

Comments/Issues/Discussion

EAOI-7 is located in Span E-35. This area of disturbed biota contains one area of white deposit.

DFT measurements indicate normal coating thickness through the entire area inspected, with slightly thinner coating adjacent to the white deposit.

The Polatrak CP gun was used to test for coating holiday through the white deposit, but valid CP measurements could not be obtained. This indicates the presence of a resistive or isolating coating on the pipe surface.

Contractor Signature

REDACTED

Enbridge Representative/ Inspector Signature

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Appendix B: Report from Stress Engineering Services

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Limitations of This Report

This report is prepared for the sole benefit of the Client, and the scope is limited to matters expressly covered within the text. In preparing this report, SES has relied on information provided by the Client and, if requested by the Client, third parties. SES may not have made an independent investigation as to the accuracy or completeness of such information unless specifically requested by the Client or otherwise required. Any inaccuracy, omission, or change in the information or circumstances on which this report is based may affect the recommendations, findings, and conclusions expressed in this report. SES has prepared this report in accordance with the standard of care appropriate for competent professionals in the relevant discipline and the generally applicable industry standards. However, SES is not able to direct or control operation or maintenance of the Client's equipment or processes.

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Figure 17: (a) Photograph of 20" pipe sample after removal from water bath; (b) photograph showing stricture still applied to Areas "A" and "B/D/E." Area "C" (patch repair with no stricture) is on right end. Numbered scale divisions are 0.1 feet.	18
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Figure 1: Photograph showing as-received 20" diameter pipe sample used for full-scale repair testing.

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Encapsulating layer applied during sample preparation

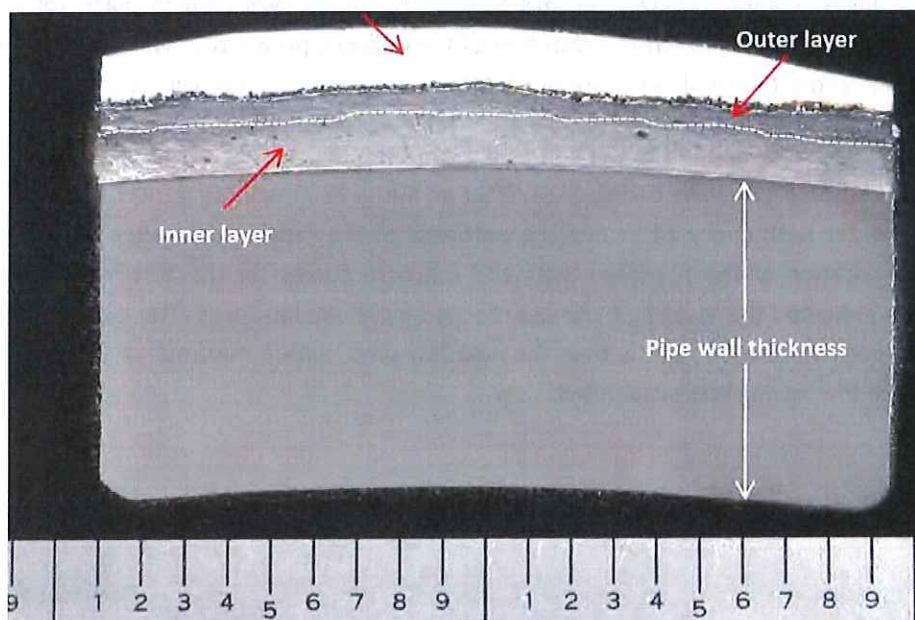


Figure 3: Metallographic cross-section through original coating. Dashed line indicates approximate boundary between inner and outer layers of coating. Numbered scale divisions are 0.1".

3. Laboratory Tests of Repair Coating System

Prior to conducting any repairs on the 20" diameter pipe section, SES performed small-scale tests on scrap pieces of carbon steel pipe. The outer surfaces of two 3-ft lengths of 6" diameter pipe were prepared to a NACE 2² finish.

The cure rate of an epoxy (and possibly its ability to cure) is largely a function of temperature. In general, the lower the temperature, the longer it will take for an epoxy to cure. An internet survey of Great Lakes water temperatures, including dive company websites, indicated that the temperature at the bottom of the Straits can be near 40°F, even in summer months. It is also known that 40°F is a standard test temperature for offshore oil & gas applications in the Gulf of Mexico. Thus, 40°F was selected as the coating application temperature for this test program.

Two modified chest freezers were filled with prepared water and chilled to 40°F using a combination of the freezer's compressor and dry ice (Figure 4). The water bath was maintained at 40°F throughout testing.

The repair coating system under evaluation (Figure 5) is a two-part epoxy system. First, the epoxy base (X100 – UW Epoxy Base – Blue) was mixed with curing agent (Bio-Seal X-100 Curing Agent – Clear) and applied to the surface of the pipe as a preparation layer (Figure 6(a)). The mixed epoxy was then saturated into a 12" wide, E-glass fabric that was wrapped around the pipe in at least four layers (Figure

² Near-white metal abrasive blast cleaning.

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Figure 6: Photographs showing application of laboratory epoxy repair wrap: (a) epoxy applied to bare steel; (b) and (c) fabric impregnated with two-part epoxy; (d) fiber mesh repair wrapped around pipe in four layers; and (e) stricture banding applied over repair.

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debris already present in the sample pipe³. Prior to affixing the end plates, SES attached two thermocouples to the inside surface of the pipe to monitor metal temperature during the test (Figure 9(a)).

A 2,700 gallon, insulated tank (see Figure 8 background) was filled with water obtained by reverse osmosis. Chemicals were added to simulate the Straits' water composition. The water was pumped continuously through a 10 ton water chiller and circulation pump with a 50 micron sediment filter until a temperature of 40°F was obtained. The water temperature was monitored via two temperature probes submerged in the tank, in addition to the thermocouples attached to the pipe. The temperature at the four probes was continuously recorded throughout the test procedure (Figure 9(b)).

Five separate areas on the 20" diameter pipe were prepared for repair. The schematic in Figure 10 shows the locations and variables of the different repairs. This information is also summarized below and in Table 1. Compass directions refer to the relative orientation of the pipe sample in the laboratory during testing. Clock/circumferential positions are viewed from the west end of the sample, with top dead center at 0°.

- A 16" square section of the (original) outer coating was removed from each end of the pipe along the top surface using a hand grinder and wire wheel. In the center of these squares, a 2" x 4" section of the inner coating was also removed, exposing bare steel. These areas were labeled "A" and "C" and designated as patch repairs.
- A 16" wide area of the outer coating was removed around the circumference of the pipe near the center of the sample length to provide space to apply a full 360° repair.
 - A 4" x 4" area of the inner coating was removed at the top of the pipe from this 16" wide area, exposing bare steel. This location was designated as Area "B."
 - Two 4" x 4" patches of the inner coating were removed at the north (Area "D") and south (Area "E") sides of the sample aligned with Area "B."

Figure 11 shows these prepared areas of the pipe prior to repair.

³ The interior of the pipe was allowed to fill with water, however, to avoid excessive buoyancy during the test.

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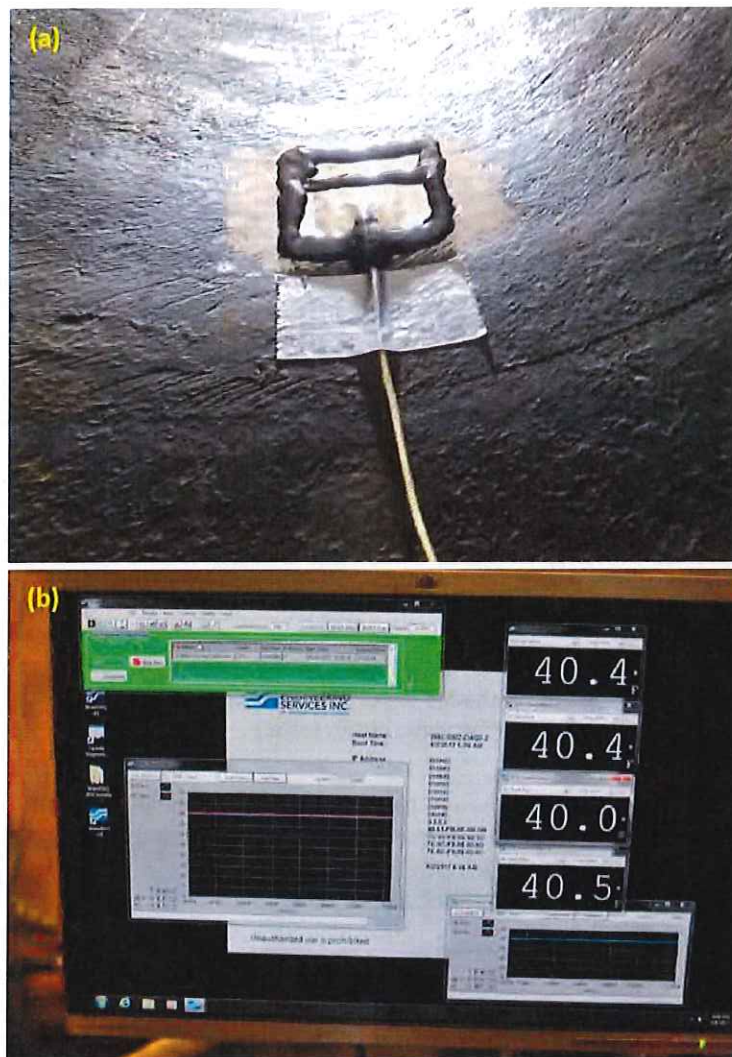


Figure 9: Photograph showing (a) thermocouple attached to inside surface of pipe and (b) temperature readout for water tank and pipe.

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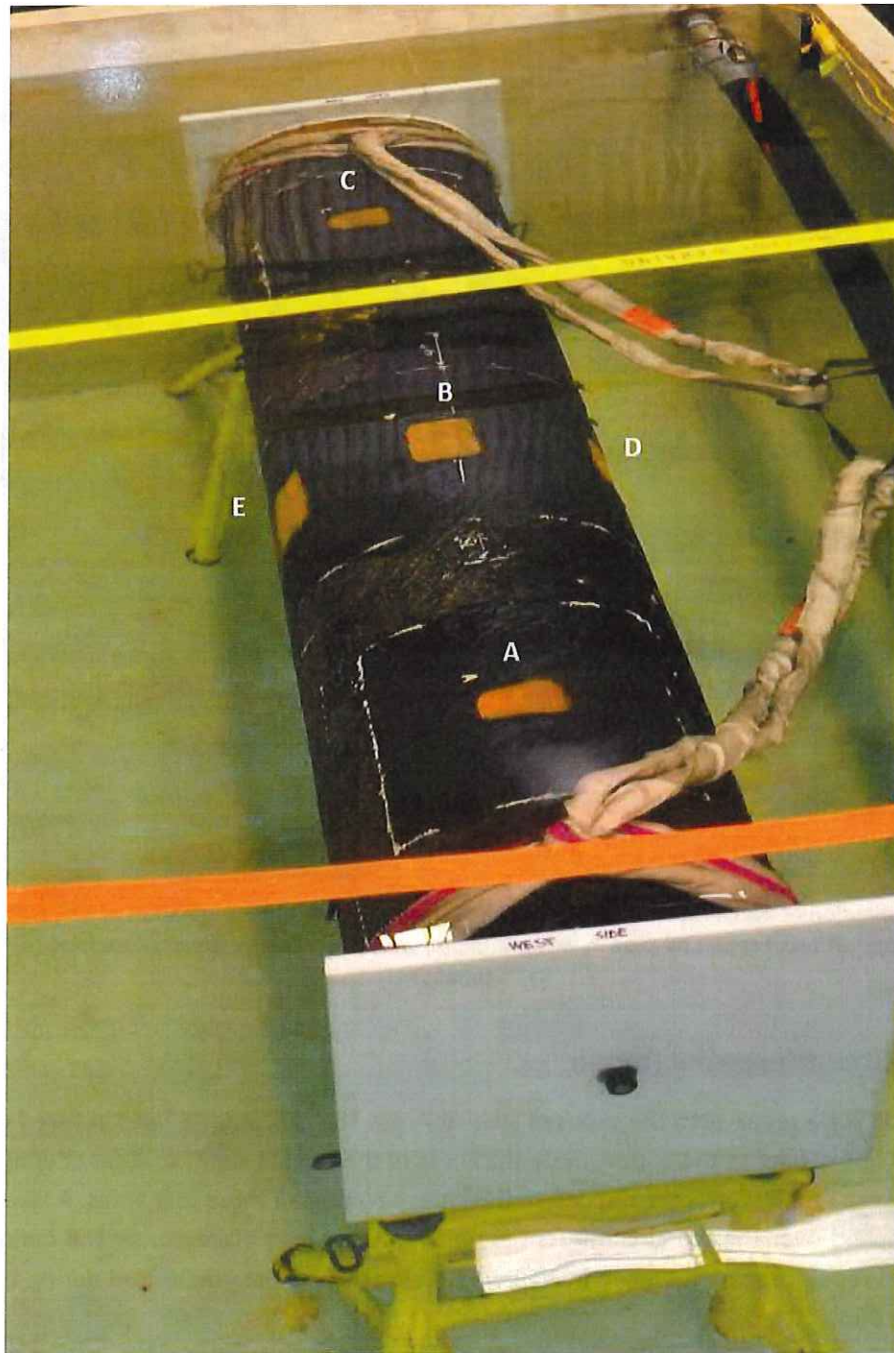


Figure 11: Photograph showing 20" pipe in 40°F water prior to application of epoxy repairs. Repair areas are labeled per Table 1 and Figure 10. Flash rust on exposed areas was removed prior to repair.

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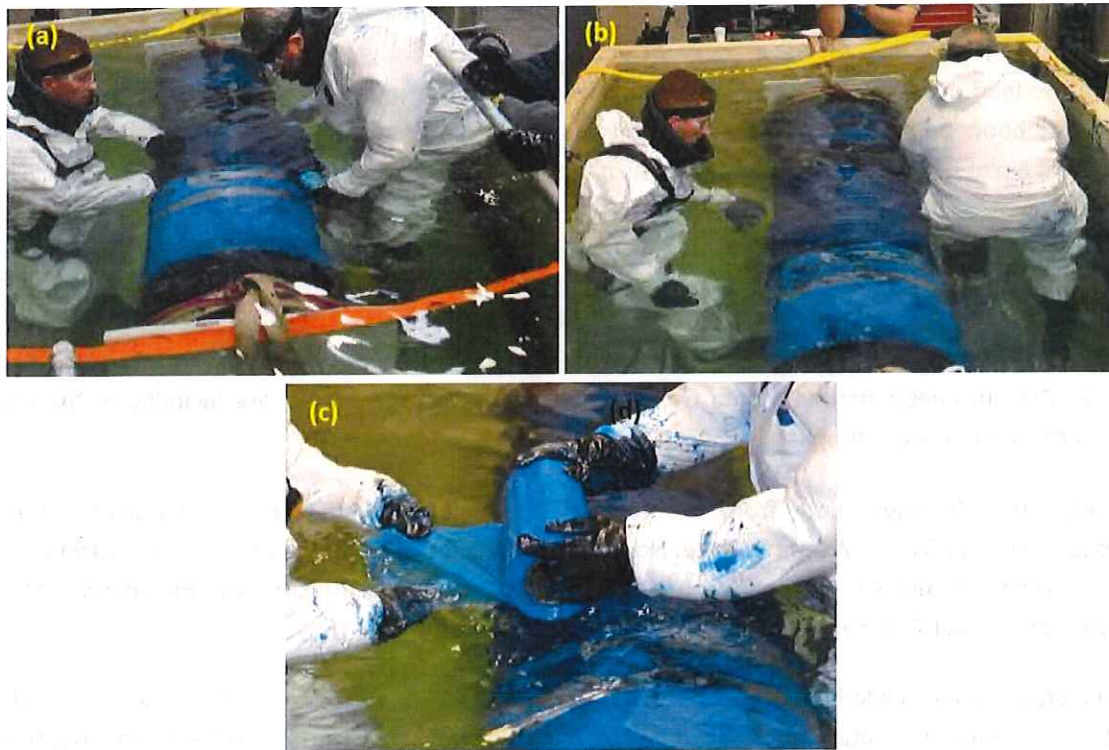


Figure 13: Application of full circumferential repair at Areas "B," "D," and "E." Photographs (a) and (b) show application of impregnated fabric around the circumference of pipe; (c) shows application of stricture.

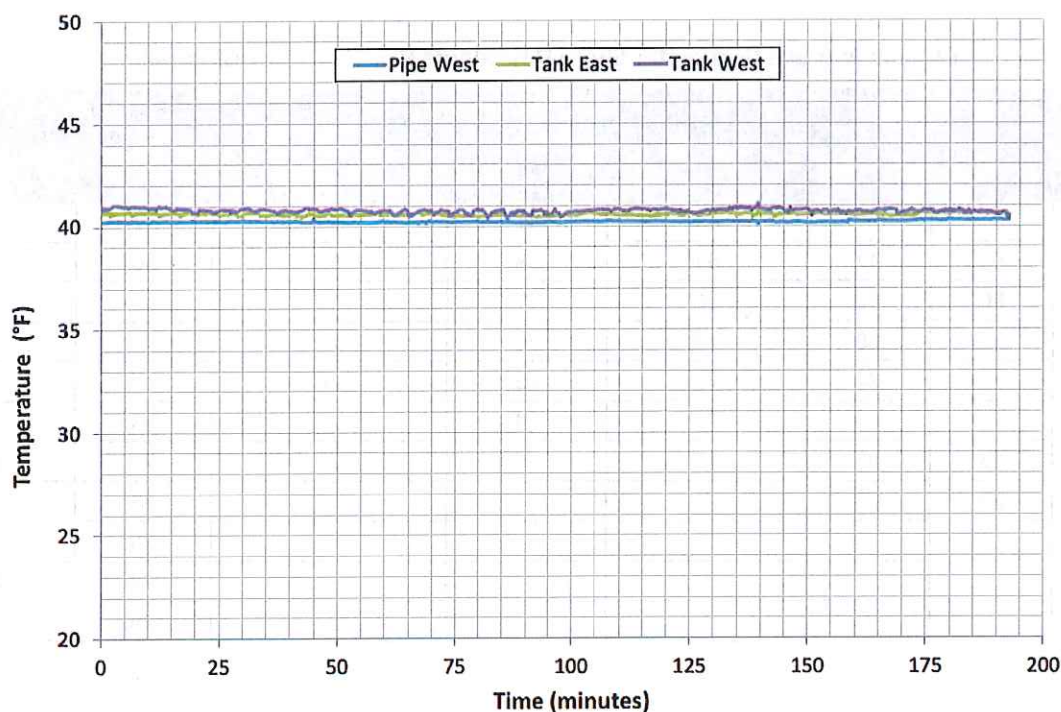


Figure 14: Graph of temperature data during application of full circumferential repair at Areas "B," "D," and "E" (see Figure 13). Water temperature remained near 40°F during installation of all repairs.

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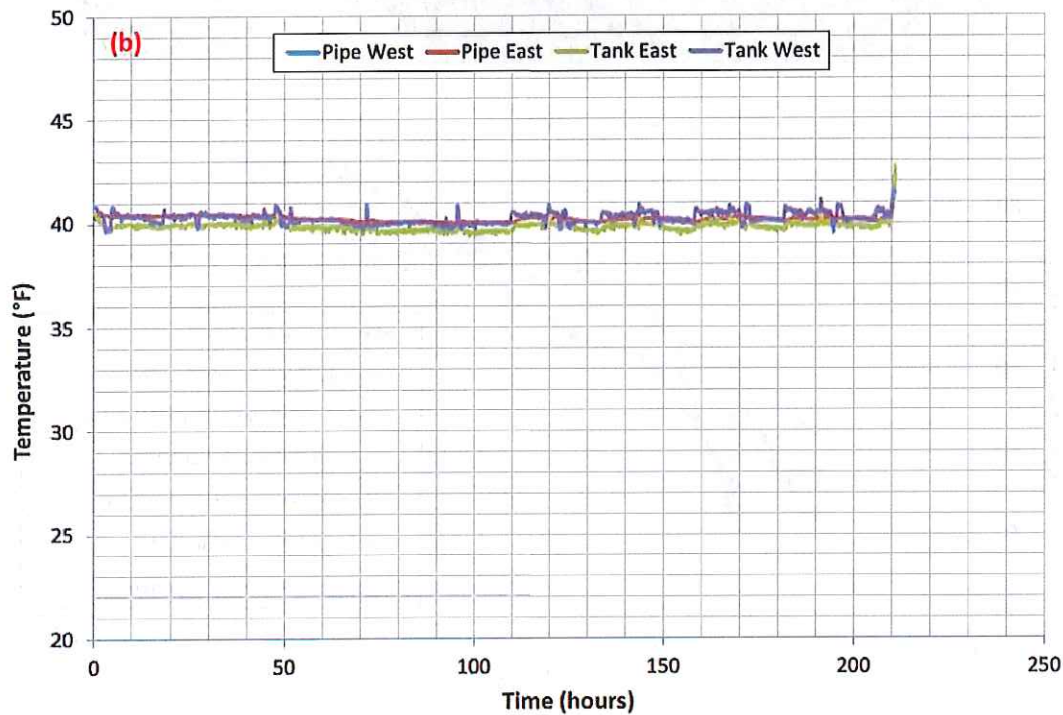


Figure 15: (a) Photograph showing water tank and (b) graph of water-bath temperature during curing period of full-scale repairs.

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and "E" are obscured by the stricture banding. Patch repair area "C" exhibits only the repair fiber wrap since no stricture was used in this area.

The full circumferential repair at the center of the pipe is shown in Figure 18(a) after the stricture was removed. The patch repair at Area "A" is shown in Figure 18(b). Both repairs appear to be well attached to the pipe, including along the perimeter of the repair patch and the edges of the circumferential wrap.

The patch repair at Area "C" is shown in Figure 19. While the majority of Area "C" appears well attached to the pipe sample, the edges of the fiber wrap layers were not completely bonded to the pipe, creating a crevice along the perimeter of the patch.



Figure 17: (a) Photograph of 20" pipe sample after removal from water bath; (b) photograph showing stricture still applied to Areas "A" and "B/D/E." Area "C" (patch repair with no stricture) is on right end. Numbered scale divisions are 0.1 feet.

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8 September 2017



Figure 19: Photographs showing patch repair at Area "C" where no stricture was applied.

5.2 Cross-Sections of Full-Scale Repairs

SES removed transverse sections through each of the repair areas to document the overall configuration of the repair. Additionally, smaller sections were removed from these cross-sections, mounted, and prepared using standard metallographic techniques. In order to maintain the integrity of the coatings during sample preparation, a large diameter diamond wafer saw was used to cut through the pipe wall thickness, original coating, and repair materials. It was found to not be necessary to encapsulate the samples prior to metallography; the coating layers remained intact using normal mounting and preparation techniques.

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8 September 2017

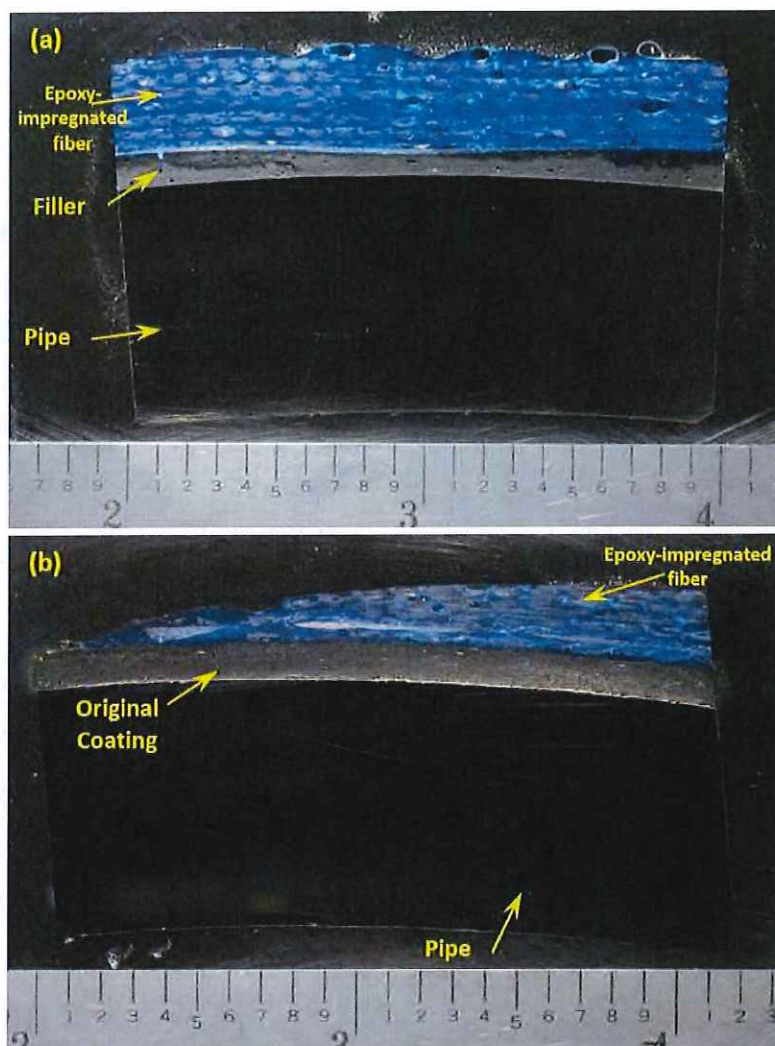


Figure 21: Metallographic cross-sections through repair Area "A." Section in upper photograph was removed through center of repair where original coating was completely removed down to bare metal. Lower photograph shows edge of repair where fiber wrap covers original coating.

5.2.2 Circumferential Repair Areas "B," "D," and "E"

A cross-section through the three areas repaired with a full 360° wrap is shown in Figure 22. Closer views of each area are shown in Figure 23 to Figure 25. As with the patch repair in Area A, the full repairs appeared to be well bonded to the pipe, including at the outer edges of the wrap. Metallographic cross-sections through each area are shown in the lower photographs in Figure 23 to Figure 25, respectively. Again, the repairs were found to be relatively uniform and appeared to have good adhesion to the pipe wall, though areas of porosity were evident in the cross sections. The porosity is not extensive and does not appear to compromise the integrity of the repair.

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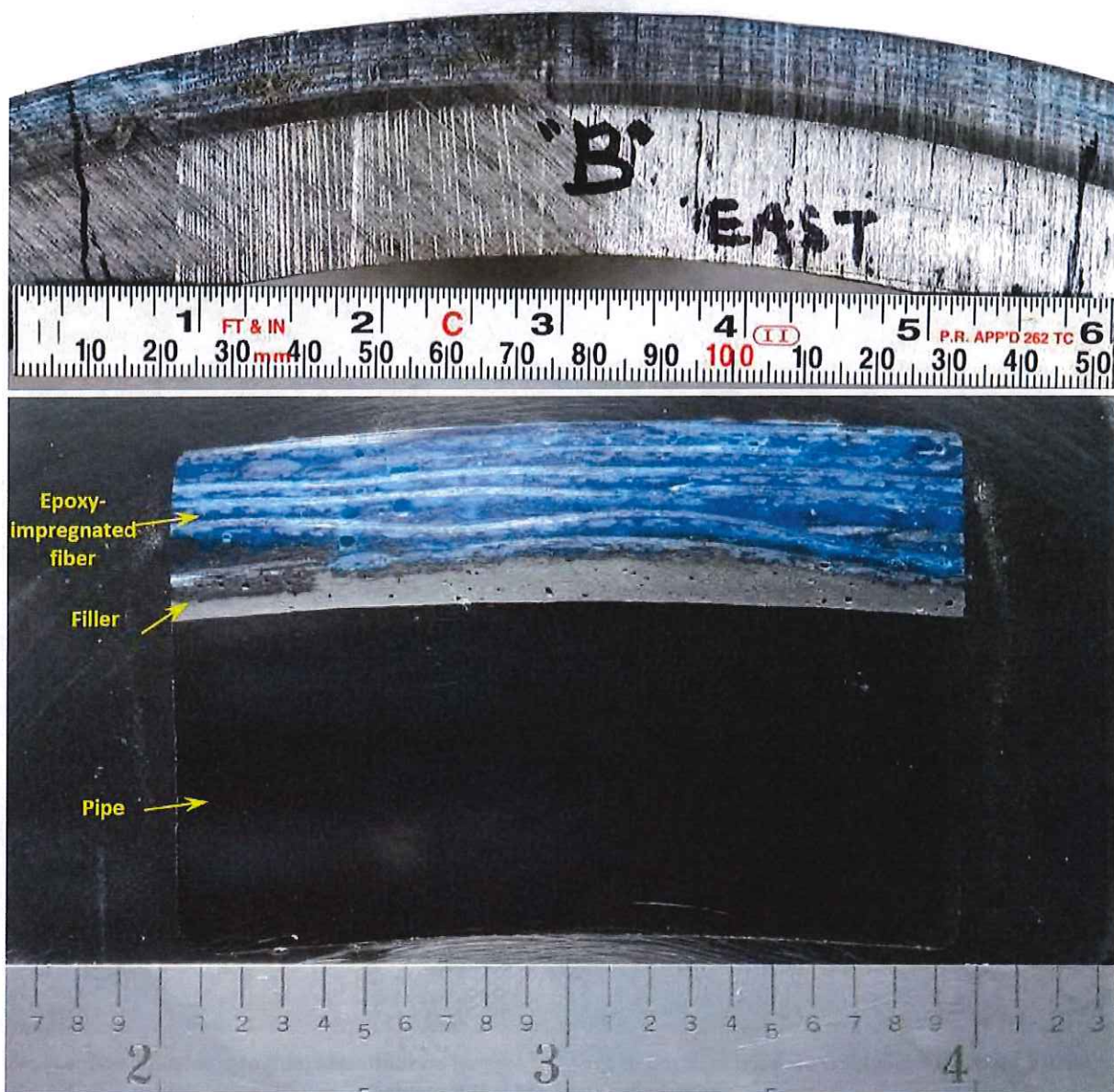


Figure 23: Metallographic cross-section of repair Area "B" located at top of pipe. A full 360° wrap and stricture was used in this repair.

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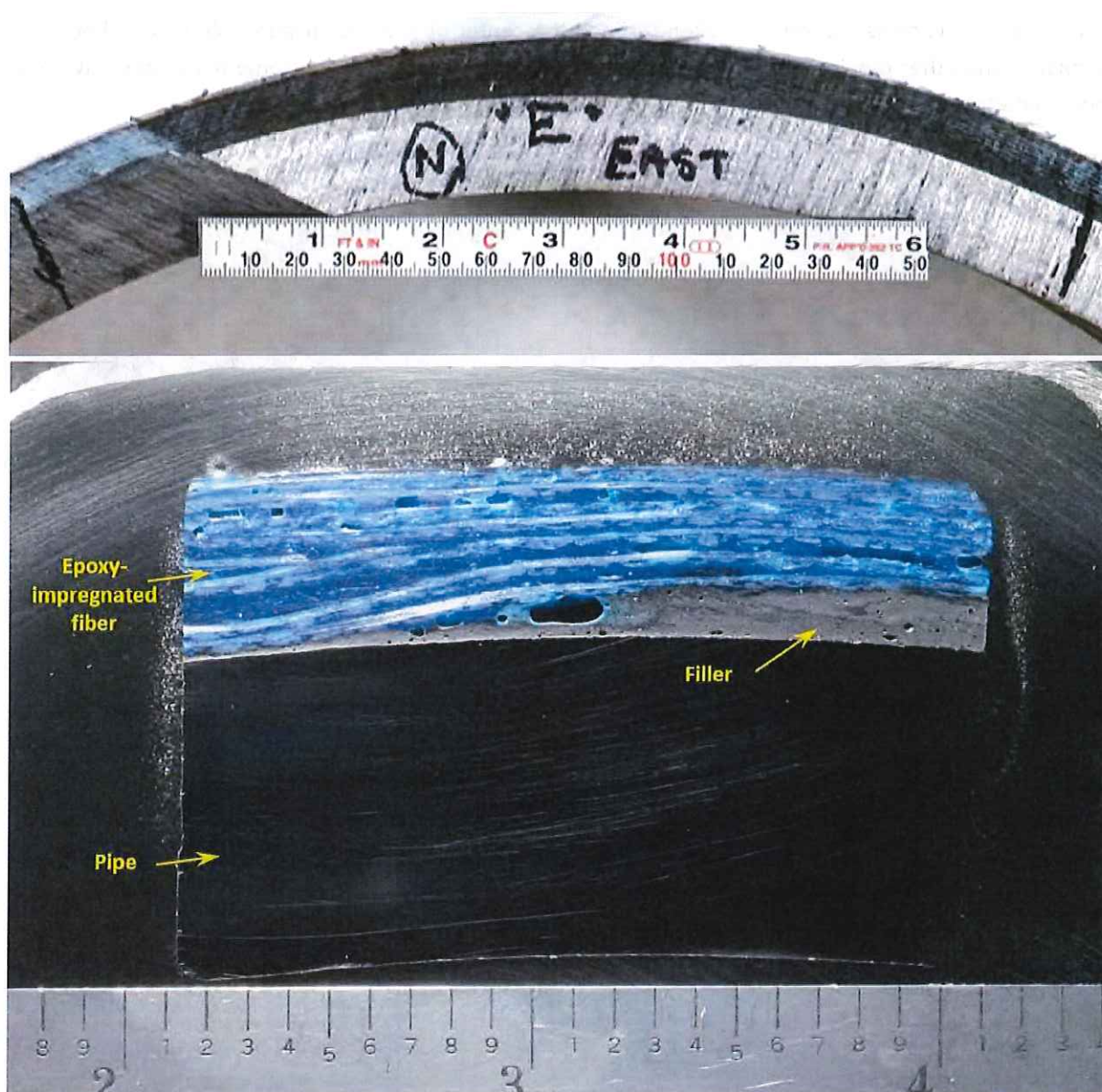


Figure 25: Metallographic cross-section of repair Area "E" located on north side (270°) of pipe. A full 360° wrap and stricture was used in this repair. (Reduction in thickness of filler material at left side of section is due to this section's being taken near edge of repair.)

5.2.3 Patch Repair Area "C"

A cross-section taken through Area "C" is shown in Figure 26 along with closer views at the perimeter of the repair. A stricture wrap was not applied to this repair site. The center of the repair (where the repair was applied over bare steel) was relatively uniform and appeared to have good adhesion to the pipe wall. At the perimeter of repair, however, the wrap layers were found to be cured, but not adhered to the pipe wall. An approximately 1" length of the wrap was not bonded to the surface, which created a small crevice around the perimeter.

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The data show that the fiber-wrap repairs were, in general, more highly adhered than the original coal-tar coating on the sample pipe and that the full 360° repair areas exhibited a higher adhesion than the patch repairs. However, it should be noted that the 20" sample pipe was not exposed to the same operational environment as Pipeline #5. This fact, along with the limited number of data points that could be obtained at each repair location, indicates that these results should be used for general comparison only.

REDACTED SUBMITTAL - PUBLIC COPY**Appendix C:
Product Data Sheets**

REDACTED SUBMITTAL - PUBLIC COPY**APPLICATION NOTES**

SURFACE PREPARATION: Remove marine biological settlement and corrosion by >5,000 psi water jetting with or without abrasive. Conventional air/abrasive blasting works well at shallow depths however efficiency falls off sharply below 10 feet. Hand held power tools such as needle guns or grinders can give good results if applied conscientiously in small areas but will be inadequate in large areas. Plan to apply the BIO-DUR®563 SW within 45 minutes maximum after surface preparation to minimize rerusting or initial settlement of fouling slime, which interferes with initial adhesion.

Application above water requires similar high-pressure water blasting or dry abrasive blasting to yield a firm, granular surface free of loose contamination.

MIXING PROCEDURE: BIO-DUR® 563 SW is supplied in 2 gallon kits of 2 x 1 gallon containers each of epoxy base and curing agent. These components are formulated in contrasting colors to facilitate complete mixing. Visible streaks of either component seen during the course of mixing indicate "hotspots" of unmixed components. It is imperative to properly mix the components since unmixed "hotspots" of either base or curing agent will never cure.

Remove equal quantities of base and curing agent from their cans and place them in a clean plastic or steel container. Mixing is accomplished by stirring with a "Jiffy" type mixer in a geared down, (high torque), 1/2" electric drill. Once mixing begins, there will be about 20 minutes of working time available at 77°F. This time may be extended by keeping the components and mixture cool, rather than leaving it in a hot area.

APPLICATION:

- 1) Using a stiff brush or roller apply mixed components from a tray aiming for a coverage rate of about 50 sq.ft. per gallon.
- 2) Apply by heated plural component airless spray using the following equipment setup:
 - Spray Unit: Graco "King" or similar with heated hoses.
 - Mix ratio: 1/1 by volume
 - Fluid pressure: 2,500 psi
 - Fluid temp: 140°F
 - Filters: Remove all filters
 - Tip size: .031" -.039" orifice

CURING BEFORE SERVICE: BIO-DUR® 563 SW may be immersed in fresh or salt water immediately after application. It will cure to a hard film within about 3 hours and is suitable for traffic after this time. Allow at least 24 hours at 77°F before subjecting to aggressive chemical service from industrial solvents and similar materials.

TYPICAL PHYSICAL PROPERTIES OF THE CURED FILM:

Compressive strength:	7,380 psi (50.9 N/mm ²)
Tensile strength:	6,000 psi (est.)
Flexural strength:	4,550 psi (31.4 M/mm ²)
Abrasion resistance:	34.0 mg/1,000 cycles (CS17 wheels with 1,000 gram weights)
Tensile adhesion:	>2,000 psi ("Near White" SA2.5 abrasive blasted dry steel)
Tensile adhesion:	>1,000 psi (>5,000 psi water jetted steel applied/cured underwater)
Tensile adhesion:	>1,000 psi (power tool cleaned then >2,500 psi water jetted dry steel)



HEMPSTEAD, TEXAS USA

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www.pipingrepairtechnologies.com

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X-100 UW RESIN SYSTEM:

The X-100 UW resin is based on pure liquid epoxy polymers and proprietary polyamine curing agents. The X-100 UW resin system is designed for use on wet surfaces or underwater applications. It is a two-component, ambient temperature epoxy matrix, and is suitable for use with a variety of reinforcement fabrics. The X-100 UW resin wets out easily and is relatively fast setting, approximately 30 minutes at 77°F (25°C). No VOC and is a 100% solids epoxy resin.

SURFACE PREPARATION:

Remove marine biological settlement and corrosion by >5,000 psi water jetting with or without abrasive. Conventional air/abrasive blasting works well at shallow depths however efficiency falls off sharply below 10 feet. Hand held power tools such as needle guns or grinders can give good results if applied conscientiously in small areas but will be inadequate in large areas. Plan to apply the X-100 UW within 45 minutes maximum after surface preparation to minimize re-rusting or initial settlement of fouling slime, which interferes with initial adhesion.

Application above water requires similar high-pressure water blasting or dry abrasive blasting to yield a firm, granular surface free of loose contamination.

MIXING PROCEDURE:

X-100 UW is supplied in size specific, factory pre-measured kits with corresponding reinforcement fabric lengths depending upon application. Kits are comprised of a Part A epoxy base in a partially filled container and a Part B curing agent to be poured into Part A container to assure proper mix ratio. After pouring the curing agent into the base, mix thoroughly for approximately 2 minutes taking care to stir in all base material from the edges and base of the container; *unmixed material will never properly cure*. No induction or "sweat-in" time is required and the mixed material may be used immediately. Pot life and reaction time is heavily dependent on temperature, as a general guide figure that each 18°F, (10°C), variation in temperature above or below 77°F, (25°C), will respectively halve or double the pot life and cure times.

APPLICATION:

When saturating the reinforcement fabric, a roller or flexible spreader should be used to evenly distribute the X-100 UW material throughout the fabric. The material will thicken in cold weather and will be noticeably thicker at temperatures of 50°F and below.

CURING BEFORE SERVICE at 77°F (25°C):

Dry time, dust free, 8 hours; light service, 12 hours; heavy service. Low temperature curing at approximately 40°F (5°C) will require approximately 7 days. Post cured Shore D scale hardness 70+.

- CAN BE APPLIED AT FULL PRESSURE
- FACTORY PRE-MEASURED FOR FAST INSTALLATION
- EGLASS AND CARBON FIBER FABRICS AVAILABLE
- CAN BE USED ON STRAIGHT RUN PIPING, ELBOWS, TEES AND FLAT SURFACES
- ISO 9001:2008 CERTIFIED MANUFACTURER

Industries Served

- Refining
- Power Generation
- Chemical Plants
- Mining
- Industrial
- Pulp and Paper
- Liquid and Gas Transportation
- Production Facilities
- Water and Wastewater Treatment

9

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Please do not hesitate to contact us if we may supply any additional information to support the statements above.

With thanks for your interest in our products,

Sincerely,

Jesse R. Sanders
President and Technical Director
Piping Repair Technologies, Inc.

40164 FM 2979 Hempstead, Texas 77445 / office (979) 826-0075 / Cell (713) 906-8650

Email: jsanders@pipingrepairtechnologies.com

Website: www.pipingrepairtechnologies.com

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**APPLICATION OF UNDERWATER
REPAIR COATINGS FOR LINE 5
STRAITS**

Version #: 2.0

Version Date: 09/08/2017

REDACTED SUBMITTAL - PUBLIC COPY**APPLICATION OF UNDERWATER
REPAIR COATINGS FOR LINE 5
STRAITS**Version #: 2.0
Version Date: 09/08/2017**Table of Contents**

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REPAIR COATINGS FOR LINE 5
STRAITS**

Version #: 2.0
Version Date: 09/08/2017



include, but are not limited to, the onsite Company Inspector, the Diver, and the coating Manufacturer. If the deviation is accepted, the requested deviation, key stakeholder inputs and risk assessment associated with the deviation will be uploaded into the Company's Business Information Management (BIM) system.

Note: No deviations will be accepted if they are not supported by the coating Manufacturer.

3.0 Surface Preparation

3.1 Pre-Preparation

The steel surface shall be cleaned using scarpers, hydroblasting cleaning, wet abrasive blasting, or pneumatic power wire wheel brush. The repair area shall be abraded using either wet abrasive blasting or pneumatic power wire wheel brush. The method shall be capable of providing a surface profile of 2.5 – 5 mils.

3.2 Parent Coating

3.2.1

Feathering shall remove the sharp edge at the transition from the parent coating.

3.2.2

The parent coating shall be roughened (abraded) using a cup disk brush to remove the loosely adherent biota, coating and provide a surface for overcoating.

3.2.3

For full circumferential composite wrap repairs (Method 1), the roughening shall extend at least 6 inches from the upstream and downstream edge of the repair area and around the entire circumference of the pipe.

For composite patch repairs (Method 2), the roughening shall extend onto the parent coating at least 6 inches from the edge of the repair area.

4.0 Coating Application

4.1 Surface Condition for Coating

Immediately prior to coating application, the Diver shall remove any flash rust and/or accumulated debris (silt, clay, etc.) using a wire brush or other method approved by the Manufacturer.

Note: The surface of the pipe shall meet all preparation requirements listed in Section 3.0 before the coating application.

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REPAIR COATINGS FOR LINE 5
STRAITS**

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Note: alternative protective wraps or encasements are allowed if approved by the coating Manufacturer.

4.3.6

The Stricture Bandings® shall extend at least 4 inches upstream and downstream of the repair.

Note: the Stricture Banding is applied in the same direction of the composite wrap and shall have tension in order to secure the composite wrap.

4.4 Preparation and Application of Composite Repairs (Method 2)**4.4.1**

The X-100 epoxy shall be prepared by thoroughly mixing the X100 – UW Epoxy Base – Blue and the BIO-SEAL™ X-100 Curing Agent – Clear.

4.4.2

The E-glass fabric shall be cut into approximately 12 inch x 12 inch patches and impregnated with the X-100 epoxy to form the composite patches.

4.4.3

Composite patch repairs shall consist of a minimum of 4 layers of the patch applied directly over the epoxy filler and abraded adjacent parent coating. The patches shall be applied in 4 layer patches until the entire repair area (filler and abraded adjacent parent coating) is coated.

4.4.4

Blue Stricture Banding® will be tightly applied 360 degrees around the pipe over the composite patch repairs to a minimum of three (3) layers to assure the radial compression and retention of the repair in place during cure.

Note: alternative protective wraps or encasements are allowed if approved by the coating Manufacturer.

4.4.5

The Stricture Bandings® shall extend at least 4 inches upstream and downstream of the edge of the coating repairs.

4.5 Cure Time**4.5.1**

After application, the coating system will be allowed to cure in place for a minimum of 7 days at 40 °F.

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**Appendix F:
OQ Checklist**

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API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio	Enbridge Employee	
5 Inspect Buried Pipe When Exposed		Group Heading Only				
5.1	Examine for mechanical damage on buried or submerged pipe	x	1:1	1:2		#15: External defect Investigation #21: Inspect/examine buried pipe when exposed
5.2	Examine for external corrosion on buried or submerged pipe	x	1:1	1:1		#21: Inspect/examine buried pipe when exposed
5.3	Inspect the condition of external coating on buried or submerged pipe	x	1:1	1:2		#19: Pipe and valve coating #21: Inspect/examine buried pipe when exposed
7 Application and Repair of External Coatings		Group Heading Only				
7.1	Visual inspection of atmospheric coatings	x	1:1	1:1		#18: Atmospheric corrosion inspection
7.2	Prepare surface for atmospheric coating using hand and power tools	x	1:2	1:2		#20: Corrosion prevention methods
7.3	Prepare surface for coating by abrasive water blasting	x	1:2	1:2		#20: Corrosion prevention methods
7.4	Prepare surface for coating by abrasive blasting methods other than water	x	1:2	1:2		#20: Corrosion prevention methods
7.5	Apply coating using hand application methods	x	1:2	1:2		#20: Corrosion prevention methods
7.6	Apply coating using spray applications		1:2	1:2		#20: Corrosion prevention methods
7.7	Perform coating inspection	x	1:2	1:2		#20: Corrosion prevention methods
8 Measure Wall Thickness of Pipe		Group Heading Only				
8.1	Measure pit depth with pit gauge	x	1:1	1:1		#22: Measure wall thickness of pipe
8.2	Measure wall thickness with ultrasonic meter	x	1:1	1:1		#22: Measure wall thickness of pipe
8.3	Measure corroded area	x	1:1	1:1		#22: Measure wall thickness of pipe
9 Cathodic Protection Remediation		Group Heading Only				
9.1	Install bonds		1:1	1:1		#10.1: Install bonds
9.2	Install galvanic anodes		1:1	1:1		#10.1: Install bonds
9.3	Install rectifiers		1:1	1:1		#8: Rectifier installation
9.4	Install impressed current groundbeds		1:1	1:1		#10: Groundbed installation and repair
9.5	Repair shorted casings	x	1:3	1:3		#11: Shorted casing inspection #12: Shorted casing clearing/repair
9.6	Install electrical insulating device		1:1	1:1		Under Development
10 Monitoring for Internal Corrosion		Group Heading Only				
10.1	Insert and remove coupons		1:1	1:1		#13: Insert and remove coupons
10.2	Monitor probes (on-line)		1:1	1:1		#14: Hydrogen foil inspection
11 Internal Corrosion Remediation		Group Heading Only				
11.0	Monitoring and controlling the injection rate of the corrosion inhibitor		1:2	1:2		#17: Corrosion inhibitor injection
12 Inspect Internal Pipe Surfaces		Group Heading Only				
12.0	Visually inspect internal pipe surface		1:2	1:2		#16: Defect investigation- internal corrosion

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API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge Employee	Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio			
22 Inspect, Maintain and Calibrate Relief Valves		Group Heading Only					
22.1	Inspect tank pressure/vacuum breakers		1:1	1:1		#83: Inspect, test and calibrate overfill protection devices #91: Pressure relief valve test	
22.2	Inspect, test and calibrate HVL tank pressure relief valves		1:1	1:1		#83: Inspect, test and calibrate overfill protection devices #91: Pressure relief valve test #CC5: Control Center: Monitor tank levels	
23 Maintain/Repair Relief Valves		Group Heading Only					
23.1	Maintain/repair relief valves		1:2	1:2		#88: In-service valve repair	
23.2	Inspect, test and calibrate relief valves		1:2	1:2		#91: Pressure relief valve test	
24 Inspect, test and calibrate pressure limiting devices		Group Heading Only					
24.1	Maintain/repair pressure limiting devices		1:1	1:1		#91: Pressure relief valve test	
24.2	Inspect, test and calibrate pressure limiting devices		1:1	1:1		#89: Pressure control Valve (PCV) maintenance	
25 Inspect, test and calibrate pressure limiting devices		Group Heading Only					
25.1	Inspect, test and calibrate pressure switches		1:1	1:1		#92: Pressure switch calibration	
25.2	Inspect, test and calibrate pressure transmitters		1:1	1:1		#93: Inspect and test pressure transmitter	
26 Verify or Set Protection Parameters for Programmable Controllers and/or Instrumentation Control Loops		Group Heading Only					
26.0	Verify or set protection parameters for programmable controllers and/or other instrumentation control loops		1:1	1:1		#90: Pressure allowable set points	
27 Inspect and Repair Breakout Tanks		Group Heading Only					
27.1	Routine inspection of breakout tanks (API 653 monthly or DOT Annual)		1:0	1:1		#52: Tank inspection	
27.2	API 653 inspection of in-service breakout tanks		1:0			Performed Only by Contractor	
27.3	API 510 inspection of in-service breakout tanks		1:0			Performed Only by Contractor	
29 Protect Breakout Tanks from Static Electricity, Lightning, and Stray Electrical Currents		Group Heading Only					
29.1	Launching in-line inspection devices		1:2	1:2		#54: Launching tool (pig) in scraper trap	
29.2	Receiving in-line inspection devices		1:2	1:2		#55: Receiving tool (pig) in scraper trap	
30 Test Overfill Protective Devices		Group Heading Only					
30.0	Test overfill protective devices		1:1	1:1		#83: Inspect, test and calibrate overfill protection devices	
31 Inspect and Calibrate Overfill Protective Devices		Group Heading Only					

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API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio	Enbridge Employee	
32 Monitoring Excavation Activities Group Heading Only						
32.0	Observation of excavation activities		1:1	1:1		#58: Damage prevention during excavation activities
33 Moving In-Service Pipe Group Heading Only						
33.1	Determine allowable line pressure in section to be moved		1:2	1:2		#58: Line lowering
33.2	Preparation for movement activities		1:2	1:2		#58: Line lowering
33.3	Moving in-service pipeline		1:2	1:2		#58: Line lowering
34 Inspect Existing Pipe Following Movement Group Heading Only						
34.0	Inspect existing pipe following movement	x	1:2	1:2		#49: Right-of-way inspections
36 Abandoning, Safe Disconnect, Purging, and Sealing of Pipeline Facilities Group Heading Only						
36.1	Safe disconnect of pipeline facilities		1:2	1:2		#59: Line deactivation
36.2	Purging of pipeline facilities		1:2	1:2		#59: Line deactivation
36.3	Sealing a disconnected portion of pipeline		1:2	1:2		#59: Line deactivation
37 Installation or Repair of Support Structures on Existing Aboveground Components x						
37.0	Install or repair support structures on existing above ground components		1:2	1:2		#82: Install or repair support structures on existing or above ground components
38 Inspection Activities for Tie-Ins, Pipe Replacement, or Other Components Connecting to an Existing Pipeline Group Heading Only						
38.1	Visually inspect pipe and pipe components prior to installation		1:2	1:2		#15: External defect investigation
38.3	Visually inspect that welds meet DOT requirements (in accordance with API 1104)		1:0			Performed Only by Certified Weld Inspectors (API 1104 Certification)
38.4	NDT - radiographic testing		1:0			Performed Only by Contractor
38.5	NDT - liquid penetrant testing		1:0			Performed Only by Contractor
38.6	NDT - magnetic particle testing		1:0			Performed Only by Contractor
38.7	NDT - ultrasonic testing		1:0			Performed Only by Contractor
39 Backfilling a Trench Following Maintenance Group Heading Only						
39.0	Backfilling a trench following maintenance		1:1	1:1		#57: Backfilling activities

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API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge Employee	Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio			
44 CPM Leak Detection Group Heading Only							
44.3	Inspect, test and maintain flow computer for hazardous liquid leak detection			1:1		#CC4: Control Center: Monitor leak detection - Computational Pipeline Monitoring (CPM) (**Liquid Pipelines only) #CC5: Control Center: Monitor tank levels	
44.4	Inspection, testing, corrective and preventative maintenance of tank gauging for hazardous liquid leak detection		1:1			Under Development	
44.5	Prove flow meters for hazardous liquid leak detection			1:1		#CC8: Control Center: Prove Flow Meters for Hazardous Liquid Leak Detection	
44.6	Maintain flow meters for hazardous liquid leak detection		1:1			Under Development	
44.7	Inspect, test and maintain gravimeters/densitometers for hazardous liquid leak detection		1:1			Under Development	
44.8	Inspect, test and maintain temperature transmitters for hazardous liquid leak detection		1:1			Under Development	
52 Leakage Survey (retained from previous version) Group Heading Only							
52.1	Conduct vegetation survey		1:1	1:1		#84 Gas leakage survey	
52.2	Conduct a leak survey with a CGD		1:1	1:1		#84 Gas leakage survey	
52.3	Conduct a leak survey with a flame ionization unit		1:1	1:1		#84 Gas leakage survey	
65 Fixed Gas Detection (retained from previous version) Group Heading Only							
55.0	Maintain fixed gas detection equipment		1:1	1:1		#94: Station gas detection calibration	
63 Operation of a Pipeline System Group Heading Only							
63.1	Start-up of a liquid pipeline (field)		1:1	1:1		#95: Local operation of pumps (start up/shut down of a pump)	
63.2	Shutdown of a liquid pipeline (field)		1:1	1:1		#95: Local operation of pumps (start up/shut down of a pump)	
63.3	Monitor pressure, flows, communications and line integrity and maintain them within allowable limits on a liquid pipeline system (field)		1:1	1:1		#89: Pressure Control Valve (PCV) maintenance #96: Pressures, flows and communications monitoring - field ops	
63.4	Locally operate valves on a liquid pipeline system		1:1	1:1		#50: Local operation of valves #86: Remote communicated valve check	
Enbridge LP Representative (Print Name):							

From: noreply@engagingplans.org
To: [MiPetroleumPipelines](#)
Subject: Form submission from: Contact Us
Date: Saturday, September 16, 2017 7:46:26 PM

Submitted on Saturday, September 16, 2017 - 7:46pm

Submitted by anonymous user: 72.106.160.15

Submitted values are:

Your Name: Carol Gilewicz

Your Email Address: gilewicz.carol@gmail.com

Your Phone Number: 231-675-4507

Subject: Submit Information/Comments

Attachment:

Your Message:

At the very least, Enbridge Line 5 should be suspended pending a full inspection & review of ALL of the information. The Great Lakes are too precious to be in this kind of preventable danger and it is evident that Enbridge cannot be trusted to self-monitor, let alone maintain the pipelines. NOW is a really good time to stop the flow - after the fact is just too late.

The results of this submission may be viewed at:

<https://mipetroleumpipelines.com/node/5/submission/139>

From: noreply@engagingplans.org
To: [MiPetroleumPipelines](#)
Subject: Form submission from: Contact Us
Date: Monday, September 18, 2017 1:05:33 PM

Submitted on Monday, September 18, 2017 - 1:04pm

Submitted by anonymous user: 68.62.56.196

Submitted values are:

Your Name: Anna Fisher

Your Email Address: irjuk@hotmail.com

Your Phone Number:

Subject: Submit Information/Comments

Attachment:

Your Message:

I resonated with what Deb Hansen said at today's meeting. Indeed, the presence of 23M gal of oil coursing through the fresh waters of our Great Lakes is a moral and ethical emergency! and I would add a spiritual emergency. It is soul crushingly painful to see that Gov Snyder and AG Schuette, and Enbridge, and perhaps even some of you on this Board don't realize the amazing beauty, energy, power, and abundance that is the gift of these Great Lakes. That these Lansing bureaucrats would jeopardize this precious gift of pure, beautiful fresh water for oil and greed driven profit is indeed unconscionable. Disgusting. How could they?! What is WRONG with them?!

We are growing more and more angry at the inaction from Lansing politicians. It's been THREE YEARS, and yet this pipeline continues to be analyzed and studied. With each growing day, with each "kicking it down the road for yet another study," the threat looms larger. Enbridge said at their presentation at Holt High School on July 6, 2017 that this pipeline can last until 2053. THAT in itself should be yet another glaring example of Enbridge's dishonesty to the people of Michigan. We're not going to stand for it and neither should you! The time has come to decommission line 5 immediately! As Dale Giddings said in his comments today, no sane or sober person would allow this game of Russian roulette to continue because the consequences are too great.

The results of this submission may be viewed at:

<https://mipetroleumpipelines.com/node/5/submission/143>

Comments by Dale Giddings at the Sept 18, 2017
Pipeline Safety Advisory Board meeting, Lansing Mich

In the game of Russian roulette, you put a bullet in one chamber of the revolver, spin the cylinder, point the gun at your head and pull the trigger. No sane and sober person plays this game because the consequences of losing are too great.

Now imagine a revolver with 10,000 chambers. The probability of losing is now much less. Yet no sane and sober person would play because the consequences of losing are too great.

Now supposed you have the 10,000 chambers, one bullet, and with each win you get a pay-off of a million dollars. Even with this incentive, no sane and sober person would play because the consequences of losing are too great.

But what if you had 10,000 chambers, one bullet, a pay-off of a million dollars with each win, and you get to point the gun at somebody else. There are people who would jump at the chance to play under these conditions, but no sane, sober, and moral person would, because the consequences of losing are too great.

Yet this is exactly the kind of game that Enbridge is playing in the Straits of Mackinaw. Each day they pump oil through line 5 is a spin of the cylinder and the people of Michigan have to look down the barrel. Enbridge gets the pay off, we pay the risk.

It should come as no surprise that we, especially those who live near the bull's eye, are not happy about being forced to play this dangerous game. Thus, because the consequences of losing are too great, we have been trying everything we can think of to end it. So far to no avail. We could use a little help from officials in Lansing, officials whose job it is to protect the people and resources of Michigan.

Help us end this dangerous game! Shut down line 5 before we all lose.

From: noreply@engagingplans.org
To: [MiPetroleumPipelines](#)
Subject: Form submission from: Contact Us
Date: Monday, September 18, 2017 6:02:46 PM

Submitted on Monday, September 18, 2017 - 6:02pm

Submitted by anonymous user: 73.73.156.185

Submitted values are:

Your Name: Dr. James Hill

Your Email Address: hilljp@cmich.edu

Your Phone Number: 989-400-0186

Subject: Submit Information/Comments

Attachment:

Your Message: As one of the CMU team members who spoke to the task force about creating a study on LIne 5 last year, I was pleased that you are forming a university team to handle the conflict of interest in the original study. However, I would suggest that data collected in the original study be used to expedite this university team analysis and that the new team have policy analysts as well as scientists on the university team to ensure that all aspects of this issue are addressed and not just the mechanical ones. Thank your for your consideration.

The results of this submission may be viewed at:

<https://mipetroleumpipelines.com/node/5/submission/144>

From: noreply@engagingplans.org
To: [MiPetroleumPipelines](#)
Subject: Form submission from: Contact Us
Date: Monday, September 18, 2017 8:47:49 AM

Submitted on Monday, September 18, 2017 - 8:47am

Submitted by anonymous user: 68.42.72.17

Submitted values are:

Your Name: Barbara Steer

Your Email Address: Barbarasteer@gmail.com

Your Phone Number: 734.834.438

Subject: Submit Information/Comments

Attachment:

Your Message: Close down line 5. Enbridge has been heel-dragging and obfuscating. Shut it down. Re-open after an appropriate fix, if necessary. But shut it down now.

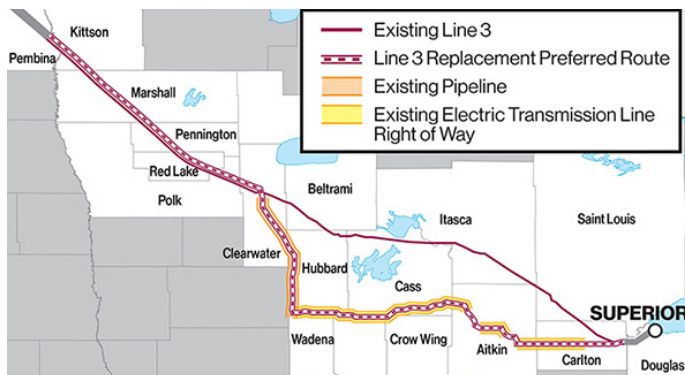
The results of this submission may be viewed at:

<https://mipetroleumpipelines.com/node/5/submission/141>

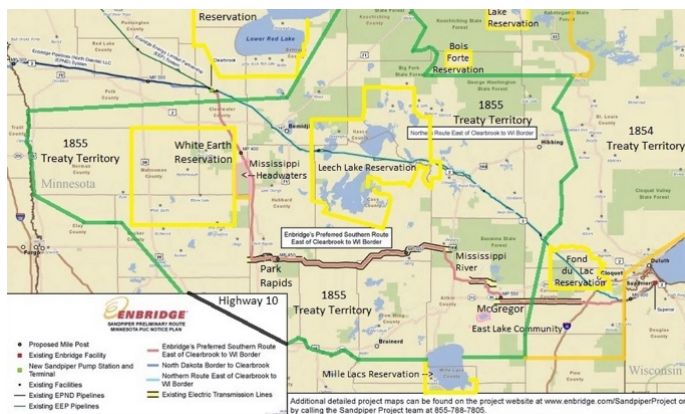
Line 3 – What it could mean for Line 5

There's tremendous value in trying to work with the state of Minnesota to evaluate the need of both Line 3 and Line 5 as vintage pipelines. Many have already noted throughout the Line 5 review process that pipeline expansions throughout MN, WI and MI have provided Enbridge more than enough additional capacity to consider the retirement of outdated pipelines like 3 and 5, including the expansion of Line 6b (now Line 78) through Michigan. Below is a breakdown on a few of Enbridge's expansion projects within the Lakehead system and a possible avenue for reconsidering other Lakehead pipelines as alternatives to Line 5.

The current Line 3 was built in the 1960's and was made from a vintage pipe that is well known within the industry and with regulators for corrosion and failure. It is a 34-inch pipeline that should have a capacity of 760,000 barrels per day (31.9 million gallons). Because of its poor condition, the current capacity is restricted to 390,000 barrels per day (16.3 million gallons). The limited capacity, excessive repair schedule and consent decree from the 2010 Enbridge oil spill has forced Enbridge to develop a plan to build a new pipeline and decommission the old. They have proposed a 36-inch pipeline that could transport up to 844,000 barrels per day (35.4 million gallons a day) at maximum capacity but as much as 1 million barrels per day (42.6 million gallons) with the ultimate design capacity. Since 2010, Line 3 has been delivering light crude (only) to Superior, Wisc. ([pg. 7](#))



This pipeline enters the US in North Dakota (ND) and travels throughout most of northern Minnesota (MN) before entering Wisconsin (WI) where it connects with other Lakehead pipelines in Superior. The old Line 3 is one of 6 Enbridge pipelines in this corridor. To the left is a map showing the existing line 3 and the proposed route for the new and larger pipeline. Enbridge's preferred route for the new pipeline circumvents most reservations but does not avoid treaty land.



Enbridge has already built the new Line 3 in most of Canada, ND and WI. The state of MN is currently in the process of trying to determine the certificate of need as well as a routing permit and this decision sits with the Public Utility Commission (PUC).

For reviewing the certificate of need, the PUC requests that agencies, such as the Department of Commerce (DOC), consider if Enbridge has properly justified the need for this pipeline through MN. The DOC has provided written testimony as part of the PUC process stating that Enbridge's proposal for a 36-inch pipeline does not meet their needs for proof of necessity.

Reasons highlighted throughout the submitted testimony on why Enbridge has not provided proof of necessity:

- There is a downturn of oil production out of Canada and the Bakkan.
- Other pipelines, such as Line 67, have already increased in capacity and MN refineries don't show a need for additional supply. *Note that Line 67 is a heavy oil pipeline only, so Line 5 does not receive oil from the increased supply running through this pipeline.*
- With the forecasted downturn of oil, Enbridge may not maintain the liquid assets they do today to properly cover significant spills in the future.
- The size of pipeline they are proposing, 36-inches, is "excessive".
- The DOC reviewed an alternative route for Line 3 oil, which would follow the Alliance Pipeline right-of-way (ROW) to the south - directly to Chicago. The ROW is a viable route alternative but would cost more and is a greater distance of new pipeline. [\(pg. 48\)](#)
- With Enbridge's acquisition of Spectra Energy, they have new access to ROW and pipelines to transport product. This would cost more for Enbridge.
- For all alternatives review by the DOC, using existing pipelines, the DOC notes that Enbridge would not provide needed data regarding throughput of their pipeline networks. The DOC could not carry out their own analysis for use of existing pipelines as an alternative. They noted that they had to rely on Enbridge's own analysis and that calculations and graphs, provided by Enbridge, were manipulated to show more need than was actual reality. [\(pgs. 53-68\)](#)
- Enbridge appears to be overinflating the jobs attached to this project. [\(pg. 69\)](#) Enbridge originally stated that government employment would increase by over 2000 but when the DOC inquired about that number, Enbridge changed that figure to 87. DOC notes that almost all jobs are limited to construction only.
- The DOC also disputes the figures Enbridge claims for property tax revenue – [Enbridge is openly trying to dispute having to pay property tax throughout MN.](#)
- A new pipeline corridor would open another door for additional pipelines at a time when supply is in decline. [\(pg. 82\)](#)
- MN has energy policy for 25% renewable sources – does this project help MN meet that goal? [\(pg. 82\)](#)
- Line 3 would likely convert to a heavy crude oil pipeline with the replacement/expansion and that conversion would add to GHG emissions regionally.
- The FEIS states that each route option would affect tribal resources, tribal identity and tribal health and that "any of the routes selected between North Dakota and Superior, Wisconsin, therefore, would have a disproportionate and adverse effect on tribal resources and tribal members, even if the route itself does not cross near residences." [\(pg. 87\)](#)
- "In light of the serious risks of the existing Line 3 and the limited benefit that the existing Line 3 provides to Minnesota refineries, Minnesota would be better off if Enbridge proposed to cease operations of the existing Line 3, without any new pipeline being built." [\(pg. 87\)](#)
- Enbridge never once, throughout their proposal, commits to ceasing operation of the old Line 3 with a replacement despite their extensive testimony on risk for continued operation. [\(pg. 87\)](#)

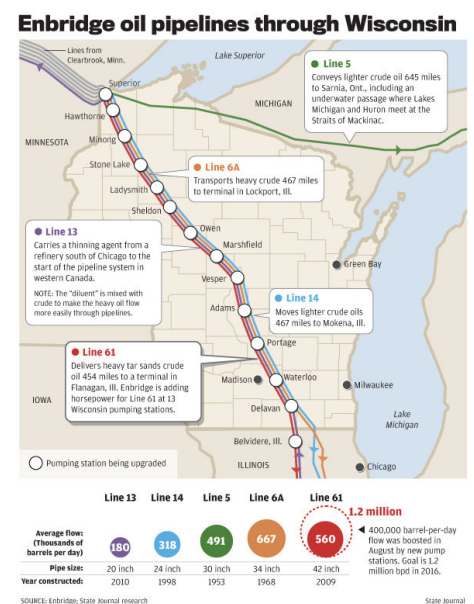
It is incredibly important to note that MN review of this pipeline, particularly from the DOC testimony, keeps MN interests as the focus of their review and does not focus on the needs of Enbridge.

Other critical points pulled from the DOC testimony to the MN PUC:

- For the existing Line 3 - “Dig and repair costs were forecasted to exceed \$6 billion through the year 2026, and replacing the segments in the worst integrity condition would only lower the forecasted cost to \$4.3 billion.” (pg. 8)
- For the existing Line 3 - “4,000 integrity digs over the next 15 years to maintain its operational integrity.”
- In addition, Section 3.1.1 of the Company’s Application concludes, that, “[w]hile Line 3 can be safely operated under a dig and repair maintenance regime, the extensive number of digs and repairs along the entire pipeline would still not remove the pressure restrictions.”
- Per the consent decree by the DOJ and EPA: “If Enbridge has not taken all portions of Original US Line 3 out of service by December 31, 2017, Enbridge shall comply with the additional requirements set forth below:
 - (1) On an annual basis with the exception of the final year of service for the Original US Line 3, Enbridge shall complete valid ILIs [In-Line Inspections] of all portions of Original US Line 3 that Enbridge continues to operate, using the most appropriate tools for detecting, characterizing, and sizing all of the following: Crack Features, Corrosion Features, and Geometric Features;
 - (2) Enbridge shall identify, excavate and mitigate or repair all Features Requiring Excavation detected in the ILIs required pursuant to Subparagraph 22.d.(1), in accordance with the requirements of Subsection VII.D; and
 - (3) Enbridge shall clean all portions of Original US Line 3 that Enbridge continues to operate and shall use biocide treatments to reduce microbiological activity on a quarterly basis.”

What’s happening downstream from Superior, Wisconsin

Line 61 is a 42-inch pipeline that travels from Superior, WI to IL and transports light, medium and heavy oil product. Prior to 2014, Line 61 carried 400,000 barrels per day but has since been upgraded to transport [1.2 million barrels per day](#). This expansion is a result of [new or increased pumping stations](#) throughout the pipeline and is not the result of additional pipeline(s). Enbridge has also hinted to investors, as well as surveyed landowners along their ROW, that they plan to [twin line 61 with a new 34’ pipeline](#), which would have the potential to add an additional 800,000 barrels per day to that corridor. A twinned pipeline would make Line 61 the largest pipeline in the world and it would run from Superior, WI to Flanagan, IL. Despite Enbridge’s action to set in motion their plans to twin Line 61, they continue to deny that it is moving forward with media and decision makers.



Based on the above points, I draw this conclusion:

- If Enbridge's rebuild/expansion of line 3 is not completed, which Enbridge anticipated would happen by late 2017, then the projected increased amounts for Line 3 are potentially freed up in downstream pipelines – most likely Line 61 since that's their focus for increased capacity south of Line 3.
- The difference in the amount of oil currently running on Line 3 vs. what Enbridge projected is 450,000 barrels per day. If the Line 3 expansion is not approved by the state of MN, and Enbridge decommissions Line 3, then anywhere between 390,000-844,000 barrels per day are no longer being used in downstream pipelines and could be available for diversion of Line 5 oil.

Next steps:

- The state of Michigan should start an open conversation with the state of Minnesota about their review process for Line 3. Where applicable, Michigan, and any future contractors, should consider some of the experts obtained for their review of Line 3. In particular, I encourage the review of testimony for [Marie Fagan](#) with London Economics and [David Dybhahl](#) on insurance and risk.
- The state of Michigan should review the set of procedures and regulations currently used by Minnesota PUC for pipeline siting decisions.
- The state of Michigan should request access to all of the Enbridge models that were supplied to the state of Minnesota but were redacted from the public DOC testimony, which would show a more complete picture on oil use on the Lakehead system.
- Enbridge needs to show complete transparency on their current and projected capacity in the region to both Michigan and Minnesota. These documents might better describe how they currently use the Lakehead system and their projected transport of the additional 450,000 barrels per day that are accounted for in the Line 3 expansion.
- Great Lakes states should consider a more regional discussion around our energy goals and how these state-to-state fossil fuel projects impact our resources and communities as a whole.



U.S. Department
of Transportation

Pipeline and Hazardous
Materials Safety
Administration

1200 New Jersey Avenue, SE
Washington, D.C. 20590

October 24, 2017

Ms. C. Heidi Grether
Michigan Pipeline Safety Advisory Board
P.O. Box 30221
Lansing, MI 48909

Dear Ms. Grether:

Thank you for your letter of September 21, 2017, regarding the National Pipeline Mapping System (NPMS). The Secretary asked that I respond on her behalf.

The Michigan Pipeline Safety Advisory Board (PSAB) requested that Pipeline and Hazardous Materials Safety Administration (PHMSA) allow the State of Michigan to enhance public access to information contained in the NPMS, at the state-wide level. The NPMS was established under 49 USC Section 60132 and is implemented through 49 CFR 191.29 and 49 CFR 195.61. Specifically, the PSAB seeks to disseminate maps to the public containing NPMS data for the state of Michigan, to increase transparency and public engagement. PHMSA appreciates your interest in improving pipeline safety and pipeline mapping through public engagement and increased transparency. We will respond to your request after consulting with security experts within the Department of Transportation and the Transportation Security Administration (TSA).

Our mission requires us to “protect people and the environment by advancing the safe transportation of energy and other hazardous materials.” Therefore, we must balance transparency and public engagement interests with public safety and pipeline security risk, particularly given the recent increase in pipeline-related security threats. Under the current NPMS data access policy, the maps you request are limited to state officials. The public may only access information for one county at a time. PHMSA established this policy in 2007 after discussions with the TSA regarding appropriate protection for pipeline data. Changing the NPMS data security policy to permit the public to view maps for more than one county per session would have national ramifications.

To support transparency and public engagement related to pipeline mapping under our existing policy, we recently updated the NPMS Public Viewer Web interface to provide a more intuitive user experience with faster performance and improved background maps, and released an iPhone app for the Public Viewer. These mapping enhancements can be accessed at:
www.npms.phmsa.dot.gov.

As we review our determination to limit the extent of pipeline maps available to the public, we will keep you informed of any changes. We also welcome information from you regarding specific ways a state pipeline map can help promote pipeline safety.

If you have any further questions or concerns, please feel free to contact me or have your staff contact Patricia Klinger, Deputy Director of the Office of Governmental, International and Public Affairs, by phone at 202-366-4831 or by e-mail at Patricia.Klinger@dot.gov. I hope this information is helpful.

Sincerely,

A handwritten signature in black ink, appearing to read "Drue Pearce", with a large, stylized "D" at the beginning.

Ms. Drue Pearce
Acting Administrator

From: Cam Spady <cam.spady@cylotech.com>
Date: November 1, 2017 at 3:22:08 PM EDT
To: <Braderv@michigan.gov>
Cc: Jennifer McKay <jenniferm@watershedcouncil.org>
Subject: Line 5 and Prior Communication with Jennifer McKay

Dear Mrs. Brader:

I have followed some of the Michigan Pipeline Safety Advisory Board proceedings with respect to your struggle with Enbridge's Line 5 since last February, when I had the pleasure of a chance meeting of a concerned Michigan resident while he was vacationing in Houston. At his urging, I have since been in contact with Board member Jennifer McKay by email and phone, and we have discussed this matter with enough detail and emotion to know that the relationship between the Board and Enbridge may at best be described as strained. This view was reinforced when I read an article by John Flesher (AP) where you are quoted as saying (in part) that "right now any trust we had in Enbridge has been seriously eroded".

With this quote in mind, I again contacted Ms. McKay to seek her advice on reaching out to you directly, which she encouraged. As Ms. McKay and I have exchanged a number of lengthy emails, I offer the following as a brief summary of some of the things discussed.

- The Board has thus far been in a position where it has had to rely on Enbridge's assertion that Line 5 is 'safe'
- This proclamation by Enbridge relies solely on their own interpretation of closely held in-line inspection data, which you have not been given access to.
- The Board's faith in Enbridge with respect to pipeline safety and business practices continues to decline.

I am part of a small, Calgary, Alberta based ILI software and data management company. We do not do business with nor have we ever been able to gain any traction trying to secure any business from Enbridge despite many attempts. I offer this to you only to verify that we have no conflict of interest with respect to Enbridge or any of its affiliates. I have previously offered to Ms. McKay and now to you the possibility that Cylo Technologies would be willing to do a limited amount of pro bono work for the Advisory Board with two purposes in mind. First and foremost is the fact that you would be able to see in a graphic three-dimensional detail every defect on Line 5 under the Straights. I would ask for the opportunity to present to you how this is possible. The second, and far less altruistic purpose of my offer is the possibility that it could lead to further for-profit work for your Board or even the highly unlikely scenario that Enbridge would secure our services to avoid further embarrassment that a regulatory body has better tools to analyse the condition of their pipelines than they do. At a minimum, the Michigan Pipeline Safety Advisory Board would gain a significant upper hand in the battle for truth about Line 5.

It would be a privilege if Cylo could be of service to you, and I would ask that we be able to further this discussion. As the tone of this email is highly critical of Enbridge, who is a major player in the business space we operate in, I would ask that this and other communication between us be kept in confidence, regardless of your decision to move forward or not. I have copied Ms. McKay on this email, and thank you so much for your time. Please call me toll free at 1.866.370.7367 ext. 702 if there is a possibility of having a conversation on this subject.

Sincerely,

Cam Spady
Director, Business Development
Cylo Technologies Inc.

www.CyloTech.com

Phone: (403) 620-5731



Protecting the Common Waters of the Great Lakes Basin
Through Public Trust Solutions

November 2, 2017

Governor Rick Snyder P.O. Box 30013 Lansing, Michigan 48909	Executive Director Valerie Brader Michigan Agency for Energy P.O. Box 30013 Lansing, Michigan 48909-7958
Attorney General Bill Schuette G. Mennen Williams Building, 7th Floor 525 West Ottawa Street P.O. Box 30212 Lansing, Michigan 48909	Director Keith Creagh Michigan Department of Natural Resources Executive Division P.O. Box 30028 Lansing, Michigan 48909
Director Heidi Grether Michigan Department of Environmental Quality P.O. Box 30458 Lansing, Michigan 48909-7958	

VIA EMAIL SUBMISSION

Dear Governor Snyder, Attorney General Schuette, Director of Michigan Department of Environmental Quality, Director of Michigan Department of Natural Resources, and Director of Michigan Agency for Energy:

As you know, For Love of Water ("FLOW") is a Michigan nonprofit corporation dedicated to researching, evaluating, and providing sound law, science, and policy to protect the waters of Michigan and the Great Lakes, their bottomlands, aquatic resources, and the public trust in these lands, waters, and their protected public trust uses. With respect to crude oil pipeline transport in the Great Lakes, FLOW has submitted numerous legal and technical reports on the high risks associated with Line 5, including the segment in the Straits of Mackinac, over the past three years.

FLOW is gravely troubled by Enbridge's recent acknowledgement of bare spots being caused by anchor supports, which have been installed along the pipeline since 2003, and further troubled by the fact that Enbridge detected the bare steel three years ago in 2014 and only disclosed the information to the State of Michigan last week. Enbridge has lost credibility and trust from state leaders and Michiganders alike. In a [letter](#) dated November 1, 2017 to Enbridge, Representative Fred Upton called Enbridge's response and lack of transparency "absolutely unacceptable."

Following last week's news, FLOW is submitting a supplemental technical paper from our technical advisor, Gary Street, a retired Dow Chemical engineer who has spent several years studying and documenting his technical concerns related to Enbridge Line 5. Mr. Street's enclosed technical paper, entitled "*Zebra and Quagga Mussels and their Impact on Bare Steel*," concludes that the twin pipelines in the Straits may have experienced pitting corrosion at the various "holiday" locations, which may have diminished the wall thickness by almost 50 percent.

Enbridge's current reliance on remote underwater video and smart pig inspection are inadequate tools to study and evaluate pitting corrosion caused by invasive mussels encrusting the Line 5 pipelines. Because pitting corrosion is more difficult to detect, predict, and design against, there could be many more damaged areas that occurred years ago and since then have been overgrown by mussels and other biologic growth and not identified by underwater video.

This technical paper's findings, combined with Enbridge's June disclosures of bends in the lines and concealed attempts to address the failure in design, conflicts of interest, and now the recent disclosure of known bare metal spots on the pipeline for a minimum of three years, elevate the risk of a catastrophic oil spill beyond any prudent or acceptable level. We therefore urge the State of Michigan to exercise its powers and take the following immediate actions:

- (1) Require Enbridge to conduct an immediate investigation on the impact of zebra and quagga mussels on bare steel. FLOW and our independent technical advisors (Gary Street, Ed Timm and Rick Kane) are available to meet with the State of Michigan for a meeting to discuss these concerns in further detail;
- (2) Revoke the 1953 easement or its use based on the imprudence of continued use of the lines because of the non-curable failures of the line and violations of the 1953 easement, which present an unreasonable threat to public and private property, the public trust in and public use of these highly valued waters and bottomlands; and
- (3) Require Enbridge, as part of the pending application for anchor supports under the GLSLA, MCL 324.32501 et seq., to obtain authorization for occupancy and permits for the continued use of the lines and new or added structures. This must include (a) a showing that the lines and supplemental structures in their entirety will not endanger or impair the public trust, safety, or health and welfare of the public; and (b) a showing that there is no feasible and prudent alternative to Line 5 and/or the lines in the Straits taking into account the entire Enbridge and related system through the Great Lakes basin and Michigan.

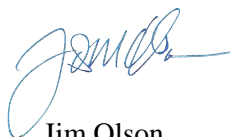
It is our hope that as leaders of the State you will take these actions and place the responsibility where it belongs—on Enbridge. We submit that this is the only reasonable and lawful means that will eliminate the imprudent and unacceptable risk of catastrophic harm to the Great Lakes, property owners, businesses, communities, and the public threatened and endangered by the transport of crude oil in the twin pipelines in the Straits' segment of Line 5.

Nothing less than Michigan's heritage, legacy, and future are at stake. Thank you.

Respectfully yours,



Liz Kirkwood
Executive Director



Jim Olson
Founder and President

Zebra and Quagga Mussels and their Impact on Bare Steel

Gary Street, M.S., P.E.

October 27, 2017

Overview:

Enbridge has acknowledged there are several large areas of the pipeline where the protective coating is missing. We know that pseudofeces from zebra mussels and quagga mussels are corrosive to bare steel. However, we do not know for certain what caused the bare spots. Enbridge has said they may have occurred when the new supports were being installed. This may or may not be the case. Making the matter even more uncertain, we do not know how long the various bare spots have been exposed to corrosion by the presence of the zebra mussels.

Given the lack of precise knowledge, and the extreme environmental hazard posed by a rupture of Line 5 at the Straits, the prudent scenario is to assume that damage originally occurred in 2003 when the first of the new supports were installed. That being the case, it is very possible that the Line 5 pipe wall has suffered serious pitting corrosion beginning at that time. Making the matter worse, pitting corrosion is difficult to detect.

Introduction

Recently, it was reported that sections of the coating on Enbridge Line 5 are missing – gone. The sections missing are as large as dinner plates¹ - and larger. Quoting the MLive article:

Seven pipeline "holidays," or areas of external anti-corrosion coating loss, are detailed in inspection documents sent to the state on Friday, Sept. 8, and obtained by MLive.

Several holidays are larger than the "Band-Aid"-sized areas Enbridge initially described when the gaps were revealed. The largest patch of exposed pipeline metal is 16 inches long and 10 inches wide. Others are narrower but also exceed a foot in length.

Also detailed in the reports is a "disturbed" coating area that's more than 3 feet long, a "dislodged" coating area that's 13 feet long and a mysterious 8-inch "white deposit" of unknown origin that Enbridge says "remains under investigation."

¹ http://www.mlive.com/news/index.ssf/2017/09/line_5_coating_inspection.html#incart_river_home

This news is very disturbing.

Enbridge attributes the bare spots to the installation of pipeline supports. If we accept the Enbridge explanation, we need to remember the first of these supports were installed in 2003² – fourteen years ago. As will be discussed later, this length of time is very important.

Impact of Zebra and Quagga Mussels on Bare Steel

The presence of bare steel raises the very real possibility of corrosion of the steel by zebra (and quagga) mussels. While the mussels were not present when Line 5 was constructed in 1953, they are a reality today.

By September of 1991, zebra mussels were found in all five of the Great Lakes.³

Numerous sources have documented the corrosive impact of zebra mussels on bare steel.^{4,5,6,7,8} Thus, there can be no doubt both zebra mussels and quagga mussels are corrosive to bare steel.

The cause of their corrosiveness is the excrement^{9,10,11,12} from the mussels, which is acidic. **An acidic deposit on bare steel leads to corrosion.**

Are all types of corrosion equally harmful? No. Some forms are far worse than others. **Pitting corrosion** is a localized form of corrosion by which cavities or "holes" are produced in the material. While corrosion of bare steel can take many forms, the most insidious, and the one we must be especially concerned with is pitting corrosion. Pitting corrosion is more dangerous

² Letter from Enbridge, dated May 20, 2003, by Adam Erickson, to John Arevalo, Michigan Department of Environmental Quality, titled "Enbridge Energy's Joint Permit Application for Repair Work to be Completed on Crude Oil Transmission Pipelines Located in the Straits of Mackinac. MDEQ Permit Number: 01-24-0046-P.

³ <https://www.oneonta.edu/academics/biofld/PUBS/OP/Biology,%20Invasion,%20and%20Control%20of%20the%20Zebra%20Mussel%20in%20North%20America%20OP%2024.pdf>, p. 9

⁴ Zebra Mussel Research Technical Notes, Prepared and published by the Zebra Mussel Research Program, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS, 39180-6199, Technical Note ZMR-2-07, and Section 2, Revised January 1998, p. 2.

⁵ Zebra mussel migration to inland lakes and reservoirs: A guide for lake managers. Ohio Sea Grant, Published by Ohio State University. Author: Robert Heath, Dept. of Biological Sciences Water Research Institute, Kent State University, 1994, p. 2.

⁶ USGS: <https://nas.er.usgs.gov/queries/factsheet.aspx?speciesid=5>, See "Impact of Introduction", paragraph 1.

⁷ U.S. Fish and Wildlife Service, Zebra Mussel (*Dreissena polymorpha*), Ecological Risk Screening Summary, published February, 2011, Revised July 2015, p. 7.

⁸ USGS: Nonindigenous Aquatic Species: Benson, A.J., D. Raikow, J. Larson, A. Fusaro, and A.K. Bogdanoff. 2015. *Dreissena polymorpha*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL.
<http://nas.er.usgs.gov/queries/factsheet.aspx?speciesid=5> Revision Date: 6/26/2014

⁹ <https://www.livescience.com/27415-shipwreck-alley-threatened-by-invasive-mussels.html>

¹⁰ https://www.michigan.gov/documents/deq/wrd-ais-dreissenids_499881_7.pdf, p. 5.

¹¹ <http://www.aquaticnuisance.org/wordpress/wp-content/uploads/2009/01/FCRPS-foul-release-coating-cost-estimate.pdf>, p. 1 – under the heading "Background".

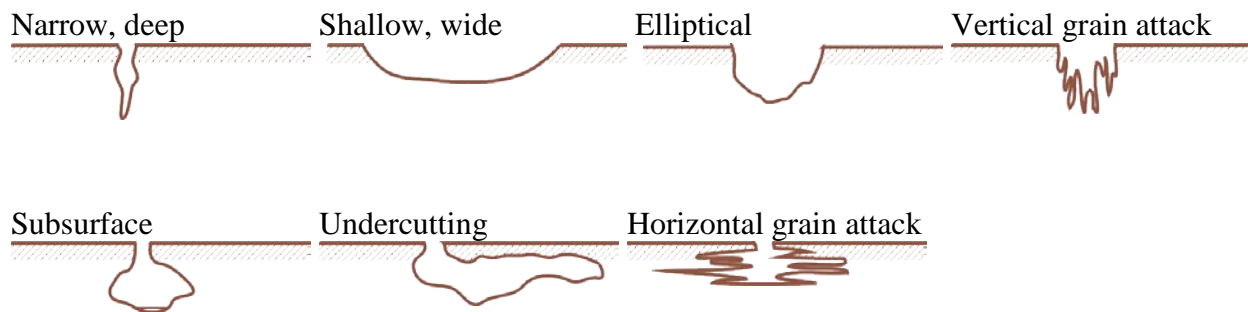
¹² https://www.fws.gov/nevada/nv_species/invasive_species/mussels.htm

than Uniform Corrosion because it is more difficult to detect, predict, and design against. Corrosion products often cover the pits.

Quoting the National Association of Corrosion Engineers (NACE),¹³

"Pitting is considered to be more dangerous than uniform corrosion damage because it is more difficult to detect, predict and design against. Corrosion products often cover the pits. A small, narrow pit with minimal overall metal loss can lead to the failure of an entire engineering system."

Typical examples of pitting corrosion are shown below:¹⁴



Limitations to the Detection of Pitting Corrosion by Smart Pigs

Enbridge relies on "Smart Pigs" to monitor corrosion in their pipelines. However, "Smart Pigs" are not 100% reliable.

Quoting a recent article in the Wall Street Journal:¹⁵

"... smart pigs might not be enough. Enbridge...a major Canadian pipeline company, has spent over \$4.4 billion to upgrade pipeline safety. It is spending big bucks after one of its pipelines spilled oil into the Kalamazoo River in 2010 – a corrosion breach that Enbridge's smart pigs failed to detect ahead of time."

"... despite recent advances, smart pigs aren't terribly accurate."

¹³ <https://www.nace.org/Pitting-Corrosion/>

¹⁴ <https://www.nace.org/Pitting-Corrosion/>

¹⁵ Fowler, Tim, and Gilbert, Daniel, "Oil-Pipeline Cracks Evading Robotic Smart Pigs", Wall Street Journal, August 16, 2013.

Corrosion Rates

Corrosion rates in the U.S. are expressed in mils per year (mpy), a mil being a thousandth of an inch.¹⁶ So how much corrosion can be tolerated before it becomes alarming?

Mils per year or mpy, is used to give the corrosion rate in a pipe, a pipe system or other metallic surfaces. To calculate the material loss or weight loss of a metal surface, there is a formula using the type of metal, the size of the sample area and the time of exposure, giving the value of mils per year. The expression mpy is mostly used in the United States. One Mil is equal to one thousandth of an Inch. In metric, one mil per year equals to 0.0254 mm/y.

*In an open water system a corrosion rate of around 1 mpy is normal. Having corrosion rate of around 10 mpy, you should take action. **Corrosion rates of 20 MPY and above, you should be concerned, as the corrosion is eating the metal rather fast.***

The 1998, the US Army Corps of Engineers issued a definitive report that addresses how much corrosion, in mpy, can be caused by the impact of zebra mussels on bare steel.¹⁷ **Their report concludes the pitting corrosion rate would be in the range of 10-30 mpy. This is within the “you should be concerned” range of the reference cited above.**

A “Most Probable Scenario” Regarding Pitting Corrosion on the Exterior of Line 5:

- US Army Corp of Engineers pitting corrosion rate on bare steel by zebra mussels: 30 mpy
- Possible years of exposed bare steel for Line 5: 14 years

30 mpy = 30/1000 inches per year = 0.03 inches per year

For 14 years, this amounts $0.03 \times 14 = 0.42$ inches of pitting corrosion.

Original wall thickness of Line 5 at the Straits = 0.812 inches (schedule 60 pipe, 20 inches outside diameter).

Probable wall thickness in 2017 due to pitting corrosion since 2003 = $(0.812 - 0.42) = 0.392$ inches.

To say it another way, where pitting corrosion due to the impact of zebra mussels on bare steel has occurred, **the wall of the pipeline may be only 48% as thick as it was in 1953 when it was originally installed.**

¹⁶ <https://www.merusonline.com/mpy-mils-per-year/>

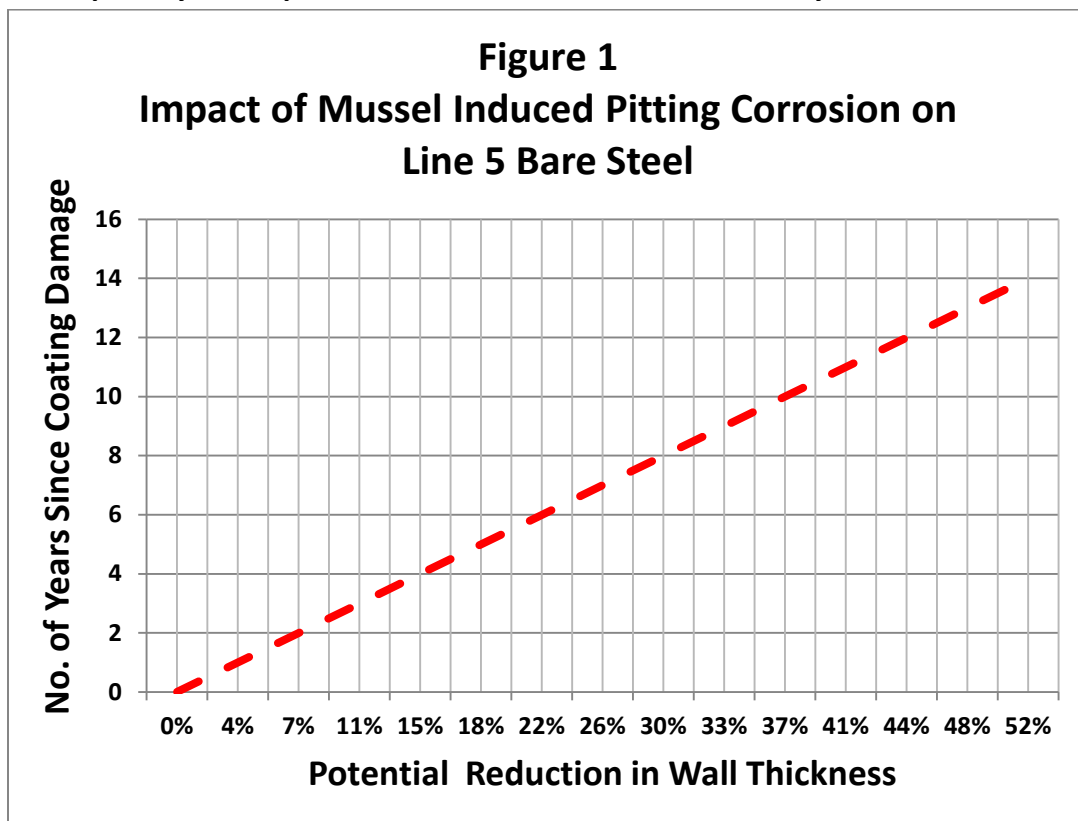
¹⁷ Zebra Mussel Research Technical Notes, Prepared and published by the Zebra Mussel Research Program, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS, 39180-6199, Technical Note ZMR-2-07, and Section 2, Revised January 1998, p. 2-3.

In addition, it must be remembered that **corrosion never stops. Every year Line 5 remains in service, pitting corrosion will increase by 0.03 inches. While this may seem small, the cumulative effect spells disaster.**

Summary

- Enbridge has admitted that large areas of the coating are missing, exposing the bare steel to the underwater environment.
- Zebra mussels had arrived in all five Great Lakes by 1991.¹⁸
- The excrement of zebra mussels is acidic, and corrosive to bare steel.
- The U.S. Army Corps of Engineers has stated the corrosion rate caused by zebra mussels can be as much as 30 mpy (mpy = mils per year. One mil per year = 1/1000 of an inch per year).
- The type of corrosion caused by zebra mussels would be pitting corrosion.
- Pitting corrosion is very difficult to detect.
- If damage to the coating took place in 2003 when the initial supports were installed, pitting corrosion has occurred for 14 years.
- Regardless of whether the damage to coating took place in 2003, or some time thereafter, where there is bare steel, pitting corrosion has occurred and continues to occur.

Figures 1 & 2 portray the impact of corrosion on bare steel caused by mussels.



¹⁸ http://www.mlive.com/news/index.ssf/2017/09/line_5_coating_inspection.html#incart_river_home

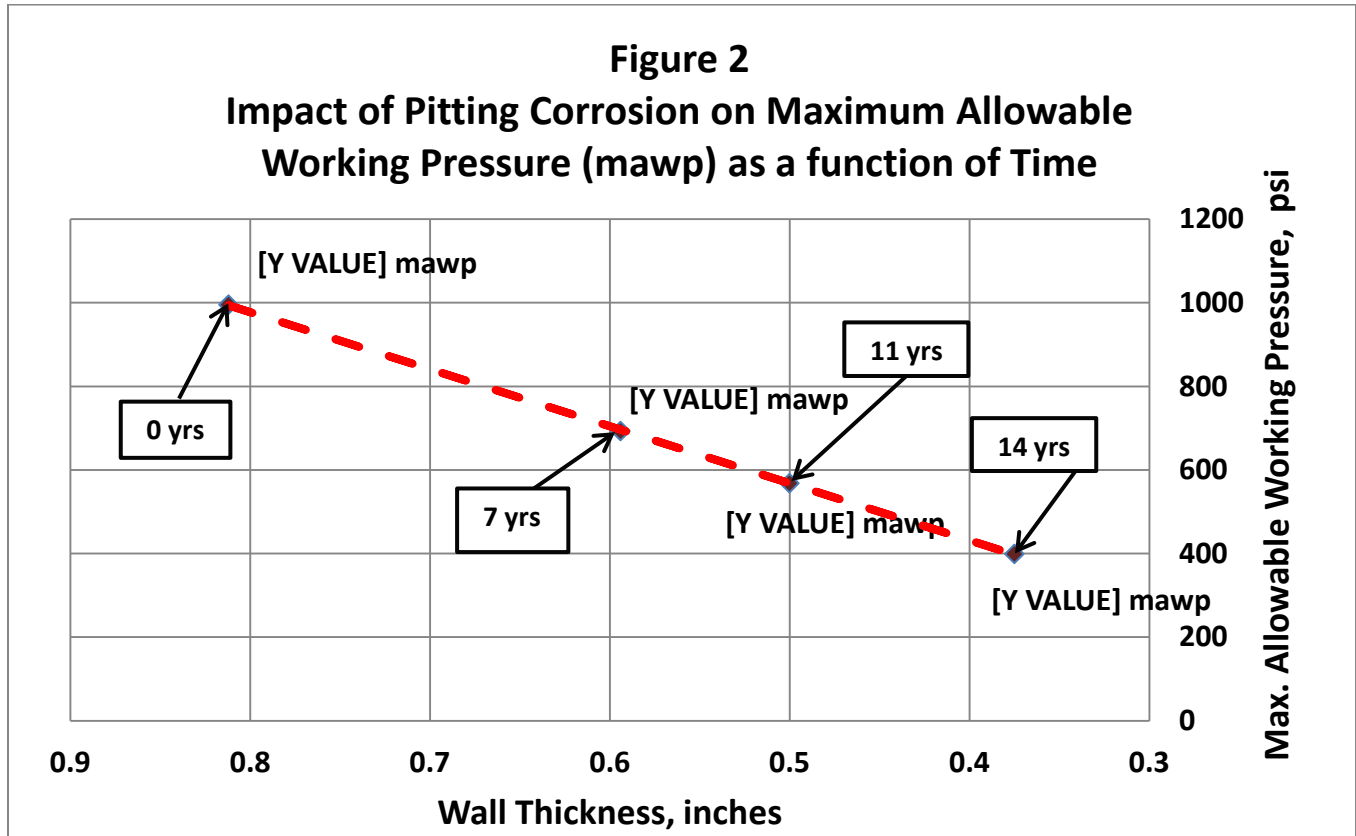


Figure 2 is a plot of Maximum Allowable Working Pressure (mawp) for schedule 60, 20 inch outside diameter, seamless carbon steel pipe.¹⁹ This is the pipe that was installed at the Straits of Mackinac in 1953.

For example, the chart tells us that in 7 years, pitting corrosion will cause the MAWP to decrease from 995 psi to 693 psi; in 14 years (the period of time from 2003 to 2017), the MAWP can decrease to 399 psi.

Figure 2 assumes that pitting corrosion did not occur prior to 2003. Enbridge has recently admitted that damage has occurred to the pipeline coating while the new supports were being installed.²⁰ They apparently have been aware of this since 2014, but only recently acknowledged it. While Enbridge claims to have discovered the damage in 2014, we do not know when it actually occurred, so have assumed that at least some of the damage to the coating took place in 2003.

¹⁹ Stritt and Priebe, 37 Clyde Avenue, Buffalo, New York, 14215, www.strittandpriebe.com

²⁰ http://www.mlive.com/news/index.ssf/2017/10/enbridge_line_5_damage_2014_de.html

Independent Risk Analysis for the Straits Pipelines

A Team Proposal to the State of Michigan
Led by Michigan Technological University

PI: Dr. Guy Meadows, Great Lakes Research Center
Robbins Professor of Sustainable Marine Engineering
Michigan Technological University

December 11, 2017

Michigan Technological University



Process and 2017 Timeline

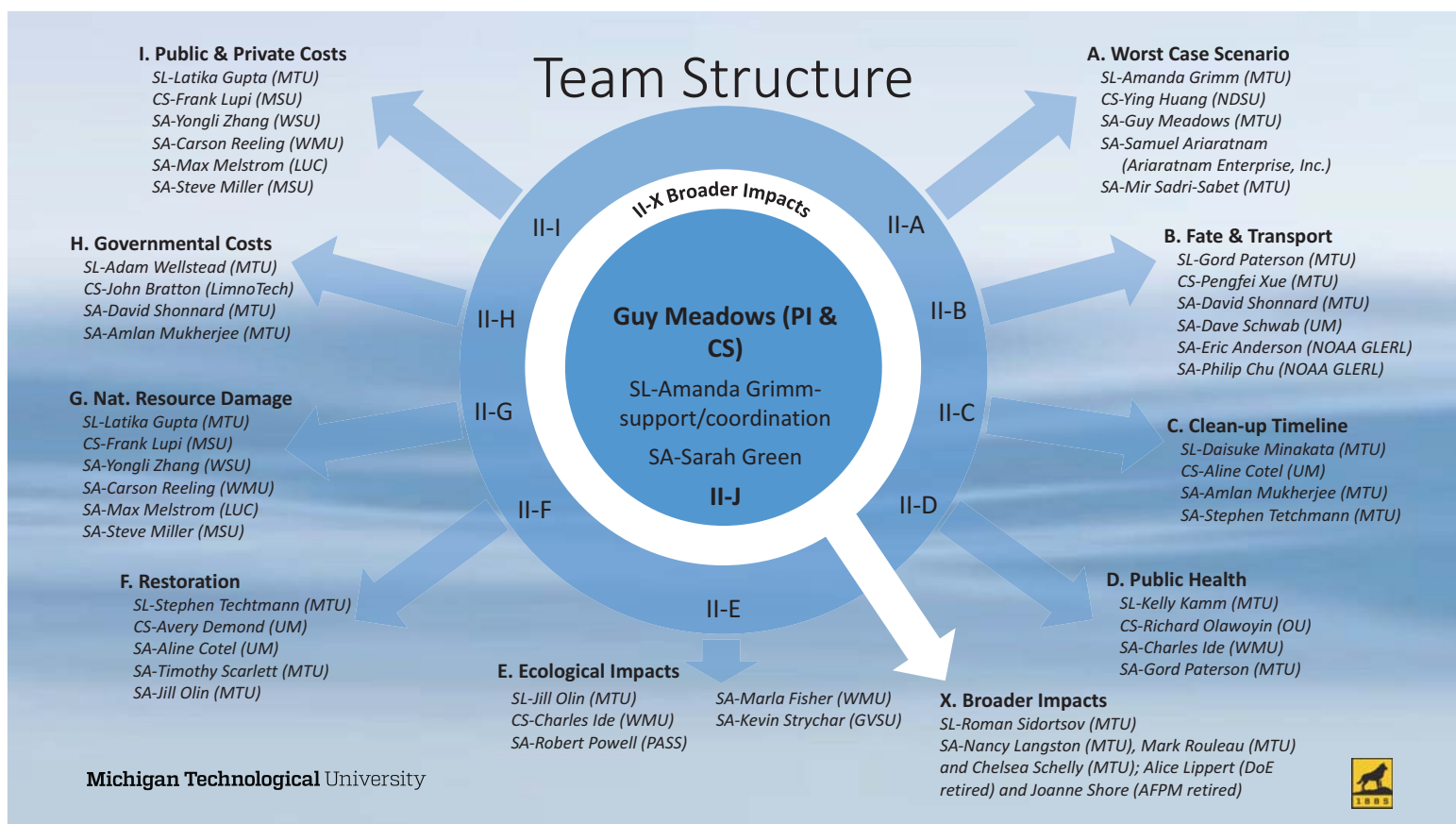
- **Sept 18** - Meadows asked to resign from PSAB and organize Michigan's public universities to respond to the Risk Analysis SOW
- **Sept 27** - With full support of Michigan Tech's Leadership, VP for Research sent request for participation to Michigan's public universities (13), with follow up to additional universities
- **Oct 23** - Michigan Tech met with State of Michigan Technical Team in Lansing to review Risk Analysis goals, data needs and team formation
- **Oct 30** - Additional subject matter experts sought and recruited from outside Michigan to complete the team
- **Nov 12** - Team structure solidified and proposal development begun
- **Dec 1** - Pre-proposal submitted to State of Michigan for review and feedback
- **Dec 11** - Meadows presentation to PSAB

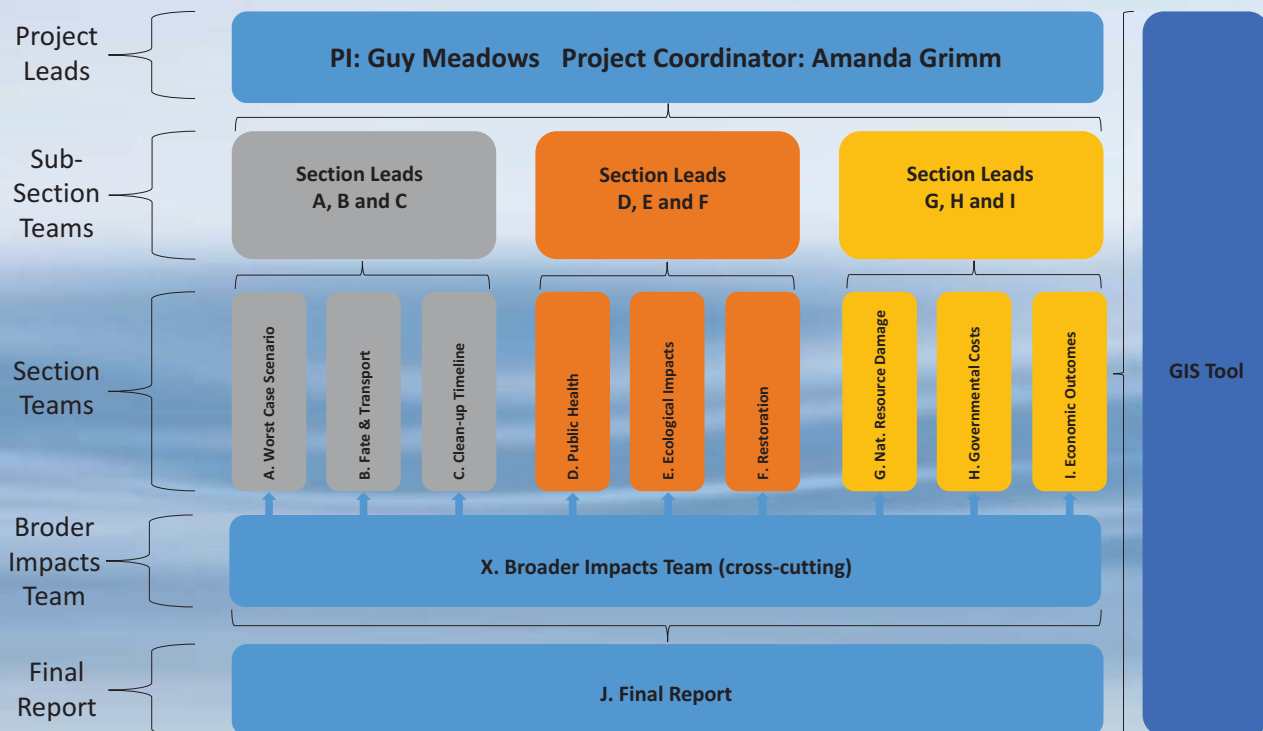
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Team Structure

- **CS- Chief Scientist:** Responsibilities include identifying data needs, ensuring validity of data and methodologies used in the section analysis, contributing to the section writing, and leadership in public outreach and addressing public comments
- **SL-Section Lead:** Responsibilities include coordination of assigned section team activities, communication with other sections and the PI and project coordinator to facilitate the timely delivery of the draft and final analysis. To facilitate overall project coordination, all Section Leads are faculty or research staff at Michigan Tech
- **SA-Section Authors (3 – 5 each team):** Apply subject area expertise to identify the section outline as it relates to the overall Risk Analysis and support the section's development





Additions to SOW

- **Team II-X Broader Impacts:** Engage in a qualitative risk identification to provide overview of risks that various affected communities perceive to arise in connections with the Straights Pipelines including Indigenous communities; state, U.S. and Canadian local government officials; environmental and historic preservation groups; as well as tourism, fishing, and recreation industries.
- **Michigan Tech High Performance Computing Cluster:** 256 cores plus 63 standby cores and 5TB memory. This will allow very high spatial resolution of the combined Lakes Michigan-Huron hydrodynamic model (FVCOM).
- **Multi-layer Web Based GIS Portal:** Will be developed as part of this effort, serve to accumulate output from each team, and will be made available to the State upon completion to serve as a rapid response resource inventory.
- **NOAA/GLERL:** Providing two lead numerical hydrodynamic modelers to assist in this effort, at no cost to the project.



Team

- **42 Researchers (21 external to Michigan Tech: 21 internal)**
 - 9 Universities
 - 7 MI – UM, MSU, WSU, WMU, GVSU, OU, and MTU
 - 2 outside Michigan – NDSU and LUC
 - 3 Consultants
 - 2 Independent Contractors (advisory capacity, former DoE and AFPM)
 - 2 Federal (NOAA GLERL)
- **Multidisciplinary:** Including Environmental Health & Safety, Biology, Geology, Civil & Environmental Engineering, Environmental Science, Chemical Engineering, Wildlife Ecology, Chemistry, Economics, Marine Science, Social Science, Petroleum Engineering, Ecology, Numerical Hydrodynamics
- **Additional support:** GIS staff, project management, hourly students(2)

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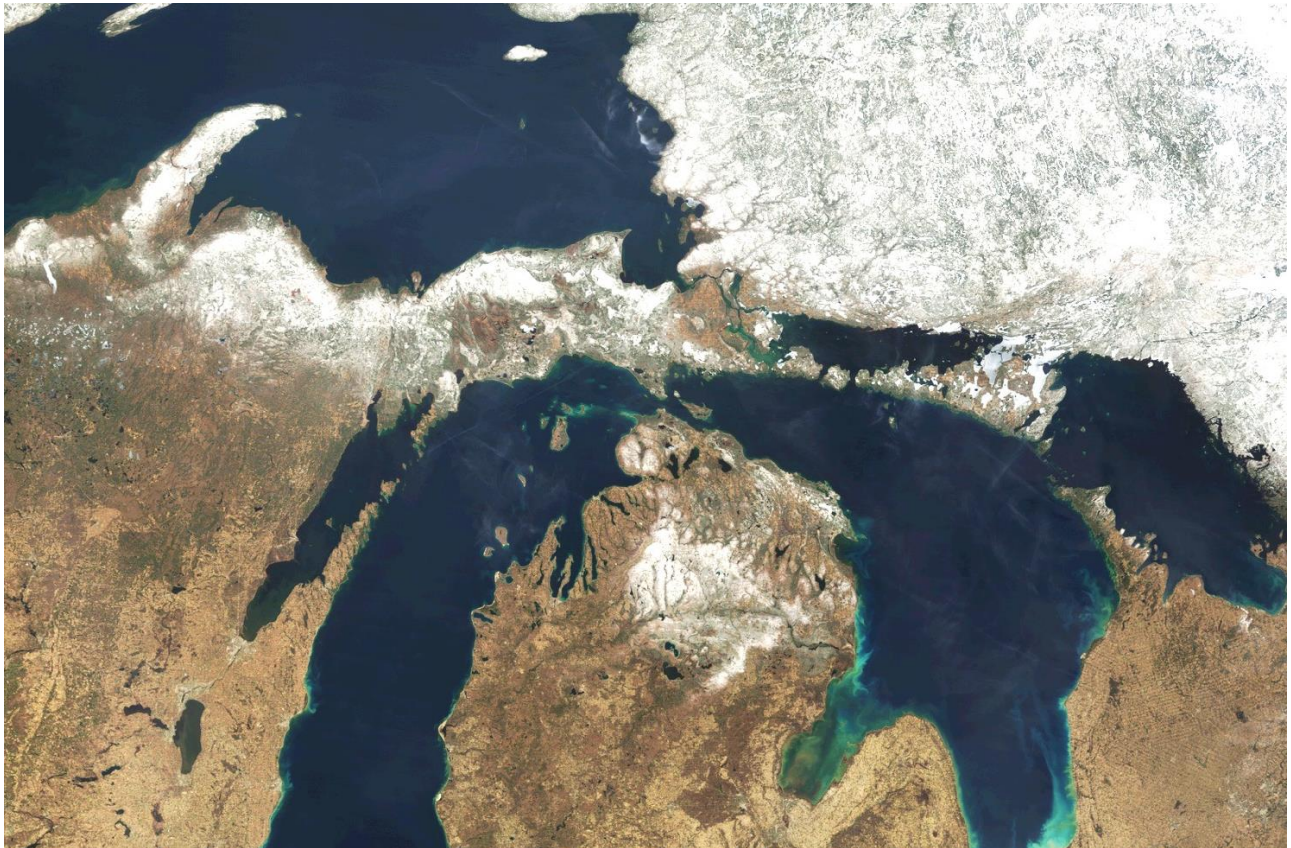
Proposed Completion Timeline

- **Dec 15** - Feedback from PSAB and State Technical Team to be incorporated into final proposal to SOM by Dec 15
- **Dec** - State and Michigan Tech enter into contract
- **Jan 2** - Project start
- **May** - Delivery of Draft Risk Analysis
- **June** - Public presentation of Draft Report
- **June/July** - Public comment period 30 days
- **July/Aug** - Respond to public and State input
- **Aug 30** - Delivery of Final Report

Michigan Technological University



- DRAFT Pre Proposal - **Independent Risk Analysis** **for the Straits Pipelines**



A Team Proposal to the State of Michigan
Led by Michigan Technological University

PI: Dr. Guy Meadows, Great Lakes Research Center
Michigan Technological University

December 7, 2017

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List of Acronyms

AWRI	Annis Water Resources Institute
CFR	Code of Federal Regulations
CS	Chief Scientist
GIS	Geographic Information System
GLAHF	Great Lakes Aquatic Habitat Framework
GLRC	Great Lakes Research Center (Michigan Tech University)
GVSU	Grand Valley State University
IC	Independent Consultant
ITAR	International Traffic in Arms Regulations
LUC	Loyola University Chicago
MSU	Michigan State University
MTU	Michigan Technological University
NDSU	North Dakota State University
NGL	Natural gas liquids
O&M	Operations and Maintenance
OU	Oakland University
PASS	Powell & Associates Science Services
PSAB	Pipeline Safety Advisory Board
SA	Section Author
SL	Section Lead
SPO	Sponsored Programs Office
T&E	Threatened and Endangered
UM	University of Michigan
WMU	Western Michigan University

1. Background & Introduction

Michigan Tech proposes to assemble a team of recognized experts from across Michigan and beyond in subjects including engineering, hydrodynamics, public health, ecology/environmental science, economics, resource management, and social science to perform an independent risk analysis of the Straits section of Enbridge's Line 5 for the State of Michigan. This analysis will estimate the total potential liability for a worst-case spill scenario at this site, including the direct costs of containment/cleanup and restoration as well as the total value of economic losses including public health, cultural and natural resources, commercial, and real estate damages.

In 2010, Michigan experienced one of the largest inland oil spills in US history when a pipeline known as Line 6B burst and spilled in excess of 1 million gallons of heavy crude into a tributary of the Kalamazoo River. To prevent future accidents of this nature, the State formed a multi-agency task force called the Michigan Petroleum Pipeline Task Force. The task force issued a report in 2015 that made 13 recommendations, including the establishment of the Pipeline Safety Advisory Board (PSAB) and the commissioning of two studies of the Mackinac Straits portion of Enbridge, Inc.'s Line 5 pipeline: a risk analysis and an alternatives analysis.

A final report on the alternatives analysis was published on November 20, 2017. The risk analysis, however, was halted in June 2017 when the State of Michigan became aware of a Conflict of Interest with the firm contracted to perform the analysis and consequently terminated its contract. The State subsequently identified Michigan Technological University (Michigan Tech, MTU) as a potential project lead for a multi-institution team to take over the risk analysis. Michigan Tech was identified because of the faculty's extensive knowledge of the complex flows in the Straits of Mackinac region. The director of Michigan Tech's Great Lakes Research Center, Dr. Guy Meadows, served on the PSAB at that time as the representative of state universities and therefore he recused himself of voting on the matter. The other members of the PSAB voted unanimously to recommend that the State of Michigan contract with Michigan Tech. Dr. Meadows subsequently resigned from the PSAB to lead this risk analysis and avoid any appearance of conflict of interest during the project.

2. Business Organization

Lead Organization

Name:	Michigan Technological University
Participating Units:	Great Lakes Research Center
	Michigan Tech Research Institute
	Sustainable Futures Institute
	School of Forest Resources and Environmental Science
	School of Business and Economics

Address: College of Engineering
 College of Sciences and Arts
 1400 Townsend Drive
 Houghton, MI 49931-1295
 Legal Form: Public University
 Project Lead and POC: Dr. Guy Meadows, Director, Great Lakes Research Center
gmeadows@mtu.edu
 906-487-1106
 Administrative Lead: Ms. Lisa Jukkala, Director, Sponsored Programs Office
lajukkala@mtu.edu
 906-487-2226

Supporting Organizations (alphabetically)

Name: Alice Lippert
 Participating in Tasks: X, consulting as-needed across project
 Address: 4188 Culpeper Lane
 Fairfax, VA 22030
 Legal Form: Sole Proprietor
 Institution POC: Ms. Alice Lippert
alice.lippert01@gmail.com
 703-508-7821

Name: Ariaratnam Enterprises, Inc.
 Participating in Tasks: A
 Address: 13663 East Geronimo Road
 Scottsdale, AZ 85259
 Legal Form: Corporation
 Institution POC: Dr. Samuel Ariaratnam
dr.s.ariaratnam@gmail.com
 480-236-5085

Name: Grand Valley State University (GVSU)
 Participating Units: Robert B. Annis Water Resources Institute (AWRI)
 Participating in Tasks: E
 Address: 1 Campus Drive
 Allendale, MI 49401
 Legal Form: Public University
 Institution POC: Dr. Kevin B. Strychar, Professor, AWRI
strychak@gvsu.edu
 616-331-8796

Name: Great Lakes Environmental Research Laboratory – NOAA
 Participating Task: B

Address: 4840 South State Rd.
Ann Arbor, MI 48108-9719

Legal Form: US Government
Institution POC: Dr. Philip Chu
philip.chu@noaa.gov
734-741-2120

Name: Joanne Shore
Participating in Tasks: X, consulting as-needed across project
Address: 400 Madison Street, #1607
Alexandria, VA 22314
Legal Form: Sole Proprietor
Institution POC: Ms. Joanne Shore
jshore4@earthlink.net
703-505-7449

Name: LimnoTech
Participating in Tasks: H
Address: 501 Avis Drive
Ann Arbor, MI 48108
Legal Form: Corporation
Institution POC: Dr. John Bratton, Senior Scientist
jbratton@limno.com
734-332-1200

Name: Loyola University Chicago (LUC)
Participating Units: Institute of Environmental Sustainability
Participating in Tasks: G, I
Address: 1032 W Sheridan Rd
Chicago, IL 60660
Legal Form: Private University
Institution POC: Dr. Richard (Max) Melstrom, Assistant Professor
rmelstrom@luc.edu
773-508-2948

Name: Michigan State University (MSU)
Participating Units: Department of Agricultural, Food and Resource Economics
Participating in Tasks: G, I
Address: 220 Trowbridge Rd
East Lansing, MI 48824
Legal Form: Public University
Institution POC: Dr. Frank Lupi, Professor
lupi@anr.msu.edu
517-432-3883

Name: North Dakota State University (NDSU)
Participating Units: Department of Civil and Environmental Engineering
Participating in Tasks: A
Address: 1340 Administration Ave.
Fargo, ND 58102
Legal Form: Public University
Institution POC: Dr. Ying Huang, Assistant Professor
Ying.Huang@ndsu.edu
701-231-7651

Name: Oakland University (OU)
Participating Units: School of Health Sciences
Participating in Tasks: D
Address: 201 Meadow Brook Rd.
Rochester, MI 48309-4401
Legal Form: Public University
Institution POC: Dr. Richard Olawoyin, Assistant Professor
olawoyin@oakland.edu
248-364-8653

Name: Powell & Associates Science Services
Participating in Tasks: E
Address: PO Box 210-145
Auburn Hills, MI 48321-0145
Legal Form: Sole Proprietorship
Institution POC: Mr. Robert M. Powell
rpowell@powellassociates.com
248-977-0317

Name: University of Michigan (UM)
Participating Units: Civil and Environmental Engineering
Participating in Tasks: B, C, F
Address: 500 S State St.
Ann Arbor, MI 48109
Legal Form: Public University
Institution POC: Dr. Aline Cotel, Associate Professor, Civil & Environmental
Engineering
acotel@umich.edu
734-763-1463

Name: Wayne State University (WSU)
Participating Units: College of Engineering
Participating in Tasks: F, G

Address: 42 W Warren Ave.
Detroit, MI 48202
Legal Form: Public University
Institution POC: Dr. Yongli Zhang, Assistant Professor of Civil and Environmental
Engineering
zhangyl@wayne.edu
313-577-9962

Name: Western Michigan University (WMU)
Participating Units: College of Arts and Sciences
Participating in Tasks: D, E, H
Address: 1903 W Michigan Ave.
Kalamazoo, MI 49008
Legal Form: Public University
Institution POC: Dr. Charles Ide, Professor of Biological Sciences
charles.ide@wmich.edu
269-387-5951

3. Qualifications and Relevant Experience

Michigan Technological University (Michigan Tech) has assembled a team of 42 subject matter experts in relevant areas of engineering, hydrodynamic modeling, risk assessment, public health, ecology, social sciences and economics. The project team comprises faculty from 10 universities as well as 3 consulting organizations, 2 independent contractors (advisory capacity, former DoE and AFPM staff) and assistance from the NOAA Great Lakes Environmental Research Laboratory (GLERL) as an unfunded contributor. MTU staff and student interns will provide needed support with project management and data management/sharing. Table 1 presents the full project team and each member's role (details follow below).

Table 1. Proposed risk analysis project team members and roles.

SECTION	TASK	LEAD	SCIENTIST	AUTHOR(S)	OTHER(S)
A	Worst Case	Amanda Grimm (MTU)	Ying Huang (NDSU)	Guy Meadows (MTU)	
				Mir Sadri-Sabet (MTU)	
				Samuel Ariaratnam (Ariaratnam Enterprise, Inc.)	
B	Fate & Transport	Gord Paterson (MTU)	Pengfei Xue (MTU)	Dave Schwab (UM)	Eric Anderson (NOAA)
				David Shonnard (MTU)	Philip Chu (NOAA)
C	Clean-up	Daisuke Minakata (MTU)	Aline Cotel (UM)	Amlan Mukherjee (MTU)	
				Stephen Techtmann (MTU)	
D	Public Health	Kelly Kamm (MTU)	Richard Olawoyin (OU)	Charles Ide (WMU)	
				Gord Paterson (MTU)	
E	Ecological Impacts	Jill Olin (MTU)	Charles Ide (WMU)	Marla Fisher (WMU)	
				Robert Powell (PASS)	
				Kevin Strychar (GVSU)	
				David Flaspohler (MTU)	
F	Restoration	Steve Techtmann (MTU)	Avery Demond (UM)	Aline Cotel (UM)	
				Timothy Scarlett (MTU)	
				Jill Olin (MTU)	
G	Nat Res Damage	Latika Gupta (MTU)	Frank Lupi (MSU)	Yongli Zhang (WSU)	
				Carson Reeling (WMU)	
				Max Melstrom (LUC)	
				Steve Miller (MSU)	
H	Gov Costs	Adam Wellstead (MTU)	John Bratton (LimnoTech)	David Shonnard (MTU)	
				Amlan Mukherjee (MTU)	
I	Public & Private Costs	Latika Gupta (MTU)	Frank Lupi (MSU)	Yongli Zhang (WSU)	
				Carson Reeling (WMU)	
				Max Melstrom (LUC)	
				Steve Miller (MSU)	
J	Final Report	Amanda Grimm (MTU)	Guy Meadows (MTU)	Sarah Green (MTU)	
SECTION	TASK	LEAD	RESOURCE TEAM		DESCRIPTION
X	Broader Impacts	Roman Sidortsov (MTU)	Alice Lipert (former DoE)	Nancy Langston (MTU)	Public Engagement, Qualitative Considerations, and Native Community Interests
			Joanne Shore (former AFPM)	Chelsea Schelly (MTU)	
				Mark Rouleau (MTU)	

To make the generation of a cohesive, integrated assessment of risk possible for this group on a short timeline, the team has been structured with defined roles for each task (Figure 1, below). Each section (II-A through II-I plus II-X) of the analysis will include a Chief Scientist (CS), whose role includes identification of data needs, ensuring validity of data used in the section analysis, contributing to the section writing, and leadership in public outreach and addressing public comments; multiple Section Authors (SA), who will apply subject area expertise to identify the

section outline as it relates to the overall Risk Analysis and support the section's development; and a Section Lead (SL), a Michigan Tech faculty/staff member who will form the Project Coordination Team with PI Meadows and project coordinator Grimm, facilitating the exchange of information and overall analysis development across section teams. Some individuals will hold multiple roles in one or more sections. Biosketches for Dr. Meadows and each of the Chief Scientists are provided below; two-page curriculum vitae for all team members are included as Appendix A.

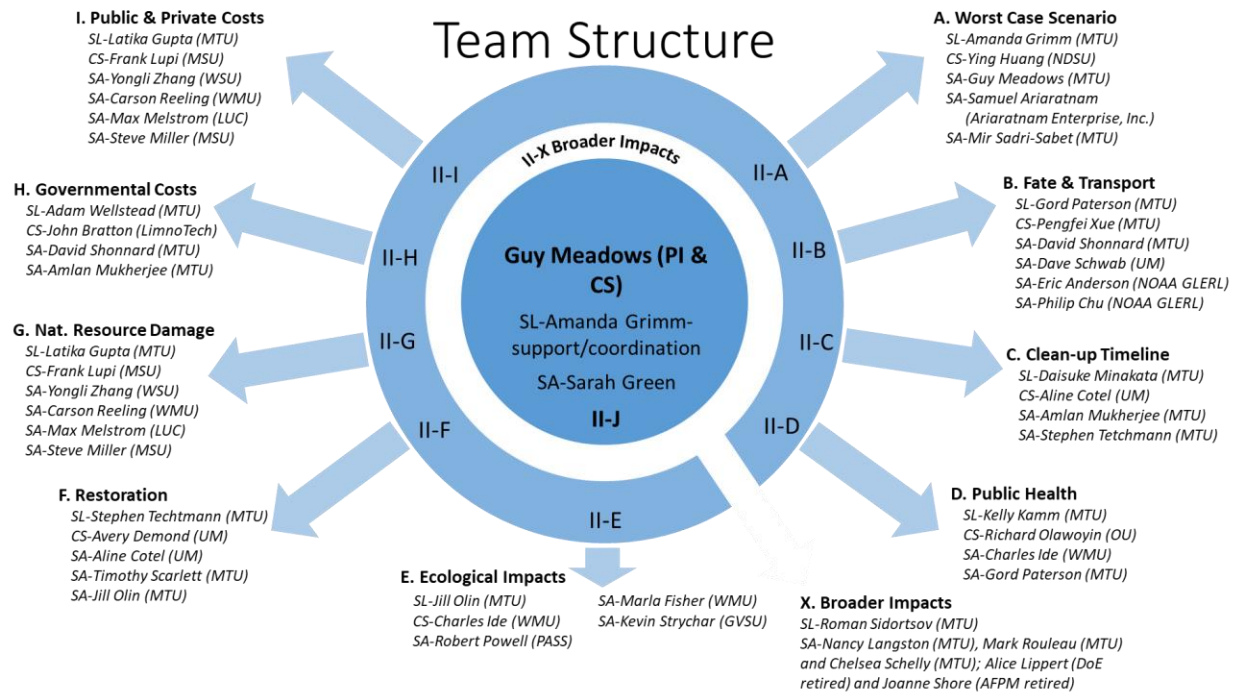


Figure 1: Structure of the multi-institution project team. The team is illustrated as a “clock” because the results of early tasks serve as inputs to later sections of the analysis.

Project PI: Dr. Guy Meadows

Upon graduation from Purdue University in 1977, Guy Meadows joined the faculty of the University of Michigan, College of Engineering, where he served as Professor of Physical Oceanography for 35 years. During his tenure, he served the College and University as Director of the Ocean Engineering Laboratory, Director of the Cooperative Institute for Limnology and Ecosystems Research (NOAA Joint Institute), Director of the Marine Hydrodynamics Laboratories and founding Academic Director of the M-STEM Academy. He joined Michigan Tech in June of 2012 to help establish the new Great Lakes Research Center where he holds the Robbins Professorship of Sustainable Marine Engineering. His primary goal is to blend scientific understanding and technological advancements into environmentally sound engineering solutions for the marine environment through teaching, research and service.

His teaching reaches beyond the University setting to less formal environments and includes

five nationally televised documentaries for the History and Discovery Channels. His primary research interests are in geophysical fluid dynamics with emphasis on environmental forecasting and full-scale, Great Lakes and coastal ocean experimental hydrodynamics. In this arena, he has influenced policy and explored societal impacts of environmental forecasting for coastal management, recreational health and safety, and regional climate change.

Task A. Chief Scientist: Dr. Ying Huang (NDSU)

Dr. Huang has more than ten years of research background in structural health monitoring and pipeline risk analysis and corrosion assessment. She has coauthored over 70 high quality peer reviewed publications that include one book chapter, 30 journals articles, and 40 conference papers, which have been cited 345 times with an i10-index of 9. She holds a PhD in Civil Engineering from Missouri University of Science and Technology, and is currently an Assistant Professor in the Department of Civil and Environmental Engineering at North Dakota State University.

Task B. Chief Scientist: Dr. Pengfei Xue (MTU)

Dr. Pengfei Xue, one of the original developers of the unstructured grid Finite Volume Community Ocean Model (FVCOM) with his major professor, Dr. Changsheng Chen, School for Marine Science and Technology, University of Massachusetts-Dartmouth, joined the Tech faculty in 2013. Since his arrival, he has worked closely with NOAA-GLERL in jointly developing FVCOM based hydrodynamic and climate models for the Great Lakes, including the combined Lakes Michigan-Huron coupled model to assess flow through the Straits of Mackinac. He has made Michigan Tech's supercomputing cluster available for joint model development and testing. Dr. Xue's areas of expertise include hydrodynamic modeling, coupled physical-biological modeling, dynamics of coupled ocean-atmosphere models, ocean data assimilation, and bio-physical processes in the Great Lakes.

Task C. Chief Scientist: Dr. Aline Cotel (UM)

University of Michigan Associate Professor Aline Cotel researches fluid dynamics, studying topics ranging from the impact of biofuel spills on aquatic environments to the impact of turbulence on fish swimming and aquaculture systems. Her expertise includes turbulent mixing and stratified flows, which would be essential physical processes at play during a worst case scenario event. Dr. Cotel also teaches a course on Aquatic Ecosystem Restoration at UM and has been involved in research in that area as well.

Task D. Chief Scientist: Dr. Richard Olawoyin (OU)

Dr. Olawoyin worked in the petroleum industry as a geologist, geophysicist, petroleum engineer, safety and environmental health scientist, both in the upstream and downstream oil & gas sectors. His research interests include human health exposure risk assessment, environmental quality assessment and sustainability, fire engineering, statistical techniques in EHS Engineering, risk management and solution innovations, hazard management and systems

safety, and occupational decision-making aspects of EHS. Richard is certified by the Academy of Board Certified Environmental Professionals (CEP) and by the Board of Certified Safety Professionals as a Certified Safety Professional (CSP) and Associate Safety Professional (ASP). He is a book chief editor and has authored numerous publications (16 as first author) on environmental health and safety, energy & mining engineering, petroleum engineering, environmental engineering, drilling innovation and environmental health sciences.

Task E. Chief Scientist: Dr. Charles Ide (WMU)

Dr. Ide, a professor in the Biology Department at Western Michigan University as well as the director of the Great Lakes Environmental and Molecular Sciences Center (GLEAMS), was involved in evaluating the effects of the 2010 Enbridge spill in Kalamazoo. Dr. Ide's research focuses are environmental risk assessment and neuroscience. Specific projects examine how industrial contaminants and pesticides found in the Great Lakes Basin alter ecosystem health.

Task F. Chief Scientist: Dr. Avery Demond (UM)

Dr. Demond is an environmental engineer by training and has been on the faculty in the Department of Civil and Environmental Engineering at the University of Michigan for nearly 30 years. Her research focuses on the fate of organic contaminants in the environment, including work on the impact of biofuel spills on the fate of regulated organic compounds in surface waters. She served as a coordinator of DOE's Subsurface Science Program's Multiphase Fluid Flow Subprogram for five years. Furthermore, she has served on a number of National Research Council boards and committees, including the Committee for the Review of DOE's Environmental Restoration Priority System. She is a Professional Engineer, registered in the State of Michigan.

Tasks G, I. Chief Scientist: Dr. Frank Lupi (MSU)

Professor Frank Lupi has a joint tenure system appointment in the Agricultural, Food, and Resource Economics and Fisheries and Wildlife Departments. He is a member of the Partnership for Ecosystem Research and Management, the Center for Systems Integration and Sustainability, the Water Science Network, and the Environmental Science and Policy Program. His research addresses the economics of ecosystem services, conservation, agriculture, fisheries, wildlife, and water.

Task H. Chief Scientist: Dr. John Bratton (LimnoTech)

Dr. Bratton is a Senior Scientist at LimnoTech with broad expertise in earth and environmental sciences, including successful leadership of projects involving remedial investigation/remedial design for contaminated sites, large ecosystem restoration, and litigation support. He has worked as a consultant, researcher, educator, and science manager for over 30 years, especially in the Great Lakes and Northeast regions, and has contributed to over 40 scientific publications and 75 research presentations since 2000. His specialties include coastal geology and groundwater, freshwater and ocean sediment geochemistry, glacial geology, environmental

history, and environmental law and policy. John previously served as Deputy Director and Acting Director of NOAA's Great Lakes Environmental Research Laboratory in Ann Arbor, MI and as a research group leader with the Coastal and Marine Geology Program of the U.S. Geological Survey in Woods Hole, Massachusetts.

Qualifications of Lead Institution:

Michigan Tech has significant experience in the administration of multi-subcontractor, collaborative awards, including large multi-university collaborative projects. Michigan Tech's Sponsored Programs Office (SPO) staff includes dedicated pre- and post-award processing specialists, including research accountants, subcontract negotiation and oversight analysts, as well as individuals whose positions include intellectual property, research integrity and compliance, and data analysis for project reporting. Experienced staff from the SPO will be available to assist the leadership team in management of the lead contract with the State of Michigan, subcontracts, billing, etc., and other contract requirements. Michigan Tech is a member of the Federal Demonstration Partnership to reduce administrative burden and streamline contracting between academic institutions. This partnership also provides tools and templates that Michigan Tech will make available to sub-awardees for greater contract processing and oversight throughout the life of the project.

The leadership team is also very experienced in the use of communication tools for web conferencing and data sharing and will develop convenient avenues of communication for use among the section teams and between the leadership team and the State. Recent relevant experience of the lead institution in projects of this scope includes the following:

- Acting as lead institution for the Midwestern Regional Center of the Department of Energy's National Institute for Climate Change Research
- Acting as lead in a multi-university industry/university collaborative research center in Advanced Sustainable Iron and Steel technologies, sponsored by the National Science Foundation
- Serving as the home of US EPA's Region 5 Environmental Finance Center
- Hosting the US DOT's Eastern Tribal Technical Assistance Program
- Partnering with the US Forest Service, the Trust for Public Land, the Council for Air and Stream Improvement and the University of Minnesota in the Northern Institute of Applied Climate Science

Michigan Tech is a STEM-dominated university with strong research capabilities that support a solid foundation of expertise as the lead institution in this integrated multi-institution risk assessment. Since 2012, the University has opened a 50,000 square foot waterfront facility, centrally located on its main campus on Lake Superior (\$25M capital investment partnership with the State of Michigan); funded the addition of six new faculty lines to support Great Lakes research; added high-performance computing capabilities to run large scale hydrodynamic models; and equipped a fleet of surface and sub-surface, science vessels/vehicles with state-of-the-art technology to enhance education, public outreach and research. The National Science Foundation's most recent survey of higher education R&D expenditures (2015) placed Michigan Tech as the highest ranked institution in the State of Michigan in Atmospheric Science,

Oceanography, and Environmental Science. Additionally, Michigan Tech's dual locations in Houghton (Upper Peninsula) and Ann Arbor (centrally located in Lower Michigan) provide geographic reach across the region that will help facilitate the coordination of the analysis. Michigan Tech brings a commitment from its faculty and university leadership to support this important, independent risk assessment at the highest level.

4. Conflicts of Interest

Lead Institution

Michigan Tech, through the Great Lakes Research Center (GLRC), has conducted research for Enbridge on a contract basis, four contracts in total. Funding was used exclusively for environmental monitoring and establishment of increased pipeline safety. The funded projects include the annual operations and maintenance (O&M) of the environmental monitoring buoy in the Straits of Mackinac, NDBC # 45175 (two, O&M consecutive contracts); collection of environmental monitoring data during the recent hydrostatic testing of the Line 5 pipelines; and the development of advanced underwater acoustic sensing and measurement techniques, utilizing an autonomous underwater vehicle, to provide observational data of the pipelines and lake floor. Guy Meadows served as lead on three of the four contracts. The hydrostatic test monitoring was led by Director of GLRC Operations Michael Abbott.

The State of Michigan is aware of Michigan Tech's contractual relationships with Enbridge. Before his appointment to the Pipeline Safety Advisory Board (PSAB), Guy Meadows disclosed to the PSAB his roles in relation to Enbridge contracts. The State found them to be of no Concern. The Enbridge projects have contributed 5.23 percent of the GLRC's overall sponsored awards portfolio:

- Total GLRC award value (2012 to current): \$14,172,154
- Enbridge award value: \$740,963

In addition, between 1974 and 2002, Michigan Tech students were beneficiaries of scholarships funded by Enbridge. The sum of these scholarships totaled \$79,250.

As a step in identifying the team of experts to support this important project, Michigan Tech implemented a number of assurances to identify and disclosure in advance of a contract any known or potential conflicts of interest. The information provided by the individual members of the project team was vetted by Michigan Tech's legal counsel and the Office of Compliance, Integrity and Safety that oversees the ethical conduct or research. All potential conflicts of interest, known or perceived, have been disclosed to the State.

Team Members

At the individual level, each member of the proposal team is providing MTU with a signed statement that either confirms that they do not have any known, potential or apparent conflicts of interest, or discloses the details of such potential conflicts. Team members have also provided a summary of their current and pending support. This documentation will be provided to the State with the final version of the project proposal.

5. Proposed Methodology and Design for the Analysis

Project Management

Section Teams

As described in Section 3, each task (II-A through II-I plus II-X) of the analysis will include a Chief Scientist (CS), multiple Section Authors (SA), and an MTU-affiliated Section Lead (SL). The Project Coordination Team, composed of PI Meadows, project coordinator Grimm, and all Section Leads, will be ultimately responsible for the timely delivery of the draft and final reports. Some individuals will hold multiple roles in one or more sections. In Figure 2 below, teams are grouped into three “sub-sections” that will work together most closely: sections A-C, who will define the worst-case scenario releases, model scenarios of their fate/transport, and analyze the consequences in terms of cleanup/containment requirements and times; sections D-F, responsible for identifying and analyzing the living costs of a worst-case spill in terms of public health, ecological damage, and restoration/mitigation needs and costs; and sections G-I, who will estimate the total costs of a worst-case spill in economic terms. The teams for sections C and H, as the groups responsible for estimating cleanup timelines and costs, respectively, will also work together closely.

Broader Impacts Team

The Broader Impacts team, or “Section X”, will provide cross-cutting support across the analysis sections by collecting and applying documentary data to ensure that qualitative risks and the perceptions of risk by potentially affected communities are adequately represented in the assessment. Section X will also engage in legal analysis to identify risks arising out of legal rights and obligations by various parties as well as play a role in planning and organizing the public information presentation and listening sessions following the release of the draft report.

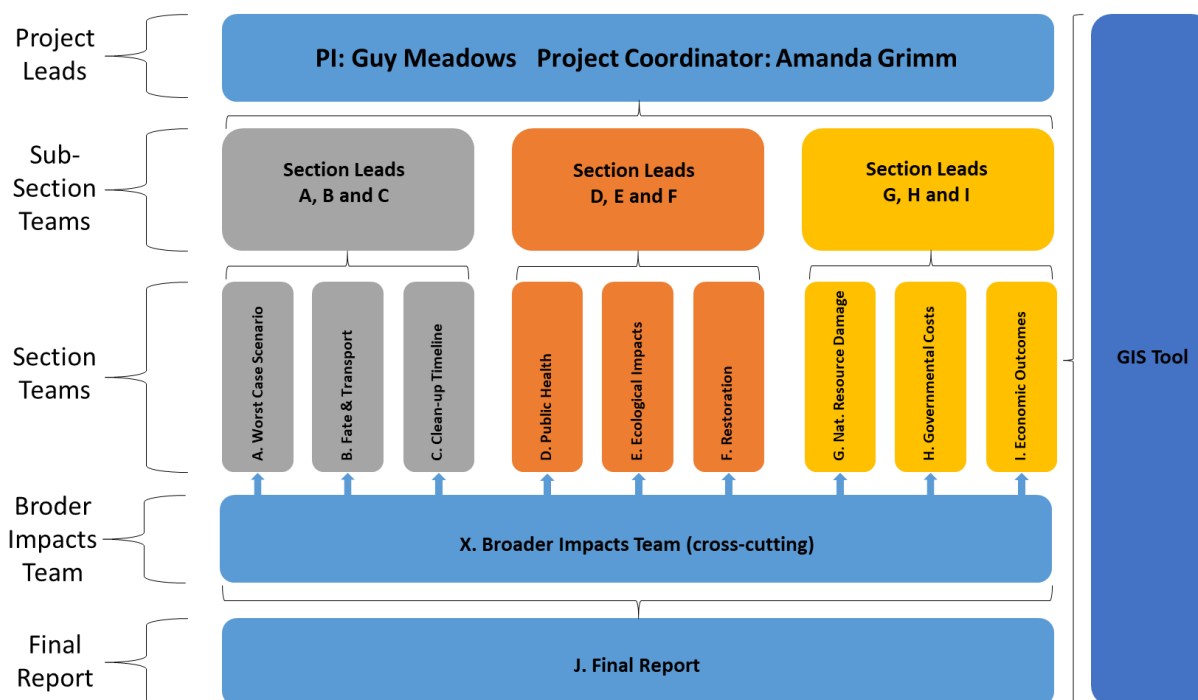


Figure 2: Project organization, including management and support structures.

Data Management and Sharing Support

For a consistent analysis, it will be important for all section teams to work from the same source data. Project data coordination will be handled by Michigan Tech Research Institute (MTRI), a multi-disciplinary education, research and technology center located in Ann Arbor with a full suite of resources for geospatial projects, including advanced image and data processing software and a large and scalable storage system. Using the spill effect areas generated by the fate and transport modeling in Task II-B, the data team will gather spatial data on affected populations, natural & cultural resources, and other assets, including but not limited to coastal wetland and submerged aquatic vegetation maps, GLAHF biological datasets, existing species distribution and environmental sensitivity maps, locations of designated Critical Habitat and Important Bird areas, shoreline type classifications, census data, and potentially affected cultural features and fisheries resources. The MTRI data team will work with the section teams to identify their data needs and retrieve, organize and provide that data. Data access and delivery will be based on a user-friendly ArcGIS Online based framework (represented by the blue “GIS tool” in Figure 2). MTRI has previously developed several web map interfaces for data hosting and sharing, including the Portal and Dynamic Decision Support System (DDSS) for the Great Lakes and Molecular Sciences (GLEAMS) Center, which was developed in collaboration with proposal team member Dr. Charles Ide and focused on the EPA designated Superfund site in Michigan’s Kalamazoo River watershed (Figure 3).

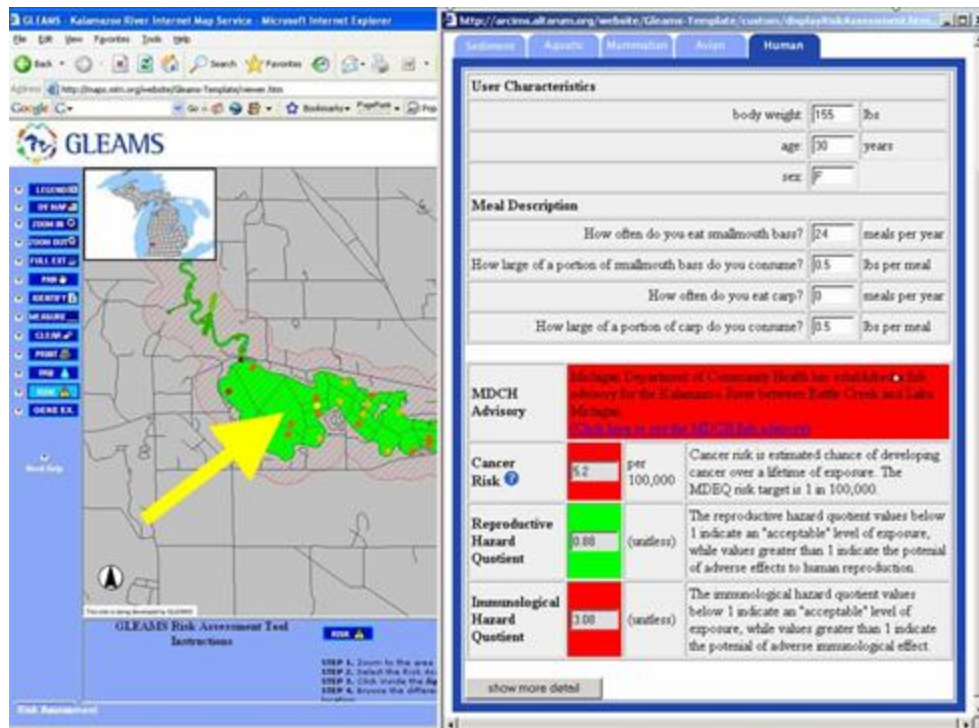


Figure 3: The GLEAMS map-based web portal and risk assessment tool for health risk assessment related to consumption of fish from the Kalamazoo River.

Data security: MTRI staff will develop a project-specific data management plan that meets State requirements and professional standards for documentation, ethics and legal compliance, storage, preservation and sharing. All Michigan Tech project team members will follow University IT policies for Data Custodians, who are required to regularly safeguard, backup, and maintain digital information that has been entrusted to the University. Data generated by subcontractors may also be stored at the user's home institutions/organization and may be governed by their data management policy. Whenever possible, data of potential scientific value generated or provided by subcontractors will be incorporated into Michigan Tech's data storage and made available to internal and external researchers.

The project team recognizes that successful development of the proposed Risk Analysis will require the secure sharing and protection of sensitive data, e.g. those related to pipeline specifications and T&E species. MTRI regularly handles sensitive data, including meeting all requirements for government Classified information, and maintains secure data storage areas where access can be controlled to specific approved users, such as a designated folder structure for ITAR information. This experience and demonstrated capabilities to handle sensitive information would be applicable to this project.

Government Roles

The proposed leadership team expects to work closely with the 6-person project coordination team and the larger technical team assembled by the State of Michigan. We anticipate a set

biweekly web/phone conference with screen-sharing capability, where the State's personnel would take on the following roles:

- Provide clear guidance for framing the task
- Facilitate drawing on state information/data resources
- Answer questions regarding the scope of work and goals
- Facilitate communication w/Enbridge
- Provide DNV's requests for information to Enbridge and the state
- Provide what information the State has available on the attendees and materials from the workshop on spill response costs convened as part of the previous effort
- Periodically review progress on the analysis and give input on possible gaps
- Lead communication/consultation with tribal entities

Separately from the State of Michigan's technical team, Philip Chu and Eric Anderson at NOAA GLERL will contribute their hydrodynamic modeling expertise as unfunded contributors to Task B of the SOW.

Detailed Methods

The subsections below describe the methods that would be used to perform each of the requested elements of the Scope of Work.

SOW II-A: Identifying and analyzing the duration and magnitude of a "worst-case" spill or release of oil or other products from the Straits Pipelines into the environment.

Section Team:

Chief Scientist: Ying Huang (NDSU)

Section Authors: Guy Meadows (MTU), Mir Sadri-Sabet (MTU), Samuel Ariaratnam (ASU)

Section Lead: Amanda Grimm (MTU)

Task Overview: The team for Section A of the analysis will identify multiple specific "worst-case" spill scenarios for the Straits pipelines that will form the basis for the work of all other section teams. Beginning from the 40 CFR 194.5 definition of worst-case as "the largest foreseeable discharge of oil, including a discharge from fire or explosion, in adverse weather conditions", Team A will also consider the maximum plausible potential release assuming failures of various engineering and procedural controls, differences in worst-case release scenarios for the different products transported through the pipelines, seasonal differences (including ice cover) in both the environmental impact and the detectability of a release, and assessment of both sudden, "catastrophic" worst-case releases and longer-term "pinhole" leaks that could result in a large total release volume over time if undetected. These scenarios will be organized based on tiers of potential system failure, beginning with the first level of safeguards and progressing to higher tiers of failure.

Methods: The regulatory “worst case discharge” defined by 40 CFR 194.5 include the situations with three hole size failures with differing volume/release duration, three different materials transported in the pipelines, and two seasons (summer/winter) including consideration of storm events. The most critical situations are the combinations with unique impact sets. To determine the critical combinations to be investigated for worst case, some critical pipeline data will need to be supplied by Enbridge and/or the State of Michigan. A visit by this technical team to the Enbridge Control Facility, may be required. These data to be reviewed and used in the analysis will include:

- 1) The structural features of the existing pipelines (design drawings and parameters such as high resolution horizontal alignment and vertical profile of the pipe, thickness and diameter of the pipe, construction methods used, etc.),
- 2) The operational and control system logic and functioning (such as types of product transported historically, currently, and planned, product transport schedule, and product transportation temperature variations),
- 3) The leak detection methods and response philosophies, inspection schedules and intervals, inspection data if any such as thickness and diameter profile,
- 4) The types, accurate locations, and operational schedules of valves used in the line including shut-off valves, manual valves, and check valves, etc.
- 5) If any system is rated higher than Safety Integrity Level 3, more specific information concerning assurance of the rating will be requested,
- 6) All other needed data is already in hand, has already been requested from Enbridge, or will be obtained from public sources.

Considering the location, the structural feature, and product transport schedules of the pipe, it may require multiple scenarios to be evaluated as “worst case” scenarios with the considerations of sudden and long-term releases in the different failure sizes. Sudden release, occurs when there is a large hole or catastrophic failure of the pipeline. Long-term release occurs when smaller holes develop in the pipeline and persist without detection. Due to the limitations of the detection tools, smaller holes may have a much longer leak duration and actually can release more products to the environment. The impact of these two types of release may be significantly different and will be investigated in this study. The potential worst-case discharge volume will be estimated as a time-based discharge curve. The detail calculations include but are not limited to, the maximum design flow rate, the maximum leak rate, the responding time to isolate the section, the quantity of products that could be released, and the quantity of products remaining in the affected pipeline.

Detailed Subtasks and Time management:

Task II-A is scheduled to be conducted within one and one-half months from contract initiation. During Task II-A, bi-weekly phone meetings will be performed between all the team members of this Task to make sure the Task is proceeded on track. Below is the detail scope of work and timeline for the seven subtasks in the Task II-A of the proposed project:

Subtask II-A 1 (Jan 1 2018 to Jan 8 2018): This subtask is intended to obtain all the required materials and documents from Enbridge and the State of Michigan with all the design and placement of the pipelines, control systems, leak detection methods, and valves listed above.

Subtask II-A 2 (Jan 8 2018 to Jan 15 2018): Based on the obtained materials and documents from agencies, this subtask will determine the various types of physical or operational failures or other potential hazards (over 20 scenarios) that could result in releases of oil or other products, including both sudden releases and longer-term releases that could be undetected using the existing systems.

Subtask II-A 3 (Jan 15 2018 to Jan 22 2018): In this subtask, the maximum design flow rate based on the maximum allowable operating pressure (MAOP) will be calculated with consideration of the types of products being transported.

Subtask II-A 4 (Jan 22 2018 to Jan 29 2018): This subtask will determine the potential failure of release detection methods, control systems, or shut-off valves to operate as intended, and calculate the maximum leak rate with the hole size being considered at the pipeline design and maximum design flow rate.

Subtask II-A 5 (Jan 29 2018 to Feb 5 2018): This subtask will analyze multiple logical tiers of failure and the associated minimum response times to isolate the failed section and quantities of oil or other products that could be released at the maximum leak rate before the flow was cut off. Maximum detection times will be based on the assumption that high-reliability engineered equipment is available. The volume of product that could leak out of the hole over time after the section is isolated will vary by product and is highly dependent on elevation changes in the pipeline and the hole locations.

Subtask II-A 6 (Feb 5 2018 to Feb 12 2018): With the quantity of oil or other product released, in this subtask, the investigators will determine the quantity and fate of oil or other products remaining in the affected pipeline(s) at the maximum design flow rate after the flow is cut off, with the assumption that no volume reduction will be calculated for response efforts to reduce the spill volume by removing product trapped in the line.

Subtask II-A 7 (Feb 12 2018 to Feb 15 2018): In this subtask, a report will be drafted and submitted to the lead engineer at Michigan Tech for evaluation and for the State of Michigan for review. With approval, Task II-A is completed and the results from Task II-A will be shared with other Task groups for other tasks of this project.

Deliverables: Team A will generate several scenarios for fate-and-transport modeling that specify released product(s), release rate, duration, location and weather conditions (including ice cover).

SOW II-B: Analyzing the likely environmental fate and transport of oil or other products released from the Straits Pipeline under a worst-case scenario.

Section Team:

Chief Scientist: Pengfei Xue (MTU)

Section Authors: David Shonnard (MTU), David Schwab (UM), Philip Chu (NOAA), Eric Anderson (NOAA)

Section Lead: Gordon Paterson (MTU)

Task Overview: Accurate estimation of the movement and fate of pipeline products released under worst-case spill scenarios is critical to the assessment of possible damage to human and environmental health and socio-economic impacts. The team for Task II-B of the analysis will employ the oil spill scenarios provided by Task II-A as inputs for hydrodynamic modeling exercises that will generate a comprehensive analysis of the transport and fate of pipeline products released under worst-case scenarios. In combination with established information quantifying water current strength and direction in the Straits region, pipeline product chemical and physical characteristics, hydrodynamic modeling efforts will predict the fate of discharged products with respect to open water transport and evaporation/weathering and the extent of shoreline oiling and deposition.

Methods: A hydrodynamic model (Combined Lakes Michigan-Huron coupled model) developed by Anderson and Schwab (2013) will serve as the foundation to describe water currents that will affect pipeline product fate and dispersal under worst-case oil spill scenarios in the Straits of Mackinac region. This three dimensional model extends across the areas of Lakes Michigan and Huron encompassed by the Straits region and is based on the Finite Volume Community Ocean Model (FVCOM) that has been previously used to predict open water and coastal circulation patterns throughout the Great Lakes basin. Hydrodynamic model predictions will be used to develop geographic information system (GIS) maps of offshore and onshore oil concentrations that result from the spill scenarios and volumes identified by Task II-A. Evaporation model predictions will provide accurate estimates of the loss of oil-spill volatile components and resultant changes in oil slick characteristics with time (density, viscosity, propensity to form emulsions with water). Atmospheric fate of volatile components in the liquid oil, including the natural gas liquids (NGL) fraction of the pipeline contents, will be modeled to assess fate and risks to human and ecological health. Life-cycle assessment modeling will also be completed to estimate the mass balance environmental fate(s) of released pipeline petroleum products. Baseline data required for the oil spill fate and transport modeling and life-cycle assessment efforts include but are not limited to;

1. Meteorological data describing regional weather conditions (air temperatures, wind direction and velocities, relative humidity), ice cover, water temperatures, currents and wave action at the predicted times/seasonality of worst case spill events.

2. Physical and chemical information (density, evaporation rates, weathering) and constituent characteristics (volatile- and semi-volatile organic compounds, polycyclic aromatic hydrocarbon) of the three pipeline products (Light crude, light synthetic crude, and natural gas liquids).
3. Location of pipeline rupture and product release (Task II-A).
4. Volume(s) of pipeline products released under worst-case scenario oil spills (Task II-A).
5. Duration of pipeline product release under worst-case scenario oil spills (Task II-A).
6. Regional geographic information system (GIS) base maps describing the bathymetry and shoreline topology for Lakes Michigan and Huron and the Straits of Mackinac region.

Given the range of environmental variables that can contribute to the transport and fate of petroleum products released during oil-spill events, multiple simulations will be required for each worst-case scenario identified by Task II-A. Specifically, regional climate considerations including wind speed and direction, air and water temperatures, wave action will be included into model predictions for understanding the fate and transport of pipeline products under worst-case release conditions.

Detailed sub-tasks and timeline

Task II-B is scheduled to be conducted in cooperation with the progress of Task II-A (Worst-case scenario evaluations) and completed within two months of the initiation of the project contract. The section leader of Task II-B will coordinate a teleconference with the Task II-A section leader within two weeks of project initiation to establish initial progress of the identification of worst-case scenarios and establish benchmarks for preliminary hydrodynamic modeling exercises. The Task II-B section team members will hold bi-weekly teleconference meetings to discuss data requirements and availability, preliminary model results and progress, and Task specific deliverables.

Subtask II-B 1 (Jan 1 – Jan 31, 2018). Section team members will discuss and identify necessary data and input requirements for hydrodynamic and other fate model operations. This information will be communicated to Task II-B section lead as associated with hydrodynamic model exercises for worst-case oil-spill scenarios.

Subtask II-B 2 (Feb 1 – Feb 21, 2018). Begin hydrodynamic model simulations to predict oil spill fate and transport as associated with worst-case scenarios identified by Task II-A including:

- A. Location of pipeline product release (e.g. north shore, central channel, south shore).
- B. Duration of pipeline product release
- C. Pipeline specific product released (e.g. Light crude, light synthetic crude, natural gas liquids)
- D. Seasonality of pipeline rupture and product release.

E. Combinations of the above.

Subtask II-B3 (Feb 21 – Feb 28, 2018). Complete volatiles evaporation modeling as well as atmospheric fate modeling of volatile components as well as NGL. Complete life-cycle emissions and release inventory of pipeline products based on fate and transport modeling results from the worst-case oil-spill scenarios.

Subtask II-B4 (March 1 – March 15, 2018). Compile hydrodynamic model predictions and life-cycle emissions and release inventory results into draft report for dissemination to project lead engineer and other section leads for evaluation and subsequent project specific tasks.

Deliverables: Team II-B will provide probability maps describing the relative risk of oiling in open water areas of Lakes Michigan, Huron and the Straits of Mackinac and also the relative risk of oiling along shoreline regions in coastal areas of these three waterbodies. GIS based maps will be developed to predict temporal changes in the degree of oiling in both open waters and along impacted shorelines. Model predictions will also provide estimates of oil deposition (density – g/m²) along coastal shorelines within impacted Lake Michigan, Huron and Straits of Mackinac regions. The life cycle-assessment approach will provide the mass balance fate (open water vs shoreline deposit vs sedimentation vs. volatilization) of pipeline products released into the environment under the worst-case scenario releases.

SOW II-C: Analyzing how long it would take to contain and clean up the worst-case release.

Section Team:

Chief Scientist: Aline Cotel (UM)

Section Authors: Amlan Mukherjee (MTU), Stephen Techtmann (MTU)

Section Lead: Daisuke Minakata (MTU)

Task Overview: This team will be responsible for collecting relevant data on private and public response plans and resources to determine the following for each of the worst-case scenarios:

- Personnel and resources required for spill containment;
- Estimated time needed for containment based on the capabilities and limitations of existing emergency response resources;
- Cleanup resources needed for different spill products and scenarios;
- Time required for both short- and long-term cleanup actions
- Effects of adverse weather conditions on containment and cleanup effort requirements

The assessment will include the identification and assessment of all federal, state, local, and private Enbridge emergency resources that are available for spill response in the Straits, including both physical (booms, skimmers), chemical (solidifiers, dispersants, shoreline pretreatment agents), and biological (bioremediation) countermeasures; consideration of recent

emergency response exercises conducted in the Straits; and where necessary, interviews with relevant authorities and response personnel.

Methods: Team C will review all available documentation and literature relevant to previous similar oil spills as well as current Enbridge documentation to evaluate the following. Physical modeling and possible numerical simulations will be used to estimate the time for containment and clean-up based on the data provided by Team A.

1. The capabilities and limitations of existing spill response plans and resources, which will be assessed by evaluating the following plans in terms of regulatory criteria and lessons learned from multi-agency pollution response exercises conducted in the Straits of Mackinac:
 - a. The Area Contingency Plan (ACP)
 - b. Relevant Spill Prevention, Control and Counter (SPCC) Measures Plans
 - c. Enbridge-specific response plans
2. The capabilities and limitations of the available resources;
 - a. identification of all response resources (i.e., physical, chemical, and biological, and short and long term) that can be brought to bear on a worst case discharge
 - b. a tiered, response time-based categorization of available resources
3. The capabilities and limitations of the available personnel;
 - a. evaluation of state, federal, and local response agencies billeted
 - b. available personnel
 - c. training criteria
 - d. exercise participation
4. The duration of activities to contain and cleanup a worst-case spill;
 - a. review of exercise and incident After Action Reports
 - b. lessons learned from resources identified from the item 1
 - c. other relevant documents
5. The limitations of spill response measures and available resources and personnel under adverse weather and seasonal conditions, including winter ice cover

Agencies to cooperate for the acquisition of relevant information will include US Coast Guard; US Fish & Wildlife Agency; US Environmental Protection Agency; Michigan Department of Environmental Quality; Michigan Department of Natural Resources; and Michigan State Police. Adequate representation of the oil spill response community will be identified through potential interviews and the Michigan Petroleum Pipeline Task Force.

Timeline:

Jan 1 – Jan 8 – Virtual team meeting. Identify team members specific tasks.

Jan 8 – Feb 1 - Obtain all relevant documentation from Enbridge and publications related to other similar studies.

Feb 1 – March 15 – Analyze data provided by Team A and make necessary calculations for cleanup and containment time periods.

March 15 – May 1 – Evaluate current resources and personnel to meet the requirements defined by calculations.

May 1 - June 1 - Write initial report for State and public comments.

June 1 – August 15 – Response to public comments, revisions and final report write-up.

Deliverables: Team C will ultimately produce informed estimates of the time span of response activities that would be expected for containment and cleanup in the event of each of the worst-case scenarios identified from Task A.

SOW II-D: Analyzing the short and long term public health and safety impacts.

Section Team:

Chief Scientist: Richard Olawoyin (OU)

Section Authors: Charles Ide (WMU), Gord Paterson (MTU)

Section Lead: Kelly Kamm (MTU)

Task Overview: The team for Task D will be responsible for assessing the scope and magnitude of impacts to public health and safety that could potentially occur in the event of a worst-case Line 5 spill, including contact or airborne exposure to waterborne and atmospheric contaminants, effects on drinking water sources, fire or explosion hazards, and associated disruptions to public health and safety systems. The team will assess the modeled pollutant concentrations generated in the Task B simulations via comparison with existing data on exposure effects and thresholds.

Methods: Fate and transport modeling results from Task II-B will be used to characterize the risk to local and regional communities based on exposure to petroleum related products, during a line 5 pipeline worst case release scenario. Local population demographics will be used to characterize individual groups and communities and identify potential susceptible populations within the petroleum product release areas. The potential hazards associated with the Line 5 pipeline products will be identified and the contaminant concentrations predicted from Task II-B modeling efforts will be evaluated against human health benchmarks for chemicals in environmental media to estimate increased level of risk posed by pipeline products dispersed into the environment. Risk based modeling approaches will be used to estimate potential short- and long-term increases in adverse health effects associated with exposure to oil-spill products, their constituents, and agents used for cleanup/containment. Information required to evaluate risks to public health and safety associated with potential Line 5 release events include but are not limited to;

1. Geographic areas at risk of exposure during worst case scenarios as identified by Task II-B's hydrodynamic modeling efforts describing pipeline product fate and transport.
2. Local coastal communities and populations at risk of exposure within geographic areas susceptible to shoreline deposition/beaching of pipeline petroleum products.

3. Magnitude, frequency and duration of potential human exposure associated with predicted fate and transport of pipeline petroleum products.
4. Population demographics (age distribution, occupation, race, sex) of at-risk communities.
5. Chemical composition and physical and chemical properties of petroleum products transported within Line 5 pipeline.
6. Baseline health status of at risk communities and populations.
7. Reference concentrations or human health benchmarks for exposures to petroleum constituents through inhalation, ingestion and/or dermal exposure pathways.
8. Acute and chronic adverse health effects associated with short- and long-term exposures to Line 5 pipeline products and their constituents released in a worst case scenario.
9. Sources and likely mechanisms of ignition that could trigger combustion or explosion of petroleum products released in an oil-spill event.

Task II-A will provide the worst-case oil spill scenarios for the three products transported by the Line 5 pipeline, in addition to location and duration specific considerations of pipeline product releases, and seasonal effects (e.g. ice-cover, temperature, wind and wave action).

Consequently, multiple modeling simulations are anticipated for Task II-B that will predict the fate and transport of pipeline related products released into the Michigan waters of Lakes Huron and Michigan and the Straits of Mackinac during an oil spill event. Thus, the evaluation of public health and safety impacts associated with a Line 5 pipeline release will require assessment across a range of spatial and temporal scales.

Detailed Subtasks and Time management

Task II-D is dependent on the outcomes of Tasks II-A and II-B and will coordinate assessment efforts in cooperation with the progress of these task groups. It is anticipated that the analysis of short- and long-term public health and safety impacts will require approximately three months to complete. The Task II-D section leader will communicate or coordinate teleconferences with the Task II-A and II-B section leaders within the first month of the project to determine initial progress for identifying geographic areas at risk and extent of oiling predicted during worst-case oil spills. Task II-D section team members will hold bi-weekly teleconference meetings to discuss Task II-A and II-B results, data availability, compilation and requirements, preliminary assessment results and outcomes, and Task specific deliverables.

Subtask II-D 1 (Feb 21 – Feb 28, 2018): Section team members will discuss, identify and assign individual tasks and responsibilities and identify any data gaps and information required for project Task completion. This information will be communicated by the section lead to the Task II-A and II-B section leads to identify any Task II-D data specific needs for the assessment

of short and long-term public health and safety impacts associated with Line 5 worst-case oil spill scenarios.

Subtask II-D 2 (March 1 – March 15, 2018): Compile data including:

- a. Geographic areas at risk of oiling under worst-case scenarios (Tasks II-A & II-B)
- b. Sources of combustion and/or explosion risk (Task II-A)
- c. US Census Bureau population demographics for State of Michigan communities at risk of exposure following worst-case scenario Line 5 pipeline rupture (Task II-B)
- d. Oil concentration information for open water regions and oiled shorelines (Task II-B)
- e. Hazard constituents of pipeline products as outlined in Environmental Protection Agency's guidance document for the characterization of spilled oils, fuels and petroleum products (EPA/600/R-03/072).
- f. Human health benchmarks for pipeline product constituents in water, food, and air.
- g. Acute and chronic health adverse health effects associated with short- and long-term exposures to oil spill products and their constituents.

Subtask II-D 3 (March 16 – March 31, 2018): Complete exposure evaluations for at risk populations including, for example, chronic daily intake estimates through inhalation, ingestion and dermal absorption pathways.

Subtask II-D 4 (April 1 – April 21, 2018): Model the risks of short- and long-term health impacts in affected populations using metrics including hazard indices, quotients, and incremental lifetime cancer risks. Correlate information on exposure doses and health outcomes that will help improve environmental health surveillance and public safety.

Deliverables: The outcomes of the analysis for Task D will consist of the delineation of areas where estimated contaminant concentrations could be expected to cause certain acute or chronic illness; quantification of the likely public exposure based on the time of year; and the likely extent of the fire/explosion hazard in an ignition scenario.

SOW II-E: Analyzing the short and long term ecological impacts.

Section Team:

Chief Scientist: Charles Ide (WMU)

Section Authors: Marla Fisher (WMU), Robert Powell (WCC), Kevin B. Strychar (GVSU) and David Flaspohler (MTU)

Section Lead: Jill Olin (MTU)

Task Overview: The effect areas generated in Task B for the several worst-case scenarios will be overlaid with relevant existing datasets on, e.g., species distributions, migration timing, wetland maps, locations of designated Critical Habitat, Essential Fish Habitat and Important Bird Areas, fisheries resources, and other sensitive ecosystems and features. The team will identify

and produce expert-informed estimates of the magnitude and duration of impacts on potentially affected natural resources, including effects on air and water quality, on fish and wildlife, and on aquatic, benthic, and coastal habitats. The team will also evaluate the ecological impacts to natural resources that may result from proposed mitigation and restoration alternatives identified in Task F. Gaps in data, knowledge or any uncertainties will be identified.

Methods: The project team will assess the ecological effects of a worst case scenario oil spill and potential mitigation and restoration alternatives (identified in Task F), based on the overlap between the affected area (identified by the spill modelling in Task B) and the natural resources, including the sensitivity of those resources, to the scenario and mitigation. The project team will conduct a comprehensive literature review to identify the resources of concern, specific to critical and sensitive habitats and organisms, in and adjacent to the affected area for this assessment. For the different natural resources, we will draw on existing data provided in habitat and wetland designation maps, species distribution maps for both plants and animals, fisheries data, Threatened and Endangered (T&E) listings, and published/grey literature to determine exposure potential and ecological effects, with key focus as follows.

1. Ecological effects on habitats (short- and long-term) will include quantification of habitat loss and contamination for the following:
 - a. Wetland, Upland
 - b. Shoreline
 - c. Intertidal shorelines (including surface waters 0–1 meter)
 - d. Mid-water (0–2 meters from the surface, but above the bottom 2 meters)
 - e. Benthic (bottom + 2 meters)
2. Ecological effects on organisms will include evaluation of the acute effects (direct mortality), chronic effects (compromised health and reduced survival and reproduction) and probable effects using Probable Effects Concentrations, when available, in addition to short- and long-term biological responses to altered or decreased habitat availability for the following:
 - a. Mammals (aquatic and non-aquatic dependent)
 - b. Birds (aquatic and non-aquatic dependent)
 - c. Reptiles and amphibians (aquatic and non-aquatic dependent)
 - d. Macroinvertebrates (aquatic and non-aquatic dependent)
 - e. Aquatic vertebrates
 - f. T & E species—Animals
 - g. T & E species—Plants
 - h. Plants (wetland, upland, submerged and floating aquatic vegetation)
3. Air and water quality will be evaluated using predictive models for parameters such as evaporation, given the outcome of Task B for specific pipeline products, under varying seasonal release scenarios with respect to the following:
 - a. Volatility
 - b. Concentration
 - c. Dispersal
 - d. Contaminant Dissolution

e. Contaminant Degradation

We will define the affected area for the natural resource assessment based on outputs from Task B, where predicted environmental concentrations are above the predicted no-effect concentration levels for direct or acute and chronic effects. We will evaluate indirect effects on a species and habitat basis. Data from historical oil spill events, for example, the 2010 Enbridge spill into the Kalamazoo River, will be used as a reference for estimating the magnitude of impacts and the recovery rates of species and habitats under worst-case scenario seasonal and spatial constraints of the spill.

Deliverables: Estimates of effects on natural resources, including the areas of affected habitats, ecological services that could be impacted, and effects on important species. Both short- and long-term, as well as direct and indirect effects will be summarized.

Detailed Subtasks and Time management:

During the course of accomplishing these above tasks, monthly phone meetings will be held. Completion of Subtask II-E will follow the schedule below:

Subtask II-E (Jan 1-Feb 15): Obtain and compile relevant data, documents and literature.

Subtask II-E (Feb 15 -March 15): Identify the natural resource considerations resulting from the worst-case spill scenarios and possible mitigation and restoration alternatives.

Subtask II-E (March 15- May 1): Evaluate the worst-case scenario effects and potential mitigation alternatives.

Subtask II-E (May 1- June 1): Draft the initial report.

Subtask II-E (June 1- August 15): Response to public comment, revisions, and draft the final report.

SOW II-F: Analyzing potential measures to restore the affected natural resources and mitigate adverse impacts upon ecological and cultural resources.

Section Team:

Chief Scientist: Avery Demond (UM)

Section Authors: Aline Cotel (UM), Jill Olin (MTU), Tim Scarlett (MTU)

Section Lead: Stephen Techtmann (MTU)

Task Overview: This Task will identify the potential measures that could be applied to restore the systems affected by the potential worst case spills identified in earlier tasks. The team for Task F will identify and assess alternative options for restoring natural and cultural resources and/or mitigating the ecological damages quantified in Task E in terms of the availability, effectiveness, requirements, and costs of each countermeasure. This section of the assessment will focus on alternatives and costs of restoring coastal and nearshore habitats, protecting drinking water and restoring water quality, protecting and restoring living coastal and aquatic

resources, mitigating damages to cultural resources, and restoring and enhancing recreational use opportunities.

Methods: Team F will review all available documentation and literature relevant to similar oil spills as well as current Enbridge documentation. Physical modeling and possible numerical simulations will be used to estimate consequences and effects of spills in the framework of ecosystem services lost due to the spill. The team will also identify the type and extent of restoration needed to compensate for the anticipated damage to natural and cultural resources for the different arenas (coastal and nearshore habitats, drinking water and water quality, living coastal and aquatic resources, underwater and coastal archaeological sites, etc.). This approach will allow for the identification of measures that can be employed to mitigate potential risk and the measures best suited for protection and/or restoration of affected resources.

The team will start by identifying available measures and those best suited for addressing the damaged resources for the different arenas. This will be accomplished through virtual meetings with the Task F team and review of relevant documents and publications. Once these measures have been identified, each measure will be evaluated by the following criteria:

- 1) Evidence for effectiveness at reducing risk, restoring damaged resources, or mitigating ecological impact of the worst-case spill.
- 2) Timeframe for best application – Some measures are better suited for early application while others may be employed as longer-term response measures.
- 3) Challenges to the implementation of these measures – The ideal measures should be ready to implement and can be done rapidly to mitigate the long-term impacts of a worst-case spill.
- 4) Costs – A thorough evaluation of potential response measures must take into account the costs for direct comparison of effective measures.

Deliverables: An evaluation of alternative options and costs for mitigating impacts to, and/or restoring, the vulnerable ecological and cultural resources and services identified in Task E. This includes both early/acute actions and longer-term projects.

Detailed Subtasks and Time management:

During the course of accomplishing this task, regular monthly phone meetings will be performed to make sure that tasks are completed in a timely manner.

Subtask II-F 1 (Jan 1 – Feb 1): Obtain relevant documents and publications.

Subtask II-F 2 (Feb 1 – March 15): Identify the relevant measures for mitigation of ecological and cultural impacts from the worst-case spill.

Subtask II-F 3 (March 15 – May 1): Evaluate the identified measures for effectiveness, timeframe of use, challenges to implementation and costs.

Subtask II-F 4 (May 1 – June 1): Write initial report.

Subtask II-F 5 (June 1 – August 15): Response to public comments, revisions, and writing of final report.

SOW II-G/I: Estimating the amount of natural resource & other economic damages, public and private, that would result from a worst-case release.

Section Team:

Chief Scientist: Frank Lupi (MSU)

Section Authors: Yongli Zhang (WSU), Carson Reeling (WMU), Richard (Max) Melstrom (LUC), Steve Miller (MSU)

Section Lead: Latika Gupta (MTU)

Section Objectives

Our work is divided between two sections:

II-G: Estimating the amount of natural resource damages that would result from a worst-case release. This would include, but not be limited to, analyzing:

1. Available information regarding the baseline ecological, natural resource and economic conditions in the areas potentially affected by a worst-case release;
2. The economic value of the natural resources destroyed or impaired;
3. The economic value of the public uses and ecological services provided by the affected resources that would be lost until a final cleanup and restoration is complete; and
4. The economic value of any residual damages to natural resources that could not be cleaned up or restored.

II-I: Estimating all other economic damages, public and private, that would result from a worst-case release. This would include, but not be limited to, identifying and estimating the scope and magnitude of damages not otherwise accounted for in Task II-G, above, to:

1. Subsistence, sport, and commercial fishing and hunting;
2. Commercial navigation;
3. Recreational boating;
4. Tourism and recreation-related businesses in the Great Lakes region;
5. Property values in areas affected by the release; and
6. Losses of tax revenues.

Methods:

We will estimate the dollar value of natural resource damages by calculating the monetary cost of injuries to natural resources that would result from a worst-case release. Damages to natural resources are evaluated by identifying the functions or “services” provided by the resources, determining the baseline level of the services provided by the injured resources, and quantifying the reduction in service levels as a result of the contamination. We will use several methods to quantify damages, including market-based and non-market resource valuation and economic impact analysis (BLM, 2008; Haab and McConnell, 2002). We describe our procedure for addressing each objective for section G below, making note of how we will measure the additional outcomes listed in section I where appropriate.

Objective II-G.1 Analysis of Baseline Ecological, Natural Resource, and Economic Conditions

We will collaborate with other scientists on the project team to predict damage scenarios for a worst-case spill. Key outcomes include (1) physical fates and transport pathways to determine injury, including oil floating on water, current driven transport, stranding on shorelines, sinking, and evaporation; and (2) biological exposure and effects pathways to quantify injury, including dermal contact, ingestion of water, prey consumption, inhalation. Specific data required include information on the characteristics of the release (e.g., substance and quantity), parameters related to the release and the resources likely to be affected (e.g., the location of the spill, the type of environment affected, wind speed at the time of the spill) and information regarding lost services (e.g., length of beach closure, area of hunting closure).

Objective II-G.2 Analysis of the Economic Value of Natural Resources Destroyed or Impaired

The value of a natural resource stock is derived from the present value of its flow benefits, or the value of the ecosystem services it provides (Costanza et al. 1997). These include provisioning, regulating, supporting, and cultural ecosystem services. The process by which we will estimate the value of these ecosystem service flows is described in detail below for Objective II-G.3.

Objective II-G.3-4 Economic Value of Public Uses and Ecological Services Lost Until Restoration is Complete or that Could Not be Cleaned Up or Restored

The economic value of public uses will be determined from demand models. These models measure the demand for ecological services as a function of costs, service attributes and user characteristics. Economists have developed revealed preference and stated preference approaches to value natural resources. Revealed preference approaches, like the travel cost method, are a preferred method for measuring the value of natural resource-based recreational activities (Farber et al. 2006; English et al. 2017). The travel cost method uses the measurable effect of travel cost on recreation demand to determine the maximum value or willingness to pay that visitors have for a recreation site or experience. Several existing demand models can be used to measure the value of ecological services in the Straits region, including beach visits (Objective II-I.4; Weicksel, 2012; Chen, 2013; Cheng 2016), sportfishing (Objective II-I.1; Melstrom and Lupi, 2013; Knoche 2014), and sport hunting (Objective II-I.1; Knoche, 2014). These models will be used to predict the loss of economic value from a worst-case release. Damage estimates will include the value of uses lost until a final cleanup and any residual damages that could not be cleaned up.

The economic value of public uses with no existing model of Michigan users (e.g., recreational boating [Objective II-I.3], visits to cultural or historic sites [Objective II-I.4]) will be measured using benefit transfer. Benefit transfer methods provide economic value estimates for non-priced natural resources based on existing studies and are useful in ex ante estimates of risks posed by unobserved events. Secondary studies are selected based on similarity of conditions and environment to the study event and may entail clustering estimates across multiple studies. The secondary study estimates are used as a basis for demand estimates but are modified based on local demographics and geography to better reflect the primary study region. There are two benefits transfer methods—value transfer and function transfer (Palm-Foster et al.,

2013). Value transfer assigns a value measured in the secondary study to the good or activity in the primary study. Function transfer applies the demand model developed in the secondary study to demand for the good or activity in the primary study. Benefits function transfer will be employed when practicable. Benefits function transfer is preferable in valuing recreational activities because it can measure the economic loss from the closure of several recreation areas more accurately than value transfer (Rosenberger and Loomis, 2017; Palm-Foster et al., 2016). Public use of natural resources will be measured by existing data. Sources include but are not limited to: state fee and license records, visitor records maintained by state and federal organizations, the MSU Michigan Recreational Angler survey, the MSU Great Lakes Beaches web survey, MDNR Game Harvest surveys, and the USFWS National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

A worst-case release may affect the value of lakefront and some inland property sold during the event and subsequent cleanup and restoration (Objective II-I.5). Hedonic regression analysis is the most common method used to estimate damage to real property from changes in environmental amenity values (Haab and McConnell, 2002). This method involves estimating the price of real property as a function of its characteristics (e.g., lot size, square footage of the building, neighborhood characteristics). Prior work estimates the effect of oil spills on surrounding property values, albeit for a regions outside of Michigan (Simons et al., 2001). We will therefore use benefit function transfer methods to estimate the effect of an oil spill on affected properties as a fractional response on property values of baseline property values.

Baseline property values of affected properties will be obtained from county assessor's offices and/or via data-sharing agreements with commercial sources such as Zillow for coastal housing up to a to-be-determined distance from the coast, as suggested by the existing literature.

We will use an input-output model of economic activity in the affected region to estimate the economic impacts of a release. Changes in economic activity in a given sector of the economy (including the composition of tourism-related industries and impacted commercial shipping and fisheries [Objectives II-I.1,2,4]) gives rise to larger economic contributions once accounting for the circular flow of transactions throughout the economy. Impact estimates will be modeled to account for secondary impacts using the economic simulation software IMPLAN, calibrated for the affected region, the state and for the nation. The economic loss of commercial activities (Objectives II-I.1,4) will be measured using market data on workers' wages and salaries. This data is collected by the U.S. Bureau of Labor Statistics (BLS) ES202 data. The ES202 is derived from required employer establishment reports on employment and wages for fulfilling unemployment insurance mandates and provides region-specific earnings profiles by industry classification down to the county level. Other data relating to production, output and value added will be collected by the Bureau of Economic Analysis for estimating relationships between employment changes and production changes, including proprietor's income.

Changes in economic activity and property values will impact two dominant channels of public tax revenues, personal income taxes and property taxes. Personal income taxes will be based on average state and local personal tax revenues (Census of Government) and state personal income (Bureau of Economic Analysis), capturing the estimated changes in wage and proprietors' incomes. These will be statewide estimates for affected states and will be reported as both direct tax revenue impacts and total tax revenue impacts that account for all secondary effects. Property tax impacts will be assessed based on regional (as small as the county level),

average millage rates applied to estimated change in assessed property values (Objective II-I.6).

Equipment and Supplies

Personal laptop computers and previously-purchased statistical software will be used to conduct the section research. No additional equipment or supplies are needed.

Deliverables:

The section contributors will assist in writing one or more draft reports of the analysis, be available to attend one or more public information presentations on the draft analysis, consider and respond to comments on the draft report(s) related to Section G and I, and assist in writing the final report.

Detailed Sub-tasks and Time Management:

Team Responsibilities

The responsibilities for each contributor to Sections G and I are listed below:

Section Lead (Latika Gupta)

- Liaison with the PI and Project Support/Coordination Staff towards overall progress success;
- Participate in section team communications (specific methodologies to be established by each section team, and may include Zoom or other video conference call sessions, email communications and cloud-based collaborative environments);
- Facilitate assigned section's communication to other section leads to support information exchange, including seeking input and responses to questions across the entire project collaboration;
- Coordinate and lead section communication, section outline development, section draft report and the assigned section's contribution to the final report;
- Support section authorship by contributing to writing, as expertise allows; and
- Schedule frequent team communications to ensure timely completion of section milestones.

Chief Scientist (Frank Lupi)

- Participate in section team communications (specific methodologies to be established by each section team, and may include Zoom or other video conference call sessions, email communications and cloud-based collaborative environments);
- Lead identification of methodologies to address assigned section information needs;
- Validate data used within the assigned section report;
- Contribute to the section outline development, section draft report and the assigned section's contribution to the final report;

- Lead public engagement related to assigned section, but only under the direction of the PI; and
- Support response to public comments pertaining to assigned section.

Section Authors (Yongli Zhang, Carson Reeling, Richard Max Melstrom, and Steve Miller)

- Participate in section team communications;
- Identify data/information needs and work collaboratively with Chief Scientist and Section Lead to acquire material in a timely manner to ensure meeting report development milestones;
- Lead the writing of the assigned report section(s), individually or collaboratively with other section authors and other members of the section team;
- Assist in formulating responses to public comments; and
- Incorporate feedback from public comments and public outreach into final section draft.

Timeline

We will adhere to the following timeline sections G and I of the analysis report:

- Jan 1 - 5: Team meeting, identify individual tasks
- Jan 8 - Feb 2: Develop economic models
- Feb 5 - 28: Obtain data
- Mar 12 - 26: Obtain worst-case release scenario
- Apr 2 - May 25: Estimate damages
- May 28 - 31: Compile draft of sections I and G
- June 1 - Aug 1: Participate in public presentation, respond to public comments, make necessary revisions and prepare the draft report
- Aug 1: Final report section due for inclusion in final report

References:

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Palm-Forster, Leah H., Frank Lupi, and Min Chen. "Valuing Lake Erie Beaches Using Value and Function Transfers." *Agricultural and Resource Economics Review* 45, no. 2 (2016): 270-292.

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SOW II-H: Estimating the governmental costs that would be incurred as a result of a worst-case release.

Chief Scientist: John F. Bratton (LimnoTech)

Section Authors: Amlan Mukherjee (MTU), David Shonnard

Section Lead: Adam Wellstead (MTU)

Task Overview: The task of this team will be to estimate the costs to federal, state, local, and tribal governments of responding to the spill emergency, conducting damage assessments, monitoring cleanup activities, overseeing restoration efforts, and negotiating a settlement with responsible parties in the event of a worst-case spill. These estimates will utilize available and State-provided cost information, such as the Coast Guard's reimbursable standard rates, Federal pay and per diem tables, and comparisons with government costs and claims from other spill responses as a cost basis, using the cleanup time estimates from Task C to guide the assessment.

Methods: The team will employ a range of methods to estimate costs of government oversight of oil spill response and recovery. We will rely on published reports and government settlement details from past oil spills in locations with comparable geographic and ecological characteristics, including marine settings, and with oil properties and volumes that are similar or can be scaled or adjusted proportionally to the worst-case spill parameters. We will also consider the particular response roles and responsibilities of various government agencies. Federal roles are outlined in the 2016 revision of the Great Lakes Geographic Annex (CANUSLAK

Plan) to the bilateral Joint Marine Pollution Contingency Plan; Canadian government response costs, if any, will not be estimated under this task. Government roles for 16 federal agencies, 8 states, tribes (12 in Michigan), and first responders are described in the coastal operational area sections of the 2015 Region 5 Regional Contingency Plan / Area Contingency Plan.

One of the most important factors in estimating oil spill response costs for the government is the length of shoreline and types of habitats impacted by the spill. Because a worst-case release into the waters of the Straits is likely to affect long stretches of shoreline on the Upper and Lower Peninsulas, as well as islands on either side of the Straits, information from Task B will be needed. We will base estimates on available data on government oversight costs for response to and recovery from past oil spills, adjusted to the particulars of the estimated worst-case spill scenario for the Straits, with methods and assumptions clearly stated. In addition to this statistical approach, we will also employ unit process cost factors (e.g., hourly or day rates for government or chartered support ships and aircraft, hourly pay and overhead rates for various labor categories of government oversight employees and contractors, rental rates for temporary command post and meeting space). Longer-term post-response costs associated with damage assessment, monitoring, restoration oversight by trustees, and litigation or negotiation with responsible parties will also be considered.

Deliverables: The team will prepare a best-estimate summary of costs to federal, state, local, and tribal governments in the event of a worst-case oil spill response and recovery scenario, including a description of methods and assumptions applied, estimates of the uncertainty range in the calculated costs, and consideration of how costs are likely to change over time due to inflation and other factors.

SOW II-X: Qualitative considerations and broader impacts

*Section Team:*¹

Section Scientists and Authors: Alice Lippert (DoE retired), Joanne Shore (DoE former), Mark Rouleau (MTU), Chelsea Schelly (MTU), Nancy Langston (MTU), Roman Sidortsov (MTU)

Section Lead: Roman Sidortsov (MTU)

Task Overview:

The Section X team will engage in a qualitative risk identification to provide a comprehensive overview of risks that various affected communities perceive to arise in connections with the Straits Pipelines. Understanding perceived risks will provide qualitative guidance for the risk analysis frameworks carried out by the other Sections thereby strengthening their analysis. The Section X team will identify key actors likely to be impacted by a potential spill, including Indigenous communities, state and U.S. and Canadian local government officials, environmental and historic preservation groups, as well as tourism, fishing, and recreation industries. The team

¹ Due to the cross-cutting nature of the task, section team members will share responsibilities of section scientist and section authors.

will first identify a range of risks and perspectives regarding the valuation of risk severity, and then explore the range of risk avoidance, tolerability, and acceptance concerns expressed by key actors. The Section X team will work closely with other sections to ensure that the identified risks, severity valuation perspectives, and other qualitative risk findings receive due consideration in the full risk analysis.

Methods:

The Section X team will rely on documentary analysis, focus groups, and qualitative semi-structured interviews to obtain relevant data. The team will employ complementary and corroborative discourse and content analyses to evaluate and assess the obtained data. To the extent necessary, team members will also engage in legal analysis to identify risks arising out of legal rights and obligations by various parties in case of transboundary pollution, fishing rights impingement, etc.

The Section X team will apply the aforementioned methods as follows:

1. Team members will identify all applicable sources of secondary documentary data such as public comments received in the process of the alternatives analysis.
2. The relevant data will be analyzed in Nvivo or Atlas.ti software.
3. Focus groups will be designed based upon the initial documentary analysis. Between one and three focus groups will be conducted.
4. Semi-structured interviews (15-25) with key actors will be designed, scheduled, and conducted based upon the results of the initial document review and/or focus group(s).
5. Legal analysis will be conducted simultaneously with the documentary analysis, focus group(s), and qualitative interviews.
6. The results of the focus group(s), semi-structured interviews, and legal analysis will be added to Nvivo or Atlas.ti; team members will be assigned to specific topical areas in which they will conduct discourse and content analyses.

Team members will ensure that all relevant project activities have received approval by Michigan Tech's Institutional Review Board.

Detailed Subtasks and Time management:

Because of the cross-cutting nature of this Task, the team will carry out its research activities in close collaboration with other section teams for the duration of the analysis. To facilitate collaboration, the team will establish an internal platform to provide qualitative guidance and receive input from other teams.

Below is the detailed scope of work and timeline for the seven subtasks in the Task II-X of the proposed project:

Subtask II-X 1 (Jan 1 2018 to Jan 15 2018): Team members will gather, organize, categorize, and upload all relevant documents into Nvivo or Atlas.ti software.

Subtask II-X 2 (Jan 1 2018 to Jan 15 2018): Team members will establish the internal collaboration platform and will develop the collaboration protocol to other teams.

Subtask II-X 3 (Jan 15 2018 to Feb 28 2018): Team members will conduct content and discourse analyses of the documentary data.

Subtask II-X 4 (Feb 1 2018 to Mar 15 2018): Team members will organize and conduct focus groups and will systematize the obtained data.

Subtask II-X 5 (Mar 1 2018 to Mar 21 2018): Team members will prepare and present an internal interim qualitative risk identification report to other project teams.

Subtask II-X 6 (Mar 15 2018 to Aug 2 2018): Upon the internal interim report presentation, team members will provide qualitative guidance to other section teams as necessary.

Subtask II-X 7 (Feb 1 to April 1 2018) Team members will develop, schedule, and conduct qualitative interviews using the results of prior analysis for guidance.

Subtask II-X 8 (Feb 1 to April 1 2018) Team members will conduct the aforementioned legal analysis.

Subtask II-X 9 (Mar 1 to May 1 2018) Team members will merge all the relevant data in Nvivo or Atlas.ti software and will conduct complementary and corroborative content and discourse analysis.

Subtask II-X 10 (May 1 to June 1 2018) Team members will prepare a section of the draft report and will assist other section teams with incorporating qualitative data into the part for which they are responsible.

Subtask II-X 11 (June 1 to August 2 2018) Team members will respond to public comments, make necessary revisions and prepare the draft report.

Deliverables:

The Section X will prepare an internal interim report to inform other section teams regarding the qualitative picture of risks in connection with the operation of the Straits Pipelines. The team will also contribute to the final report by presenting its qualitative assessment of the identified risks, severity valuation perspectives, and other qualitative risk findings.

6. Proposed Schedule and Deliverables

The project team will, according to a schedule agreed on with the State:

1. Prepare a draft report of the analysis, with periodic input/review from the State's project technical team as the drafting progresses;
2. Prepare and conduct a public information presentation on the draft analysis;
3. Conduct up to three public "listening sessions" to gather critical feedback;
3. Consider and respond to listening session and written comments on the draft report;
4. Prepare the final report.

The proposed project schedule for completing task activities, communicating with the State and the public, and delivering draft and final reports is presented in the form of a Gantt chart (Table

2 below). Because the analysis is designed in such a way that later tasks depend on the results of earlier tasks as inputs, the analysis will be drafted in stages.

Table 2: Timeline of project communications, tasks and deliverables.

Activity/Deliverable		Jan	Feb	Mar	Apr	May	June	July	August
Comm	Weekly meeting of core team and section leads								
	Biweekly web conference w/SoM technical team								
Analysis & Drafting	Task A								
	Task B								
	Task C								
	Task D								
	Task E								
	Task F								
	Task G/I								
	Task H								
	Task X								
Input Gathering & Revision	Synthesis of complete draft report								
	Delivery of draft to State of Michigan								
	Draft report public release								
	Public presentations & listening sessions								
	Public comment period								
	Comments on comments period								
	Consider and respond to comments								
	Delivery of final report								

	More work-intensive period of drafting the analysis for this team's task
	Team will still be active planning and gathering data (before analysis) or helping other teams integrate the results into their own tasks (after analysis)

7. Proposed Budget

Budget

As this Draft Pre-Proposal is under review by the State of Michigan, the project team is proceeding with acquisition of all sub-contractors financials commitments. At the present time, our total project costs are estimated at:

\$749,109.00

Complete budget detail will be provided in the final proposal.

Supporting Budget Rationale

Scope of Work Recommendations

The proposal team recommends combining tasks G and I into one larger analysis conducted by a single team because the work of these tasks is so closely related. The analyses requested for both sections would still be included in the project reports. This suggestion is reflected in the use of “Task G/I” throughout this proposal.

Independent Risk Analysis for the Straits Pipelines

Appendix A: Curricula Vitae

Anderson, Eric (NOAA Great Lakes Environmental Research Laboratory)	1
Ariaratnam, Samuel (Ariaratnam Enterprises, Inc.)	3
Bratton, John (LimnoTech)	5
Chu, Philip (NOAA Great Lakes Environmental Research Laboratory)	7
Cotel, Aline (University of Michigan)	9
Demond, Avery (University of Michigan)	11
Fisher, Marla (Western Michigan University)	13
Flaspohler, David (Michigan Technological University)	15
Green, Sarah (Michigan Technological University)	17
Grimm, Amanda (Michigan Technological University)	19
Gupta, Latika (Michigan Technological University)	21
Huang, Ying (North Dakota State University)	23
Ide, Charles (Western Michigan University)	25
Kamm, Kelly (Michigan Technological University)	27
Langston, Nancy (Michigan Technological University)	29
Lippert, Alice (DoE, Ret.)	31
Lupi, Frank (Michigan State University)	33
Meadows, Guy (Michigan Technological University)	34
Melstrom, Richard "Max" (Loyola University Chicago)	36
Miller, Steven (Michigan State University)	38
Minakata, Daisuke (Michigan Technological University)	40
Mukherjee, Amlan (Michigan Technological University)	42
Olawoyin, Richard (Oakland University)	44
Olin, Jill (Michigan Technological University)	46
Paterson, Gordon (Michigan Technological University)	48
Powell, Robert (Powell & Associates Science Solutions)	50
Reeling, Carson (Western Michigan University)	52
Rouleau, Mark (Michigan Technological University)	54
Sadri-Sabet, Mir (Michigan Technological University)	56
Scarlett, Timothy (Michigan Technological University)	58
Schelly, Chelsea (Michigan Technological University)	60
Schwab, David (University of Michigan)	62
Shonnard, David (Michigan Technological University)	64
Shore, Joanne (AFPM, Ret.)	66
Sidortsov, Roman (Michigan Technological University)	68
Strychar, Kevin (Grand Valley State University)	70
Techtmann, Stephen (Michigan Technological University)	72
Wellstead, Adam (Michigan Technological University)	74
Xue, Pengfei (Michigan Technological University)	76
Zhang, Yongli (Wayne State University)	78

ERIC J. ANDERSON, PH.D.

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MAJOR RESEARCH INTERESTS

- Hydrodynamic modeling of the Great Lakes and connecting channels
- Developer of the next-generation NOAA Great Lakes Operational Forecasting System (GLOFS)
- Contaminant transport in the Straits of Mackinac

EDUCATION

- | | | |
|--------------|---|------|
| Ph.D. | Mechanical & Aerospace Engineering
Case Western Reserve University, Cleveland,
Ohio | 2007 |
| B.S. | Mechanical Engineering
Case Western Reserve University, Cleveland,
Ohio | 2003 |

PROFESSIONAL EXPERIENCE

- | | |
|---|-------------------------|
| <i>Physical Scientist / Oceanographer</i>
<i>Physical Oceanography and hydrodynamic modeling</i>
Great Lakes Environmental Research Laboratory
National Oceanic and Atmospheric Administration, Ann Arbor, MI | August 2012 – present |
| <i>Assistant Research Scientist</i>
Cooperative Institute for Limnology and Ecosystem Research
University of Michigan, Ann Arbor, MI | August 2010 – July 2012 |
| <i>Postdoctoral Research Associate</i>
National Research Council
NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, MI | July 2007 – July 2009 |

SYNERGISTIC ACTIVITIES

- Development lead for the Lake Michigan-Huron Operational Forecast System (LMHOFS), including the Straits of Mackinac at high-resolution, present
- Hydrodynamic Data and model output provider to the State of Michigan in support of Risk Assessment and Worst Case Scenario report, 2016
- Provided forecasted currents in the Straits of Mackinac for NOAA and to USCG for the Spill Exercise in the Straits of Mackinac, 2015
- Provided the hydrodynamic model base for the UM Water Center report "Statistical Analysis of Straits of Mackinac Line 5: Worst Case Spill Scenarios, 2016

SELECT GRANTS

02/2016 – 02/2017, **NOAA NMFS**, *Assessment of contaminated sediment transport in the Manistique River*, **Principal Investigator**, \$185,000

10/2014 – 09/2017, **NOAA Coastal Storms Program**, A high-resolution wave and circulation model guidance system for the Great Lakes Region, **Co-Principal Investigator**, \$890,000

05/2012 – 04/2013, **NOAA NMFS**, *Contaminant transport and seiche effects on a lake-tributary system and sediment dynamics*, **Principal Investigator**, \$60,000

08/2009 – 08/2010, **GLOS**, *An Operational Hydrodynamic Model of the Huron to Erie Corridor: Dye experiments in the St. Clair River*, **Principal Investigator**, \$80,000

SELECT RELEVANT PUBLICATIONS

1. **Anderson E.J.** and D.J. Schwab, **2017**. Meteorological influence on summertime baroclinic exchange in the Straits of Mackinac, *J. Geophysical Research – Oceans*, doi:10.1002/2016JC012255
2. **Anderson E.J.** and D.J. Schwab, **2013**. Predicting the oscillating bi-directional exchange flow in the Straits of Mackinac, *J. Great Lakes Research* 39(4):66671 (DOI:10.1016/j.jglr.2013.09.001)
3. Sun Y., Wells M.G., Bailey S.A., **Anderson E.J.**, **2013**. Physical dispersion and dilution of ballast water discharge in the St. Clair River, *Water Resources Research* 49:1-13 (DOI:10.1002/wrcr.20201)
4. **Anderson E.J.** and Schwab D.J., **2012**. Contaminant transport and spill reference tables for the St. Clair River, *Marine Technology Society* 46(5).
5. **Anderson, E.J.**, Phanikumar M.S., **2011**. Surface storage dynamics in large rivers: Comparing three-dimensional particle transport, one-dimensional fractional derivative, and multirate transient storage models, *Water Resources Research*, 47, W09511, doi:10.1029/2010WR010228.
6. Szalinska E., Drouillard K.G., **Anderson E.J.**, Haffner G.D., **2011**. Factors influencing contaminant distribution in the Huron-Erie Corridor sediments. *Journal of Great Lakes Research* 37(1): 132-139, doi: 10.1016/j.jglr.2010.11.005.

SCIENCE ADVISORY PANELS

Michigan Departments of Environmental Quality, DNR, and Agriculture and Rural Development, Great Lakes Net-Pen Commercial Aquaculture: A Short Summary of the Science, science panel member (2015)

NOAA Coastal Storms Program – science panel (2014)

AWARDS, HONORS, SEMINARS

U.S. Dept. of Commerce Bronze Medal Award for Superior Federal Service, NOAA – For successfully developing and transitioning the next-generation Lake Erie Operational Forecast System into NOAA operations - 2017

U.S. Dept. of Commerce Bronze Medal Award for Superior Federal Service, NOAA – For response activities for the Lake Erie harmful algal bloom that impacted drinking water supplies in Ohio and Michigan - 2016

Samuel T. Ariaratnam, Ph.D., P.E., P.Eng., F.ASCE

(I). Education

University of Waterloo (Canada)	Civil Engineering	B.A.Sc.	1989
University of Illinois at Urbana-Champaign	Civil Engineering	M.S.	1991
University of Illinois at Urbana-Champaign	Civil Engineering	Ph.D.	1994

(II). Relevant Experience

2008-present	Professor & Construction Engineering Program Chair, Arizona State University
2001-2008	Associate Professor, Del E. Webb School of Construction, Arizona State University
2000-2001	Associate Professor, Civil and Environmental Engineering, University of Alberta
1996-2000	Assistant Professor, Civil and Environmental Engineering, University of Alberta
1995-1996	Visiting Assistant Professor, Civil Engineering, United States Airforce Academy

(III). Products

(i) Products Most Closely Related to the Project

1. Bennett, R.D., and S.T. Ariaratnam (2017), *Horizontal Directional Drilling Good Practices Guidelines* 4th Edition, NASTT, Cleveland, OH, ISBN 1-928984-17-7, 300 pp.
2. Francom, T., M. El-Asmar, and S.T. Ariaratnam (2017). "Longitudinal Study of Construction Manager at Risk for Pipeline Rehabilitation", *Journal of Pipeline Systems Engineering and Practice*, ASCE, 04017001-1 to 04017001-11.
3. Ariaratnam, S.T. and M. Chandrasekaran (2010). "Pipeline Integrity Evaluation of Oil Pipelines using Free-Swimming Acoustic Technology", *Proceedings of the 8th International Pipeline Conference*, ASME, Calgary, Alberta, September 27-October 1, on CD Paper IPC2010-31489.
4. Ariaratnam, S.T. and M. Chandrasekaran (2010). "Development of an Innovative Free-Swimming Device for Detection of Leaks in Oil and Gas Pipelines", *Proceedings of the 2010 ASCE Construction Research Congress "Innovation for Reshaping Construction Practices"*, ASCE, Banff, Alberta, May 8-10, pp. 588-596.
5. Ariaratnam, S.T. and M. Chandrasekaran (2010). *Development of a Free-Swimming Acoustic Tool for Liquid Pipeline Leak Detection including Evaluation for Natural Gas Pipeline Applications*, Prepared for U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, Washington, DC, 66 pp.

(ii) Other Significant Products

1. Francom, T., M. El Asmar, and S.T. Ariaratnam (2016). "Performance Analysis of Construction Manager at Risk on Pipeline Engineering and Construction Projects", *Journal of Management in Engineering*, ASCE, 04016016-1 to 04016016-14.
2. Ariaratnam, S.T., K. Piratla, A. Cohen, and M. Olson (2013). "Quantification of a Sustainability Index for Underground Utility Infrastructure Projects", *Journal of Construction Engineering and Management*, ASCE, Vol. 139, pp. A4013002-1 to A4013002-9.
3. Lau, S.C., M. Lu, and S.T. Ariaratnam (2010). "Applying Radial Basis Function Neural Networks to Predict Next-Cycle Production Rates in Tunnelling Construction", *Tunneling and Underground Space Technology*, Elsevier Science, U.K., Vol. 25, Issue 4, pp. 357-365.
4. Koo, D.H., S.T. Ariaratnam, and E. Kavazanjian (2009). "Development of a Sustainability Assessment Model for Underground Infrastructure Projects", *Canadian Journal of Civil Engineering*, CSCE, May, Vol. 36, No. 5, pp. 765-776.
5. Ariaratnam, S.T., B.C. Harbin, and R.L. Stauber (2007). "Modeling of Annular Fluid Pressures in Horizontal Boring", *Tunneling and Underground Space Technology*, Elsevier Science, U.K., Vol. 22, Nos. 5-6, pp. 610-619.

(IV). Synergistic Activities

1. International engagement. Served as Chairman of the International Society for Trenchless Technology (2010-2013). Developed formal relationships between ASU and Chinese universities including Guest Professorship appointment at two institutions. Invited lectures on trenchless pipeline construction methods for Professional Engineering Societies and over 20 countries.
2. Service to the scientific and engineering community outside of the individual's immediate organization. Currently, I am the Chair of the American Society of Civil Engineers (ASCE) Pipeline Division Executive Committee, where I engage in activities mainly related to pipeline infrastructure. I current serve on the Committee for "Study of Propone Gas Pipeline Facilities", National Academies, Transportation Research Board. I previously served on the Committee on "Underground Engineering for Sustainable Development", National Academies, Division on Earth and Life Studies (2010-2012). I was a member of the Plastics Pipe Institute's HDPE Municipal Advisory Board (2008-2012). I helped write MAG Specifications 608 "Horizontal Directional Drilling", which were officially adopted on January 1, 2016.
3. Professional recognition. Recipient of 2015 Arthur M. Wellington Prize from the American Society of Civil Engineering (ASCE), 2015 Elected Fellow of ASCE, 2003 Young Civil Engineer Achievement Award from the University of Illinois. Received other significant awards from the American Society of Civil Engineers, North American Society for Trenchless Technology, California Department of Transportation, Halliburton Energy Services, Phoenix Business Journal, and the City of Los Angeles, CA
4. Industry impact. I am the co-author of several books related to trenchless installation methods for sewer and water pipelines. In particular, several States have adopted the "Horizontal Directional Drilling Good Practices Guidelines" as the standard of care in this area. Additionally, I co-authored the "Pipe Bursting Good Practices" book. Both are published by the North American Society for Trenchless Technology (NASTT). Have consulted and/or provided educational training to the oil and gas sector including; Comgas (Brazil), Petrobras (Brazil), India Oil Company (India), China National Petroleum Corporation (China), Sinopec (China), Towne Gas (Hong Kong), TransCanada Pipeline, Enbridge, Exxon-Mobile, Sunoco, Shell, Southwest Gas Corporation, British Petroleum, Williams, ConocoPhillips, Pacific Gas & Electric (PG&E).



John F. Bratton, PhD
Senior Scientist

Areas of Specialization:

Sediment Biogeochemistry
Shallow Groundwater Flow
Coastal and Glacial Geology
Environmental History
Environmental Law

Education:

Ph.D., Geology, University of California at Berkeley
Sc.B., Geology-Chemistry, Brown University

Career Highlights:

- Author of dozens of research publications in multiple disciplines in earth and environmental sciences.
- University teaching experience in environmental geology, glacial geology, field geology, land resources, marine geology, biogeochemistry, and physical and biological oceanography.
- Experience conducting and managing all phases of contaminated site remediation and restoration projects including site investigation and RCRA closure activities; sampling plan design and development; environmental sampling, monitoring, and testing in all media for complex suites of compounds; oversight of land-based and over-water drilling including soil boring, rock coring, and monitoring or recovery well installation and operation; litigation and cost allocation support.

John F. Bratton, Ph.D., is a Senior Scientist at LimnoTech with broad expertise in earth and environmental sciences, including successful leadership of projects involving large ecosystem restoration with a nutrient reduction focus, remedial investigation/remedial design for contaminated sites, and litigation support. He has worked as a consultant, researcher, educator, and science manager for over 30 years, especially in the Northeast, Great Lakes and Pacific regions, and has contributed to over 100 scientific publications and research presentations. His specialties include groundwater-surface water interaction and contaminant transformations, coastal and glacial geology, freshwater and ocean sediment biogeochemistry, environmental history on decade to century scales, and environmental law and policy.

John previously served as Deputy Director and Acting Director of NOAA's Great Lakes Environmental Research Laboratory, and as a research group leader with the Coastal and Marine Geology Program of the U.S. Geological Survey in Woods Hole, Massachusetts. He received a doctorate from the University of California at Berkeley, and has taught undergraduate and graduate-level courses at institutions including Boston University, Au Sable Institute of Environmental Studies, and Wayne State University.

Select Professional Publications

Szymczycha, B., Kroeger, K.D., Crusius, J., and Bratton, J.F., 2017, Depth of the vadose zone controls aquifer biogeochemical conditions and extent of anthropogenic nitrogen removal, *Water Research*, 123:794-801.

Verhamme, E.M. T.M. Redder, D. Schlea, J. Grush, J.F. Bratton, J.V. DePinto, 2016, Development of the Western Lake Erie Ecosystem Model (WLEEM): Application to connect phosphorus loads to

cyanobacteria biomass, *Jour. of Great Lakes Research*, 42(6):1193-1205.

Bratton, J.F., 2016, Algal bloom researchers adjust to demand for data, *Great Lakes Connection*, International Joint Commission (online).

Gronewold, A.D., E.J. Anderson, B. Lofgren, ... J. Bratton, 2015, Impacts of extreme 2013-2014 winter conditions on Lake Michigan's fall heat content, surface temperature, and evaporation, *Geophysical Research Letters*, 42:3364-3370, doi: 10.1002/2015GL063799.

Baskaran, M., and J.F. Bratton, 2013, Investigating human-induced changes of elemental cycles in the Great Lakes, *Eos*, 94(28):248.

Bratton, John F., 2010, The three scales of submarine groundwater flow and discharge across passive continental margins, *Jour. of Geology*, 118:565-575.

Bratton, John F., Böhlke, J.K., Krantz, David E., and Tobias, Craig R., 2009, Flow and geochemistry of groundwater beneath a back-barrier lagoon: The subterranean estuary at Chincoteague Bay, Maryland, USA, *Marine Chemistry*, vol. 113, p. 78-92, doi: 10.1016/j.marchem.2009.01.004.

Bratton, John F., 2007, The importance of shallow confining units to submarine groundwater flow, *Int'l Assoc. of Hydrol. Sciences Publication* 312, p. 28-36.

Bratton, J.F., Colman, S.M., and Seal, R.S., II, 2003, Eutrophication and carbon sources in Chesapeake Bay over the last 2700 years: Human impacts in context, *Geochimica et Cosmochimica Acta*, 67(18):3385-3402.

Bratton, J.F., S.M. Colman, E.R. Thieler, and R.R. Seal, II, 2002, Birth of the modern Chesapeake Bay estuary 7,400 to 8,200 years ago and implications for global sea-level rise, *Geo-Marine Letters*, 22:188-197.



Key Project Experience

Support of U.S. Army Corps of Engineers Research, Management, and Outreach. Dr. Bratton has overseen two support contracts for research on mitigation of impacts of munitions and heavy metals at Army facilities that has been conducted at the Engineer Research and Development center in Vicksburg, MS. He has also briefed USACE staff, and supported joint meetings with partners including congressional staff, leadership of other agencies, and environmental non-profit groups on approaches to reduce sediment and nutrient loading to Lake Erie, and resulting impacts on harmful algal blooms in the lake.

Great Lakes "State-of-the-Science" Assessments.

Dr. Bratton has managed several projects and supported government agencies and Great Lakes Water Quality Agreement annex committees that required synthesis of the most recent research results for the Great Lakes. This work has included an assessment of oil spill ecological impacts in the Great Lakes, basin-wide nutrient loads and impacts, fertilizer and manure impacts on Western Lake Erie, changes in the food web of Lake Huron due to invasive species and proposed net pen aquaculture, and determination of nutrient reduction targets for Lake Erie and Lake Ontario to reduce algae and hypoxia.

Incorporating Science-Based Adaptive Management into Great Lakes Restoration.

As part of the federal USEPA-led Regional Working Group, including the U.S. Army Corps of Engineers, Dr. Bratton contributed significantly to development of the *Science-Based Adaptive Management Process for Great Lakes Restoration Initiative Action Plan II* (2014). This process was designed to identify the most critical ecosystem problems in the Great Lakes, select projects to address those problems, assess effectiveness of actions implemented, and inform future restoration efforts.

Understanding Coastal Aquifer Systems. Dr. Bratton led a national effort to study groundwater-surface water interactions in coastal settings including sandy shorelines, marshes, limestone karst environments, and rocky coasts. The project showed that onshore water table fluctuations interacted with daily and monthly tidal cycles to move groundwater from land to sea, but with significant chemical transformations of nitrogen species and other compounds in the subsurface mixing zone both under the shore and offshore prior to discharge.

Documenting Chesapeake Bay's Environmental History.

By collecting continuous sediment cores up to 68 feet long using novel techniques, and analyzing physical, geochemical, and biological proxy data from the cores, Dr. Bratton contributed to a team that helped document the detailed history of Chesapeake Bay and its watershed. A chronology was constructed that showed when the Bay transitioned from fresh to brackish water during post-glacial sea level rise, how sedimentation rates increased in the Bay after agricultural development of the watershed, and how and where seasonal hypoxia developed in Bay

bottom waters as a result of excess nutrient delivery.

Characterizing and Restoring Contaminated Sites.

Dr. Bratton has been involved in all phases of site investigations and remediation work for clients from New Jersey to Maine, as well as in California and Washington. He has worked with contaminants including PCBs, solvents, heavy metals, mercury, radioisotopes, nitrate, and petroleum products at landfills, waste lagoons, airports, chemical plants, tanker truck depots, wastewater treatment plants, bulk fuel storage sites, and manufacturing facilities. Dr. Bratton has also supported toxic tort litigation efforts and CERCLA negotiations including document discovery and review, depositions, site visits, and multi-party allocation of remediation costs.

Select Professional Service

- National Center for Water Quality Research, Heidelberg University, Advisory Council, 2016-present
- Presenter, Operational Ecosystem Modeling to Support Adaptive Management in the Great Lakes; Integrated Modeling for Adaptive Management of Estuarine Systems Workshop, Univ. of California-Davis, 2015
- U.S.-Canada International Joint Commission, Science Advisory Board—Research Coordination Committee, 2013-2015
- U.S.-Canada Great Lakes Water Quality Agreement Annex 10 (Science) Subcommittee, 2013-2015
- Steering committee, NASA/NOAA/MTRI Great Lakes Workshop Series on Remote Sensing of Water Quality, 2013-2014
- Co-director, Great Lakes Biogeochemistry Initiative, including NSF-funded workshop at Wayne State University; Purdue, San Francisco, and Italy town hall meetings; and journal articles; 2013-2015
- Convener, Climate Change Executive Forum, Federal Executive Institute, Leadership for a Democratic Society Program, Charlottesville, Virginia, 2013
- Presenter, A conceptual typological model for coastal environments in the Great Lakes, 56th Annual Conference of the International Association for Great Lakes Research, 2-6 June 2013, Purdue University, West Lafayette, Indiana
- Great Lakes Restoration Initiative Regional Working Group and Science Subgroup, 2012-2014
- Presenter, Coupling hydrodynamic and ecological models in North America's freshwater seas, 2nd NOAA-Norway/Statoil Science Workshop, NOAA Headquarters, Silver Spring, Maryland, 2012
- USGS Chesapeake Bay Science Advisory Committee, 2006-2010
- Session co-chair, Geological Society of America Annual Meeting, What goes up must come down: The science and policy of dam removal, 2005
- USGS Atlantic Coastal Plain Science Advisory Committee, 2003-2010
- Chair, Geological Society of America Research Grants Committee, 2002

Philip Chu, Ph.D., P.E., MBA
NOAA Great Lakes Environmental Research Laboratory
4840 South State Road, Ann Arbor MI 48108

Tel: 734.741.2120
E-mail: philip.chu@noaa.gov
<http://www.glerl.noaa.gov>

PROFESSIONAL PREPARATION:

The Ohio State University	Columbus, OH	Civil Engineering	MSCE	1989
The Ohio State University	Columbus, OH	Civil Engineering	Ph.D.	1998
Tulane University	New Orleans, LA	Business Mgmt.	MBA	2014

APPOINTMENTS:

2015-present: Supervisory Physical Scientist and Branch Chief
Integrated Physical and Ecological Modeling and Forecasting,
NOAA Great Lakes Environmental Research Laboratory (GLERL), Ann Arbor, MI
2015-present: Adjunct Faculty and dissertation/thesis committee at Ohio State University,
Tulane University, Michigan Technological University, University of Wisconsin,
University of Maryland and University of Michigan
2008-2015: Research Oceanographer, Naval Research Laboratory (NRL)
NASA Stennis Space Center, MS
2003-2007: Founder and Principal Scientist
Aqualinks Technologies Inc., Columbus, OH
1998-2003: Senior Research Engineer,
Dept. of Civil and Environmental Engineering, Ohio State University

PRODUCTS: Recent Publications

Xue, P., J. Pal, X. Ye, J. Lenters, C. Huang and P.Y. Chu, 2016: Improving the Simulation of Large Lakes in Regional Climate Modeling: Two-way Lake-atmosphere Coupling with a 3-D Hydrodynamic Model of the Great Lakes. *J. Climate*. Doi:10.1175/JCLI-D-16-0225.1
Xiao, C., B. M. Lofgren, J. Wang, and P. Y. Chu, 2016: Improving the lake scheme within a coupled WRF-Lake model in the Great Lakes. *J. Adv. Model. Earth Syst.*, doi:[10.1002/2016MS00717](https://doi.org/10.1002/2016MS00717)
Allard, R.A., T.J. Campbell, T.A. Smith, T.G. Jensen, P. Chu, J. Dykes, J. Veeramony and E. Rogers, 2016: Coupled Ocean-Wave-Air-Ice Prediction System, DoD High Performance Computing Modernization Annual Report, p80-81
Allard, R.A., E.R. Rogers, P. J. Martin, T.G. Jensen, P.Y. Chu, T. Campbell, J. Dykes, T.A. Smith, "The US Navy Coupled Ocean –Wave Prediction System", *Journal of Oceanography*, p92-103, 2014.
Allard, Campbell, Smith, Chu, Dykes, Veeramony and Rogers, "Coupled Ocean-Wave-Air Prediction System". FY13 NRL DoD High Performance Computing Modernization Program Annual Reports, p70-71, 2014.
Chu, P., G. A. Jacobs, M.K. Cambazoglu and R.S. Linzell, "Multi Model Validation of Currents in the Chesapeake Bay Region in June 2010", *J. Marine Geodesy*, 35:399-428, 2012.
Allard, R.A., T.J. Campbell, T.A. Smith, T.G. Jensen, P. Chu, E.W. Rogers, U.M. Gravois and S.N. Carroll, Validation Test Report for the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS) Version 5.0 Ocean/Wave, NRL/MR/7322-11-2012, 110pp, 2012.
Smith S., J. Cummings, C. Rowley, P. Chu, J. Shriver, R. Helber, P. Spence, S. Carroll and O.M. Smedstad, Validation Test Report for the Navy Coupled Ocean Data Assimilation 3D

Variational Analysis (NCODA-VAR) System Version 3.43, NRL/MR/7320-12-9363, 148pp, 2012.

Allard, R.A., T.J. Campbell, T.A. Smith, T.G. Jensen, P. Chu and J. Dykes, Coupled Ocean-Air Prediction System, DoD High Performance Computing Modernization Program Annual Report, p68-69, 2012.

Chu, P. and J. Kelley, G. Mott, A.J. Zhang and G. Lang, "Development, Implementation and Skill Assessment of the NOAA/NOS Great Lakes Forecast System", J. of Ocean Dynamics, Vol61, No9, p1305-1316, 2011.

Chu, P. J. Kelley, A.J. Zhang, G. Lang and K. Bedford, "Skill Assessment of NOS Lake Erie Operational Forecast System (LEOFS)", NOAA Technical Report NOS CS12, 73p, 2007.

Other Significant Products:

- Patent, "An automated method and system for predicting high resolution tidal heights and currents in coastal and estuarine zones", U.S. Patent and Trademark Office, 2014
- Contribution Award, Naval Research Laboratory, Department of the Navy, 2010, 2012, 2013
- Invention Award, Naval Research Laboratory, Department of the Navy, 2011, 2014
- American Meteorological Society (AMS) Special Award, for developing the first U.S. coastal forecasting system to make routine operational predictions of currents, temperature and key constituents, 2001 (12 scientists)
- Adjunct Faculty and dissertation/thesis committee at Ohio State University, Tulane University, Michigan Technological University, University of Wisconsin, University of Maryland and University of Michigan

Aline J. Cotel

Department of Civil and Environmental Engineering, University of Michigan
Ann Arbor, MI 48109-2125
Email: acotel@umich.edu

Education

- Ph.D., Aeronautics and Astronautics, University of Washington, 1995
- Master of Science, Aeronautics and Astronautics, University of Washington, 1992
- Aeronautical Engineering Diploma, Ecole Polytechnique Feminine, France, 1991

Employment

- Associate Professor (2007- present), University of Michigan, Civil and Environmental Engineering
- Assistant Professor (1999 - 2007), University of Michigan, Civil and Environmental Engineering
- Assistant Professor (1996 - 1999), University of Manitoba, Mechanical and Industrial Engineering

Honors and Awards

2016/2017 Fulbright U.S. Scholar to South Africa, University of KwaZulu Natal.
2016 Arthur F. Thurnau Professorship
2015 Willie Hobbs Moore Mentoring Award
2014 Global Engagement Recognition Award
2012, 2009 and 2008 Visiting Professor, Institut de Mecanique des Fluides de Toulouse, France
2012 University Undergraduate Teaching Award
2011 and 2002 Elizabeth Crosby Research Award
2005 Civil and Environmental Engineering Department Excellence Award
2005 National Science Foundation Career Award
2001 James M. Robbins Excellence in Teaching Award (Chi Epsilon, Great Lakes District)

Refereed Journal Publications

1. Oyanedel-Craver, V., Cotel, A.J., Saito, L., Abu-Dalo, M., Gough, H. and Verstraeten, I., "Water Nexus for Sustainable Global Water Resources", *Journal of Water Resources Planning and Management* 143 (8), 2017.
2. Standridge, C., Zeitler, D., Clark, A., Spoelma, T., Nordman, E., Boezaart, T.A., Edmonson, J., Graham Howe, G., Meadows, G., Cotel, A. and Marsik, F., "Lake Michigan Wind Assessment Analysis, 2012 and 2013", *Int. Journal of Renewable Energy Development*, in press, 2017.
3. Cagney, N., Crameri, F., Newsome, W.H., Lithgow-Bertelloni, C., Cotel, A.J., Hart, S.R., and Whitehead, J.A "Predicting the composition of mantle plumes", *Earth and Planetary Science Letters*, 435, 55-63, 2016.
4. Cotel, A.J. and Webb, P.W. "Living in turbulent world – a new conceptual framework for flow-fish interactions", *Integrative and Comparative Biology*, 55, doi:10.1093/icb/icv085, 2015.
5. Cagney, N., Newsome, W.H., Lithgow-Bertelloni, C., Cotel, A.J., Whitehead, J.A. and Hart, S.R. "Temperature and velocity measurements of a rising thermal plume", *Geochemistry, Geophysics, Geosystems*, 16, 579–599, doi:10.1002/2014GC005576, 2015.
6. Whitehead, J.A., Cotel, A.J., Hart, S., Lithgow-Bertelloni, C. and Newsome, W. "Numerical calculations of two-dimensional large Prandtl number convection in a box", *Journal of Fluid Mechanics*, 729, 584-602, 2013.
7. Liao, J. and Cotel, A.J. "Effects of turbulence on fish swimming in aquaculture", in *Swimming Physiology of Fish*, 2012.
8. Cotel, A.J. and Webb, P. W. "The challenge of understanding and quantifying fish responses to turbulence-dominated physical environments", special IMA volume on Natural Locomotion in Fluids and on Surfaces: Swimming, Flying, and Sliding, 2012.

9. Meadows, L.M., Cotel, A.J., Webb, P.W., Meadows, G.A. and W.J. Neal. "Interactions between shoreline flow, morphology and biota: considerations for management and conservation", in press in *Habitat Loss*, 2012.
10. Webb, P. W. and Cotel, A. J. "Stability and Turbulence". In Farrell A.P., (ed.) *Encyclopedia of Fish Physiology: From Genome to Environment*, San Diego: Academic Press, 2011.
11. Webb, P.W. and Cotel, A.J. "Assessing possible effects of fish-culture systems on fish swimming: the role of stability in turbulent flows," *Fish Physiology and Biochemistry*, 37 (2), 297-305, 2011.
12. Webb, P.W. and Cotel, A.J. "Turbulence: Does vorticity affect the structure and shape of body and fin propulsors?" *Integrative and Comparative Biology*, 50(6), 1155-1166, 2010.
13. Tritico, H.M. and Cotel, A.J. "The Effects of Turbulent Eddies on the Stability and Critical Swimming Speed of Creek Chub", *Journal of Experimental Biology*, 213 (13), 2284-2293, 2010.
14. Cotel, A.J. "A Review of Recent Developments for Turbulent Entrainment in Stratified Flows", *Physica Scripta*, T 142, 014044, 2010.
15. Webb, P.W. Cotel, A.J. and Meadows, L.M. "Waves and Eddies: Effects on fish behavior and habitat distribution", in the book entitled "Fish Locomotion, an etho-ecological approach" published by P. Domenici et al., 2009.
16. Castro-Santos, T., A. Cotel, and P. Webb. 2009. Fishway evaluations for better bioengineering--an integrative approach. In A. J. Haro, R.A. Rulifson, C.M. Moffitt, M.J. Dadswell, R.A. Cunjak, R.J. Klauda, K. Smith, T. Avery, J. E. Cooper, and K.L. Beal, eds. *Challenges for Diadromous Fishes in a Dynamic Global Environment*.
17. Cotel, A.J. and Kudo, Y. "PIV and LIF measurements of buoyancy driven flows impinging on a stratified interface." *Experiments in Fluids*, 45(1), 131-138, 2008.
18. Tritico, H., Cotel, A.J. and Clarke, J. "Development of small scale submersible PIV system," *Measurement Science and Technology*, 18, 255-2562, 2007.
19. Samothrakis, P. and Cotel, A.J. "Finite volume gravity current impinging on a stratified interface." *Experiments in Fluids*, 41(6), 991-1003, 2006.
20. Cotel, A.J., Webb, P. and Tritico, H. "Do trout choose habitats with reduced turbulence?" *Transactions of the American Fisheries Society* 115, 610-619, 2006.
21. Samothrakis, P. and Cotel, A.J. "The dynamics of a gravity current impinging on a stratified interface," *Journal of Geophysical Research* 111, C01012, doi:10.1029/2005JC003125, 2005.
22. Cotel, A.J., Golingo, R., Oakes, J.E. and Riewe, R.R. "Analysis of heat transfer in ancient Inuit fur parka ruffs," *J. of Climate Research*, 26, 77-84, 2004.
23. Cotel, A.J. "Turbulence inside a vortex – Take two", *Physics of Fluids*, 14(8), 2933-2934, 2002.
24. Zhang, Q. and Cotel, A.J. "Entrainment of a thermal with and without buoyancy reversal impinging on a stratified interface," *Journal of Geophysical Research* 105(D12), 15457- 15467, 2000.
25. Cotel, A.J. and Breidenthal, R.E. "Turbulence inside a vortex," *Physics of Fluids* 11(10), 3026-3029, 1999.
26. Cotel, A.J. "A trigger mechanism for the Lake Nyos disaster," *Journal of Volcanology and Geothermal Research*, 88, 343-347, 1999.
27. Cotel, A.J., Gjestvang, J.A., Ramkhelawan, N.N. and Breidenthal, R.E. "Laboratory experiments of a jet impinging on a stratified interface," *Experiments in Fluids* 23(2), 155-160, 1997.
28. Cotel, A.J. and Breidenthal, R.E. "Jet detrainment at a stratified interface," *Journal of Geophysical Research*, 102(D20), 23813-23818, 1997.
29. Cotel, A.J. and Breidenthal, R.E. "A model of vortex persistence effects in stratified entrainment," *Applied Scientific Research*, 57, 349-366, 1997.

Name: Avery H. Demond, Ph.D., P.E.

Education:

Williams College, Williamstown, MA	Biology	B.A., 1977
Massachusetts Institute of Technology	Civil Engineering	B.S., 1980, M.S., 1982
Stanford University	Civil Engineering	Ph.D., 1988

Academic Experience:

Professor, Environmental and Water Resources Engineering, Department of Civil and Environmental Engineering, The University of Michigan, Sept. 2013 – present.

Associate Professor, Environmental and Water Resources Engineering, Department of Civil and Environmental Engineering, The University of Michigan, Sept. 1996 - Aug. 2013.

Assistant Professor, Environmental and Water Resources Engineering, Department of Civil and Environmental Engineering, The University of Michigan, Sept. 1989 - Aug. 1996.

Assistant Professor, Environmental Engineering Program, Department of Civil Engineering, University of Massachusetts, Amherst, MA, Jan. 1988 - Aug. 1989.

Non-academic Experience:

Staff Engineer, Environmental Sciences and Engineering Group, Geomatrix Consultants, San Francisco, CA, Sept. 1994 - June 1995.

Hydrologist, Water Resources Division, U.S. Geological Survey, Menlo Park, CA, June 1982 - Sept. 1982.

Loss Control Engineer, Sentry Insurance, Concord, MA, July 1977 - Aug. 1978.

Certifications:

Professional Engineer, State of Michigan, since 1996

Hazardous Waste Operations and Emergency Response (HAZWOPER) Certificate

Current Memberships in Professional Organizations:

AEESP (Association of Environmental Engineering and Science Professors)

AGU (American Geophysical Union)

Honors and Awards (since 2011):

Distinguished Professor Award	2016
Monroe-Brown Foundation Service Excellence Award	2014
Sarah Goddard Power Award	2013
Raymond J. and Monica E. Schultz Outreach and Diversity Award	2012
Harold R. Johnson Diversity Service Award	2011
Rackham Mentoring Award	2011

Selected Service Activities:

Chair, BSE and Minor in Environmental Engineering, 2015-present.

AEESP Awards Committee, 2015-present.

ABET Chair, BSE in Environmental Engineering, 2014 and 2017.

Director, Environmental and Water Resources Engineering, 2011-2014.

Director, METS (Michigan Engineering Transfer Support), College of Engineering, 2009-2013.

Admissions Office, University of Michigan, 25% Appointment, 2003-2004, 2016-2018.

Associate Editor, Environmental Engineering Science, 2002-2007.

Committee Member, Review of DOE Environmental Restoration Priority System, National Research Council, Board on Radioactive Waste Management, 1992-1994.

Board Member, National Research Council, Board on Engineering Education, 1991-1995.

Committee Member, Science and Engineering Review Group, Office of Environmental Restoration and Waste Management, U.S. Dept. of Energy, 1990-1991.

Selected Publications (since 2012):

Otero-Diaz, M., B. Woo, N. Bhattacharyya, and A. Demond, 2017. "Enhancement of the Aqueous Solubility of Organochlorine Pesticides by Ethanol," *Journal of Environmental Engineering-ASCE*, 143(9).

Jayawan, I. A. Demond and B. Ellis, 2016. "Using an Analytical Solution Approach to Permit High Volume Groundwater Withdrawals," *Environmental Science: Water Research and Technology*, 2:942-952.

Ayral-Cinar, D., M. Otero-Diaz, and A. Demond, 2016, "A Mechanism of Basal Spacing Reduction in Sodium Smectitic Clay Materials in Contact with DNAPL Wastes," *Chemosphere*, 159: 577-583..

Huang, J., J. Christ, M. Goltz, and A. Demond, 2015. "Modeling NAPL Dissolution from Pendular Rings in Idealized Porous Media," *Water Resources Research*, 51(10):8182-8197.

Ayral, D., M. Otero, M. Goltz, and A. Demond, 2014, "Impact of DNAPL Contact on the Structure of Smectitic Clay Materials," *Chemosphere*, 95: 182-187.

Broadwater, K., J.D. Meeker, W. Luksemburg, M. Maier, D. Garabrant, A. Demond, and A. Franzblau, 2014, "Evaluation of Release of Dioxins and PCBs During Kiln-Firing of Ball Clay," *Chemosphere*, 94:70-75.

Han, Y.S., A.H. Demond, and K.F. Hayes, 2013, "Impact of Dissolved Silica on Arsenite Removal by Nano-Particulate FeS and FeS-Coated Sand," *Chemosphere*, 92:477-481.

Henderson, A., and A. H. Demond, 2013, "Permeability of Iron Sulfide (FeS)-Based Materials for Groundwater Remediation," *Water Research*, 47:1267-1276.

Towey, T., N. Barabas, A. Demond, A. Franzblau, D. Garabrant, B. Gillespie, J. Lepkowski, and P. Adriaens, 2012, "Polytopic Vector Analysis of Soil, Dust and Serum Samples to Evaluate Exposure Sources of PCDDs/Fs," *Environmental Toxicology and Chemistry*, 31:2191-2200.

Demond, A., A. Franzblau, D. Garabrant, X. Jiang, P. Adriaens, Q. Chen, B. Gillespie, W. Hao, B. Hong, O. Jolliett, J. Lepkowski, 2012, "Human Exposure from Dioxins in Soil," *Environmental Science and Technology*, 46:1296-1302.

Brief Professional Biography:

A native of New York City, Dr. Demond has held positions in both industry and academics, and is currently a professor of Environmental and Water Resources Engineering in the Department of Civil and Environmental Engineering at The University of Michigan. Her research is in the field of hazardous waste and the rehabilitation of industrial properties; she has published on a variety of topics including the effect of contamination on soil transport properties and the impact of historic soil contamination on human health, and is a Professional Engineer, registered in the State of Michigan. As part of her service activities, she served as a coordinator of DOE's Subsurface Science Program's Multiphase Fluid Flow Subprogram for five years. Furthermore, she has served on a number of National Research Council boards and committees, including the Board on Engineering Education and the Committee for the Review of DOE's Environmental Restoration Priority System.

Marla Fisher, Ph.D.

Dept. of Biological Sciences
Western Michigan University
Kalamazoo, MI 49008

(269) 387-2541
Marla.Fisher@wmich.edu

Nationality: U.S.A.
Research Interests: Human and ecosystem health
Academic Degrees: Ph.D. 2004 Western Michigan University (Biology)
M.S. 1995 University of Idaho
B.A. 1990 Indiana University, Golden Key National Honors Society

Dissertation: *Health Impacts of Polychlorinated Biphenyls in Aquatic Organisms*

Developed carp as a model system to examine metabolic and health effects in fish from the Kalamazoo River. Results used for risk-assessment and to evaluate organism and ecosystem health

Awards: Western Michigan University All-University Creative Scholar, American Association for the Advancement of Science (AAAS) Student Poster Competition, Distinguished Biology Graduate Student, Graduate Research and Creative Scholar, Monroe-Brown Life Science Research Presentation award

Research Papers

- Chan, YL, X Pochon, MA Fisher, D Wagner, GT Concepcion, S Kahng, RJ. Toonen, RD Gates (2009) Host genotypes and endosymbiotic dinoflagellate diversity in the coral *Leptoseris* sampled between 60-110 meter depths. *BMC Ecology* 9:21
- Fisher, MA, Oleksiak, MF (2007) Convergence and Divergence in Gene Expression Among Natural Populations Exposed to Pollution. *BMC Genomics* 8:108
- Fisher, MA., R Eversole, C Mehne, C Delong, JC Means, D Mihalko, CF Ide (2008) Liver cyp1A protein expression and pigmented macrophage aggregates as indicators of polychlorinated biphenyl exposure in carp (*Cyprinus carpio*) from the Kalamazoo River Superfund Site, MI. *Journal of Fish Biology* 72: 1960-1975
- Fisher, MA., C Mehne, JC Means, CF Ide (2006) Induction of CYP1A mRNA in Carp (*Cyprinus carpio*) from the Kalamazoo River Polychlorinated Biphenyl-Contaminated Superfund Site and in a Laboratory Study. *Archives of Environmental Contamination and Toxicology* 50: 14-22
- Fisher, MA., AM. Jelaso, A Predenkiewicz, L Schuster, J Means, CF Ide (2003) Exposure to the polychlorinated biphenyl mixture Aroclor 1254 alters melanocyte and tail muscle morphology in developing *Xenopus laevis* tadpoles. *Environmental Toxicology and Chemistry*. Vol. 22(2): 321-328
- Rossbach, S, ML. Kukuk, TL Wilson, SF Feng, M Pearson, MA Fisher (2000) Cadmium regulated gene fusions in *Pseudomonas fluorescens*. *Environmental Microbiology*. Vol 2(4): 373-382

Grants

- River Network, Training & Transition Partner Grant (2014), " Kalamazoo River Cleanup Coalition: Developing web-based tools for outreach and education." Marla Fisher, D Keele, S Hill, G Wager, \$1800
- National Science Foundation, University of Hawaii Research Enhancement Activities Program (REAP, 2007), "An evolutionary perspective on gene expression: A collaboration between EPSCoR post-doctoral researchers." Marla Fisher and Yvonne Chan, \$21,000
- West Michigan Chapter of the Air and Waste Management Association (2003), "Quantifying gene expression and histological biomarkers in adult and juvenile carp." Marla Fisher and Charles Ide, \$1000
- Western Michigan University, Monroe-Brown Life Science Research Award, College of Arts and Sciences, (2003), "Using biotechnology for environmental risk assessment: quantifying levels of gene expression in the common carp (*C. carpio*) exposed to environmentally relevant levels of PCB contaminants, II." \$2400
- Western Michigan University, Graduate Student Travel Grant, American Association for Advancement of Science, Denver, CO (2002), \$600
- Western Michigan University, Monroe-Brown Life Science Research Award, College of Arts and Sciences (2002), "Using biotechnology for environmental risk assessment: quantifying levels of gene expression in the common carp (*C. carpio*) exposed to environmentally relevant levels of PCB contaminants." \$2200

Post Degree Work

- University of Hawai'i at Hilo, Hilo, HI, Postdoctoral Research Associate. Co-PI, NSF EPSCoR grant, deep-sea coral population genetics and Hawaiian drosophila genomics
- North Carolina State University, Raleigh, NC Postdoctoral Research Associate
Examined nine fish populations along the East Coast from Massachusetts to North Carolina including from three US Superfund Sites, used custom metabolic gene expression microarrays for global gene expression analysis, evaluated data for evolutionary responses to exposure to environmental pollution stress
- Glen Oaks Community College, Centreville, MI Temporary Full-Time Faculty
- Sanford-Brown College, Grand Rapids, MI Adjunct Faculty
- BioPath Solutions, Analyst
Compiled analytical data of completed bioremediation projects
- Dirigo Food Safety, Analyst
Provided analyses of current issues related to beef production and consumption for a large industrial agriculture company; topics included biotechnology, ecosystem health, antibiotic use, animal welfare, human health

Current Work

- Western Michigan University, Research Associate
Multiple Systems Atrophy (Atypical Parkinson's disease): limiting neurodegenerative spread among cultured oligodendroglial cells as a model of human synucleinopathies

Biographical Sketch – David J. Flaspohler, October 2017

David Flaspohler
Professor
School of Forest Resources and Environmental Science
Michigan Technological University
Houghton, MI, 49931

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fax: (906) 487-2915
e-mail: djflaspo@mtu.edu
<http://www.mtu.edu>

A. PROFESSIONAL PREPARATION

Univ. of Michigan Ann Arbor	Arch. and Urban Planning	BS	1987
Univ. of Wisconsin-Madison	Cons. Biol. and Sust. Dev	MS	2001
Univ. of Wisconsin-Madison, PhD	Wildlife Ecology	PhD	1998

B. APPOINTMENTS

September 2010-present: Professor, MTU

September 2006-August 2009: Associate Professor, MTU

March 1998-August 2006: Assistant Professor, School of Forest Resources and Environmental Science, Michigan Technological University (MTU), Houghton, MI

January 1998-May 1998: Faculty Associate, Department of Wildlife Ecology, University of Wisconsin-Madison

C. PRODUCTS most closely related to the proposed project

Youngman, J., D. Flaspohler, J. Knowlton, and L. Dombroski. Fall waterbird migration in Lake Superior: Numbers, timing, weather, and connectivity. *Journal of Great Lakes Research* <https://doi.org/10.1016/j.jglr.2017.08.012>

Knowlton, J., D. Flaspohler, N.T. Rotzel, and R. Fleischer. 2014. First record of hybridization in the Hawaiian Honeycreepers: Iiwi (*Vestiaria coccinea*) x Apapane (*Himatione sanguinea*). *Wilson Bulletin of Ornithology* 126: 562-567.

Sullivan, A., D. Flaspohler, R. Froese, and D. Ford. 2015. Climate variability and the timing of spring raptor migration in Eastern North America. *Journal of Avian Biology* 47(2): 208-218.

Webster, C., D. Flaspohler, S. Pawson, and E. Brockerhoff. 2012. Ecologically sustainable bioenergy communities: Species selection and habitat considerations. In: *Handbook of Bioenergy Crop Plants*, S. Joshi, D. Shonnard, and C. Kole, eds. Taylor and Francis Group, Boca Raton, Florida. (invited contribution).

Ford, M. and D.J. Flaspohler. 2010. Scale-dependent response by breeding songbirds to residential development along Lake Superior. *Wilson Bulletin of Ornithology* 122(2):296-306.

Other Significant Products

Henschell, M., C. Fortin, C. Webster, and **D. Flaspohler**. Productivity-diversity relationships in planted grasslands: species quality vs. quantity. 2015. *PLOS ONE*. DOI: 10.1371/journal.pone.0125758. <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0125758>

Aldinger, K.R., T.M. Terhune, D.A. Buehler, P.B. Wood, M.H. Bakermans, J.L. Confer, **D.J. Flaspohler**, J.L. Larkin, J.P. Loegering, K.L. Percy, A.M. Roth, and C.G. Smalling. 2015. A range-wide assessment of factors influencing Golden-winged Warbler nesting demographics. *Avian Conservation and Ecology* 10 (1): 6-

Roth, A.M., D.J. Flaspohler, and C.R. Webster. 2014. Legacy tree retention in young aspen forest improves nest habitat quality for Golden-Winged Warbler (*Vermivora chrysoptera*). *Forest Ecology and Management* 321:61-70.

Fargione, J.E., T.R. Cooper, D.J. Flaspohler, J. Hill, C.L. Lehman, T. McCoy, S. McLeod, E.

J. Nelson, K. S. Oberhauser, and D. Tilman. 2009. Bioenergy and wildlife: Threats and opportunities for grassland conservation. *BioScience* 59(9):767-778.

D. SYNERGYSTIC ACTIVITIES

I was contracted with the *New York Times* to submit field notes for their Scientists At Work blog during field work at field sites on the Big Island of Hawaii (16-30 May, 2012)

Co-organizer (w/ C. Webster and R. Froese) IUFRO symposium, Biodiversity and Bioenergy, IUFRO Conference in Forest Biodiversity, Cork, Ireland, Aug. 2012.

Co-organizer (w/C. Meine, C. Webster), Society for Conservation Biology Symposium: "Biodiversity and Biofuels: Implications of Bioenergy for Species and Ecosystems" at July 2008 International meeting, Chattanooga, TN.

PI, IREU with NSF and CAPES (Brazil), supplement of \$48,000 to support 2 U.S. and 2 Brazilian undergraduates involved in field work in the two countries between May and August, 2015.

E. COLLABORATORS & OTHER AFFILIATIONS

(i) Collaborators and Co-Editors during the Past Four Years – TOTAL = 22

Heidi Asbjornsen, Univ. of New Hampshire, Rod Chimner, MTU, Fred Clark (WI State Assembly), Rob Fleischer, Smithsonian Inst., Wash., D.C., Robert Froese, Michigan Technological University (MTU), Tadashi Fukami, Stanford Univ., Christian Giardina, USFS, Inst. of Pacific Island Forestry, Dan Gruner, Univ. of Maryland, K. Halvorson, MTU, Casey Huckins, MTU, Jessie Knowlton, MTU, Erik Lilleskov (USFS-Houghton, MI), Curt Meine (WI Acad. Arts, Sci. and Letters), Eben Paston, USGS, Volcanoes N.P., Hawaii, Tom Pypker, MTU, Sigrid Resh, MTU, Robert Rosenfield (Univ. WI-Stevens Point), Dave Shonnard, MTU, Barry Solomon, MTU, John Sutherland, Purdue Univ., Chris Webster, MTU

(ii) Investigator's Graduate and Postdoctoral Advisors – TOTAL = 2

Ph.D. Advisor: Stanley Temple (University of Wisconsin-Madison, Aldo Leopold Foundation)

M.S. Advisor: Tim Moermond University of Wisconsin-Madison, retired

Graduate Thesis Advisees: Sam Oliveira, M.S. (ongoing), Colin Phifer (ongoing), Amber Roth (PhD, Asst. Prof. Univ. of Maine), Steve Windels (PhD, National Park Service, Minnesota), Audra Bassett (PhD, Western North Carolina Community Coll.), Peter Hurley (PhD, St. Francis University, Indiana), Greg Corace (PhD, US Fish and Wildlife Service, MI), Marian Snively (MS, Alaska Fish and Game), Michelle Manarolla (MS, Baystate Environmental Consultants, MA), Tammie Martinson (MS, Wisconsin DNR), Brian Bub (MS, Natural Resources Consulting, WI), Dan Haskell (MS-Wisconsin Dept. of Nat. Resources), Alexandra Wrobel (MS-Great Lakes Fish and Wildlife Commission), Max Henschell (MS-MTU-School of Forest Resources and Environmental Science, now PHD candidate, UW-Madison)

M.S. Students w/Thesis: (Total = 8) Ph.D.

Students: (Total = 6)

Post-Doctoral Scholars Sponsored: (Total=1)

Dr. Sarah A. Green

Department of Chemistry Michigan
Technological University 1400
Townsend Drive
Houghton, MI 49931
sgreen@mtu.edu
906-487-3419



Education

Ph.D. (1992) Marine Chemistry

MIT/WHOI Joint Program in Oceanography

Massachusetts Institute of Technology, Cambridge, MA and Woods Hole Oceanographic Institution, Woods Hole, MA. *Advisors:* Dr. N.V. Blough and Prof. F.M.M. Morel

B.A. (1983), Chemistry, minor in Mathematics, University of Minnesota, Minneapolis, MN

Professional Experience

2013 – 2014 **Jefferson Science Fellow**, U.S. Department of State, Bureau of East Asian and Pacific Affairs.

2006 – Present **Professor**, Department of Chemistry, Michigan Technological University

2004 – 2013 **Chair**, Department of Chemistry, Michigan Tech University

2000 – 2006 **Associate Professor**, Department of Chemistry, Michigan Tech University

2003 **Visiting Scientist**, Consiglio Nazionale delle Ricerche, Istituto di Biofisica, Pisa

1994 – 2000 **Assistant Professor**, Department of Chemistry, Michigan Tech University

Other Professional Activities

2015 – Present Co-chair, Scientific Advisory Panel on the Sixth Global Environmental Outlook (GEO-6), United Nations Environment

2008 – Present Member Green Chemistry Roundtable, State of Michigan
Green Chemistry Governor's Awards Committee (2012)
Education Workgroup (2012-present)

2010 – 2014 Board of Directors, Council for Chemical Research

2011 – 2012 Chair, Upper Peninsula Local Section of the American Chemical Society

1997 – 2002 Director: Keweenaw Interdisciplinary Transport Experiment in Superior (KITES), an NSF/NOAA funded program (15 PIs, 9 institutions)

Spring 2003 Sabbatical leave at Istituto di Biofisica, Pisa Italy, hosted by Dr. Alfredo Seritti

GEO-6 Scientific Advisory Panel activities

- Co-chair of the Scientific Advisory Panel for the Global Environmental Outlook (GEO-6) with the mandate to “guide the assessment process and to ensure scientific credibility and overall quality and integrity of GEO 6”.

Jefferson Science Fellow activities

- Senior Science Advisor in the Bureau of East Asia and Pacific Affairs, Office of Economy Policy; responsible for engagement on environmental issues with the Asia Pacific Economic Cooperation (APEC) forum.
- State Department liaison and U.S. Delegate to the APEC Oceans and Fisheries Working Group, Qingdao, China (May 2014), APEC Blue Economy Forum, Xiamen, China (August 2014), and APEC Oceans Ministerial, Xiamen, China (August 2014).

- U.S. Delegate to the APEC Chemical Dialogue, Ningbo, China (February 2014) and Beijing, China (August 2014). Presented talk “Michigan’s Green Chemistry Roundtable” at APEC *Chemical Dialogue Regulators’ Forum*, Beijing, China (August 2014).
- Founding member of the APEC Virtual Working Group on Marine Debris.
- Advanced U.S. priority actions on wildlife trafficking within APEC; helped obtain funding for Demand-reduction workshop in Hanoi, Vietnam (October 2014).
- Contributed to APEC groups Subcommittee on Standards and Conformance, Urbanization Forum, Experts Group on Illegal Logging.
- Completed course “Washington Statecraft” at U.S. Foreign Service Institute (2014).

Awards

- Certificate of Appreciation, U.S. Department of State. “*For significant contributions to the President’s National Strategy for Combating Wildlife trafficking, and raising the profile of wildlife trafficking as a U.S. diplomatic priority and international and security concern.*” 2014.
- ‘Best article of 2013’ prize for: “[Quantifying the consensus on anthropogenic global warming in the scientific literature](#)” (Cook, Nuccitelli, Green, et al., 2013), awarded by the Editorial board of *Environmental Research Letters*; also included in the ‘Highlights of 2013’ collection. Paper downloaded >740,000 times.
- [Chandler-Misener Award](#), International Association for Great Lakes Research, 2011 (with co-authors W.C. Kerfoot, et al.).

Other Activities

- Community presentations to community groups, planning commissions, teachers.

Recent Publications (selected from > 45)

1. Green, S. A. (2017), Green Chemistry: Progress and Barriers, in Sustainable Green Chemistry, vol. 1, edited by M. A. Benvenuto, pp. 17–27, Berlin/Boston.
2. Cook, J., Oreskes, N., Doran, P., Anderegg, W., Verheggen, B., Maibach, E., Carlton, S., Lewandowsky, S., Skuce, A., Green, S., Nuccitelli, D., Jacobs, P., Richardson, M., Winkler, B., Painting, R., Rice, K. (2016). Consensus on consensus: a synthesis of consensus estimates on human-caused global warming. *Environmental Research Letters*, 11(4), 048002. <http://doi.org/10.1088/1748-9326/11/4/048002>.
3. Veverica, T. J., Kane, E. S., Marcarelli, A. M., & Green, S. A. (2016). Ionic Liquid Extraction Unveils Previously Occluded Humic-Bound Iron in Peat Soil Pore Water. *Soil Science Society of America Journal*, May, 2016. <http://doi.org/10.2136/sssaj2015.10.0377>.
4. Hering, J. G., D. A. Dzombak, S.A. Green, R. G. Luthy, D. Swackhamer. (2014). Engagement at the Science–Policy Interface. *Environmental Science and Technology*, 48 (19), 11031–11033. [doi:10.1021/es504225t](http://doi.org/10.1021/es504225t).
5. Cook, J., D. Nuccitelli, A. Skuce, P. Jacobs, R. Painting, R. Honeycutt, S. A. Green, S. Lewandowsky, M. Richardson, R. G. Way (2014). Reply to ‘Quantifying the consensus on anthropogenic global warming in the scientific literature: A re-analysis’ *Energy Policy*, [doi:10.1016/j.enpol.2014.06.002](http://doi.org/10.1016/j.enpol.2014.06.002).
6. J. Cook, D. Nuccitelli, S. A. Green, M. Richardson, B. Winkler, R. Painting, R. Way, P. Jacobs, A. Skuce (2013). Quantifying the consensus on anthropogenic global warming in the scientific literature. *Environ. Res. Lett.* 8, 024024. [doi:10.1088/1748-9326/8/2/024024](http://doi.org/10.1088/1748-9326/8/2/024024).
7. Kerfoot, W. C., Yousef, F., Green, S. A., Regis, R., Shuchman, R., Brooks, C. N., Sayers, M., et al. (2012). Light detection and ranging (LiDAR) and multispectral studies of disturbed Lake Superior coastal environments. *Limnology and Oceanography*, 57(3), 749–771. [doi:10.4319/lo.2012.57.3.0749](http://doi.org/10.4319/lo.2012.57.3.0749).

Amanda G. Grimm

Assistant Research Scientist ▪ Michigan Tech Research Institute ▪ Michigan Tech University
Ann Arbor, MI 48105 ▪ Phone: (734) 994-7233 ▪ Email: aggrimm@mtu.edu

EDUCATION

- Master of Science, Conservation Biology** **University of Michigan,** **December 2011**
- Thesis topic: “Lidar-based modeling of understory vegetation structure and insectivorous bird habitat in a lowland rainforest”; Thesis advisor: Dr. Kathleen Bergen
 - Conservation Biology track of Natural Resources & Environment MS
 - Concentrations in remote sensing, GIS, landscape ecology, land cover/land use change
- Bachelor of Science, Environmental Biology/Zoology** **Michigan State University** **April 2006**
- Researched the ecological effects of management of invasive *Phragmites* as part of the Cary Institute for Ecosystem Studies’ Research Experiences for Undergraduates (REU) program
- Certified Mapping Scientist, Remote Sensing** **ASPRS** **2016**

RELEVANT PROFESSIONAL EXPERIENCE

Assistant Research Scientist January 2012 - Present
Michigan Tech Research Institute Ann Arbor, MI

- Manage complex, grant-funded research and applied science projects to ensure that the activities described in the proposal and project plan are on schedule and that deliverable and reporting requirements are met
- Create and support grant proposals and reports, white papers, and journal articles
- QA/QC and manage the datasets acquired for projects to facilitate data analysis and maintain consistent metadata records to required standards (ISO, OGC)
- Have assisted in organizing and orchestrating two technical workshops
- Assist in designing and maintaining web maps and portals for sharing MTRI data products and prepare MTRI data for inclusion in external data platforms.
- Collect field data including vegetation surveys, bird and frog/toad point counts, harmful algal bloom sampling, various water quality measurements, sonar bathymetry, and LAI; integrate those data with a variety of remotely sensed geospatial data to generate new information and solutions
- Utilize GIS, image processing, statistical and database software to manipulate and analyze spatial data as well as Python and R to perform statistical analyses in support of research projects
- Maintain and organize datasets, metadata and documentation to accepted standards
- Train and supervise interns in the use of field equipment and completion of analyses

Research Assistant August 2009 – December 2011
Environmental Spatial Analysis Laboratory Ann Arbor, MI

- Assisted with a NASA-funded project focused on combining SAR, InSAR and lidar data to measure vegetation biomass and 3D structure in the context of the proposed DESDynI mission
- Used GIS, image processing, and statistical software (ArcGIS, ERDAS Imagine, Matlab, Stata) to conduct spatial and non-spatial statistical analyses
- Built and managed spatial (ArcGIS) and nonspatial (Access) databases
- Prepared reports, maps and white papers

Natural Resources Specialist
Oakland County Parks & Recreation

October 2007 - April 2008
Waterford, MI

- Researched and co-wrote a system-wide natural areas management plan for the county parks system and assisted with writing grant applications
- Trained and provided support for coworkers in the operation of GPS technology
- Applied GPS and GIS technologies to invasive species mapping and control, prescribed burn site selection, aerial deer surveys, grassland bird surveys, and trails mapping
- Prepared presentations, posters, and public education pieces related to natural resource topics such as prescribed burning, wetland restoration, and threatened species

ARTICLES PUBLISHED/IN PRESS

Grimm, A. G., Brooks, C. N., Binder, T. R., Riley, S. C., Farha, S. A., Shuchman, R. A., & Krueger, C. C. (2016). Identification of lake trout *Salvelinus namaycush* spawning habitat in northern Lake Huron using high-resolution satellite imagery. *J Great Lakes Res.* 42(1): 127-135.

Woelmer, W. M., Kao, Y.-C., Bunnell, D. B., Deines, A. M., Bennion, D. H., Rogers, M. W., Brooks, C. N., Sayers, M. J., Banach, D. M., **Grimm, A. G.**, & Shuchman, R. A. (2016). Assessing the influence of watershed characteristics on chlorophyll a in water bodies at global and regional scales. *Inland Waters*, 6(3), 379-392.

Kuczynski, A., Auer, M. T., Brooks, C. N., & **Grimm, A. G.** (2016). The Cladophora resurgence in Lake Ontario: characterization and implications for management. *Can. J. Fish. Aquat. Sci.*, 73(999), 1-15.

Sayers, M.J., **Grimm, A. G.**, Shuchman, R. A., Deines, A. M., Bunnell, D. B. Raymer, Z. B., Rogers, M. W., Woelmer, W., Bennion, D. H., Brooks, C. N., Whitley, M. A., Warner, D. M., & Mychek-Londer, J.. 2015. A new method to generate a high-resolution global distribution map of lake chlorophyll. *Int. J. Remote Sens.* 36(7): 1942-1964.

Brooks, C., **Grimm, A.**, Shuchman, R. A., Sayers, M., & Jessee, N.. 2015. A satellite-based multi-temporal assessment of the extent of nuisance *Cladophora* and related submerged aquatic vegetation for the Laurentian Great Lakes. *Remote Sens. Environ.* 157: 58-71.

PROFESSIONAL AFFILIATIONS

American Society of Photogrammetry and Remote Sensing, Society for Conservation GIS, International Association for Great Lakes Research

SOFTWARE

- GIS: ArcGIS incl. Spatial Analyst, 3D Analyst and Geostatistical Analyst; QGIS; Google Earth Pro
- Image analysis: ENVI with intermediate IDL programming, ERDAS IMAGINE
- Programming: Python & ArcPy, Matlab (intermediate)
- Statistical packages: R, Python statistical analysis tools (NumPy, SciPy)

Latika Gupta

(formerly Latika Gupta Lagalo)
School of Business and Economics
Michigan Technological University
906-487-2311 | latika@mtu.edu

Personal statement

My fields of interest include Energy and the Macroeconomy, Applied Time Series Econometrics, International Economics, Inventory Studies, and Business Fluctuations and Cycles. I study models that examine the impact of shocks in the crude oil market on industrial production in the US. In addition, my research agenda includes the effect of oil prices on labor markets; role of energy policy; and effects of steel industry on the economy. I frequently present new research at conferences. I have publications in journals such as *Macroeconomic Dynamics* and *Journal of International Money and Finance*. In addition to numerous presentations on the energy-macroeconomic relationship, I have presented and written papers in areas of environmental economics and natural resource economics.

I received my PhD at Wayne State University in Economics where I attended Wayne-UM-MSU Energy Environmental workshops where I networked and connected with many economists. This has helped me identify economic researchers who could be on an economics team with me as a potential MTU lead coordinator for the Straits Pipeline project.

My interest in pipelines deepened when I was interviewed on the issue of Dakota Access Pipeline on *Copper Country Today*. The interview won the Best Feature Programming award, Michigan Association of Broadcasters. I examined the issue from the perspective of negative externalities of pipelines and global oil market issues. This and other local media appearances have not only acquainted me with regional economic issues, but also exposed me to public scrutiny while dealing with controversial topics.

Lastly, the SBE had appointed me to serve as their representative on the Advisory Committee of the Center for Water and Society for 2 years. I got several opportunities to interact with the local community when I organized and moderated the World Water Day and Green Film Series events at Michigan Tech. Since I specialize in energy economics and econometrics this was a great opportunity for me to contribute through my expertise and pursue inter-disciplinary research. I worked on an inter-disciplinary research project on bottled water use in Mexico (with Alex Mayer, Civil and Environmental Engineering, MTU) which is currently under review. In addition, I attended an NSF funded food-energy-water nexus workshop at MTU; I co-authored a white paper as sub-section lead describing the results and conclusions from this workshop.

Professional Preparation

University of Delhi, Delhi, India, Economics,	BA , 2004
Jamia Millia Islamia University, New Delhi, India, Economics,	MA , 2006
Wayne State University, Detroit, Michigan, Economics,	MA , 2010
Wayne State University, Detroit, Michigan, Economics,	PhD , 2013
<i>Mendelson Dissertation Award</i> , Wayne State University, 2011.	

Appointments

2014 – Present: Assistant Professor, Michigan Technological University, Houghton, MI
 2011 – 2014: Visiting Professor, Emory University, Atlanta, GA
 2010 – 2011: Research Assistant, Wayne State University, Detroit, MI
 2007 – 2010: Part-Time Faculty, Wayne State University, Detroit, MI
 2006 – 2007: Research Assistant, Wayne State University, Detroit, MI
 2006 – 2010: Graduate Teaching Assistant, Wayne State University, Detroit, MI
 2006: Research Intern, Pipal Research, New Delhi, India

Contributions

1. Watkins D,..., **Gupta L** et al. (2016) "[Coupled Production-Consumption Systems for Climate Change Mitigation: Designing Equitable Food, Energy, and Water Conservation Strategies](#)", *NSF White Paper (grant #1541816)*.
2. Herrera AM, **Lagalo LG** & Wada T, (2015) "[Asymmetries in the Response of Economic Activity to Oil Price Increases and Decreases?](#)", *Journal of International Money and Finance*, Vol. 50, pp. 108-133.
3. Herrera AM, **Lagalo LG** & Wada T, (2011) "[Oil Price Shocks and Industrial Production: Is the Relationship Linear?](#)", *Macroeconomic Dynamics*, 15 (Suppl. 3), 472–497.

Research Support

1. **Gupta, L**, Mayer A, Eastmond A, & Herrera-Cruz A, *In Review*. "Analysis of drinking water supply choices in a rural community in the Yucatan, Mexico reveals bottled water consumption is related to distrust of tap water".
2. **Gupta L** & Rho Y, "Separating Demand and Supply Shocks in the Oil Market – An Analysis Using Disaggregated Data"
3. **Gupta L** & Rho Y, "Demand and Supply Shocks in the Oil Market: Evidence from Developed Countries"
4. **Gupta L**, "Steel Prices, Energy, and Industrial Production"
5. **Gupta L**, "Oil Prices and Fiscal Balances of Net Oil Exporting Countries"
6. **Gupta L**, "Wind Energy and the Steel Industry: Comparison of China and the U.S."

Collaborators & Other Affiliations

Collaborators (last 5 years)

Amarella Eastmond (University of the Yucatan), Catherine Closner (MTU), Ana María Herrera (University of Kentucky), Alex Mayer (MTU), Jessica McCarty-Kern (Miami University), Yeonwoo Rho (MTU), Tatsuma Wada (Wayne State University)

Graduate Advisors (total number: 2)

Ana María Herrera (University of Kentucky) and Somesh K. Mathur (Indian Institute of Technology Kanpur)

Thesis Advisor (past 5 years)

Master's students: Catherine Closner (Michigan Technological University), Jing Han (Michigan Technological University)

Undergraduate Students: Hongbo Liu (Oliver Wyman), Mingjie Jiao (University of Chicago)

Total number advised: 2 Master's, 2 Undergraduates

Synergistic Activities

1. *Copper Country Today* Interview, Dakota Access Pipeline, 2016.
Best Feature Programming, Michigan Association of Broadcasters award
2. Member, GLRC World Water Day Planning Committee, 2016 - 2017
3. Advisory Board Member, Michigan Tech Center for Water and Society, 2014-2016
4. Moderator and Organizer, Michigan Tech World Water Day Panel Discussion, 2015-2017
5. Member/Organizer/Moderator, Michigan Tech Green Film Series, 2014 – 2017
6. Instructor, Energy Economics, (2015-Present)
7. Instructor, Economics Forecasting/Econometrics, (2011-Present)
8. Advisor, Economics Club Panel Discussion "Economics of Climate Change", 2017
9. *Daily Mining Gazette*, "Slow jobless recovery - Statistics don't factor workforce dropouts", 2015.
10. *Daily Mining Gazette*, "Fewer without jobs in Michigan, locally - Unemployment on par with national average for first time in over a decade ", 2015.
11. *Daily Mining Gazette*, "Moving on up 2015 - gas prices could peak around \$3 a gallon", 2015.
12. *Daily Mining Gazette*, "Unemployment down in Copper Country - Economist questions statistics' value", 2015.

Ying Huang, Ph.D.

Assistant Professor, Department of Civil and Environmental Engineering
North Dakota State University (NDSU)
Dept. 2470, PO Box 6050, Fargo, ND 58108-6050
Phone: (701) 231-7651, Fax: (701) 231-6185
Email: ying.huang@ndsu.edu

APPOINTMENTS:

Assistant Professor, 2012-Present, Civil Engineering, NDSU
Research Assistant, 2008-2012, Civil Engineering, Missouri University of Science and Technology

PROFESSIONAL PREPARATION:

Guangzhou University, China	Civil Engineering	B.Eng., 2006
Harbin Institute of Technology, China	Civil Engineering	M.S., 2008
Missouri University of Science and Technology	Civil Engineering	Ph.D., 2012

COURSRS TEACHING:

- **CE452/652 Introduction to Oil and Gas Pipelines: Design, Construction, Maintenance, and Assessment (Tech Elective to junior, senior and graduate students, Spring, 15+ enrollments)**
- **CE441/641 Finite Element Analysis (Tech Elective to junior, senior and graduate students, Fall, 30+ enrollments)**
- **CE782 Introduction to Intelligent Infrastructure (Graduate level, Spring, 5+ enrollments)**
- CE204 Surveying (Required, Sophomore, Fall, 100+ student enrollments)
- CE303 Civil Engineering Materials (Required, Junior, Spring, 100 + student enrollments)
- CE303L Civil Engineering Materials Lab (Required, Junior, Spring, 100 + student enrollments)
- CE 458/658 Bituminous Materials and Mixtures (Tech Elective, Fall, 25+ enrollments)
- CE456/656 Railroad Planning and Design (Tech Elective, Fall, 35+ enrollments)
- CE489 Senior Design Consultant and Mentor (Required, Fall & Spring, 50+ enrollments)

PUBLICATIONS AND PROJECTS MOST CLOSELY RELATED TO THE PROPOSED PROJECT:

1. **Related Patent:** F. AZARMI and Y. HUANG, "Corrosion mitigation and prevention using self-sensing thermal spraying coating", Provisional Patent Filed in 2016.
2. **Related Project:** "Mitigating Pipeline Corrosion Using A Smart Thermal Spraying Coating System", U.S. DOT Pipeline and Hazardous Materials Safety Administration (PHMSA), 09/30/2015-09/29/2018
3. **Related Project:** "Composite Thermal Sprayed Coatings for Pipeline Corrosion Prevention and Mitigation" U.S. DOT Pipeline and Hazardous Materials Safety Administration (PHMSA), 10/01/13-12/31/15,

Related Papers:

4. F. Deng, Y. Huang, F. Azarmi, and Y. C. Wang, "Pitted Corrosion Detection of Thermal Sprayed Metallic Coatings Using Fiber Bragg Grating Sensors", Coatings, Vol. 7, No. 35, 1-17, (2017).
5. F. Deng, Y. Huang, and F. Azarmi, "Steel corrosion detection of soft coatings using fiber Bragg grating sensors," 2017 SPIE Conference of Smart Structures & NDE, Portland, OR, March 24 2017.
6. F. Deng, Y. Huang, and F. Azarmi, "Steel corrosion detection using fiber Bragg grating sensors," 2016 ASCE Pipelines Conference, Kansas City, MO, July 2016.
7. F. Deng, Y. Huang, and F. Azarmi, "In-line fiber Bragg grating sensors for steel corrosion detection," 2016 SPIE Conference of Smart Structures & NDE, Las Vegas, NV, March 24 2016.

8. **Y. Huang**, X. Liang, S. A. Galedar, and F. Azarmi, “Integrated fibre optic sensing system for pipeline corrosion monitoring”, 2015 ASCE Pipelines Conference, Paper ID: 141, Baltimore, Maryland, August 23-26 2015.
9. X. Liang, **Y. Huang**, S. A. Galedari, and F. Azarmi, “Pipeline corrosion assessment using embedded fiber Bragg grating sensors,” 2015 SPIE Conference of Smart Structures & NDE, Paper ID: 9435-69, San Diego, CA, March 24 2015.
10. **Y. Huang**, L. Xiao, and F. Azarmi, “Innovative fiber optic sensors for pipeline corrosion monitoring,” 2014 ASCE Pipelines Conference, 2014.
11. **Y. Huang**, F. Tang, X. Liang, G. Chen, H. Xiao, and F. Azarmi, “Steel bar corrosion monitoring with long period fiber grating sensors coated with nano iron/silica particles and polyurethane”, Structural Health Monitoring, 1475921714560070, 2014.
12. **Y. Huang**, Z. Gao, Z. Zhou, G. Chen, and H. Xiao, “Long period fiber grating sensors coated with nano iron/silica particles for corrosion monitoring”, Smart Materials and Structure, 22(7) 075018, (2013).

SYNERGISTIC ACTIVITIES:

- Has more than ten years of research background in structural health monitoring and pipeline risk analysis and corrosion assessment
- Featured by *Paint Square (Paint and Coating Industry News)*: “**University Team Tackles Corrosion**”, September 28, 2015
- Featured by *NDSU News, Banner Stories*: “**NDSU engineers improve pipeline safety**”, September 23, 2015
- Featured by *International Society for Structural Health Monitoring of Intelligent Infrastructure (ISHMII) Membership Notes*, Vol. 3, No. 5, 2013
- Possess *two* related US approved and pending patents and one Chinese patent on related fields
- Over *70* high quality peer reviewed publications that include one book chapter, *30* journals, and *40* conference papers, which were cited *345 times* with an i10-index of *9*
- Over *10* invited presentations and *20* international and national presentations in related field
- Associate editor and editorial board member for *five* international journals
- Committee member for *five* distinguishing professional society such as ASCE Structural Condition Assessment and Rehabilitation of Buildings Committee, ASTM Fiber Optic Practices Committee, and SPIE Sensors and Smart Structures Technologies Committee
- Organizer and session modulator for *four* international conferences such as ASME IMECE, IWSHM, SPIE Smart Structures & NDE Conference, and the ASCE Pipelines Conference
- Grant reviewer for NSF CMMI Program, U.S. DOT PHMSA R&D Program, National Research Foundation (NRF) of Singapore R & D, and Energy Market Authority of Singapore R & D
- Journal peer reviewer for *35* international journals and conferences
- Academic advisor of over *40* undergraduate students and major advisor for *8* graduate students
- Featured by *Go! Magazine: Exploring the World of Transportation*, featured news “Ying Huang: Making transportation smarter”, 2013
- NDSU Ozbun Economic Development Award, May 2015
- NDSU Forward Leap Research Award, 2016
- NDSU College of Engineering Researcher of the Year, April 2017
- NDSU Centennial Award, April 2017

CHARLES FRANK IDE, Ph.D.

Dept. of Biological Sciences
Western Michigan University
Kalamazoo, MI 49008
(269) 387-5951
charles.ide@wmich.edu

Nationality: U.S.A.

Research Interests: Environmental Health Risk Assessment Using Genomics Based Tools

Academic Degrees: Ph.D. 1975 Princeton University
(Biology)
M.A. 1973 Princeton University
(Biology)
B.A. 1971 University of Oregon
(Honors College Independent Scholar)

Research/Professional Experience:

2003- Gwen Frostic Professor of Biological Sciences, Western Michigan University
2002- Director, Great Lakes Center for Environmental and Molecular Sciences, Western Michigan University
1999-10 Director, Environmental Institute, Western Michigan University
1998-10 Director, Environmental Research Center, Western Michigan University
1998- Professor of Biological Sciences, Western Michigan University
1998 Professor of Cell and Molecular Biology, Tulane University
1990-93 Founding Chairman, Department of Cell and Molecular Biology, Tulane University
1991-98 Director, State of Louisiana DOE/EPSCOR Interdisciplinary Research Program
1989-98 Founding Deputy Director, Tulane/Xavier Center for Bioenvironmental Research
1993-98 Co-Director, Tulane/Xavier DOE/Environmental Restoration and Waste Management Program 'Hazardous Materials in Aquatic Environments of the Mississippi River Basin'

Relevant Grants:

2009-2010 NSF Grant, "Global Climate Change First Year Seminar: How Science is Working to Save the Planet"; \$149,951; C.F. Ide (PI), Toni Woolfork-Barnes, and David Karowe (Co-PI's).
2000-2007 EPA Grant, "Great Lakes Center for Environmental and Molecular Sciences"; \$3,598,750.; C.F. Ide (PI) and co-PIs.
2000-2005 EPA Grant, "Kalamazoo River Watershed Council, Technical Assistance Grant—Allied Paper/Portage Creek/ Kalamazoo River Superfund Site"; \$62,070. C. F. Ide (PI)
2000-2002 Private Grant: Environmental Institute Research Projects Fund; \$220,000; C.F. Ide (PI)
1999-2002 EPA Grant, "Kalamazoo River Watershed Initiative"; \$950,200; C.F. Ide (PI)
1996-1999 DOE Grant, "Environmental Analysis of Endocrine Disrupting Effects from Hydrocarbon Contaminants in the Ecosystem" \$619,995; J. McLachlan (PI), C.F. Ide and Co-PI's.
1995-1998 Private Grant, "Water Quality in the Mississippi River" \$50,735 (Ide portion only); W. George (PI); C.F. Ide and Co-PI's.

- 1992-1998 DOE Grant; “Hazardous Materials in Aquatic Environments of the Mississippi River Basin;” \$24,999,992. J. McLachlan (PI), C.F. Ide and S. O’Connor (Co-PI’s) Award #DE-FG-01-93EW53023.
- 1993-1999 US Department of Energy Cooperative Agreement; “Enhancement of Energy Related Research and Education in Louisiana” (Louisiana DOE EPSCOR program); \$7,560,627; C.F. Ide (PI) with R. Ford and P. Kilcrease (Co-PIs); Award #DE-FC-02-91ER75669.
- 1993-1999 Louisiana State Board of Regents LEQSF Matching Funds Grant; “Enhancement of Energy Related Research and Education in Louisiana” (Louisiana DOE EPSCOR program); \$3,947,768; C.F. Ide (PI) with R. Ford (Co-PI).

Bibliography: Relevant Articles (of 61 total)

Zaya, R.M., Z. Amini, A.S. Whitaker, and C.F. Ide (2011) Exposure to atrazine affects the expression of key genes in metabolic pathways integral to energy homeostasis in *Xenopus laevis* tadpoles. *Aquatic Toxicology* 104: 254-262.

Zaya, R.M., Z. Amini, A.S. Whitaker, S.L. Kohler, and C.F. Ide (2011) Atrazine exposure affects growth, body condition and liver health in *Xenopus laevis* tadpoles. *Aquatic Toxicology* 104: 243-253.

Langerveld, A.J., R. Celestine, R. Zaya, D. Mihalko, and C. F. Ide (2009) Chronic Exposure to High Levels of Atrazine Alters Expression of Genes that Regulate Immune and Growth-Related Functions in Developing *Xenopus laevis* Tadpoles. *Environmental Research*, 109 (4): 379-389.

Fisher, M.A., R. Eversole, C. DeLong, J. C. Means, D. Mihalko, and C. F. Ide (2008) Liver cyp1A protein expression and pigmented macrophage aggregates as indicators of polychlorinated biphenyl exposure in carp (*Cyprinus carpio*) from the Kalamazoo River Superfund Site, MI. *Journal of Fish Biology*, 72: 1-16.

Katbamna, B., A. Jelaso Langerveld, and C.F. Ide (2006) Aroclor 1254 impairs the hearing ability of *Xenopus laevis*. *Journal of Comparative Physiology A: Sensory, Neural, and Behavioral Physiology* 192 (No. 9): 971-983.

Shirey, E.L., A. Jelaso Langerveld, D. Mihalko, and C.F. Ide (2006) PCB exposure delays metamorphosis and alters thyroid hormone system gene expression in developing *Xenopus laevis*. *Environmental Research* 102 (No.2): 205-214.

Fisher, M.A., C. Mehne, J.C. Means, and C.F. Ide (2006) Induction of CYP1A mRNA in carp (*Cyprinus carpio*) in laboratory studies and in carp from a PCB contaminated Superfund site. *Archives of Environmental Contamination Toxicology* 50, 14-22.

R. Shuchman, S. Savage, T. Erickson, R. Edson, M. O’Haver, J. Means, and C. Ide (2005) Enabling watershed analysis and data sharing through the GLEAMS portal and dynamic decision support systems. *Proceedings of the Eighth International Conference on Remote Sensing for Marine and Coastal Environments*.

Jelaso, A.M., E. Lehigh-Shirey, J. Means, and C.F. Ide (2003) Gene expression patterns predict exposure to PCBs in developing *Xenopus laevis* tadpoles. *Environmental and Molecular Mutagenesis* 42:1-10.

Ide, C.F., A. Jelaso (1998) River Symposium Paper “Hazardous Materials in Aquatic Environments: Molecular Biomarkers and Risk Assessment in Bayou Trepagnier, LA”. *Proceedings from The Mississippi River Symposium Meeting*.

Ide, C.F., S. O’Connor, G. Flowers. (1998) Tulane/Xavier Center for Bioenvironmental Research Project “Hazardous Materials in Aquatic Environments. *Proceedings from “Industry Partnerships to Deploy Environmental Technology Meeting”*”.

BIOGRAPHICAL SKETCH

NAME: Kelly B Kamm

POSITION TITLE: Research assistant professor

EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE	Completion Date	FIELD OF STUDY
Washington State University, Pullman, WA	BS	05/1996	Microbiology
Johns Hopkins School of Public Health and Hygiene, Baltimore, MD	MHS	05/1997	Molecular Microbiology and Immunology
State University of New York at Buffalo, Buffalo, NY	PhD	02/2014	Epidemiology
Postdoctoral fellowship, State University of New York at Buffalo, Buffalo, NY		07/2016	Epidemiology

A. Personal Statement

I am trained as an epidemiologist with an emphasis on infectious diseases and maternal and child health. In my research and training, I am involved in the design, conduct, and analysis of epidemiologic studies. These observational and experimental studies evaluated the impact of health promotion programs on health and health behaviors. I developed protocols, data collection instruments, managed IRB submissions, developed and maintained enrollment tracking forms, coordinated data collection teams, and trained field teams. I have analyzed data and presented results to government, NGO, and academic stakeholders. Prior to my academic career, I spent two years at a state public health laboratory and 7 years in management roles at a high volume pharmaceutical testing contract lab. I managed a small research team and lab operations for the facility. My training and experience designing, conducting, and analyzing epidemiologic studies will allow me to lead the public health portion of the risk assessment. Although my experience is not in environmental health, the methodology for epidemiologic studies and public health considerations are similar. My management experience in a contract lab provides a background to be able to manage a team and successfully meet short turnaround times.

B. Positions and Honors

2017-present Research assistant professor, Kinesiology and Integrative Physiology, Michigan Technological University, Houghton, MI

2007-2008 Manager of Lab Operations, Cerep, Inc, Redmond, WA
 2001-2007 Metabolism Group Lead/Research associate and Lab Supervisor, Cerep, Inc,
 Redmond, WA

Honors

2016, 2015 Saxon Graham Award for Academic Excellence in Epidemiology, Department of
 Epidemiology and Environmental Health, State University of New York at
 Buffalo, Buffalo, NY

C. Contributions to Science

Diarrhea and pneumonia are the two largest killers of young children worldwide and can be reduced by adequate hand hygiene. My doctoral work focused on measuring hand hygiene behavior, understanding the drivers of hand hygiene in mothers and young children, and evaluating interventions developed to address these drivers and improve behavior. We have found that access and convenience to soap and water make handwashing possible, but psychosocial factors, such as social norms, perceptions of risk, and desire to nurture are important. Addressing barriers can improve behavior, but barriers change as a child grows and interventions must be adaptive.

1. Ram PK, Nasreen S, Kamm KB, Vujcic J, Kumar S, Rahman MA, Zaman K, El Arifeen S, Luby SP. Impact of an intensive perinatal handwashing promotion intervention on maternal handwashing behavior in the neonatal period: findings from a randomized controlled trial in rural Bangladesh. *BioMed Res Intl* 2017 In press.
2. Kamm KB, Crabtree-Ide CR, Thomas A, Ram PK. Evaluation of the SOPO school handwashing promotion programme: Nyanza and Rift Valley Provinces, Kenya. Nairobi, Kenya: UNICEF-ESARO; 2015.
3. Kamm KB, Feikin DR, Bigogo GM, Aol G, Audi A, Cohen AL, Shah M, Yu J, Breiman RF, Ram PK. Associations with handwashing in the home and respiratory and diarrheal illness in children under five years old in rural western Kenya. *Trop Med Int Health* 2014 Apr; 19(4):398-406.

D. Additional Information: Research Support and/or Scholastic Performance

Ongoing Research Support

MTU/PHF REF-Research Seed Grant	Kamm (PI)	2017-2018
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Infant feeding practices in the U.P.

This study will assess knowledge, perceptions, sources of support and information, and practices related to infant feeding among mothers and health professionals in the U.P.

Role: Primary investigator

Completed Research Support

UNICEF	Kamm (student PI); Ram (faculty advisor)	2012-2013
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Evaluation of the SOPO school-based handwashing promotion program, Kenya

This study assessed the impact of a school-based handwashing program on knowledge and behavior in Kenya. We evaluated the impact on school children at home and at school, and mothers of school-aged children at home.

Role: Student PI

BIOGRAPHICAL SKETCH Nancy Langston; nelangs3@mtu.edu

a. Professional Preparation

Dartmouth College	English	BA 1984
University of Oxford	English	MPhil 1986
University of Washington	Environmental Studies	PhD 1994
University of Washington	Zoology	Postdoctoral 1994-5

b. Appointments

2013-on. Professor of Environmental History, Department of Social Sciences and Great Lakes Research Center, Michigan Technological University

2012-2013. King Carl XVI Gustaf Professor of Environmental Science, Department of Historical, Philosophical and Religious studies, Umeå University, Sweden.

2007-2012. Professor, Nelson Institute for Environmental Studies and Dept. of Forest and Wildlife Ecology. University of Wisconsin-Madison.

2001-2007. Associate Professor, Nelson Institute for Environmental Studies and Dept. of Forest Ecology & Management. University of Wisconsin-Madison.

1995-2001. Assistant Professor, Nelson Institute for Environmental Studies and Dept. of Forest Ecology & Management. University of Wisconsin-Madison.

c. Products: Most closely related to proposed project

Langston, N. 2017 *Sustaining Lake Superior: An Extraordinary Lake in a Changing World*. Yale U. Press

Langston, N. In press. "Environment and sustainability in mining." Chapter for *Environment and Sustainability in a Globalizing World*, Ed. A. Nightingale and T Bohler, ME Sharpe Press 2017.

Baeten, J. P., Langston, N., Lafreniere, D. J. In press. "A Spatial Evaluation of Historic Iron Mining Impacts on Current Impaired Waters in Lake Superior's Mesabi Range." *Ambio*.

Langston, N. 2017 "Iron Mines, Toxicity, and Indigenous Communities in the Lake Superior Basin," pp. 313-338 in *Mining North America*, eds. G. Vrtis and J. McNeil, U of CA Press.

Langston, N. 2017. "Resiliency and Collapse: Lake Trout, Sea Lamprey, and Fisheries Management in Lake Superior." Pp. 239-262 in Lynne Heasley and Daniel Macfarlane, eds *Border Flows: A Century of Canadian-American Water Relations*, U. Calgary Press.

John Baeten, Nancy Langston, and Don Lafreniere. 2016. "A geospatial approach to uncovering the hidden waste footprint of Lake Superior's Mesabi Iron Range." *The Extractive Industries and Society* 3(4): 1031-1045.

Thistle, J. and N. Langston. 2016. "Entangled histories: Iron ore mining in Canada and the United States." *The Extractive Industries and Society* 3(2): 269-277.

Steen-Adams, M. M., Langston, N., Adams, M.D., & Mladenoff, D. J. 2015. "Historical framework to explain long-term coupled human and natural system feedbacks: application to a multiple-ownership forest landscape in the northern Great Lakes region, USA." *Ecology and Society*, 20(1): 28ff.

Langston, N. 2013. "Mining the Boreal North," *American Scientist* March/April 101:2-4.

Steen-Adams MM, Mladenoff DJ, Langston NE, Liu F, Zhu J. 2012. "Influence of biophysical factors and differences in Ojibwe reservation versus Euro-American social histories on forest landscape change in northern Wisconsin, USA."

Landscape Ecology 26: 1165-1178.

Langston, N. 2010. *Toxic Bodies: Hormone Disruptors and the Legacy of DES*. Yale University Press.

Other

Langston, N. 2015. "Thinking Like A Microbe: Borders and Environmental History." *Canadian Historical Review*. 95(4): 592-603.

Langston, N. 2014. "Precaution and the History of Endocrine Disruptors." in *Powerless Science? Science and Politics in a Toxic World*, ed. S. Boudia and N. Jas. New York: Berghahn Books. 29-45.

Langston, N. 2014. "New Chemical Bodies: Synthetic Chemicals, Regulation, and Health." Chapter for *Oxford Handbook of Environmental History*, ed. Andrew Isenberg. 259-281.

Langston, N. 2010. ["Toxic Inequities: Chemical Exposures and Indigenous Communities in Canada and the United States."](#) *Natural Resources Journal* 50:2.

Steen-Adams, M., N. Langston, and D. J. Mladenoff. 2010. ["Logging the Great Lakes Indian Reservations: The Case of the Bad River Band of Ojibwe."](#) *American Indian Culture and Research Journal* 34: 41-66.

Langston, N. 2003. *Where Land and Water Meet: A Western Landscape Transformed*. University of Washington Press.

Langston, N. 1995. *Forest Dreams, Forest Nightmares: the Paradox of Old Growth in the Inland West*. University of Washington Press.

d. Synergistic Activities

- *Science and Policy*: I served on the National Research Council, Committee on Endangered Fishes in the Klamath River Basin. 2001-3. I also served with the National Council for Science and Sustainable Forestry, PI for one major workshop and project on old growth forests in the Great Lakes states, and co-author for publications on climate change and forest resiliency.
- *Promoting public engagement within professional societies*. As Vice-President and then President of American Society for Environmental History, (2005-2009) I established committees to engage scholars with broader publics. We were instrumental in protecting the libraries and collections of the EPA, for example.
- *Promoting interdisciplinary research and outreach*: With ASEH, I was PI for an NSF-sponsored workshop on the intersection of civic science and toxic contamination (2007).
- *Promoting public engagement within academic journals*: As Editor in Chief of *Environmental History*, 2010-2013, I worked with science studies scholars, environmental historians, and historians of science to create annual forums in the journal engaged with contemporary issues such as Fukushima.
- *Service on international stakeholder forums*: From 2010 to 2015, I served as a US member of the Lake Superior Binational Forum, Binational Program, International Joint Commission. I led the Mining Committee's efforts to draft a statement on responsible mining in the basin.

Alice A. Lippert
Senior Energy Analyst and Strategic Advisor
Alice.Lippert01@gmail.com
(703) 508-7821

PROFESSIONAL EXPERIENCE

Senior Energy Analyst and Advisor, Independent Consultant, Apr 2016-Present

Responsible for strategic planning, development and technical support of projects related to energy assurance planning, energy security, risk analysis, emergency response, and public/private energy portfolio planning for reliability, resilience and sustainability.

Senior Technical Advisor, Sept 2013 – Jan 2016

Acting Deputy Assistant Secretary, Oct 2012 – Sept 2013

Office of Electricity Delivery and Energy Reliability (OE), US Department of Energy (DOE)

Served as the **Acting Deputy Assistant Secretary** for the newly created Energy Infrastructure Modeling and Analysis Division within OE. In this position, managed and led a team of electricity experts and engineers to establish an organization responsible for three program areas: Transmission Reliability, Advanced Modeling Grid Research, and Energy Systems Risk Predictive Capability (modeling and analysis). Responsible for budget formulation.

As Senior Technical Advisor responsible for key projects related to modeling and risk analysis of domestic energy infrastructure; performed risk assessments and published analytic products; Prepared various analyses for informing stakeholders on events impacting energy reliability; developed processes for providing analysis and analytic products during energy emergencies; Initiated research and analysis of sea level rise and storm surge and the impact on energy infrastructure.

Created the State Energy Risk Assessment Initiative; Conducted State Energy Risk Assessment Workshops; Initiated the production/publication of State and Regional Energy Risk Profiles; Designed and produced the Energy Risk Resource Library, a web-based risk tool.

Senior Technical Advisor, Dec 2008 – Oct 2012

Infrastructure Security and Energy Restoration, DOE Office of Electricity Delivery and Energy Reliability

Served as the Senior Technical Advisor to the Deputy Assistance Secretary, Infrastructure Security and Energy Restoration: **Manager for the State and Local Energy Assurance Program, including the American Reinvestment and Recovery Act Energy Assurance and Planning Initiative (2009-12), a \$50 million grant** project provided to State and Local Governments to develop energy assurance plans in responding to energy security and emergencies.

Responsible for risk and resiliency programs as well as domestic energy reliability, infrastructure and security projects. Senior expert on domestic energy markets and infrastructure and the relationship to worldwide distribution systems and energy-supply trends. Principal contact for a variety of complex energy issues and energy-emergency events requiring the review of interdependencies and market impacts.

Expertise in DOE authorities and government programs related to Clean Air Act, Jones Act, Homeland Security, Pipeline Security and Safety, including waiver processes involving federal government energy programs. Liaison for special, high-visibility exercises, studies and analyses involving senior representatives from the Department, Federal, State and local governments, National Laboratories, and private sector; Served as **Emergency Response**

Director during energy emergencies and Office Continuity of Operations (COOP) Coordinator.

Senior Infrastructure Analyst and Team Leader, Jan 2003 – Dec 2008

Infrastructure Analysis and Planning Directorate, DOE Office of Electricity Delivery and Energy Reliability

Managed and led a team of infrastructure systems analysts who monitored and tracked domestic energy infrastructure, conducted energy security and reliability analysis projects, and assessed situational awareness for OE and DOE; this Directorate supported the analytic needs of the Infrastructure Security and Energy Restoration Division's Operations and International Directorates and Response Deployment Teams.

Served as Senior Infrastructure Systems Analyst to Deputy Assistant Secretary and Assistant Secretary on energy supply, reliability, and security issues. Responsible for State and Local Government energy reliability, emergency response and information sharing programs; Conducted due diligence for the Department of Energy with respect to Jones Act waivers, Clean Air Act and Fuel Waivers, and Driver- Hour Waivers.

Responsible for the Energy Emergency Assurance Coordinators System, a communications protocol of over 200 State officials from across the country who could be contacted in the event of an energy emergency.

Economist, Apr 1985 – Jan 2003

Energy Information Administration, US Department of Energy

Served as the Project Manager for a large scale national petroleum sales survey; Served as the Project Manager for the State Heating Oil and Propane Project, a cooperative agreement with twenty-five State Energy Offices; Coordinated and responded to energy emergencies for EIA;

Performed research projects analyzing oil and gas data; Conducted ad hoc economic analyses related to the energy industry; Authored market assessment reports; assessed changes in the energy industry as a result of legislation or environmental laws and regulations.

Developed data collection systems and implemented quality assurance and data verification methods necessary for evaluating data; Served on team projects assessing the quality of survey data systems and process improvements; Conducted training workshops to oil companies required to complete EIA survey forms; Prepared and made presentations to State, federal, and industry officials regarding market trends and heating fuel outlooks; Coordinated and conducted numerous energy workshops and conferences;

EDUCATION

Postgraduate Coursework, Economics George Mason University, Fairfax VA

Master of Science, Consumer Economics University of Wisconsin, Madison, WI

Bachelor of Arts, German Literature University of North Dakota, Grand Forks, ND

JOB-RELATED HONORS, AWARDS, MEMBERSHIPS

Secretary of Energy Distinguished Service Award, 2016

Samuel J. Heyman Service to America Medals Award (Sammie) Finalist, 2014

Outstanding Recognition for excellence and strategic vision in assisting State and Local Governments - National Association of State Energy Officials (NASEO) and Public Technology Institute

Member Emeritus, Energy Security and Data Committee, NASEO

Former Subcommittee Member, Critical Infrastructure Committee, National Association of Regulatory Utility Commissioners (NARUC)

Former Member of Women's Council on Energy and the Environment (WCEE) Fulbright Scholarship

Biographical Sketch: Lupi, Frank, Ph.D.

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[Google Scholar](#)

EDUCATION

Ph.D., Applied Economics, with Economics minor, University of Minnesota, 1997.
M.S., Agricultural Economics, University of Illinois, 1988.
B.S., Economics, University of Illinois, 1986.

ACADEMIC APPOINTMENTS

Professor (since 2009), Associate Professor (2003-8) and Assistant Professor (1999-03):
Department of Food, Agricultural and Resource Economics, Michigan State University
& Department of Fisheries and Wildlife, Michigan State University
Visiting Assistant Professor (1997-8) and Specialist (1993-6), Michigan State University

PROFESSIONAL EXPERIENCE

- Lupi is an Environmental Economist and expert in benefit-cost analyses, natural resource damage assessments, and valuation of natural resources, with over 20 years of experience in the Great Lakes.
- He has performed over 100 technical peer reviews of economic analyses performed in academia and government and industry.
- Lupi has served as an economic expert on natural resource damage assessments under the public trust doctrine, CERCLA and OPA.
- Lupi has extensive project experience, with over 50 grants from: NSF, EPA, G.L. Fishery Commission, G.L. Fishery Trust, International Joint Commission, MDEQ, MDNR, MI & National Sea Grant Programs, NOAA, USACOE, USFWS, USFS & USDA.
- He teaches a graduate course on nonmarket valuation of ecosystem services.
- Lupi has 83 peer-reviewed publications, has over 300 professional presentations, and has chaired 20 and served on 45 other graduate student committees.
- He has served on many science advisory committees including the NOAA's Blue Ribbon Panel on Economic Valuation of Great Lakes Environmental Benefits.

SOME RELATED PUBLICATIONS

Valuing Lake Erie beaches using value and function transfers (with L. Palm-Forster and M. Chen).
Agricultural and Resource Economics Review. 45(2): 270-292, 2016.

Valuing recreational fishing quality at rivers and streams (with R. Melstrom, P. Esselman, R.J. Stevenson).
Water Resources Research, 51, 140-150, 2015.

Valuing recreational fishing in the Great Lakes (with R. Melstrom). *N. Amer. J. of Fish. Mgmt* 33:1184-1193, 2013.

Environmental constraints on hydropower: an ex-post benefit-cost analysis of dam relicensing (with M. Kotchen, M. Moore and E. Rutherford), *Land Econ.* 82:384-403, 2006.

Using an economic model of recreational fishing to evaluate benefits of sea lamprey control on the St. Marys River (with J. Hoehn and G. Christie), *J. Great Lakes Research*. 29:742-754, 2003.

Guy A. Meadows

Director, Great Lakes Research Center, Michigan Technological University
 Robbins Professor of Sustainable Marine Engineering
 1400 Townsend Dr. Houghton, MI 49931 Phone: 906.487.1106, gmeadows@mtu.edu
<http://www.mtu.edu/greatlakes/contact/faculty-staff/meadows/>

Individual Expertise

- Large scale field experimentation in the Inland Seas of the Great Lakes and coastal oceans
- Nearshore hydrodynamics and prediction
- Autonomous and semi-autonomous environmental monitoring platforms (surface and sub-surface)
- Underwater acoustic remote sensing
- Marine engineering

Professional Preparation

Michigan State University	Mechanical Engineering	B.S.E. 1972
Michigan State University	Mechanical Engineering	M.S.E. 1974
Purdue University	Marine Science	Ph.D. 1977

Professional Positions

Robbins Professor of Sustainable Marine Engineering Director	Michigan Technological University Great Lakes Research Center Michigan Technological University	2014-present 2012-present
Adjunct Professor	Dept. of Geological and Mining Eng. Sciences Michigan Technological University	2012-present
Graduate Program Advisor	Dept. of Naval Architecture and Marine Eng. University of Michigan	2009-2011
Academic Director	M-STEM Academy University of Michigan	2009-2012
Director	Marine Hydrodynamics Laboratory University of Michigan	2003-2011
Professor	Dept. of Naval Architecture and Marine Eng. University of Michigan	1999-2011
Professor	Dept. of Atmospheric Oceanic and Space Science University of Michigan	1999-2012
Director	Cooperative Institute for Limnology and Ecosystems Research (NOAA – JI)	1996-2000
Director	Ocean Engineering Laboratory University of Michigan	1988-2012
Associate Professor	Dept. of Naval Architecture and Marine Eng. University of Michigan	1985-1999
Associate Professor	Dept. of Atmospheric and Oceanic Science University of Michigan	1983-1999
Assistant Professor	Dept. of Atmospheric and Oceanic Science University of Michigan	1977-1983

Selected Bibliography of Recent/Relevant Publications (of 37 total)

Josberger, E., R. Shuchman, **G. Meadows**, S. Savage and J. Payne “Hydrography and Circulation of Ice-Marginal Lakes at Bering Glacier, Alaska,” Arctic, Antarctic and Alpine Research, Vol. 38, No. 4, pp. 547-560, 2006.

O’Shea, J.M. and **G. Meadows**, “Evidence for Early Hunters Beneath the Great Lakes,” Proceedings of the National Academy of Sciences, vol. 106, no. 25, pp. 10120-10123, June, 2009.

- Meadows, G.A.**, “A Review of Low Cost Underwater Acoustic Remote Sensing for Large Freshwater Systems,” *Journal of Great Lakes Research*, vol 39, pp. 173-182, Sept, 2013.
- Meadows, G.**, V. Schmidt, M. Luther and R. Downs (2015). “Autonomous Surface Vehicle Workshop Proceedings.” U.S. Integrated Ocean Observing System (IOOS), CBL 2016-005.
- Luther, M.E., **G. Meadows**, E. Buckley, S.A. Gilbert, H. Purcell and M.N. Tamburri, “Verification of Wave Measurement Systems,” *Journal of Marine Technology*, 47(5), pp 104-116, 2013.
- Meadows, L., **G. Meadows**, A. Troesch, S. Cohen, K.P. Beier, G. Root, O. Griffin, and T. Swann, “Lagrangian Velocity Profiles in the Wake of a High Speed Vessel,” *Ocean Engineering*, Vol. 21, No. 2, pp. 221-242, 1994.
- Norton, R.K., L.A. Meadows and **G.A. Meadows**, “Drawing Lines in Law Books and on Sandy Beaches: Marking Ordinary High Water on Michigan's Great Lakes Shorelines under the Public Trust Doctrine,” *Coastal Management*, Vol 39, No. 2, p. 133-157, 2010.
- Meadows, L.A., C. Whelan, D. Barrick, R. Kroodsma, C. Ruf, C.C. Teague, **G.A. Meadows** and S. Wang, “High Frequency Radar and its Application to Fresh Water,” *Journal of Great Lakes Research*, vol 39 Supl. 1 pp 183 - 193, Sept. 2013.
- Shuchman, R.A., **G. A. Meadows** and D. Dean, “Comparisons of MODIS Satellite Derived Lake Surface Temperature (LST) with Coincident MTU/GLOS Buoy Data in Lake Superior,” *Journal of Great Lakes Research*, in press, 2013.
- Schwab, D., P.C. Liu, J.R. Bennett and **G.A. Meadows**, “Lake Erie Coastal Boundary Layer Study Measures Flux of Energy During Storms,” *Coastal Oceanography and Climatology News*, 4, 1, 1981.

Synergistic activities

1. NOAA IOOS Program Office, Review Panel for US Wave Measurement Program, August, 2007
2. NOAA National Development Team Leader - Wave Sensor Test and Evaluation, April, 2010-11
3. Canada Foundation for Innovation; Neptune / Venus Deep Ocean Observatories, Chair – International Review Panel, 2011-2012
4. Department of Energy, Principal Investigator, “Measurement and Analysis of Extreme Wave and Ice. Actions in the Great Lakes for Offshore Wind Platform Design”. 2011
5. “Developing a Talent Pipeline: Inspiring Future Naval Engineers and Scientists Using Real-World Project Based Instruction,” Office of Naval Research, Co-PI, \$643,954, 8/01/2015 – 1/31/2018

Collaborators and other affiliations (* denotes Michigan Technological University)

Collaborators during past 48 months: Atkinson, M. (deceased); Auer, M. *; Barnard, A. *; Barrick, D. (CODAR); Bourgeau Chavez, L.*; Brooks, C.*; Buckley, E. (consultant); Chimner, R.*; De Roo, R. (U Mich); Davis, C. (U Mich); Dean, D.*; Downs, R. (NOAA); England, A. (U Mich) Flaspohler, D.*; Gierke, J.*; Gilbert, S. (U South Fl); Green, S.*; Gretz, M. *; Grimm, A.*; Guyer, S. (Alaska BLM); Hatt, C.*; Huckins, C.*; Jenkins, L.*; Johnngen, T. (U Mich); Joshberger, E. (retired USGS); Karr, D. (U Mich); Kerfoot, W.C.*; Koch, D. (U Mich); Kramer, L. J. (U of Birmingham); Kroodsma, R. (CODAR); Luther, M. (U South Fl); MacLennan, C. *; Mahmoudian, N. *; Marcarelli, A. *; Masarik, M.*; Mazzoleni, C.*; Meadows, L.*; Norton, R. (U Mich); O'Shea, J. (U Mich); Payne, J. (retired Alaska BLM); Perlinger, J.*; Purcell, H. (U Mich); Reynolds, R. (Wayne State U); Ruf, C. (U Mich); Sayers, M.*; Schmidt, V. (U of NH) Scott, D. (U Mich); Shuchman, R.*; Smith, J. (Moss Landing Marine Lab); Standridge, C. (GVSU); Tamburri, M. (U of Md); Teague, C. (consultant); Turpening, R.*; Van Nieuwstadt, L. (U Mich); Wang, Z.*; Whelan, C. (CODAR)

Investigator's graduate and postdoctoral advisor: William L. Wood (deceased)

Thesis advisor and postgraduate-scholar sponsor (Total = 16): Shuchman, Robert, A. (*); Schultz, Howard, J. (U Mass); Tseng, Yun Chi (General Motors Corp.); McCormick, Michael, J. (retired NOAA); Gwinn, Allen (K-12, teacher); Song, Museok (Korea); Wu, Zhijian (General Motors Corp.); Gottlieb, Eric (unknown); Haus, Brian, (U Miami); Gbah, Masson (U Mich); Dondurdur, Mehmet (Turkey); Tannis, Fredrick (unknown); Kim, Nam Chul (Korea); Lettvin, Ellen (US Dept of Ed); Caufield, Brian (STAR Inc.); Bretl, James (Ocean Power Tech)

Richard “Max” Melstrom

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Web: www.luc.edu/sustainability

Experience

Loyola University Chicago

Endowed Assistant Professor, Institute of Environmental Sustainability, 2017–present.

Oklahoma State University

Assistant Professor, Department of Agricultural Economics, 2014–2017.

Salisbury University

Assistant Professor, Department of Economics and Finance, Department of Environmental Studies, 2012–2014

Education

Ph.D. Economics and Agricultural, Food and Resource Economics (dual major)

Michigan State University, East Lansing, MI 2012

M.A. Economics

Michigan State University, East Lansing, MI, 2008

B.A. Economics and Business

Kalamazoo College, Kalamazoo, MI, 2007

Selected Publications

Melstrom, R.T and C. Murphy. In press. Do Agritourism Visitors Care about Landscapes? An Examination with Producer-Level Data. *Journal of Travel Research*.

Melstrom, R.T. 2017. Where to drill? The petroleum industry’s response to an endangered species listing. *Energy Economics*, 66: 320-327.

Daniels, B. and R.T. Melstrom. 2017. Examining recreation demand for lakeshore parks in Oklahoma: What is causing the downward trend in attendance? *Journal of Park and Recreation Administration*, 35(2): 25-36.

Wietelman, D.C. and R.T. Melstrom. 2017. The effect of listing the lesser prairie chicken as a threatened species on rural property values. *Journal of Environmental Management* 191: 155–161.

Melstrom, R.T. and D.H. Jayasekera. 2017. Two-stage estimation to control for unobservables in a recreation demand model with unvisited sites. *Land Economics* 93(2): 328–341.

Melstrom, R.T. 2017. Estimating a model of sportfishing trip expenditures using a quasi-maximum likelihood approach. *Tourism Economics* 23: 448–459.

Richard “Max” Melstrom

Melstrom, R.T., F. Lupi, P.C. Esselman and R.J. Stevenson. 2015. Valuing recreational fishing quality at rivers and streams. *Water Resources Research* 51: 140–150.

Melstrom, R.T. 2014. Valuing historic battlefields: An application of the travel cost method to three American Civil War battlefields. *Journal of Cultural Economics* 28: 223–236.

Melstrom, R.T. and F. Lupi. 2013. Valuing recreational fishing in the Great Lakes. *North American Journal of Fisheries Management* 33: 1184–1193.

Selected Presentations

The Effect of License Prices and Senior Discounts on Fishing Participation, AFS Annual Meeting, Tampa, Florida, August 2017.

The Petroleum Industry’s Response to an Endangered Species Listing, AAEA Annual Meeting, Chicago, Illinois, July 2017.

The Effect of Endangered Species Regulations on Local Employment: Evidence from the Listing of the Lesser Prairie Chicken, AAEA Annual Meeting, Boston, Massachusetts, August 2016.

Valuing Aquatic Ecosystem Services: Applications to Recreational Fisheries in Oklahoma, Oklahoma Clean Lakes and Watersheds Annual Meeting, Stillwater, Oklahoma, March 2016.

The Impact of Water Levels and Climate Variation on Recreation Demand at Ft. Cobb Reservoir, Oklahoma Clean Lakes and Watersheds Annual Meeting, Stillwater, Oklahoma, April 2015.

Valuing Recreational Fishing Quality of Rivers and Streams, Pathways to Success: Integrating Human Dimensions into Fish and Wildlife Management Conference, Estes Park, Colorado, October 2014.

Selected Professional Activities

Served as a PI on eight grants, four as lead investigator, totaling \$400,000.

Reviewer for 17 academic journals.

Discussant at 7 professional conferences.

Organizer and chair for session on ecosystem services valuation, Pathways Conference, Estes Park, Colorado, 2014

Named an Emerging Scholar by the Southern Agricultural Economics Association.

Biosketch

Dr. Max Melstrom is a natural resource economist with an appointment at Loyola University Chicago’s Institute of Environmental Sustainability. Dr. Melstrom’s research addresses topics related to ecosystem services, conservation, fisheries, outdoor recreation, and environmental regulations. Recently, his research has focused on measuring the economic effects of land use regulations and different methods for valuing the environment. Prior to his current appointment, Dr. Melstrom was a research and extension economist at Oklahoma State University, where he worked closely with specialists at the Oklahoma Department of Wildlife Conservation, the City of Oklahoma City, the Oklahoma Department of Agriculture, Food and Forestry, and the Grand River Dam Authority.

Steven R. Miller

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Agriculture Hall: Center for Economic Analysis 446 W.

Circle Drive, Room 88

East Lansing, MI 48824-1039 Mill1707@msu.edu

Educational Background

Ph.D., Economics, Oklahoma State University, July, 2005. B.A.,

Economics, Oklahoma State University, April, 1995.

Research Experience

Fellow: February 2008 – Current Institute

for Public Utilities *Director*: October 2006 –

Current

Center for Economic Analysis: Michigan State University

Visiting Scholar: July 2014 – June 2017

US Army Corps of Engineers: Institute for Water Resources

Regional Economic Analyst: July 2005 – September 2006

The Center for Economic Development and Business Research: Wichita State University

Adjunct Faculty: August 2004 – April 2005

Oklahoma State University: Tulsa

Selected Reports and Publications

Lyons, TS, SR Miller and JT Mann. (forthcoming). "A New Role for Land Grant Universities in the Rural Innovation Ecosystem" with Thomas S. Lyons and John T. Mann. *Journal of Regional Analysis and Policy*.

Miller, S. R., John T. Mann (forthcoming). "On measuring the importance of local food to regional economies." *Journal of Regional Analysis and Policy*.

Miller, S. R., & Mann, J. T. (2017, February). Valuing Michigan Wetlands for the Expressed Purpose of Quantifying Barriers to Growth in Blueberry Acres. United States.

Miller, Steve R. 2017. Economic Analysis, in *The Great Lakes and Mississippi River Interbasin Study*. edited by US Army Corps of Engineers. Available at <http://glmris.anl.gov/glmris-report/>. Sep. 2017.

Lee, G.-E., S. R. Miller and S. Loveridge (Fourthcoming). "Modelling Local Food Policy and Greenhouse Gas Emission due to Transportation." *Journal Region Analysis and Policy* Forthcoming.

Mann, J., S. R. Miller, D. Rozeboom, A. Leschewski, J. Smith and S. Safferman (Submitted). "Michigan Residents' Perceptions of Agriculture's Impact on Water Quality." *Journal of Agricultural and Resource Economics*.

Weatherspoon, D. D., S. R. Miller, M. E. Steele, C. J. Newkirk, O. Santiago, A. S. Dembele and S. L. Hoerr (2015). "What Social, Program, and Behavioral Factors Influence the Healthy Eating Index for EFNEP and SNAP-Ed Adult Participants?" *American Journal of Lifestyle Medicine*.

Miller, S. R., Mann, J. T., & Knudson, W. A. (2015, November). Expected economic impact of cage trout aquaculture on Michigan's Great Lakes. United States.

Miller, S. R., J. Mann, J. Barry, T. Kalchik, R. Pirog and M. W. Hamm (2015). "A Replicable Model For Valuing Local Food Systems." *Journal of Agricultural and Applied Economics* 47(4): 441- 461.

Miller, S. R. and W. A. Knudson (2014). "Nutrition and Cost Comparisons of Select Canned, Frozen, and Fresh Fruits and Vegetables." *American Journal of Lifestyle Medicine* 8(6): 430-437.

Loveridge, S., S. R. Miller, T. Komarek and T. Satimanon (2012). "Assessing Regional Attitudes about Entrepreneurship." *Journal of Regional Analysis & Policy* 42(3): 210-222.

Loveridge, S., S. Miller and T. Komarek (2012). "Residents Support Entrepreneurship but Policy Lags." *Choices* 27(2).

Loveridge, S., S. R. Miller, T. Komarek and T. Satimanon (2012). "Assessing Michigan's Entrepreneurial Attitudes." *Policy Directions* May 2012.

Recent Funded Research

IR-4 Project Impact Estimate. Rutgers University. 2017.
\$26,500.

Review of 20 Years of Project GREEN. MSU AgBioResearch. 2017-2018.
\$29,350.

Michigan Craft Beer: An Economic Impact Assessment of the Locally-Sourced Supply Chain. Michigan Department of Agriculture and Rural Development. 2017. \$26,420

Coop Elevator Winter White Wheat Production. Mondelez International. 2018. with John Whims.
\$24,600.

Ecosystem Regional Economic Development Review. US Army Corps of Engineers.
\$12,000.

Soo Locks Economic Impacts. US Army Corps of Engineers. 2016.
\$15,200.

Flint Community Schools. CRIM Fitness Foundation. with \$121,396. Acevedo, Ignacio D, McNall, Miles A., Boggs, Brian J., Kher, Neelam, Markle, Barbara K., Pfeiffer, Karin A., Van Egeren, Laurie A., and Ilardo, Joan L., 2017
Economic Impact of Michigan's Small Business and Technology Development Centers. MI- SBDC. 2016.
\$11,000.

Coop Elevator Winter White Wheat Production. Mondelez International. 2017. with John Whims.
\$24,600.

Economic Impact of Community Events: Delta County, MI. Delta County Chamber of Commerce. 2016.
\$2,000,

Midwest Pensions. North Central Regional Center for Rural Development. 2016. with Judy Stallman and Steve Deller. \$20,000.

Tanzania Partnership Program. Michigan State University: International Studies Program. 2016.
\$7260.

Coop Elevator Winter White Wheat Production. Mondelez International. 2016. with John Whims.
\$23,000.

Expected Distributional Effects of East Lansing Income Tax. MSU Governmental Affairs. 2016.
\$9,075.

Economic Impact of the MSU FRIB. MSU Governmental Affairs. 2016.
\$19,424.

Economic Impact of Delta County Community Events. Delta County Chamber of Commerce. 2016.
\$2,000.

Policy Evaluation of Chicago Regional Food Systems. Chicago Metropolitan Agency for Planning. 2016. with John T. Mann. \$50,890

2016 Solid Set Canopy Delivery Systems: and efficient, sustainable and safer spray technology for tree fruit. National Institute of Food and Agriculture. \$1,555,953 with Matthew Grieshop, John Wise, Glies Brereton, James Flore and Guoming Zhu.

2016 Michigan Craft Beer: An Economic Impact Assessment of the Locally-Sourced Supply Chain. Michigan Department of Agriculture & Rural Development. \$29,300 with Ashley McFarland, J. Sirrine and Philip Howard.

2015 MDARD Wetlands Evaluation. Michigan Department of Agriculture and Rural Development.
\$24,500 with John Mann

2014 Impact of Agricultural Practices on Michigan Water Supply: Residents' Perceptions and Willingness to Pay for Policy Changes. Michigan Applied Public Policy Research Grants. \$25,000 with John Mann and Dale Rozeboom.

2014 Economic Assessment of Policy Threats to Winter Manure Application Practices. Michigan Alliance for Animal Agriculture. \$26,577 with Dale Rozeboom and John Mann.

2013 Economic Impact of Michigan's Small Business and Technology Development Centers.
\$18,300.

Development of Profitable Michigan-Based Meat and Livestock Value Chains Supplying Local and Regional Markets. USDA 2013-2017. \$500,000 with Richard Pirog, Judith Barry, Jason Rowntree, Craig Harris, Sarah Wells, Richard Ehrhardt, William Knudson.

MSU IPM Evaluation. North Central IPM Center. 2013
\$27,000

Draft Meat Processing Capacity Assessment. MSU Department of Community Sustainability. 2013.
\$4,000.

2013. Survey of Newaygo County Businesses. Fremont Area Community Foundation.
\$25,000.

BIOGRAPHICAL SKETCH—DAISUKE MINAKATA

Daisuke Minakata
Assistant Professor
Department of Civil and Environmental Engineering
Technological University
1400 Townsend Drive, Houghton, MI, 49931

tel: (906) 487-1830
fax: (906) 487-2943
e-mail: dminakat@mtu.edu Michigan
http://mtu.edu/

A. PROFESSIONAL PREPARATION:

Kyoto University,	Kyoto, Japan, Environmental Engineering, B.S., 2002
Kyoto University,	Kyoto, Japan, Environmental Engineering, M.S., 2005 Georgia
Institute of Technology,	Atlanta, GA, Environmental Engineering, Ph.D., 2010

B. APPOINTMENTS:

August 2013 – present, Assistant Professor, Michigan Technological University
January 2010 - July 2013, Research Engineer I, Brook Byers Institute for Sustainable System, Georgia Institute of Technology

C. PRODUCTS:

(i) Products Most Closely Related to the Proposed Project.

1. Zhang, M.; Howe, K.J.; Minakata, D. Predicting the Partitioning of Organic Compounds through Polymer Materials: Quantum Mechanical Applications. *J. Env. Eng.* 2017, accepted.
2. Minakata, D.; Kamath, D.; Maetzold S. Mechanistic insight into the reactivity of chlorine-derived radicals in the aqueous-phase UV/chlorine advanced oxidation process: Quantum mechanical calculations. *Environ. Sci. Technol.* 2017, 51(12), 6918-6926.
3. Minakata, D.; Song, W.; Mezyk, S.P.; Cooper, W.J. Experimental and theoretical studies on aqueous-phase reactivity of hydroxyl radicals with multiple carboxylated and hydroxylated benzene compounds. *PCCP*, 2015, 17, 11796-11812.
4. Minakata, D.; Mezyk, S.P.; Jones, J.W.; Daws, B.R.; Crittenden, J.C. Development of linear free energy relationships for aqueous phase radical-involved chemical reactions. *Environ. Sci. Technol.* 2014, 48, 13925-13932.
5. Guo, X.; Minakata, D.; Crittenden, J.C. On-the-fly kinetic monte carlo simulation of aqueous phase advanced oxidation processes. *Environ. Sci. Technol.* 2015, 49 (15), 9230- 9236.

(ii) Other Significant Products.

1. Guo, X.; Minakata, D.; Junfeng, N.; Crittenden, J.C. Computer-based first-principles kinetic modeling of degradation pathways and byproduct fates in aqueous phase advanced oxidation processes. *Environ. Sci. & Technol.* 2014, 48(10), 5718-5725.
2. Minakata, D.; Crittenden, J. Linear Free Energy Relationships between the Aqueous Phase Hydroxyl Radical (HO•) Reaction Rate Constants and the Free Energy of Activation. *Environ. Sci. & Technol.* 2011, 45, 3479-3486.
3. Minakata, D.; Song, W.; Crittenden, J.C. Reactivity of aqueous phase hydroxyl radical with halogenated carboxylate anions: Experimental and theoretical studies,” *Environ. Sci. & Technol.* 2011, 45, 6057-6065.

4. Westerhoff, P.; Mezyk, S.P.; Cooper, W.J.; Minakata, D. Electron pulse radiolysis determination of hydroxyl radical rate constants with Suwannee river fulvic acid and other dissolved organic matter isolates. *Environ. Sci. & Technol.* 2007, *41*, 4610-4646.
5. Minakata, D.; Li, K.; Westerhoff, P.; Crittenden, J. Development of a group contribution method to predict aqueous phase hydroxyl radical (HO•) reaction rate constants. *Environ. Sci. & Technol.* 2009, *43*, 6220-6227.

D. SYNERGISTIC ACTIVITIES:

1. **Research Interests:** Dr. Minakata's research interests include fate of organic chemicals and dissolved organic matter (DOM) in natural and engineered aqueous systems. Dr. Minakata has developed several computational tools to predict the performance and kinetics of various reactive radical species with numerous organic chemicals and DOM.
2. **Professional Services:** Dr. Minakata served as an associate editor of Journal of Advanced Oxidation Technologies (2013-2015). Dr. Minakata is also a co-organizer of AOP session for ACS National Conference in 2014, 2015, and 2016. Dr. Minakata was a conference co-organizers for 2017 AEESP conference and 2017 Borchardt conference at University of Michigan.
3. **Educational Module Development:** Dr. Minakata is one of the developers for the *Center for Sustainable Engineering* educational module: Development of Simplified Models for Advanced Oxidation Processes. This material is used in undergraduate and graduate course work in physical chemical water treatment processes.
4. **Outreach to High/Middle School Students via 'Cleaning Water' Activity:** Dr. Minakata has been active in showing the STEM CAREER tour and lab demonstration to several local high/middle school students and teachers in Upper Peninsula of Michigan and the Detroit region. Dr. Minakata enhances awareness of chemical contamination in water and advanced water treatment technologies including water treatment at international space station via the Michigan Tech Center for Outreach and the Detroit Zoological Society.
5. **Consulting Work:** Dr. Minakata has numerous consulting experiences for government and industries, including.
 - California Department of Health Service. Drinking water taste and odor quality control in 2012-2013.
 - Drinking water standard guideline for toluene, ethylbenzene and xylenes. Primary contractor for treatment technology section with Health Canada. 2013.
 - Coca Cola beverage bottle washing treatment processes improvement. 2008-2013
 - Process improvement, design and caustic soda recovery in bottle washing process
 - Assessment of water quality
 - Technical advisory for Coca Cola treatment plant water quality parameters resulting from radionuclides due to earth quake hit in Japan
 - Chlorine dioxide panel response to government in July 2008
 - Methyl tert butyl ether ground water contamination expert advisory for various court cases. 2008-2013
 - Worked for State of New Hampshire, City of Santa Monica, and oil company.

BIOGRAPHICAL SKETCH — AMLAN MUKHERJEE

Associate Professor
Department of Civil & Environmental Engineering
Michigan Technological University
Houghton, MI 49931

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<http://www.cee.mtu.edu/~amlan>

PROFESSIONAL PREPARATION:

Birla Institute of Technology and Science	Pilani, India	Civil Engineering	B.E.	2000
University at Buffalo (SUNY)	Buffalo, NY	Civil Engineering	M.S.	2001
University of Washington	Seattle, WA	Civil Engineering	Ph.D.	2005

APPOINTMENTS:

2011-Current Associate Professor, Dept. of Civil & Env. Engineering, Michigan Tech, Houghton, MI
2013-Current CTO, Founder and Owner, TriSight, LLC., Houghton, MI
2014-2015 EPD Program Facilitator, National Asphalt Pavement Association, Lanham MD
2005-2011 Assistant Professor, Dept. of Civil & Env. Engineering, Michigan Tech, Houghton, MI
2004-2005 Pre-Doctoral Instructor, Dept. of Civil Engineering, University of Washington, Seattle, WA
2001-2003 Research Associate, Human Interface Technology Lab, Seattle, WA
Aug 2000-2001 Teaching Assistant, Dept. of Civil, Structural & Env. Eng., University at Buffalo, Buffalo, NY.
Jan – July 2000 Junior Engineer, Development Consultants Ltd., Bombay, India.

SYNERGISTIC ACTIVITIES: Life cycle assessment (LCA) and Sustainability

- Dr. Mukherjee is leading an effort supported by FHWA to address the developmental and operational challenges of delivering a centralized database that will provide convenient access to comprehensive, reliable, and transparent life cycle inventory data for construction materials. He is actively involved in collaborating with contractors and other industry partners, including international collaborators, in identifying ways of integrating life cycle assessment into the construction decision-making process.
- Dr. Mukherjee served as the facilitator for the Environmental Product Declaration program for asphalt mixtures, for the program operated by the National Asphalt Pavement Association. He conducted an ISO 14040 compliant, third party reviewed life cycle assessment (LCA) for asphalt mixtures in North America to support the program.
- Dr. Mukherjee has been serving on the FHWA Sustainable Pavements Technical Working Group since 2011. He is currently liaising with the Federal LCA Commons to develop reliable, transparent and freely accessible inventory data sources.
- Dr. Mukherjee is serving as a Co-PI on Sustainable Construction Practices - NCHRP 10-91A, in collaboration with Dr. Steve Muench and Dr. Giovanni Migliaccio at University of Washington.
- Dr. Mukherjee was PI on a Michigan DOT project that used LCA methods to estimate project emissions of highway construction projects. The project was funded by Michigan Department of Transportation and led to the development of an extensive online inventory of construction project emissions data. In addition, a web-based tool called the Project Emissions Estimator (PE-2) was developed to estimate emissions for highway construction and rehabilitation operations, as well as the life cycle emissions of highway sections.
- Dr. Mukherjee serves on the Board of Control for the Green Building Initiative (the Green Globes rating system), and on the Advisory Council of Green Roads (a highway construction rating system).

- Dr. Mukherjee was the Guest Editor for a Special Issue on Considerations of Sustainability in Construction, Engineering and Management for the Journal of Construction Engineering and Management, ASCE.

SYNERGISTIC ACTIVITIES: Project Simulation and Uncertainty Analysis

- Dr. Mukherjee is currently Co-PI on a project funded by Michigan DOT on Implementation of Unmanned Aerial Vehicles (UAVs) for Assessment of Transportation Infrastructure. His specific role is to study the efficacy of applying UAV technologies for infrastructure condition assessment.
- Dr. Mukherjee serves on the ASCE Digital Project Delivery committee, and the TRB standing committee on Construction Management (AFH10). He has chaired workshops on digital project delivery related theory and practice at TRB annual meetings.
- Dr. Mukherjee's work in simulation and education has given him a deep understanding of the construction process, and how it can influence other aspects of a project including the effects of risk, schedule, management policy, and other construction decisions.
- Dr. Mukherjee's Ph.D. research was in developing interactive multi-purpose simulations for studying risk and uncertainty in construction schedules. He also continues to be involved in interdisciplinary research efforts with colleagues in Computer Science and Systems Engineering in developing effective decision-support systems for construction management.

RELEVANT RESEARCH PUBLICATIONS

1. Mukherjee, A. & Dylla, H. (2017) "Challenges to using environmental product declarations in communicating LCA results: the case of the asphalt industry," Transportation Research Record: Journal of the Transportation Research Board, No. 2639, Transportation Research Board of the National Academies, Washington DC. DOI:10.3141/2639-11.
2. Jin, Y. & Mukherjee, A. (2014) "Markov chain applications in modeling facility condition deterioration," International Journal of Critical Infrastructures 10 (2), 93-112.
3. Mukherjee, A., Stawowy, B. & Cass, D. (2013) "Project Emissions Estimator (PE-2): Tool to Aid Contractors and Agencies in Assessing Greenhouse Gas Emissions of Highway Construction Projects," Transportation Research Record: Journal of the Transportation Research Board, No. 2366, Vol. 1, Transportation Research Board, National Academies, Washington DC. pp 3-12
4. Tang, P., Cass, D & Mukherjee, A. (2013) "Investigating the Effect of Construction Management Strategies on Project Greenhouse Gas Emissions," Journal of Cleaner Production, Vol. 54 (2013), 78-88.
5. Tang, P., Mukherjee, A. & Onder, N. (2013) "Using an interactive schedule simulation platform to assess and improve contingency management strategies," Automation in Construction, Vol 35, pp 551-560

OTHER RESEARCH PRODUCTS: Reports, Databases and Software Developed

1. Mukherjee, A. (2016) "Life Cycle Assessment of Asphalt Mixtures in Support of an Environmental Product Declaration," ISO 14025 compliant document published at NAPA EPD Program website: <http://www.asphaltpavement.org/EPD>.
2. IRI Explorer: a web based service for exploring and analyzing IRI data in the FHWA Long Term Pavement Performance (LTPP) database to gain insights into the factors that have historically governed and/or influenced the change in pavement IRI over time.
3. Project Emissions Estimator (PE-2) - a web-based highway construction project GHG emissions inventory and estimator.
4. Interactive Construction Decision-Making Aid (ICDMA) - An interactive construction process simulation.

BIOGRAPHICAL SKETCH

Name: Richard Olawoyin **Position:** Assistant Professor, Environmental Health and Safety, Oakland University

Education/Training:

Institution and Location	Degree	Completion Date	Field of Study
University of Calabar, Nigeria	B.S	05/2005	Geology
Pennsylvania State University, University Park, PA	M.S.	05/2010	Petroleum & Natural Gas Engineering
	Ph.D	12/2012	Energy & Mineral Engineering

Positions and Employment

1997-2000	Safety Specialist, Nigeria Gas and Steel, Lagos Nigeria
2000-2005	Health Safety and Environmental Intern, Eny Construction Company Limited, Calabar Nigeria
2004-2006	Geologist, Shell Petroleum (CNT-MCL), Warri Nigeria
2006-2008	EHS Manager and Trainer, Quaternary International Company Limited, Nigeria
2008- Present	Consultant, Quaternary International Company Limited
2010-2012	Research Assistant and Instructor, Penn. State University, University Park, PA
2012-2013	Quality Engineer, Abcov Conversion Systems, New York, New York
2014- Present	Assistant Professor, Environmental Health and Safety Program, Oakland University, Michigan Graduate Program Assessment Coordinator, Master of Science in Safety Management Faculty Research Adviser Environmental Health and Safety Program, Oakland University, MI Chair, Committee on Instruction, School of Health Sciences

Contributions to Science

1. Environmental pollution in vulnerable communities
 - a. **Olawoyin, R.O.**, Madu, C., Enab, K. (2012). Optimal Well Design for Enhanced Stimulation Fluids Recovery and Flowback Treatment in the Marcellus Shale Gas Development Using Integrated Technologies. *Hydrol. Current Res.* 3:141.
 - b. **Olawoyin, R.O.**, Oyewole, S.A., Grayson, R.L (2012). Potential risk effect from elevated levels of soil heavy metals on human health in the Niger delta, *Ecotoxicol. Environ. Saf.*, Volume 85, 1 November 2012, Pages 120–130
 - c. **Olawoyin, R.O.**, Grayson, R.L., Okareh, O.T. (2012). Eco-toxicological and Epidemiological Assessment of Human
 - d. Exposure to Potentially Petrogenic Polycyclic Aromatic Hydrocarbons in the Niger Delta, Nigeria. *Toxicol. Environ. Health. Sci.* Vol. 4(3), 173-185, 2012
 - e. **Olawoyin R.O** (2017). Exposure to Toxic Pollutants: Assessing Potential Human Health Risk. *Professional Safety*, 62(2), 40-45.
 - f. **Olawoyin R.O.**, Schweitzer L, Zhang K., Okareh O, Slates K. (2018). Index analysis and human health risk model application for evaluating ambient air-heavy metal contamination in Chemical Valley Sarnia. *Ecotoxicol. Environ. Saf.*, Volume 148, February 2018, Pages 72-81
2. System safety
 - a. Heidrich, B., Oyewole, S.A., **Olawoyin, R.O.** (2013). An Assessment of the Efficiency of Extended Power Up-Rates at US Boiling Water Reactors. *J. Nuclear Tech.* Vol. 182. No. 1. Pp. 13-25
3. Hydraulic fracturing
 - a. **Olawoyin, R.O.**, Wang, J.Y., Oyewole, S.A., (2012). Environmental Safety Assessment of Drilling Operations in the Marcellus Shale Gas Development, *SPE Drill & Compl.* 28 (2): 212-220. SPE-163095-PA.
 - b. **Olawoyin. R.O.**, Nieto, A.V., Grayson, R.L., Hardisty, F., Oyewole, S.O. (2013). Application of Artificial Neural Network (ANN) – Self-Organizing Map (SOM) for the Categorization of Water, Soil and Sediment Quality in Petrochemical Regions. *Expert Systems with Applications* 40, (9) 3634-3648

- c. **Olawoyin R.O.**, (2015). Modelling the Health Risks of exposure to Respirable Crystalline Silica from Hydraulic Fracturing Operations in the USA Shale Plays. *J. Biomed. Eng. Informatics*, 2015, (1) 1.
- d. **Olawoyin, R.O.**, McGlothlin, C., Conserve, D. F., & Ogutu, J. (2016). Environmental health risk perception of hydraulic fracturing in the US. *Cogent Environmental Science*, 2(1), 1209994.
4. Chemometrics in the assessment of toxicants
 - a. **Olawoyin, R.O.**, Oyewole, S.A., McGlothlin, C.W., Heiderich, B., Abegunde, S.O., Nieto, A.V., Okareh, O.T. (2014). Characteristic Fingerprints of Polycyclic Aromatic Hydrocarbons & Total Petroleum Hydrocarbons Pollution in Petrochemical Areas, *Int. J. Environ. Pollut. Solut.*, 2 (1) 1-19
 - b. **Olawoyin, R.O.**, Heidrich, B., Oyewole, S.A., Okareh, O.T., McGlothlin, C.W., (2014). Chemometric analysis of ecological toxicants in petrochemical environments. *Chemosphere* 112, 114–11
 - c. **Olawoyin R.O.**, (2013). Exploration of the spatial-Composite Risk Index (CRI) for the characterization of toxicokinetics in petrochemical active areas, *Chemosphere*, 92(9) 1207-1213
 - d. **Olawoyin, R.O.** (2016). Application of backpropagation artificial neural network prediction model for the PAH bioremediation of polluted soil, *Chemosphere*, 161: 145-150
5. Gas connectors
 - a. **Olawoyin R.**, McGlothlin, C.W. (2015). Explorative History of Fuel Gas Connectors Development and Related Regulatory Standards. *J. Nat. Gas Sci. Eng.*, 27,1470-1481
 - b. **Olawoyin R.** (2017). Risk and Reliability Evaluation of Gas Connector Systems Using Fuzzy Theory and Expert Elicitation. *Cogent Engineering*, 4: 1372731. <https://doi.org/10.1080/23311916.2017.1372731>

Research Support

Ongoing Research Support

Faculty Research Grant Olawoyin (PI) 02/01/15-12/01/16
 Collaboration with the Department of Health Behavior, Gillings School of Global Public Health, University of North Carolina Chapel Hill and other colleagues to conduct a study on the risk perception of hydraulic fracturing in communities across the United States. The rationale for the study was predicated upon the community sentiment due to the advent of new technologies such as directional drilling and the hydraulic fracturing technique.

Prevention Research Award Olawoyin (PI) 12/01/14-12/30/16
 The on-going study examines the potential environmental risk impact of chemical spills originating from the Chemical Valley Sarnia, affecting human health in and around adjoining localities. The quantities of ubiquitous carcinogenic chemicals in local air, water, soil and vegetation are continuously monitored to ensure the safety, security, and the quality of human health. This study is a preliminary assessment of the toxicokinetics of industrial substances and the respective epidemiological effects on humans, especially children, in the Sarnia region.

Space Consortium Grant Olawoyin (PI) 06/01/16-12/01/17
 With longer amounts of time being spent in space at a time, the need for food products that are both high in shelf-life and nutritional value is quintessential. The current investigation attempts to explore nanotechnology for enhanced food packaging, quality, and nutritional value, in support of astronaut's dietary needs.

Completed Research Support

Industry Funded Olawoyin (PI) 10/01/14-10/01/15
 Residential and industry-based evaluation of gas delivery to appliances.
 The goal of this project was to assess the history and development of the standards for fuel gas connectors and building safety. As the PI, I conducted a comprehensive analysis of system components associated with fuel gas delivery in buildings. Building fire is a leading cause of fire-induced injuries and fatalities.

- c. **Olawoyin, R.O.**, McGlothlin, C.W. (2015). Explorative History of Fuel Gas Connectors Development and Related Regulatory Standards. *J. Nat. Gas Sci. Eng.*, 27(3) 1470-1481
- d. **Olawoyin R.O.** (2017). Risk and Reliability Evaluation of Gas Connector Systems Using Fuzzy Theory and Expert Elicitation. *Cogent Engineering*, 4: 1372731.

BIOGRAPHICAL SKETCH—J.A. OLIN

Dr. Jill A. Olin
Research Scientist
Great Lakes Research Center
Michigan Technological University
Houghton, MI 49931

Phone: 906-487-1121
Email: jaolin@mtu.edu

A. PROFESSIONAL PREPARATION

University of New Hampshire, Durham, NH
Hofstra University, Hempstead, NY
University of Windsor, Windsor, ON

B.S. Marine and Freshwater Biology, 1997
M.S. Marine Biology, 2005
Ph.D. Environmental Science, 2012

B. APPOINTMENTS

2017-Present Research Scientist, GRLC, Michigan Technological University
2017-Present Adjunct Assistant Professor, Department of Biological Sciences, Michigan Technological University
2015-2017 Postdoctoral Researcher, SOMAS, Stony Brook University
2012-2014 Postdoctoral Researcher, DOCS, Louisiana State University

C. PRODUCTS

i. Products Most Closely Related to the Proposed Project

1. Olin JA, Sagarese SR, Frisk MG, Nye JA, Zacharias JA, Cerrato RM. Winners and losers: Predicting the response of fishes to available habitat resulting from Hurricane Sandy using generalized additive models. *Submitted*.
2. Olin JA, Bergeon Burns CM, Woltmann S, Taylor SS, Stouffer PC, Bam W, Hooper-Bui L, Turner RE. 2017. Seaside Sparrows reveal contrasting food web responses to large-scale stressors in coastal Louisiana saltmarshes. *Ecosphere* 8 (7): e01878
3. McCann M, Able K, Christian R, Fodrie J, Jensen O, Johnson J, Lopez-Duarte P, Martin C, Olin JA, Polito M, Roberts B, Zeigler S. 2017. Key taxa in food web responses to stressors: The Deepwater Horizon Oil Spill. *Frontiers in Ecology & the Environment* 15 (3): 142–149.
4. Bergeon Burns CM, Olin JA, Woltmann S, Stouffer PC, Taylor S. 2014. Effects of oil on terrestrial vertebrates: Predicting impacts of the Macondo blowout. *BioScience* 64 (9): 820–828.
5. Hussey NE, MacNeil MA, McMeans BC, Olin JA, Dudley SFJ, Cliff G, Wintner SP, Fennessy S, Fisk AT. 2014. Rescaling the trophic structure of marine food webs. *Ecology Letters* 17 (2): 239–250.

ii. Other Significant Products

1. McCann M, Able K, Christian R, Fodrie J, Jensen O, Johnson J, Lopez-Duarte P, Martin C, Olin JA, Polito M, Roberts B, Zeigler S. 2016. Identifying key species in marsh food web responses to The Deepwater Horizon Oil Spill: A literature review. Coastal Water Consortium II, Gulf of Mexico Research Initiative Information & Data Cooperative <http://dx.doi.org/10.7266/N7RN35V6>
2. Olin JA, Turner RE. Stable carbon and nitrogen isotope composition of seaside sparrow and salt marsh arthropod species, Barataria Bay, LA. 2014. Coastal Water Consortium I, Gulf of Mexico Research Initiative Information & Data Cooperative <http://dx.doi.org/10.7266/N7KK98P7>
3. Nye JA, Frisk MG, Cerrato RM, Sclafani M, Flagge CN, Sagarese SR, Olin JA. 2017. Effects of a storm-induced barrier breach on community assemblages and ecosystem structure within a temperate lagoonal estuary: A post-Hurricane Sandy analysis. Natural Resource Report, National Park Service, Fort Collins, Colorado.

4. Olin JA, Stevens PW, Rush SA, Hussey NE, Fisk AT. 2015. Loss of seasonal variability in nekton community structure in a tidal river: Evidence for homogenization in a flow-altered system. *Hydrobiologia* 744 (1): 271–286.
5. Olin JA, Beaudry M, Fisk AT, Paterson G. 2014. Age-related PCB dynamics in immature bull sharks *Carcharhinus leucas*. *Environmental Toxicology & Chemistry* 33 (1): 35–43.

D. Synergistic Activities

1. At Stony Brook University (2015-2017) I was involved with the Women in Science and Engineering (WISE) program that seeks to increase the involvement of women in science careers at the high school, college and graduate levels. As part of this program I organized meetings and presentations.
2. At Louisiana State University (2012-2014), I mentored disadvantaged high school students through the EnvironMentors program. The program is designed to teach students the scientific method and assist them in the development and implementation of a research project conducted over the course of an academic year. Students present their findings orally at an annual Science Fair.
3. At the University of Windsor (2008-2010), I worked with several graduate students to introduced elementary school-aged female students to STEM fields, specifically aquatic field biology and chemistry. Students received experience collecting, identifying and dissecting fish and insect species collected during group field trips. In addition to learning techniques and anatomy of organism, students had the opportunity use the scanning electron microscope housed at the University to image the biological materials and organisms collected in the field including fish scales, butterflies and diatoms.
4. I have been a journal referee for Aquatic Ecology, Canadian Journal of Fisheries & Aquatic Sciences, Ecological Research, Food Webs, Hydrobiologia, ICES Journal of Marine Science, Journal of Fish Biology, Journal of Experimental Marine Biology & Ecology, Limnology & Oceanography, Marine Biology, Marine Ecology Progress Series, Marine & Freshwater Research, Oecologia, PLoS ONE and Rapid Communications in Mass Spectrometry.

Gordon Paterson

Assistant Professor, Department of Biological Sciences, Great Lakes Research Center, 110 Great Lakes Research Center, Michigan Technological University, Houghton, Michigan, 49931

Tel: (906) 487-1628 Email: gpaterso@mtu.edu

(a) Professional preparation

University of Waterloo	Biological Sciences	BS 1993
Trent University	Environmental & Resource Studies	MS 1996
University of Windsor	Biological Sciences	PhD 2006

(b) Appointments

2017-current:	Assistant Professor, Department of Biological Sciences, Great Lakes Research Center, Michigan Technological University
2013-2016:	Assistant Professor, Department of Environmental & Forest Biology, State University of New York, College of Environmental Science and Forestry
2011-2013:	Research Associate, Great Lakes Institute for Environmental Research, University of Windsor
2010-2011:	Research fellow, Norwegian Institute for Water Research & Norwegian University of Life Sciences
2009-2010:	Post-doctoral fellow, Great Lakes Institute for Environmental Research, University of Windsor
2007-2009:	NSERC Post-doctoral fellow, Environmental and Resources Studies Dept., Trent University
2006-2007:	Post-doctoral fellow, Great Lakes Institute for Environmental Research, University of Windsor

(c) Products

(i) Products most closely related to proposed project

1. McPhedran K., Grgicak-Mannion A., **Paterson G.**, Briggs T., Ciborowski J., Haffner G.D., and Drouillard, K.G. 2017. Field validation of multi-chemical hazard metrics for predicting benthic invertebrate toxicity in the Detroit River, Ontario, Canada. *Int. Environ. Assess. Man.* 13: 410-422.
2. McLeod AM., **Paterson G.**, Drouillard KG. and Haffner GD. 2016. Ecological implications of steady state and non-steady state bioaccumulation models. *Environ. Sci. Technol.* 50: 11103-11111.
3. McLeod AM., Arnot JA., Borgå K., Selck H., Kashian D., **Paterson G.**, Drouillard KG. and Haffner GD. 2015. Quantifying uncertainty in the trophic magnification factor related to spatial movements of organisms in a food web. *Int. Environ. Assess. Man.* 11: 306-318.
4. **Paterson G.**, Ryder M., Drouillard KG., and Haffner GD. 2016. Contrasting PCB bioaccumulation patterns among Lake Huron lake trout reflect basin specific ecology. *Environ. Toxicol. Chem.* 1: 65-73.
5. **Paterson G.**, Macken A. and Thomas KV. 2011. The need for standardized methods and environmental monitoring programs for anthropogenic nanoparticles. *Anal. Meth.* 3:1461-1467.

(ii) Other significant products

1. Pitt JA., Drouillard KG., and **Paterson G.** Polychlorinated biphenyl bioaccumulation patterns among Lake Erie lower trophic level consumers reflect species ecologies. *Bull. Environ. Contam. Toxicol.*, 98: 65-70.

2. McLeod AM., Arnot JA., Borgå K., Selck H., Kashian D., **Paterson G.**, Drouillard KG. and Haffner GD. 2015. Quantifying uncertainty in the trophic magnification factor related to spatial movements of organisms in a food web. *Int. Environ. Assess. Man.* 11: 306-318.
3. Abma RA., **Paterson G.**, McLeod A., and Haffner GD. 2015. Cross-basin comparison of mercury bioaccumulation in Lake Huron lake trout emphasizes ecological characteristics. *Environ. Toxicol. Chem.* 34: 355-359.
4. McLeod AM., **Paterson G.**, Drouillard KG. and Haffner GD. 2015. PCB food web dynamics quantify nutrient and energy flow in aquatic ecosystems. *Environ. Sci. Technol.* 49: 12832-12839.
5. Daley JM., Paterson G., and Drouillard KG. 2014. Bioamplification as a non-steady state bioaccumulation mechanism for persistent organic pollutants (POPs) in wildlife. *Rev. Environ. Contam. Toxicol.* 227: 107-155.

(d) Synergistic Activities & Experience

1. Senior Editor, Bulletin of Environmental Contamination and Toxicology. 2012 – current.
2. Instructor, Environmental Toxicology, Michigan Technological University 2017 - current.
3. Instructor, Toxic Health Hazards; State University of New York, College of Environmental Science and Forestry, 2013 – 2016.
4. Instructor; Environmental Risk Assessment, State University of New York, College of Environmental Science & Forestry, 2013 – 2016.
5. Session Panelist, Mercury Science in the Great Lakes workshop - Non-mercury factors that could impact Great Lakes mercury levels. Chicago Illinois. May 30-31, 2012.
6. Risk analysis consultant, Mills Consulting, Chicago Illinois 2005-2007.

(e) Collaborators and Other Affiliations:

(i) Collaborators in the past 48 months (*Michigan Technological University)

Arts, MT (Ryerson U.); Auer, MT*; Bramburger, AJ. (U. Minn); Boyer, GL. (SUNY-ESF); Drouillard, KG. (GLIER); Farrell, JP. (SUNY-ESF); Fisk, AT. (GLIER); Gupta, L.*; Haffner GD. (GLIER); He, JX. (MDNR); Hebert, CE. (Env. Canada), Johnson, TB. (OMNRF), Kapuscinski, KL. (St. Lawrence U.); Kamm, K.*; Kerfoot, WC.*, Lantry, BF. (USGS); Lantry, JR. (NYDEC); Madenjian, CP. (USGS); Marcarelli, A.*; Meadows, GA.*, Mills, WJ. (Northern Illinois University); Minakata D*; Mohr, LC. (OMNRF); Olin, JA. (Stonybrook U.); Razavi, NR. (HWS College); Reavie, ED. (U. Minn.); Rennie, MD. (Lakehead U.); Ringler, NE. (SUNY-ESF); Roy, D. (U. Conn); Rudstam, LG, (Cornell); Rush, SA. (Mississippi State U.); Steevens, JA. (USGS); Stewart, DJ. (SUNY-ESF); Techtmann SM.*; Twiss, MR. (Clarkson U.); Walsh, MG. (USGS); Weidel, BC, (USGS); Xue, PF*.

(ii) Investigator's graduate and postdoctoral advisors: Dr. Ken G. Drouillard; Dr. G. Douglas Haffner; Dr. Brendan E. Hickie; Dr. Chris D. Metcalfe; Dr. Kevin V. Thomas

(iii) Graduate Students (7): Rachel Abma (MS, U. Windsor); Lauren DiPierdomenico (MS, U. Windsor); Stacy Furgal (MS, SUNY-ESF); Mark Ryder (MS, U. Windsor); Nicole Saavedra (MS, SUNY-ESF); Caitlin Slife (MS, SUNY-ESF); Bailey Duxbury (MS, MTU)

ROBERT M. POWELL

SENIOR ENVIRONMENTAL SCIENTIST/INSTRUCTOR/CONSULTANT/MANAGER

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Website: <http://www.powellassociates.com>

Robert Powell has worked for state and federal government and dozens of clients, including industrial, legal firms and tribes by framing environmental questions for better public understanding, investigating and finding the best answers to suit client circumstances within the data context, and recommending/implementing needed innovative solutions and corrective actions in a cost-effective manner.

He has extensive knowledge and expertise that includes soil, air, subsurface, and aquatic environmental media, geochemistry and analytical chemistry, hydrogeology, contaminant transport, fate, and remediation, management, client relations, leadership and mentoring, environmental health and safety, research and development, exploratory and inferential data analysis and validation, and general problem solving.

Career highlights include:

- Instructor at both Washtenaw Community College and MIAT College of Technology for the past several years, teaching Introduction to Environmental Science and Environment and Society.
- Worked as an analytical and environmental chemist (Oklahoma Geological Survey, 11 years), an environmental research scientist (USEPA's National Risk Management Research Laboratory, Ada, OK, 11 years) and an environmental consultant and manager (Powell & Associates Science Services, 1997 to present).
- Served as an expert advisor to the Los Alamos National Laboratory as a member of the six-person External Advisory Group to the Water Quality and Hydrology division for seven years.
- Originated and developed methods of low-flow and passive purging and sampling of ground water, the speciation and mechanisms of facilitated transport of contaminants on colloids and as organic complexes, and in situ permeable reactive barriers (PRB) of zero-valent iron and other reactants for USEPA.
- Identified chemical causes/sources of sediment toxicity in Michigan's Manistee Lake, using exploratory data analysis (stepwise multiple regression), and created sampling plans for the Little River Band of Ottawa Indians.
- Consulted for several years on Lake Michigan's Bay Harbor Cement Kiln Dust Release Site (a former Brownfield redevelopment site) for the Little Traverse Bay Bands of Odawa Indians and USEPA.
- Provided litigation and expert witness support on several court cases, including alleged industrial urban soil contamination, allegations of improperly installed monitoring wells, environmental zoning issues, etc., for industrial, tribal and consultant clients.
- Authored 40+ scientific publications, given more than 50 presentations and keynotes, abstracts, and posters for meetings, and written innumerable reports for clients.
- Editor of the MDPI Special Issue "Groundwater Monitoring and Remediation" along with colleague Dr. Robert Puls. (http://www.mdpi.com/journal/water/special_issues/groundwater_monitor_remediation).
- Peer and proposal reviewer for many journals and agencies including Environmental Science & Technology, The Journal of Contaminant Hydrology, The Journal of Hazardous Materials, Elsevier, the Strategic Environmental Research and Development Program (SERDP, USDOD), USEPA, the Small Business Innovative Research Program (SBIR, USEPA), and many more.

Some of Mr. Powell's projects include:

- Prepared conceptual designs and preliminary cost estimates for a PRB in the subsurface to remediate 1,1,1-TCA at a manufacturing site.
- Analyzed innovative PRB designs proposed for contaminants impacting property boundaries and development of compliance and performance monitoring for the Washington State Dept. of Ecology.

- Analyzed the use of in situ oxidation by permanganate versus reductive dechlorination by an injected PRB of nanoparticle zero-valent iron (ZVI) for contaminants in a fractured bedrock aquifer.
- Served as an expert witness on complex airborne soil contamination cases for a legal firm and industry.
- Developed a sampling plan for Manistee Lake and its sediments for a tribal government.
- Advised on the Bay Harbor cement kiln dust site along Lake Michigan for a tribal government.
- Characterized industrial sites using site data and statistical exploratory data analysis; e.g., identified RCRA WMU locations from raw materials storage areas chemically and spatially for an industry.
- Developed sampling guidance for combustion of recycled materials for a large industrial client to reduce fossil fuel consumption.
- Provided chemistry support on organic compound volatilization and emissions calculations for air modeling of a volatile pesticide release for an industrial client lawsuit.
- Developed NPDES permits, review, and oversight; assessed wetlands impacts on mill intake water chemistry exceedances and worked with MDEQ for the client on the issue.
- Carried out and published original research on numerous subsurface research projects, including:
 - Techniques for low-flow and passive purging and sampling of ground water.
 - Permeable reactive barriers to determine reaction rates and the geochemical mechanisms by which certain metals and organic contaminants, e.g., hexavalent chromium and TCE, are reduced and immobilized/degraded.
 - Concept, design and construction of the pilot and full-scale PRB at the U.S. Coast Guard Air Support Station, Elizabeth City, NC, and others.
 - Facilitated transport of metals in the subsurface after synthesizing radioactive hematite particles and performing soil tracer studies; also transport via organic complexation.
- Supervised scientists and students and carried out laboratory and field research.
- Prepared and analyzed environmental samples; soils, coal, mineral and water.
- Participated in the design of custom software to improve instrument control and data analysis.
- Method development, quality control, report writing, computer programming, and supervision.
- Was the State of Oklahoma expert on the analysis of coal and coal ash.
- Operated small service companies, notably Powell & Associates Science Services, Great Plains Laboratories (past President), and Powell & Associates Analytical Services (former owner). These provided consulting, analytical methods and training to consultants, hospitals, and industry as well as providing specialty chemical analyses of water, oilfield brines, paints, solder, and failed aircraft components.

Mr. Powell has received several awards and honors, including:

- President's Award for Excellence, 1995, ManTech Environmental Technology, Inc.
- Scientific and Technological Achievement Award, Level III, U. S. Environmental Protection Agency, 1996
- Two-time winner of the Performance Incentive Program Award, ManTech Environmental Technology, Inc.
- Interim Mayor, 1985-86, for the Town of Slaughterville, Oklahoma. Appointed by Oklahoma Governor George Nigh following the resignation of the previous town board.

Mr. Powell's education:

M.S. Environmental Science	The University of Oklahoma	Norman, OK.
Thesis: Geochemical Effects on Subsurface Chromate Reduction and Remediation Utilizing the Thermodynamic Instability of Zero-Valence-State Iron		
B.S. Zoology	The University of Oklahoma	Norman OK.

Carson J. Reeling

Department of Economics
Institute for the Environment and Sustainability
Western Michigan University
Kalamazoo, MI 49008-5330

Phone: (269) 387-5548
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Education

Ph.D. Agricultural, Food, and Resource Economics, 2015

Michigan State University, East Lansing, MI

M.S. Agricultural Economics, 2011

Purdue University, West Lafayette, IN

B.A. Economics and Spanish, 2009

University of San Diego, San Diego, CA

Employment

Western Michigan University

Assistant Professor, Department of Economics and Institute for Sustainability and the Environment, 2015–Present

Michigan State University

Graduate Research Assistant, Department of Agricultural, Food, and Resource Economics, 2011–present

Purdue University

Graduate Research Assistant, Department of Agricultural Economics, 2009–2011

Research

Grants

"Policy Instruments, Strategic Interactions, and Incentives for Habitat Conservation for Imperiled Species." 1/2016-12/2017. Lead Investigator with Leah H. Palm-Forster (U. Delaware) Richard T. Melstrom (Oklahoma State U.). Center for Behavioral & Experimental Agri-Environmental Research. \$9,988.

"Using Markets to Coordinate the Provision of Multiple Agri-Environmental Services." 8/2017 to 8/2020. Co-PI. USDA National Institute for Food and Agriculture. \$499,973.

"Valuing Natural Resources Allocated by Preference Point Lottery," 3/2016–3/2017. Lead Investigator. Western Michigan University Support for Faculty Scholars Award. \$1,083.

Publications

Horan, R.D., E.P. Fenichel, and D. Finnoff, and C. Reeling. "A Portfolio-Balancing Approach to Natural Capital and Liabilities: Managing Livestock and Wildlife Diseases with Cross-

- Species Transmission and Trade." *Environ. Resour. Econ.* doi: 10.1007/s10640-017-0161-4.
- Reeling, C.J. and R.D. Horan. "Economic Incentives for Managing Biological Pollution Risks from Trade." *Environ. Resour. Econ.* doi: 10.1007/s10640-017-0160-5.
- Finnoff, D., R.D. Horan, J.F. Shogren, C. Reeling, and K. Berry. "Natural vs Anthropogenic Risk Reduction: Facing Invasion Risks Involving Multi-Stable Outcomes." *J. Econ. Behav. Organ.* doi:10.1016/j.jebo.2016.05.015
- Horowitz, A., W.R. Moomaw, D. Liptzin, B. Gramig, C. Reeling, J. Meyer, and K. Hurley. 2016. "A Multiple Metrics Approach for Measuring and Managing Reactive Nitrogen in the San Joaquin Valley of California." *Environ. Res. Lett.* 11(6): 064011
- Reeling, C.J. and R.D. Horan. 2015. "Self-Protection, Strategic Interactions, and the Relative Endogeneity of Disease Risks." *Am. J. Agr. Econ.* 97(2): 452–468.
- Gramig, B.M., C.J. Reeling, R. Cibir, and I. Chaubey. 2013. "Environmental and Economic Tradeoffs in a Watershed when Using Corn Stover for Bioenergy." *Environ. Sci. Technol.* 47(4):1784-1791.
- Reeling, C.J., J.G. Lee, P. Mitchell, G.H. Halimi, and A. Carver. 2012. "Policy Options to Enhance Agricultural Irrigation in Afghanistan: A Canal Systems Approach." *Agr. Syst.* 109, 90-100.
- Reeling, C.J. and B.M. Gramig. 2012. "A Novel Framework for Analysis of Cross-Media Environmental Effects from Agricultural Conservation Practices." *Agr. Ecosyst. Environ.* 146(1), 44-51.
- Birch, M., B.M. Gramig, W. Moomaw, O. Doering, and C.J. Reeling. 2011. "Why Metrics Matter: Evaluating Policy Choices for Reactive Nitrogen in the Chesapeake Bay Watershed." *Environ. Sci. Technol.* 45(1), 168-174.

Submitted Papers

- Horan, R.D., D. Finnoff, K. Berry, C. Reeling, and J.F. Shogren. "Managing Wildlife Faced with Pathogen Risks Involving Multi-Stable Outcomes." *Environ. Resour. Econ.*
- Reeling, C.J., C. Garnache, and R.D. Horan. "Efficiency Gains from Integrated Multipollutant Trading." *Resour. Energy. Econ.*

Papers in Preparation

- "Valuing Natural Resources Allocated by Dynamic Lotteries" (with F. Lupi and V. Verdier.)
- "Policy Instruments and Incentives for Coordinated Habitat Conservation" (with R.T. Melstrom and L.H. Palm-Forster).
- "When the Levee Breaks: Linking Markets to Remove Barriers to Trade" (with R.D. Horan and C. Garnache).

Mark D. Rouleau

1414 Cedar St.
Hancock, MI 49930
mdroulea@mtu.edu

Appointments

8/11 – Present	Michigan Technological University , <i>Assistant Professor</i>
8/09 – 5/11	Michigan Technological University , <i>Instructor</i>
8/07 – 5/09	George Mason University , <i>Research Assistant</i>
5/07 – 8/07	US Department of Agriculture , <i>Assistant Economist</i>
5/06 – 8/06	US State Department/University of Delaware , <i>Leadership Mentor</i>

Education

05/11	George Mason University <i>PhD Computational Social Science</i> <i>Advisor: Dr. Claudio Cioffi-Revilla</i>
05/06	University of Delaware <i>MA Political Science and International Relations</i> <i>Advisor: Dr. Matthew Hoffmann</i>
05/04	Michigan Technological University <i>BS Computer Science</i> <i>Minor: Social Sciences (major application area)</i>

Grants Awarded

7/17 – Present	Michigan Tech Research Excellence Funds (REF) , P.I., “Establishing a Research Network for Computational Advancements in Environmental Management”
7/16 – Present	Michigan Tech Research Excellence Funds (REF) , P.I., “A Survey of Private Forest Owners in the Upper Peninsula of Michigan”

- 9/14 – Present **National Science Foundation**, Co-P.I., “Coupling Experimental and Theoretical Molecular Level Investigations to Visualize the Fate of Organic Compounds in Aqueous Phase Advanced Oxidation Systems”
- 8/13 – 4/15 **National Science Foundation**, P.I., “Research Experience for Undergraduates Supplemental Funding”
- 5/13 – 4/15 **National Science Foundation**, P.I., “A Study of Land Use Management Practices among Non-Industrial Private Forest Owners”
- 4/13 – Present **Superior Ideas**, P.I., “NormSim: Simulating Norm Change and Metastability”
- 5/11 – 5/12 **Michigan Tech Research Excellence Funds (REF)**, co-P.I., “ForestSim: An Agent-Based Model of Private Forest Harvesting”

Selected Publications

- Rouleau, Mark, Terry Sharik, Adam Wellstead, and Samantha Whitens. “Enrollment Decision-Making in US Forestry and Natural Resource Related Programs,” *Natural Sciences Education* (in press).
- Rouleau, Mark. 2016. “ForestSim: An Agent-Based Simulation for Bioenergy Sustainability Assessment,” in *Advances in Complex Societal, Environmental, and Engineered Systems*, Mohammed Nemiche (ed.), *Springer*.
- Rouleau, Mark D, Jennifer Lind-Riehl, Miranda N Smith, and Audrey L Mayer. 2016. “Failure to Communicate: Inefficiencies in Voluntary Incentive Programs for Private Forest Owners in Michigan,” *Forests*, 7(9), 199.
- Riehl, Jennifer, Gabriela Shirkey, Magaret Morrison, Audrey Mayer, Mark Rouleau, and Richelle Winkler. 2015 “Family legacies and community networks shape private forest management.” *Land Use Policy* 45:95-102.
- Mayer, Audrey and Mark Rouleau. 2013. “ForestSim model of impacts of smallholder dynamics in the forested landscapes of the Upper Peninsula of Michigan. *International Journal of Forestry Research*, article ID 520207, 13pp.
- Cioffi-Revilla, Claudio, and Mark Rouleau. 2010. “MASON RebeLand: An Agent-Based Model of Politics, Environment, and Insurgency.” *International Studies Review* 12(1): 31-46.

Mir Sadri-Sabet

Summary

Engineering Manager with expertise in Design, Production, and R & D. Multiple engineering degrees. Experience with FOXBORO and SIEMENS Distribution Control Systems (DCSs), and PLC programming.

A track-record of improving performance by increasing process efficiencies, and by improving quality. Experience in domestic and international, union and non-union environments. Strong communication and team building skills, excellent problem solver.

Areas of Expertise

Advance process control, G2
System Design
Combustion simulations

CFD modeling
Auditing Control systems
Vision systems

Plant operations
Predictive modeling

Education

M.S. Petroleum Engineering, University of Wyoming
Thesis: "Chemical flooding to improve production"
B.S. Chemical Engineering, University of Arizona
B.S. Mechanical Engineering, University of Arizona

Employment History

Michigan Technological University: Instructor, Engineering Fundamentals Department, 2004-present (Houghton, Michigan)

Instructor for Formation Evaluation (Logging petroleum well), Reservoir Engineering, Static, Mechanics of Materials, Mathematical Modeling, Process simulations, Design, and Engineering Fundamentals courses. Emphasized skills essential for an engineer to perform independently. Advised engineering honor society.

Cliffs Technology Services: Senior Process Control Engineer 1996-2003 (Hibbing, Minnesota & Ishpeming, Michigan)

In-house consultant for 6 mining operations capable of producing 44 million tons of pellets annually for the steel industry. Responsible for improving production rates and pellet quality, increasing productivity, and bringing testing procedures into compliance with ISO 9000 standards. Managed Process Control, Analytical Chemistry, Information Technology groups, eight, four, and two members respectively.

- Upgraded process control software to control moisture contents and minimize process variation. Resulted in an annual savings of \$2 million.
- Conducted the analysis of abnormal levels of natural gas consumption; identified cause and retrofitted Great Kiln. Fuel consumption was reduced 6%.
- Automated test procedures at R&D facilities, using FOXBORO and SIEMENS DCSs. Achieved 100% increase in testing productivity.

- Combined an infrared camera and vision system software to monitor equipment and prevent downtime (restart is expensive and dangerous).
- Invented an on-line moisture analyzer. Designed and tested the analyzer at a mine.
- Computational Fluid Dynamic (CFD) modeling, "Simulation/design of a can combustor"

SCA Consulting: Manager of Air Permitting section 1994-1996 (Marquette, Michigan)

Established an air pollution section for a consulting firm

- Trained staff engineers, submitted competitive bid proposals for Renewable Operating Permits (ROP) under Title V of the Clean Air Act
- Completed successful ROP applications
- Negotiated permit conditions with the Michigan Department of Environmental Quality

Air Quality District: Environmental Manager 1992-1994 (Pinal County, Arizona)

Managed monitoring and data analysis section (modeling)

- Established permit review program and load analysis for Title V
- Established refined model review program for Title V, NSR and PSD
- Contributed to Hazardous Air Pollutants (HAPs) research, Title III & IV

Shell Oil Co., LP. : Production Engineer 1988-1992 (Azusa, California & Houston Texas)

Manipulated variables to produce hydrotreating catalysts according to customers' specifications.

- Arranged to test a new process to replace a 25-year-old best practice. The test run became the longest production in plant history, and reduced fuel consumption and Nox emissions. Plant produced lowest cost product in the market.
- Influenced management to secure a letter of guarantee from a large equipment supplier. This saved the company \$2 million in labor and materials when the equipment required redesign.
- Modified batch process to increase metal concentration to 17% from 13% by weight.
- Implemented a tight temperature/fuel control on rotary kiln and reduced consumption of chemicals for Nox control.
- Initiated a reduction in the production of hazardous waste.
- Upgraded procedures to meet OSHA's requirements on storage and shipment of hazardous waste.
- Performed job safety analysis, implemented accident prevention and investigation practices.

Enhanced Oil Recovery Institute: Research engineer 1985-1987 (Laramie, Wyoming)

Professional Engineering Technology: 1979-1981 & 1983-1984 (Tucson, Arizona)

Curriculum Vitae

Timothy James Scarlett

Department of Social Sciences, AOB 209
Michigan Technological University
1400 Townsend Dr.
Houghton, MI 49931
scarlett@mtu.edu
(906) 487-2359 (office)
(414) 418-9681 (cell)

Degrees / Affiliations:

Ph.D., Department of Anthropology, University of Nevada, Reno, 2002.
Master of Arts, Department of Archaeology, Boston University, 1994
Bachelor of Arts, Department of Anthropology, University of Arizona, 1991

Position History:

Associate Professor of Archaeology, Department of Social Sciences, Michigan Technological University, Houghton, Michigan. 2008-Present.
Assistant Professor of Archaeology, Department of Social Sciences, Michigan Technological University, Houghton, Michigan. 2002-2008.

Recent and Relevant Publications

- Scarlett, Timothy James. (2017). A Dangerous Discipline: Practicing Historical Archaeology in the Mormon Domain. In Margaret Purser and Mark Warner (eds.), *Historical Archaeology through a Western Lens*, University of Nebraska Press, Lincoln.
- Zhao, Shan, Bowen, Patrick. K., Drelich, Jaroslaw., and Scarlett, Timothy James. (2015). "Modeling Reproducibility in Rehydroxylation of Ceramic Artifacts." *Journal of the American Ceramic Society* 98(10):3367–3372.
- Scarlett, Timothy James and Samuel Sweitz. (2012). Constructing new knowledge in Industrial Archaeology. In Harold Mytum (ed.), *Global Perspectives on Archaeological Field Schools*. Springer Verlag, New York, pp. 119-145. <http://link.springer.com/book/10.1007/978-1-4614-0433-0>
- Deegan, Michael and Timothy James Scarlett. (2008). The Conservation of Ferrous Metals from the West Point Foundry Site. *Bulletin of the New York State Archaeological Association* 124: 56-68.
- Scarlett, Timothy James, Robert J. Speakman, and Michael D. Glascock. (2007). Pottery in the Mormon Economy: an Historical and Archaeometric Study. *Historical Archaeology*. 41(4):70-95.

Recent and Relevant Technical Reports.

Scarlett, Timothy and Steven Walton. (2017). *Archaeological Overview and Assessment, Pullman National Monument, Chicago, Illinois*. Submitted to the Midwest Archaeology Center, National Park Service, United States Department of the Interior. June 9th, 2017.

Scarlett, Timothy James. (2017). *White Paper: Designing Best Practice for Industrial Archaeology and Industrial Heritage at Pullman National Monument*. Submitted to the Midwest Archaeology Center, National Park Service, United States Department of the Interior. June 9th, 2017

Scarlett, Timothy James and Jarowslaw Drelich. (2016). *Final Project Report: Testing and Refining Ceramic Rehydroxylation Dating, Collaborative Research, Award 1219540*. National Science Foundation. March 9th, 2016.

Scarlett, Timothy James. (2016). *Potential Applications of Supercritical Carbon Dioxide Extraction and Impregnation for the Stabilization and Conservation of Industrial Heritage Artifacts*. Final Project Report (Grant #P11AP60840) submitted to the National Center for Preservation Technology and Training, National Park Service, United States Department of the Interior. January 15th, 2016.

Grants, Contracts, and Agreements (sole author unless otherwise noted):

Cooperative Agreement for Work with Pullman National Monument. Sponsor: National Park Service. Total Project Budget \$149,685 (No MTU Cost Share). 2016-2019. Co-PIs: Laura Rouleau, Steven Walton, Sam Sweitz, Sarah Scarlett, Melissa Baird, Don Lafreniere, LouAnn Wurst. (pending)

A Proposal for Archaeological Testing at the Ghyllbank Townsite (20.IR.0224), Isle Royale National Park, Keweenaw County, Michigan. Sponsor: National Park Service. Total Project Budget \$20,000 (no MTU Cost Share). Summer 2016.

Novel Techniques for the Stabilization and Conservation of Ferrous Metals in Industrial Heritage. Sponsor: The National Center for Preservation Technology and Training, National Park Service. Total project budget: \$61,620 (\$25,000 sponsored, \$36,620 MTU cost share). Co-PI Gerard Caneba, Summer 2012.

Survey and Evalutation of Stamp Sands Poor Rock, and Slag Piles in Houghton, Keweenaw, Ontonagon, and Baraga Counties. Sponsor: Keweenaw National Historic Park Advisory Commission. Total project value: \$10,000 (\$10,000 sponsored, no MTU cost share). Co-PIs Samuel Sweitz, Louise Dyble, Fredric Quivik, and Susan Martin.

Research Interests:

Historical and Industrial Archaeologies
Archaeological Science
Artifact Conservation

Chelsea Schelly, Ph.D.
Assistant Professor of Sociology
Environmental and Energy Policy MS and PhD Programs
Department of Social Sciences
Michigan Technological University
Email: cschelly@mtu.edu
Website: <http://ss.sites.mtu.edu/schelly/>

EMPLOYMENT

2017-Present	Associate Professor of Sociology Department of Social Sciences Environmental and Energy Policy Graduate Program Michigan Technological University Director of Graduate Studies, 2017-
2013-2017	Assistant Professor of Sociology Department of Social Sciences Environmental and Energy Policy Graduate Program Michigan Technological University

EDUCATION

2013	Ph.D., Sociology, University of Wisconsin-Madison Minor in Science and Technology Studies Certificate in Humans and the Global Environment (NSF-IGERT)
2008	M.A., Sociology, Colorado State University
2005	B.A. with honors, Sociology, University of Wisconsin-Madison Certificate in Environmental Studies

BOOKS (* indicates student collaborator)

Halvorsen, K.E., Schelly, C., Handler, R., and Knowlton, J., Eds. (forthcoming). *A Research Agenda for Environmental Management*. Under contract with Edward Elgar.

Schelly, C., and Banerjee, A.,* Eds. (In Press, 2018). *Environmental Policy and Pursuit of Sustainability*. In Press with Routledge.

Schelly, C. 2017. *Dwelling in Resistance: Living with Alternative Technologies in America*. Rutgers University Press.

Schelly, C. 2014. *Crafting Collectivity: American Rainbow Gatherings and Alternative Forms of Community*. Boulder, CO: Paradigm Publishers. Reprinted by Routledge, 2016

SELECT PUBLICATIONS (* indicates student collaborator; last three years listed)

Schelly, C., Louie, E.P.,* and Pearce, J.M. (Forthcoming). Examining Interconnection Policy and Net Metering Compensation for Distributed Generation in the United States. Forthcoming in *Renewable Energy Focus*

Aparajita Banerjee,* Emily Prehoda,* Roman Sidortsov, and Chelsea Schelly. (2017).

- Renewable, ethical? Assessing the energy justice potential of renewable electricity. *AIMS ENERGY* 5(5): 768-797. doi: 10.3934/energy.2017.5.768
- Prehoda, E.,* Schelly, C., and Pearce, JM. (2017). U.S. Strategic Solar Photovoltaic-Powered Microgrid Deployment for Enhanced National Security. *Renewable & Sustainable Energy Reviews* 78: 167-175. <https://doi.org/10.1016/j.rser.2017.04.094>
- Banerjee, Aparajita*, Chelsea L. Schelly, and Kathleen E. Halvorsen. (2017). Understanding public perceptions of wood-based electricity production in Wisconsin, United States: place-based dynamics and Social Representations. *Environmental Sociology* 3(4): 381-393. <http://dx.doi.org/10.1080/23251042.2016.1272181>.
- Schelly, C. and Banerjee, A.* (2016). Soft Energy Paths Revisited: Politics and Practice in Energy Technology Transitions. *Challenges* 7, 16, doi:10.3390/challe7020016.
- Kreuze, A.* Schelly, C, and Norman, E.S. (2016). To Frack or not to Frack: Perceptions of the Risks and Opportunities of High-Volume Hydraulic Fracturing in the United States. *Energy Research and Social Sciences* 20: 45-54. <http://dx.doi.org/10.1016/j.erss.2016.05.010>
- Schelly, C. (2016) Understanding Energy Practices: A Case for Qualitative Research. *Society & Natural Resources* 29(6): 744-749. <http://dx.doi.org/10.1080/08941920.2015.1089613>
- Schelly, C. (2016). Unconventional oil and gas: Influence of politics and proximity on perceptions. *Nature Energy*. Invited News and Views contribution October 6: 1-2
- Schelly, C. (2015). What's Political about Solar Electric Technology? The User's Perspective. *Engaging Science, Technology & Society* 1: 25-46.
- Schelly, C. (2015). Frameworks for Understanding and Promoting Solar Energy Technology Development. *Resources* 4: 55-69.
- Schelly, C., Anzalone, G., Wijnen, B.,* and Pearce, J. (2015). Open-Source 3-D Printing Technologies for Empowered and Transformative Education: Bringing Additive Manufacturing to the Classroom. *Journal of Visual Languages and Computing* 28: 226-237.
- Schelly, C. (2014). Are Residential Dwellers Marking and Claiming? Applying the Concepts to Humans Who Dwell Differently. *Environment and Planning D: Society and Space* 32(4): 672-688.
- Schelly, C. (2014). Residential Solar Electricity Adoption: What Motivates, and What Matters? A Case Study of Early Adopters. *Energy Research and Social Science* 2: 183-191.
- Schelly, C. (2014). Implementing Renewable Energy Portfolio Standards: The Good, the Bad, and the Ugly in a Two State Comparison. *Energy Policy* 67: 543-551.
- Schelly, C., and Price, J. (2014). Utilizing GIS to Examine the Relationship Between State Renewable Portfolio Standards and the Adoption of Renewable Energy Technologies. *International Journal of Geo-Information* 3(1): 1-17.

SELECT FUNDING AWARDS

Fall 2016 "Climate Change Mitigation via Reducing Household Food, Energy and Water Consumption: A Quantitative Analysis" NSF-INFEWS. David Watkins, PI, Chelsea Schelly, co-PI. Total funding: 2,983,358, 5 year grant.

Biographical Sketch for State of Michigan's Independent Risk Analysis of the Straits Pipelines

David J. Schwab, Research Scientist
University of Michigan Water Center
<http://graham.umich.edu/users/djschwab>

My professional expertise is in the field of hydrodynamic modeling of the Great Lakes and other coastal regions. Before joining the U-M Water Center in 2013, I was a research scientist and division chief at NOAA's Great Lakes Environmental Research Laboratory for 37 years. My work covered a wide range of topics in geophysical fluid dynamics including theoretical, numerical, and observational investigations of circulation, thermal structure, seiches, storm surges, wind waves, and air-sea interaction.

During my career at NOAA/GLERL I was instrumental in designing, developing, and implementing a comprehensive coastal forecasting system for the Great Lakes which is currently in use by NOAA for operational marine forecasting, oil spill response, and search and rescue support for the US Coast Guard. The Great Lakes Coastal Forecasting System was the first of its kind in the country and has served as a model for several other systems around the world. My current interests are in applications of hydrodynamic modeling to water quality problems, including transport of bacteria from tributary sources to swimming beaches and predictive tracking of oil spills and algal blooms.

In 2013, shortly after my retirement from NOAA, I received two awards for sustained scientific contributions to Great Lakes research: the Distinguished Career Award from the National Oceanic & Atmospheric Administration (NOAA) and the Lifetime Achievement Award from the International Association for Great Lakes Research (IAGLR).

I have over 40 yrs experience in understanding and predicting Great Lakes hydrodynamic properties with over 120 scientific publications in this area. I also have specific expertise and experience with currents in the Straits of Mackinac as well as oil spill trajectory modeling.

Recently I performed a comprehensive fate and transport analysis of a spill from Line 5 in the Straits and published a report on the results (<http://graham.umich.edu/water/project/mackinac-oil-spill>). This report documents the results of 840 transport scenarios for three potential levels of oil discharge in the Straits — measured in barrels (bbl), each containing 42 US gallons of oil — including 5,000 bbl, 10,000 bbl and 25,000 bbl. The methods used in this report are equivalent to those used in the operational NOAA oil spill model and an earlier pilot study from 2014. Some of the conclusions of this analysis include:

- More than 700 miles of shoreline in Lakes Michigan and Huron and on their islands are potentially vulnerable to an oil release in the Straits that would result in accumulation requiring cleanup.
- Areas at highest risk include Mackinac and Bois Blanc Islands, Mackinaw City, the shorelines east and west of the city and areas on the north shore of the Straits near the

Mackinac Bridge. Communities at risk also include Beaver Island, Cross Village, Harbor Springs, Cheboygan and other areas of the Lake Huron-Michigan shoreline

- In a single case (worst case), more than 150 miles of shoreline could be impacted with a spill amount of 25,000 bbl. The maximum amount of shoreline impacted by a 10,000 bbl spill is more than 100 miles and for a 5,000 bbl spill is more than 70 miles.
- More than 15% of Lake Michigan's open water (3,528 square miles) and nearly 60% of Lake Huron's open water (13,611 square miles) could be affected by visible oil from a spill in the Straits.

I would be happy to share the results of this report with the risk analysis group and assist them in carrying out the objectives of Task II-B as well as assisting in application of the fate and transport calculations to the rest of the Tasks in the study. I would be interested in participating on Task II-B in the role of Subsection Author.

David R. Shonnard, Ph.D.

Professor and Richard and Bonnie Robbins Endowed Chair

Department of Chemical Engineering

Director: Sustainable Futures Institute (SFI)

Michigan Technological University (MTU)

Houghton, MI 49931

(906)-487-3468

(906)-487-3213 (FAX)

drshonna@mtu.edu

Webpage ; http://www.chem.mtu.edu/chem_eng/faculty/drshonnard.htm

SFI Homepage ; <http://www.sfi.mtu.edu/>

EDUCATION

Ph.D., Chemical Engineering, University of California, Davis; 1991.

Dissertation: "An experimental and theoretical study of the effects of environmental conditions and nonlinear adsorption on the emission rates of volatile organic compounds from contaminated soils". Advisor: Dr. Richard L. Bell.

M.S., Chemical Engineering, University of California, Davis; 1985.

Thesis: "Experimental determinations of unit cell effective thermal conductivities for point contact". Advisor: Dr. Stephen Whitaker.

B.S., Chemical/Metallurgical Engineering, University of Nevada, Reno; 1983.

Dr. Shonnard is professor and Richard and Bonnie Robbins Endowed Chair in Sustainable Use of Materials in the Department of Chemical Engineering at Michigan Technological University and director of the Sustainable Futures Institute. He has over 25 years of academic experience in sustainability issues in the chemical industry and green engineering. His research interests are in environmental fate and transport of pollutants, health risk assessment from pollutants in the environment, wood-based advanced biofuel processes, environmental life cycle assessments and techno-economic analyses of advanced biofuels. He has extensive experience in conducting experimental investigations and mathematical modeling of the transport and fate of pollutants in water bodies, in soils, sediments, and in the surface boundary layer of the atmosphere. He is co-author of the textbooks "Green Engineering: Environmentally-Conscious Design of Chemical Processes", published by Prentice Hall in 2002, and "Sustainable Engineering: Concepts, Design, and Case Studies", published by Prentice Hall in 2012. Dr. Shonnard has co-authored over 200 peer-reviewed publications, conference proceedings papers, and technical reports and received numerous honors and awards for teaching and research into environmental and sustainability issues of the chemical industry.

HIGHLIGHTS

RESEARCH ACCOMPLISHMENTS

Administrative: Director of the Sustainable Futures Institute, a campus-wide research institute focusing on multidisciplinary sustainability research (\$18,000,000 in new funding since 2010) with participation of 70 faculty.

Funding: 57 grants, (total projects \$28,050,000; as PI \$8,350,000; to DRS \$6,150,000)

Publications: 100 peer-reviewed articles and book chapters

Ph.D. Mentored: as advisor 12 graduated, 4 current as sole adviser (2) and co-adviser (2)

M.S. Mentored: 15 graduated

B.S. Mentored: 120 undergraduate researchers

Postdocs Mentored: 3 graduated (now SFI Operations Manager, at CARB, at UND), 1 current

Research Reports: 33 reports to research sponsors

Proceedings Papers: 35 proceedings papers and extended abstracts Presentations: 150 presentations at conferences

Invited Seminars: 36 presentations by invitation Keynote Addresses: 4

Edited Books: 2, one edited book and one 3-volume handbook on bioenergy crop plants

Awards: Outstanding Undergraduate Research Mentor Award (AIChE Student Chapter, Michigan Technological University, 2011, 2012, 2016, 2017)
NSF/Lucent Technologies Foundation Industrial Ecology Research Fellowship, 1998

Biofuels Pilot Plant: Set up a 1 kg/hr forest-based pyrolysis biofuels pilot plant at Michigan Tech

EDUCATION ACCOMPLISHMENTS

My education interests are in chemical engineering transport phenomena, unit operations, environmental fate and transport processes, green engineering in the chemical engineering curriculum, sustainability in engineering education, and sustainability in secondary education.

Awards: *Ray Fahien Award*, ASEE Chemical Engineering Division, 2003
 2016, Provost recognition of Teaching Excellence - top 10% at Michigan Tech based on the "Average of 7 Dimensions" ranking system

Textbooks: 2 textbooks (Green Engineering; Sustainable Engineering), 2 solution manuals

Workshops: 14 national workshops on Green Engineering education and other topics

Grants: NSF Research Experience for Teachers (RET) award (2009-2014), education is embedded into NSF-funded research grants through undergraduate student involvement and course development. 2 additional NSF grants.

Certificate: Developed-manage a multidisciplinary Graduate Certificate in Sustainability

Sustainability: Created multi-disciplinary graduate-level courses in Sustainability

Green Engineering: Incorporating green engineering education materials into the chemical engineering curriculum at multiple points, including a required course

SERVICE ACCOMPLISHMENTS

My service work includes committee assignments in the Department of Chemical Engineering and at the university level, mentoring of new tenure track faculty, and dean of engineering search committee

Faculty Fellow: 2017-2019 - Office of the Vice President for Research

Presidential Search: Selected as a member of the 2017-19 Presidential Search Committee

AIChE: leadership on technical programming in the Environmental Division and the Sustainable Engineering forum

Committees: Ph.D. committees; 8 graduated, 6 current: M.S.; 13 graduated, 1 current

ABET: led MTU's Chem. Eng. Dept. successful ABET accreditation 2003-2004.

JOANNE M. SHORE

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 ◆ www.linkedin.com/in/joanne-shore-energy

EXECUTIVE ORGANIZATIONAL & BUSINESS ANALYST

Organizational Leadership || Expert Analysis & Forecasting || Optimal Results

Award-winning executive organizational and business analyst combining extensive technical expertise with solid business acumen to deliver structure and focus through in-depth analysis, forecasting and comprehensive leadership. Maximizing processes through insightful review, identifying areas for improvement and implementing effective solutions. Leveraging national and international networks to provide top-tier subject matter knowledge and thought leadership. Translating complex information into strategy, planning and profitable impact on public, government and corporate organizations.

Core Skills and Knowledge:

In-Depth Market Analysis	Long-/Short-Term Modeling & Forecasting	Strategic Planning
Organizational Improvement	National/International Networking	Public Speaking
Subject Matter Expertise	Detailed Reporting & Presentations	Public Relations
Project Management	Cross-Functional Team Leadership	Business Planning & Development

PROFESSIONAL EXPERIENCE

Downstream Petroleum Markets LLC

2016-Current

Independent Consultant

After retiring from a rewarding and interesting position at AFPM, I am continuing to work in downstream petroleum market analysis - my primary area of interest.

American Fuel and Petrochemical Manufacturers

2013-2016

Chief Industry Analyst

Supported the organization with market and economic information. This included contributing to and developing educational products about the oil industry, analyzing potential impacts associated with proposed regulatory and statutory changes directly or leading studies of such issues, contributing to senior management speeches, and participating in forums interested in the evolving U.S. downstream. Participated as AFPM representative on National Petroleum Council study of Enhancing Emergency Preparedness for Natural Disasters (2014) and its Addendum.

Office of Policy and International Affairs, Department of Energy

2012-2013

Senior Operations Research Analyst

Supported policy analysis for Iran sanctions, critical materials strategies, and energy emergency responses.

U.S. Energy Information Administration

2000-2012

Team Leader and Lead Operations Research Analyst

Delivered petroleum industry analysis and forecasting materials directly to the Secretary of Energy, Congress, the White House, and the public, distilling detailed and complex information to provide quick and comprehensive understanding for the purpose of education, planning and decision making throughout the U.S. and abroad.

Expert Analysis and Forecasting

Recognized and hired as a top-level, non-political expert in the field of global petroleum product and refining market analysis and forecasting.

- ◆ **Provided crucial and unbiased insight** into the petroleum market and its public impact through the collection, review and translation of U.S.-related energy data into **expert global analysis and forecasting** for public callers, politicians and senior leaders within the administration.
- ◆ **Directed a team of 9-18 analysts in cross-functional groups** including petroleum and biofuels liquids processing, and natural gas markets to compile data and deliver comprehensive reports, testimony, presentations and forecasting
- ◆ **Leveraged prominent national and international networking** to gain expert collaboration and provide 10-15-year projections

Public Reports, Publications and Presentation

Managed highly detailed projects and schedules to provide top-quality products within strict deadlines.

- ◆ **Generated daily situation reports** for the Department of Energy and managed and contributed weekly articles for [This Week in Petroleum](#) addressing general petroleum-related energy topics.
- ◆ **Published federally mandated reports** such as the semiannual [Market Assessment of Refinery Outages](#) summarizing the major refinery maintenance schedules to identify and prevent multiple shutdowns and reduce public pricing impact, Congressional and Administration requests, including [Analysis of Gasoline Markets Spring 1996](#) in response to a request from President Clinton and [Supply Impacts of an MTBE Ban](#), and topical issue analyses such as [Increasing Distillate Production at U.S. Refineries](#).
- ◆ **Delivered public presentations to general and political audiences** including [Drivers Behind Growing U.S. Product Exports and Shrinking Light-Heavy Price Differences](#); [Atlantic Basin Refining Dynamics](#); [Are Refinery Investments Responding to Market Changes](#).

Major Accomplishments and Impact

Delivered operational and organizational leadership, translating complex technical information into easily understandable plans and projects to lead teams, inform groups at all levels and drive improvements.

- ◆ **Improved the overall reputation of the organization** through demonstrating deep knowledge in the marketplace, producing frequent and credible products and promoting the spread of good information.
- ◆ **Increased editing efficiency** by implementing a process of strategic estimating techniques, identifying potential errors in survey results before totaling and reducing rework by ensuring accuracy before processing information.
- ◆ **Guided policy makers in determining best-impact decisions** through the delivery of critical industry analyses generated upon specific topics as requested.

Honors and Awards

Recognized industry-wide as a downstream refining and market expert and rewarded for major contributions to the U.S. Energy Administration and the international petroleum industry.

- ◆ Presented with the Recognition Award by the Secretary of Energy for outstanding performance in the planning and execution of the Presidential initiative to exchange 30 million barrels of Strategic Petroleum Reserve crude oil.
- ◆ Received the Superior Performance Award from the Secretary of Energy for the comprehensive support of oil production, consumption and developing countries to stabilize world oil markets.
- ◆ Awarded the University of Pittsburgh Marshal Alan Robinson Prize for leadership.

PROFESSIONAL DEVELOPMENT

Previous Experience

Executive-level business development, consulting, project management, policy implementation, market analysis and planning for various commercial and government organizations.

Vice President , Cameron Cybernetics	1998-2000
Senior Program Manager , The Dynamac Corporation	1997-1998
Principal , Onlocation, Inc.	1988-1997
Principal Consultant , Ogden Energy & Environment	1985-1987

EDUCATION

M.B.A., Marketing and Finance
M.S., Physics
B.S., Physics

University of Pittsburgh, Katz Graduate School of Business, Pittsburgh, PA
Carnegie Mellon University, Pittsburgh, PA
Harvey Mudd College, Claremont, CA

Roman V. Sidortsov
Assistant Professor of Energy Policy
Department of Social Sciences

tel: (906) 487-1095
email: rsidortsov@mtu.edu
Michigan Technological University
Houghton, Michigan

A. PROFESSIONAL PREPARATION:

Irkutsk State University School of Law, Irkutsk, Russia,	Law, Bachelors' and Master's,	1999
Vermont Law School, South Royalton, VT,	Law, JD,	2008
Vermont Law School, South Royalton, VT,	Environmental Law, LL.M,	2012
University of Cambridge, Cambridge, United Kingdom,	Polar Studies/Geography, PhD,	2016

B. APPOINTMENTS:

2016 – Present, Assistant Professor of Energy Policy, Michigan Technological University, Houghton, MI
2011 – Present, Senior Global Energy Fellow, Vermont Law School, Institute for Energy and the Environment, South Royalton, VT
2011 – 2016, Faculty, Distance Learning and Summer Programs, Vermont Law School, South Royalton, VT
2010 – 2011, Research Associate, Vermont Law School, Institute for Energy and the Environment, South Royalton, VT
2010 – 2012, Adjunct Faculty, Marlboro College Graduate School, Brattleboro, VT
1999 – 2000, Assistant Professor, Baikal State University of Economics and Law (formerly Irkutsk State Academy of Economics and Law), Irkutsk, Russia
1999 – 2010, Various professional engagements in the private and non-profit sectors.

C. PRODUCTS (BOLDED indicates member of the research team on this proposal):

i) Products Most Closely Related to Proposed Project.

- 1) **Sidortsov, R.** 2014. Reinventing Rules for Environmental Risk Governance in the Energy Sector, *Energy Research & Social Science* (1) 171-182.
- 2) **Sidortsov R.**, Ivanova, A., & Stammler, F., 2016. Localizing Governance of Systemic Risks: A Case Study of the Power of Siberia pipeline in Russia, *Energy Research and Social Science*, (16) 54-68.
- 3) Sovacool, B., **Sidortsov, R.**, Jones, B. 2014. Energy Security, Equality, and Justice. Routledge.
- 4) **Sidortsov, R.** & Sovacool B. 2014. Why Legal Regimes and Institutional Frameworks Matter: State-Market Interrelations in the U.S. Onshore and Offshore Oil and Gas Sectors, in *States and Markets in Hydrocarbon Sectors*. Palgrave.
- 5) Baker, B. & **Sidortsov, R.** 2014. The Legal and Regulatory Regime for Offshore Hydrocarbon Resources in the U.S. Arctic, in *Energy Law in the 21st Century: Views from the U.S. and Russia*. ABA-SEER.

ii) Other Significant Products.

- 1) Dworkin, M., **Sidortsov, R.** & Sovacool, B. 2013. Rethinking the Scale, Structure and & Scope of U.S. Energy Institutions. *Daedalus* 142(1)129-145.
- 2) **Sidortsov, R.** 2017. At the Crossroads of Policy Ambitions and Political Reality: Reflections on the Prospects of LNG Development in Russia, *Oil, Gas & Energy Law Journal*, Liquefied Natural Gas (LNG) Special Issue (in press)
- 3) **Sidortsov, R.**, 2014. The Myth of Liberalization: The 2013 Changes in the Russian LNG Export Regime, *Energy Law Journal*, 35(2) 323-345.
- 4) **Sidortsov, R.**, 2012. Measuring Our Investment in the Carbon Status Quo: Case Study of the New Oil Development in the Russian Arctic. *Vermont Journal of Environmental Law*, (13)614-649.
- 5) **Sidortsov, R.** 2016. A Perfect Moment during Imperfect Times: Arctic Energy Research in a Low-Carbon Era, *Energy Research and Social Science*, (16) 1-7.

C. SYNERGISTIC ACTIVITIES:

- 1) Editorial Board Member of *Energy Research and Social Science* and Special Issue Editor, Arctic Energy: Views from the Social Sciences (2016).
- 2) Team Researcher “Indigenous Peoples and Resource Extraction in the Arctic – Evaluation of Ethical Guidelines” sponsored by the Norwegian Ministry of Foreign Affairs (2013-2017).
- 3) Member of the U.S.-Russia Bilateral Presidential Commission’s Energy Scholarship Working Group (2012-2013).
- 4) Reviewer and analyst for: Applied Energy, Energy Policy, The Yearbook of Polar Law, International Institute for Sustainable Development (Government Support to Upstream Oil & Gas in Russia How Subsidies Influence the Yamal LNG and Prirazlomnoe Projects) (2014), Overseas Development Institute (Exploration Subsidies in Russia) (2014), Norwegian Institute of International Affairs’ PRIX Index on Politics and Oil Exports.
- 5) Lead on Vermont’s Energy Future: A Conceptual Map of Vermont’s Energy Goals and Decision Makers, a project commissioned and funded by the Vermont’s Department of Public Service.

Kevin B. Strychar

Associate Professor, Climate Change Studies of Aquatic & Marine Ecosystems
Annis Water Resources Institute | 740 W. Shoreline Dr. | Muskegon, MI 49441-1678
Tel: 616-331-8796 | Email: strychak@gvsu.edu | Web: <http://www.gvsu.edu/wri/strychar>

(a) Professional preparation

Central Queensland University, Qld., Australia	Conservation Ecology	Ph.D.	July 2002
University of New Brunswick, Saint John, CDN	Aquatic Ecology	M.S.	July 1997
University of New Brunswick, Saint John, CDN	Biology	B.S.	April 1995

Appointments

2017-	Full Professor of Climate Change Studies of Aquatic & Marine Ecosystems, Annis Water Resources Institute, Grand Valley State University
2012-2017	Associate Professor of Climate Change Studies of Aquatic & Marine Ecosystems, Annis Water Resources Institute, Grand Valley State University
2012-	Adjunct Professor of Zoology, Michigan State University
2005-2012	Assistant Professor of Marine Microbiology, Department of Marine Science, Texas A&M University
2003-2005	Killam Fellowship, Dept. Geology (marine genetics), Dalhousie University
2002-2004	EPA Fellowship, Dept. Marine Science (marine physiology), University of Connecticut

(b) Products

(i) Products most closely related to the proposed project (i.e. pathogens)

1. Sammarco P.W., Brazeau D.A., McKoin M., **Strychar K.B.** 2017. *Tubastraea micranthus*: comments on the population genetics of a new invasive coral in the Western Atlantic and a possible secondary invasion. *Journal of Experimental Marine Biology and Ecology*. 490:56-63
2. Hauff-Salas B., Haslun J.A., **Strychar K.B.**, Ostrom P.H., Cervino J.M. 2017. Site-specific variation in gene expression from *Symbiodinium* spp. associated with offshore and inshore *Porites astreoides* in the lower Florida Keys is lost with bleaching and disease stress. *PLoS ONE* 12(3): e0173350. DOI:10.1371 / journal.pone.
3. Sammarco P.W., **Strychar K.B.** 2016. Ecological and evolutionary considerations regarding corals in a rapidly changing environment. In: *The Cnidaria, Past, Present, and Future. The world of Medusa and her sisters*. Eds: Zvy Dubinsky and Stefano Goffredo, Springer. Chapter 34. doi: 10.1007/978-3-319-31305-4
4. Antonelli P., Rutz S., Sammarco P.W., **Strychar K.B.** 2016. Evolution of symbiosis in hermatypic corals: A model of the past, present, and future. *Nonlinear Analysis: Real World Applications*. 32: 389-402. doi:10.13140/RG.2.1.2105.7769.
5. Hauff B., † Haslun J.A., **Strychar K.B.**, Ostrom P., Cervino J.M. 2016. Symbiont diversity of zooxanthellae (*Symbiodinium* spp.) in *Porites astreoides* and *Montastraea cavernosa* from a reciprocal transplant in the lower Florida Keys. *International Journal of Biology*. 8: 9-22.

(ii) Other significant products

1. Nielsen-Gammon, J. Karpanty S., Lauenroth W., Martin T., Nejstgaard J., **Strychar K.B.**, Teel P.D., Waskom R., Wu J.J. 2014. Climate change and natural resources. Board of Natural Resources and Board on Oceans, Atmosphere, and Climate – Research, Education, and Outreach Road Map (2013-2018). 98 p. Available at: <http://www.aplu.org/page.aspx?pid=2964>

2. Sabourin DT., Silliman J, **Strychar KB.** 2013. Polycyclic aromatic hydrocarbon (PAH) concentrations within sediments and corals in the Inter-coastal waterways of South Texas. *International Journal of Biology.* 5:1-12.
3. White M., **Strychar K.B.** 2011. Coral as environmental bioindicators: Ecological and morphological effects of gasoline on Gorgonian corals, *Leptogorgia virgulata*. *International Journal of Biology.* 3: 63-73.
4. Bright-Diaz L.M., **Strychar K.B.**, Shirley T.C. 2011. Compounds from deep-sea bubblegum corals, *Paragorgia arborea*, elicit anti-predation behavior in fish. *The Open Marine Biology Journal.* 5:58-67.
5. Miller A.N., **Strychar K.B.**, Shirley T.C., Rützler K. 2010. Effects of heat and salinity stress on the sponge *Cliona celata*. *International Journal of Biology.* 2:3-16.

(c) Synergistic activities

1. Conference Organizer for “2nd International Electronic Conference on Water Sciences (ECWS-2). See: <http://sciforum.net/conference/ecws-2>
2. IAGLR 2017 (Detroit, MI, USA) May 15-17, Session Chair and Organizer for “Diseases and Pathogens of the Great Lakes and Inland Waters”.
3. IAGLR 2016 (Guelph, ON, Canada) June 6-10, Session Chair and Organizer for “Diseases and Pathogens of the Great Lakes and Inland Waters” (see <http://www.iaglr.org/conference/sessions.php>)
4. Organizing committee for Oceanography 2016, to be held in Brisbane, Australia. July 18-21, 2016. <http://www.oceanographyconference.com/organizing-committee.php>
5. Editorial board member for the journal Nature - “Scientific Reports.” Dr. Richard White (Editorial Manager). 2016-2018

(d) Collaborators and other affiliations, *Denotes Annis Water Resources Institute

(i) Collaborators and co-editors during the past 48 months (Total = 14) O. Levy, Bar-Ilan University, Israel; Y. Benayahu, Tel Aviv U., Israel; TJ Piva – RMIT, Austr.; P. Antonelli – U. of Alberta, CDN; J. Nielsen-Gammon – Texas A&M U. , USA; PW Sammarco - LUMCON, USA; J. Cervino, WHIO, USA; E. Cooper – UCLA, USA; K. Hirabayashi – UCLA, USA; E Kenchington - Bedford Institute of Oceanography, CDN; C. Gong, senior editor IJB, USA; Q. Jiao, senior editor J. Water, USA; C. Dedman, senior editor J. Nature, UK.

(ii) Investigator’s graduate and postdoctoral advisor(s): Post-Doctoral Advisors: DB Scott, Dalhousie U., CDN (2003-2005); JE Ward - UConn, USA (2002-2004). **Ph.D.**

Advisors: PW Sammarco - LUMCON, USA (1998-2002); TJ Piva, Medical Institute of Technology, Austr. (1998-2002); M Coates, Central Queensland U., Austr. (1998-2002); PT Scott, U. Queensland, Austr. (1998-2002). **M.S. Advisors:** BA MacDonald & JJ Johnson, University of New Brunswick, CDN (1995-1997).

(iii) Thesis advisor and postgraduate-scholar sponsor (Total = 14) B. Hauff-Salas (U. Texas), J. Haslun (MSU), O. Sherwood (U. Colorado), N. Gezon (AWRI), J. Skutnik (QARA Biopharmaceutical Solutions), S. Swinney (GC Reef and Aquaculture), D. Sabourin (American Sugar Refining), L. Lloyd (Conrad Blucher Institute), M. White (Argus Environmental), L. Squiers (Naismith Engineering), E. Williamson (Texas General Land Office), A. Dailey (Texas State Aquarium), A. Miller (Texas Parks and Wildlife), L. Bright (Texas A&M).

STEPHEN M. TECHTMANN

Assistant Professor
Department of Biological Sciences
Michigan Technological University
Houghton, MI 49931

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A. PROFESSIONAL PREPARATION

Univ. Maryland, Baltimore Co.	Baltimore, MD	Biochem. & Mol. Biol.	B.S	2004
Univ. of Maryland, Baltimore	Baltimore, MD	Cell and Mol. Biol.	PhD	2009
Uniformed Services University	Bethesda, MD	Biochemistry	Postdoctoral	2009 – 2012
University of Tennessee	Knoxville, TN	Microbial Ecology	Postdoctoral	2012 – 2015

B. APPOINTMENTS

Since 2015 Assistant Professor Michigan Tech University
2012 - 2015 Postdoctoral Research Associate University of Tennessee Knoxville
2009 – 2012 Postdoctoral Fellow, Uniformed Services University

C. PRODUCTS

(i) Products Most Closely Related to the Proposed Project

- 1) **Techtmann, S. M.**, Zhuang, M., Campo, P., Holder, E., Elk, M., Hazen, T. C., Conmy, R., and Santo Domingo, J. W. (2017). Corexit 9500 Enhances Oil Biodegradation and Changes Active Bacterial Community Structure of Oil-Enriched Microcosms. *Applied and Environmental Microbiology*, 83(10), e03462-1
- 2) Liu, J., **Techtmann, S. M.**, Woo, H. L., Ning, D., Fortney, J. L., & Hazen, T. C. (2017). Rapid Response of Eastern Mediterranean Deep Sea Microbial Communities to Oil. *Scientific Reports*, 7.
- 3) Smith, M.B; Rocha. A.M.; Oleson, S.W.; Paradis, C.; Smillie, C.S.; Campbell. J.H.; Fortney, J.L.; Mehlhorn, T.L.; Lowe. K.A.; Earles, J.E.; Phillips, J.; **Techtmann, S.M.**; Joyner, D.C.; Preheim, S.P.; Sanders, M.S.; Mueller, M.A; Brooks, S.; Watson, D.B.; Wu, L; Zhang, P.; He, Z.; Zhou, J.; Adams, M.W.W.; Lancaster, A.; Poole, F.; Adams, P.D.; Arkin, A.P.; Fields, M.; Alm, E.J.; Hazen, T.C. (2015) Natural bacterial communities as quantitative biosensors. 6.3 (2015): e00326-15.
- 4) **Techtmann, S.M.**, Fitzgerald, K.S., Stelling, S.C., Joyner, D.C., Uttukar, S.M., Harris, A.P., Alshibli, N.K., Brown, S.D. and Hazen, T.C., (2016). Colwellia psychrerythraea strains from distant deep sea basins show adaptation to local conditions. *Frontiers in Environmental Science*, 4, p.33.
- 5) **Techtmann, S.M.**, and T.C. Hazen. Metagenomic applications in environmental monitoring and bioremediation. *Journal of Industrial Microbiology & Biotechnology* (2016): 1-10.

(ii) Other Significant Products

- 1) Olesen, S.W., S. Vora, **S.M. Techtman**, J.L. Fortney, J.R. Bastidas-Oyanedel, J. Rodríguez, T.C. Hazen, and E.J. Alm. "A Novel Analysis Method for Paired-Sample Microbial Ecology Experiments." *PloS one* 11, no. 5 (2016): e0154804.

- 2) Mahmoudi, N.; Robeson, M.S.; Castro, H.; Fortney, J.L.; **Techtmann, S.M.**; Joyner, D.C.; Paradis, C.; Pffner, S.M.; Hazen, T.C. (2015) Microbial community composition and diversity in Caspian Sea sediments. *FEMS Microbial Ecology* Dec 2014 DOI: 10.1093/femsec/fiu013
- 3) **Techtmann, S. M.**, Mahmoudi, N., Whitt, K. T., Campa, M. F., Fortney, J. L., Joyner, D. C., & Hazen, T. C. (2017). Comparison of thaumarchaeotal populations from four deep sea basins. *FEMS Microbiology Ecology*.
- 4) **Techtmann, S.M.**; Fortney, J.L.; Ayers, K.A.; Linley, T.D.; Pfiffner, S.M.; Hazen, T.C. (2015) The Unique Chemistry of Eastern Mediterranean Water Masses Selects for Distinct Microbial Communities by Depth. *PLoS ONE* 10(3): e0120605. doi:10.1371/journal.pone.0120605
- 5) Hazen, T.C.; Rocha, A.M.; **Techtmann S.M.** (2013) Advances in monitoring environmental microbes. *Current Opinions in Biotechnology*.
- 6) **Techtmann S.M.**, Robb, F.T. (2010) Archaeal-like Chaperonins in Bacteria. *Proc Natl Acad Sci U S A.* 107(47):20269-74. Epub 2010 Nov 5.

d. Synergistic Activities

1. PI on DARPA Young Faculty Award 2016 – 2019
2. Participated in assessment of oil biodegradation potential of microbial communities in five oceanic basins and contributed to internal reports to BP for assessment of the potential role of microbes in cleaning of up oil spills.
3. Presented to the Azerbaijani ministries of Emergency Situations and Ecology and Natural Resources on oil biodegradation and the use of dispersants as a response measure for oil spills
4. Instructed undergraduate and graduate courses in Environmental Microbiology, Microbial Physiology, and Biological Concepts for Engineers.
5. Invited manuscript reviewer for *Environmental Science and Technology*, *Applied and Environmental Microbiology*, *Frontiers in Microbiology*, *FEMS Microbial Ecology*, *Journal of Industrial Microbiology and Biotechnology*, *Ecological Indicators*, *Journal of Great Lakes Research*, *Extremophiles Journal*, and *Methods X*.
6. Outreach presentations to Cedar Bluff Middle School 7th grade science and social studies classes (2014 and 2015) “Oil and Microbes a Match Made in the Depths”. Presentation to Hardin Valley Academy - Science Matters Seminar Series (2013) “Can Mother Nature Take a Punch? – The Microbiology of the Deepwater Horizon Spill”
7. Supervised more than 20 Undergraduate Students and 5 Graduate students at Michigan Tech. Mentored 22 graduate and undergraduate students at University of Tennessee, Uniformed Services University and University of Maryland, Baltimore. Published three papers with mentored students including undergraduates and one more in review.

Updated: August 23, 2017

TWO PAGE CURRICULUM VITAE

ADAM M. WELLSTEAD, Ph.D.

Michigan Technological University
Department of Social Sciences
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Phone: (906) 487-2115
<http://www.social.mtu.edu/people/awellste.htm>

PROFESSIONAL EXPERIENCE

2015-Present: Michigan Technological University (Department of Social Sciences, Houghton, Michigan)

- Associate Professor of Environmental and Energy Policy

2011-2015: Michigan Technological University (Department of Social Sciences, Houghton, Michigan)

- Assistant Professor of Environmental and Energy Policy

1996-2011: Natural Resources Canada, Canadian Forest Service (Climate Change Adaptation research group, Northern Forestry Centre, Edmonton, Alberta)

- Natural Resource Social Scientist

EDUCATION

2006: Ph.D. (Renewable Resources)

University of Alberta, Edmonton, Alberta

1996: Master of Science (Forestry)

University of Toronto, Toronto, Ontario

1993: Master of Arts (Political Science)

Dalhousie University, Halifax, Nova Scotia

1991: Honors Bachelor of Arts (Political Science and Economics)

Wilfrid Laurier University, Waterloo, Ontario

RESEARCH INTERESTS

Climate change adaptation, administration traditions, forestry issues, governance, theories of the state, oil sands development, policy capacity, political economy, policy design, policy failure, policy mechanisms, policy

process frameworks, regional government, risk perception, role of indigenous people in natural resource decision-making, structural equation modeling (LISREL), and survey research.

PUBLICATIONS

Summary of publications

Books: **1**

Articles under review: **6**

Peer reviewed articles: **46**

Non-peer reviewed commentaries: **2**

Book chapters: **13**

Grey literature publications: **13**

Papers in conference proceedings: **12**

Book reviews: **2**

Google Scholar:

<https://scholar.google.com/citations?user=rOEzbLkAAAAJ&hl=en>

Selected Publications

Howlett, M. **Wellstead, A.** and J. Craft. Eds., *Policy Work in Canada: Professional Practices and Analytical Capacities in Canada's Policy Advisory System*. Toronto: University of Toronto Press.

Biesbroek, R., Dupuis, J. and **A. Wellstead**. Explaining through Causal Mechanisms: Resilience and Governance of Social-Ecological Systems. *Current Opinion in Environmental Sustainability*. (Paper accepted)

Cairney, P., Oliver, K. and **Wellstead, A.** 2016. To Bridge the Divide between Evidence and Policy: Reduce Ambiguity as Much as Uncertainty. *Public Administration Review*, 76: 399–402.

Wellstead, A., Rayner, J. and Howlett, M., 2016. Alberta's oil sands reclamation policy trajectory: the role of tense layering, policy stretching, and policy patching in long-term policy dynamics. *Journal of Environmental Planning and Management*. 59(10). 1873-1890.

Biesbroek, R., Dupuis, J., Jordan, A., **Wellstead, A.**, Howlett, M., Cairney, P., Rayner, J., and D. Davidson. 2015. Opening up the black box of adaptation decision making. *Nature Climate Change*. 5:6 493-494.

Wellstead, A., R. Stedman, and M. Howlett. 2011. Multi-Level Policy Analytical Capacity in Canada: A Structural Equation Model (SEM) Study of Federal, Provincial and Territorial Policy Analysts and Analysis. *Public Policy and Administration*. 26:3, 353-373.

BIOGRAPHICAL SKETCH—PENGFEI XUE, ASSISTANT PROFESSOR

Department of Civil & Environmental Engineering
Michigan Technological University
Houghton, Michigan

Tel: (906) 487-1837
E-mail: pexue@mtu.edu
<http://www.cee.mtu.edu/~pexue>

A. Professional Preparation

East China Normal University	Shanghai, China	Applied Mathematics	Sc.B. 2004
University of Massachusetts (IMS)	Dartmouth, MA		
		Marine & Atmospheric System Modeling & Analysis	PhD. 2012
Massachusetts Institute of Technology	Cambridge, MA		
		Regional climate modeling	Postdoc, 2012-2013

B. Appointments

2013-present: Assistant Professor
Department of Civil and Environmental Engineering
Michigan Technological University

2012-2013: Postdoctoral Associate
Department of Earth, Atmospheric and Planetary Sciences
Massachusetts Institute of Technology

2006-2012: Research Assistant
School for Marine Science and Technology
University of Massachusetts-Dartmouth

2005-2006: Visiting Scholar
School for Marine Science and Technology
University of Massachusetts-Dartmouth

C. Products

(i) Relevant Products to the Proposed Project

1. Xue, P, J. S. Pal, X. Ye, J. D. Lenters, C. Huang, P. Y. Chu (2017), Improving the Simulation of Large Lakes in Regional Climate Modeling: Two-way Lake-atmosphere Coupling with a 3-D Hydrodynamic Model of the Great Lakes, *J. Climate*, 30, 1605–1627, doi: 10.1175/JCLI-D-16-0225.1
2. Xue, P, D. J. Schwab, R. W. Sawtell, M. J. Sayers, R. A. Shuchman, G. L. Fahnenstiel (2017), A Particle-tracking Technique for Spatial and Temporal Interpolation of Satellite Images Applied to Lake Superior Chlorophyll Measurements, *J. Great Lakes Res.*, doi:<http://doi.org/10.1016/j.jglr.2017.03.012>
3. Xue, P, D.J. Schwab, S. Hu (2015), An Investigation of the Thermal Response to Meteorological Forcing in a Hydrodynamic Model of Lake Superior, *J. Geophys. Res. Oceans*, 120, 5233–5253
4. Xue, P., C. Chen, R.C. Beardsley, (2012). Observing System Simulation Experiments (OSSEs) of dissolved oxygen monitoring in Massachusetts Bay, *J. Geophys. Res.*, 117, C05014, doi:10.1029/2011JC007843.
5. Xue, P., C. Chen, R. C. Beardsley, R. Limeburner, (2011). Observing System Simulation Experiments (OSSEs) with Ensemble Kalman Filters in Nantucket Sound, Massachusetts, *J. Geophys. Res.*, .doi: 10.1029/2010JC006428

(ii) Other Significant Products

1. Xue, P and E. A.B. Eltahir (2015), Estimation of the Heat and Water Budgets of the Persian (Arabian) Gulf Using a Regional Climate Model, *J. Climate*, 28, 5041-5062. doi: 10.1175/JCLI-D-14-00189.1
2. Xue, P., C. Chen, J. Qi, R. C. Beardsley, R. Tian, L. Zhao, and H. Lin. (2014). Mechanism studies of seasonal variability of dissolved oxygen in Mass Bay: A multi-scale FVCOM/UG-RCA application, *J. Mar. Syst.*, 131, 102-119. doi:10.1016/j.jmarsys.2013.12.002
3. Xue, P, E. A.B. Eltahir, P. Malanotte-Rizzoli and J. Wei (2014), Local feedback mechanisms of the shallow water region around the Maritime Continent, *J. Geophys. Res. Oceans*, 119, 6933–6951. doi: 10.1002/2013JC009700
4. Chen, C. P. Xue, P. Ding, R. C. Beardsley, Q. Xu, X. Mao, G. Gao, J. Qi, C. Li, H. Lin, G. Cowles and M. Shi, (2008). Physical mechanisms for the offshore detachment of the Changjiang diluted water in the East China Sea, *J. Geophys. Res.*, 113, C02002, doi: 10.1029/2006JC003994.
5. Xue, P., C. Chen, P. Ding, R.C. Beardsley, H. Lin, J. Ge, and Y. Kong, (2009). Saltwater intrusion into the Changjiang River: A model-guided mechanism study. *J. Geophys. Res.*, 114, C02006.

D. Synergistic Activities

1. **Reviewer for Journals:** 1) Environmental Modelling & Software, 2) Advances In Water Resources, 3) Science of the Total Environment, 4) Journal of Hydrometeorology, 5) Journal of Geophysical Research-Oceans, 6) Journal of Physical Oceanography, 7) PLOS ONE, 8) Journal of Hydrology, 9) Journal of Advances in Modeling Earth Systems, 10) Earth System Dynamics, 11) Journal of Marine Systems, 12) Journal of Great Lake Research, 13) Estuarine, Coastal and Shelf Science, 14) Journal of Applied Meteorology and Climatology, 15) Journal of Atmospheric and Oceanic Technology, 16) Ocean Dynamics, 17) Stochastic Environmental Research and Risk Assessment, 18) Applied Ocean Research, 19) Meteorology and Atmospheric Physics, 20) Journal of Coastal Research, 21) Nature Hazards
2. **Associate Editor:** Frontiers (*Nature Publishing Group*) in Marine Science: Coastal Ocean Processes
3. **Proposal reviewer/panel member:** Sea Grant, NOAA, NSF
4. **Member of Professional Association**
 - American Geophysical Union (AGU)
 - American Meteorological Society (AMS)
 - Association for the Sciences of Limnology and Oceanography (ASLO)
 - The Oceanography Society (TOS)
 - International Association for Great Lakes Research (IAGLR)
5. **Teaching Experience:**
 - ENVE 5590: Introduction to Hydrodynamic Modeling (Fall 2014)-Michigan Tech
 - ATM/PH 5680: Geophysical Fluid Dynamics (Fall 2015)-Michigan Tech
 - ENVE 5590: Introduction to Hydrodynamic Modeling (Spring 2016, 2017)-Michigan Tech
 - CE3620: Water Resources Engineering (Fall 2016, 2017)-Michigan Tech
 - Guest Lecturer: Numerical Methods (2011)- University of Massachusetts
 - Guest Lecturer: Ecosystem Processes in the Gulf of Maine, Georges Bank, and New England Shelf (2010)- University of Massachusetts

BIOGRAPHICAL SKETCH

Yongli Zhang
Assistant Professor
5050 Anthony Wayne Dr. Engineering Building #2168
Detroit, MI 48202
Phone: 313-577-9962; Email: zhangyl@wayne.edu

A. PROFESSIONAL PREPARATION

<u>College/University</u>	<u>Major</u>	<u>Degree & Year</u>
Sichuan University	Food Engineering	B.E., 1995
Guangxi University	Microbiology	M.S., 2001
University of Virginia	Environmental Engineering	Ph.D., 2013

B. ACADEMIC/PROFESSIONAL APPOINTMENTS

2017 – Present	Co-director, Sustainability Engineering Program, Wayne State University
2016 – Present	Director, the Healthy Urban Waters research station at the Great Lakes Water Authority Water Treatment Plant
2014 – Present	Assistant Professor, Department of Civil and Environmental Engineering, Wayne State University, Detroit MI
2013 – 2014	Postdoctoral Research Associate, Department of Civil and Environmental Engineering, University of Virginia, Charlottesville VA

C. PRODUCTS

(i) Five Products Closely Related to Proposed Project

Roostaei, J., ***Zhang, Y.L.** “Spatially explicit life cycle assessment: opportunities and challenges of integrating algae cultivation with wastewater for biofuel production,” *Algal Research*, June 2017, pp. 395-402, <https://doi.org/10.1016/j.algal.2016.08.008>.

***Zhang, Y.L.**, Roostaei, J., Ochocki, A. “Stratified multilayer algae-biofilm reclamation technology (SMART) for enhancing algal biomass productivity/quality and pollution mitigation from wastewater and flue gas,” patent, filed in May 2016 (file No: 16-1367).

Zhang, Y.L., Habteselassie, M.Y., Resurreccion, E.P., Mantripragada, V., Peng, S.S., Bauer, S., Colosi, L.M. “Evaluating removal of steroid estrogens by a model alga as a possible sustainability benefit of hypothetical integrated algae cultivation and wastewater treatment systems,” *ACS Sustainable Chemistry & Engineering* (2014), 2 (11), pp. 2544-2553. doi: 10.1021/sc5004538.

Zhang, Y.L., White, M.A., Colosi, L.M. “Environmental and economic assessment of integrated systems for dairy manure treatment coupled with algae bioenergy production,” *Bioresource Technology*, 130, pp. 486-494, 2013, doi: 10.1016/j.biortech.2012.11.123.

Zhang, Y.L., Liu, X.W., White, M.A., Colosi, L.M. “Economic evaluation of algae biodiesel based on meta-analyses,” *International Journal of Sustainable Energy* (2015) doi:10.1080/14786451.2015.1086766.

(ii) Five Other Significant Products

Treemore-Spears, Lara J., et al., **Zhang, Y. L.** "A workshop on transitioning cities at the food-energy-water nexus." *Journal of Environmental Studies and Sciences* 6.1 (2016): 90-103.

Zhang, Y.L., Colosi, L.M. “What are we missing by focusing on algae biodiesel?” *Biofuels* (2013), 4 (60), pp. 591-593 (Invited Editorial). doi:10.4155/bfs.13.52.

Colosi, L.M., Resurreccion, E.P., **Zhang, Y.L.** “Assessing the energy and environmental performance of algae-mediated tertiary treatment of estrogenic compounds,” *Environmental Science: Processes & Impacts*, 17, pp. 421-428, 2015, doi: 10.1039/C4EM00541D.

Zhang, Y.L., Marrs, C.F., Simon, C., Xi, C.W. “Wastewater treatment contributes to selective increase of antibiotic resistance among *Acinetobacter* spp.,” *Science of the Total Environment*, 407(12), pp. 3702-3706, 2009, doi: 10.1016/j.scitotenv.2009.02.013.

Xi, C.W., **Zhang, Y.L.**, Marrs, C.F., Ye, W., Simon, C., Foxman, B., and Niragu, J. “Prevalence of antibiotic resistance in drinking water treatment and distribution systems,” *Applied and Environmental Microbiology*, 75(17), pp. 5714-5718, 2009, doi: 10.1128/AEM.00382-09.

D. SYNERGISTIC ACTIVITIES

- **Student mentoring:** currently mentoring three PhD students, one postdoctoral researcher, and five undergraduate students in algae-based biotechnology development and life cycle modeling.
- **Research and outreach activities:** Serve for a number of research, education, and out-reach programs funded by U.S. EPA and National Science Foundation, including: PI of EPA funded project “Stratified Multilayer Algae-Biofilm Reclamation Technology (SMART) with the Internet of Things (IoT)””; senior personnel of NSF funded research/training program “NRT: Transformative Research in Urban Sustainability Training””; core member of NSF funded REU site (Summer Academy in Sustainable Manufacturing); core member of NSF funded “Huron to Erie Alliance for Research and Training Field Station Improvements for Urban Watershed Research and Education””; director of the Healthy Urban Waters research station at the Great Lakes Water Authority Water Treatment Plant; co-director of “Sustainable Engineering” program at Wayne State University; core member of The Flint Area Community Health and Environment Partnership; core member of the “2+2 Water” education and research program in WSU and MaComb Community College; core member of Urban Watershed and Environmental Research Group at WSU.
- **Education and outreach activities:** Detroit Climate Action Collaborative - Climate Change Youth Summit; STEMinista female role model at the Michigan Science Center; Future City Competition; Michigan SMart Competition; WSU Sciences Saturdays.
- **Journal service:** paper review for *Water Research*, *Water Science and Technology*; *Water Supply*, *Environmental Science and Technology*, *DOE’s National Algal Biofuels Technology Review*; serve as the Associate Editor for the journal of MOJ Civil Engineering; serve in the editorial board of *Journal of Advanced Civil Engineering Practice and Research*, and *Austin Tissue Engineering*;
- **Conference organizing committee:** AEESP 2017 conference, Ann Arbor, MI, USA, June 20-22, 2017; World Summit on Recycling and Environmental Management, Malaysia, May 22 -24, 2017; International Conference on Sustainable Civil Engineering, Cape Town, South Africa, June 20-21, 2016.



November 27, 2017

The Honorable Rick Snyder
Governor, State of Michigan
Romney Building
111 S. Capitol Avenue
P.O. Box 30013
Lansing MI 48909
USA

Dear Governor Snyder:

This agreement, which is signed today between Enbridge and the State of Michigan, sets forward a plan to improve coordination between Enbridge and the State for the operation and maintenance of Enbridge's Line 5 pipeline located in Michigan, while providing enhanced transparency to the citizens of Michigan.

Enbridge is committed to the letter and spirit of this important agreement and to the actions outlined in the agreement that move us toward a longer-term set of decisions about the future of pipeline operations. We strongly affirm our recognition of the Great Lakes as an international treasure that must be preserved now and for future generations.

We appreciate the emphasis that you, other state leaders and the public place on the stewardship responsibilities that come with being part of the Great Lakes community. We also will do our part through the meaningful and concrete actions contained in this agreement.

Sincerely,

A handwritten signature in black ink, appearing to read 'Al Monson', written in a cursive style.

**AGREEMENT BETWEEN THE STATE OF MICHIGAN AND ENBRIDGE ENERGY,
LIMITED PARTNERSHIP AND ENBRIDGE ENERGY COMPANY, INC.**

This Agreement is entered between the State of Michigan (referred to herein as “the State”), AND Enbridge Energy, Limited Partnership and Enbridge Energy Company, Inc., formerly known as Lakehead Pipe Line Company, Inc. (collectively referred to herein as “Enbridge”) concerning those segments of Enbridge’s Line 5 that are located within the State of Michigan.

WHEREAS, the segments of Line 5 located within Michigan extend 547 miles, from the border of Wisconsin near Ironwood, Michigan to Marysville, Michigan, where it crosses the St. Clair River to the border with Sarnia, Ontario (“St. Clair River Crossing”);

WHEREAS, the segments of Line 5 located within Michigan must be operated and maintained in compliance with all applicable laws that are intended to protect the public health, safety, and welfare and prevent pollution, impairment, or destruction of the natural resources of the State of Michigan, including the unique resources of the Great Lakes;

WHEREAS, the continued operation of Line 5 through the State of Michigan serves important public needs by providing substantial volumes of propane to meet the needs of Michigan citizens, supporting businesses in Michigan, and transporting essential products, including Michigan-produced oil to refineries and manufacturers;

WHEREAS, the State issued an “Easement” to Lakehead Pipeline Company, Inc. (“Lakehead”), subsequently renamed Enbridge Energy Company, Inc., on April 23, 1953 pursuant to Act No. 10, PA 1953 “for the purpose of erecting, laying, maintaining and operating” an approximate 4-mile segment of Line 5 across the Straits of Mackinac (“Straits”) upon determining that such crossing would “be of benefit to all of the people of the State of Michigan and in furtherance of the public welfare”;

WHEREAS, in accordance with the Easement, Enbridge constructed two parallel pipelines, each 4.09-miles long (referred to herein as the “Dual Pipelines”) across the Straits in 1953 (referred to as the “Straits Crossing”), and since that time continues to operate and maintain such pipelines as part of Line 5;

WHEREAS, the State and Enbridge recognize that the Straits Crossing and the St. Clair River Crossing are located in the Great Lakes and connecting waters that include and are in proximity to unique ecological and natural resources that are of vital significance to the State and its residents, to tribal governments and their members, to public water supplies, and to the regional economy and the Crossings are also present in important infrastructure corridors;

WHEREAS, the State and Enbridge recognize that other important ecological and natural resources are located near other segments of Line 5 that cross or approach other waters of the State that are also of vital significance to the State and its residents, to tribal governments and their members, to public water supplies, and to the regional economy;

WHEREAS, the State and Enbridge desire to establish additional measures and undertake further studies with respect to certain matters related to Enbridge's stewardship of Line 5 within Michigan and the transparency of its operation;

WHEREAS, the State acknowledges that the stipulations specified in this Agreement are intended to further protect ecological and natural resources held in public trust by the State of Michigan, and that the terms of this Agreement will serve Enbridge's interest by providing clarity as to State's expectations concerning the safety and integrity of Line 5;

NOW, THEREFORE, the parties further agree as set forth below.

I. STIPULATIONS

Enbridge and the State agree to the following measures, which are designed to increase coordination between the State and Enbridge concerning the operation and maintenance of Enbridge's Line 5 pipeline located in the State of Michigan, including enhancing its operation in the interest of the citizens of Michigan.

A. Increased Coordination Between the State and Enbridge: In order to enhance coordination with the State concerning the operation and maintenance of Line 5 located in the State of Michigan, and to facilitate the implementation of the measures described at Paragraphs B-G below, the Parties agree as follows:

1. The State will provide in a timely fashion and at its own costs, personnel to participate in the Evaluations and Assessments specified in Paragraphs D-G, and will initially designate such personnel within 30 days of execution of this Agreement. In the event that the State does not designate such personnel by the time that Enbridge is ready to move forward with such Evaluations and Assessments, Enbridge may proceed with initiating the Evaluations and Assessments specified in Paragraphs D-G before the State has designated personnel to participate, provided that Enbridge will update such personnel on any work done prior to their participation.
2. The State will further provide designated representatives to participate in the stewardship and transparency consultations and communications to be carried out under this Agreement.

3. Enbridge will provide the State's representative with the opportunity to fully and directly participate in the preparation of Studies and Assessments specified in Paragraphs D-G below. As part of this effort, Enbridge will make available to the State's representative data and other materials generated under this Agreement, including but not limited to geologic, engineering, or other technological information concerning Line 5 located in the State of Michigan and Enbridge's implementation of the measures described herein. Enbridge will also make available to the State all requested information concerning the operation, integrity management, leak detection, control room operations, and emergency preparedness for Enbridge's Line 5 pipeline located in the State of Michigan. Enbridge and the State agree to work cooperatively to identify the nature and scope of the information to be provided, focusing on that which is most relevant to the State's interests.
4. Enbridge will facilitate the ability of State-designated representatives to participate in semi-annual reviews that Enbridge agrees to conduct to assess the operating plans for Enbridge's Line 5 located within the State of Michigan.
5. Enbridge and representatives designated by the State agree to meet semi-annually to discuss any changes to engineering parameters, risks, new technologies, and innovations pertaining to the operation and maintenance of Line 5 located within the State of Michigan and the U.S. portion of the St. Clair River Crossing.

B. Replacement of Line 5 St. Clair River Crossing: Enbridge will seek all US and Canadian authorizations and approvals (hereinafter "authorizations and approvals") necessary to replace Line 5's crossing of the St. Clair River ("St. Clair River Crossing") by the use of a horizontal directional drill ("HDD") method as expeditiously as practicable. Enbridge will begin compiling the information to support all applications for the authorizations and approvals necessary for the replacement of the St. Clair River Crossing upon the execution of this Agreement. By December 31, 2017, Enbridge will request pre-application consultations with the US regulatory agencies for which such pre-application consultations are necessary regarding the contents and requirements for the US authorizations and approvals for the replacement of the St. Clair River Crossing. Enbridge will report to the State the status of Enbridge's efforts to prepare applications for the US authorizations and approvals following completion of pre-application consultations. By February 28, 2018, Enbridge will file applications to seek all permits issued by the State of Michigan and by any of its political subdivisions necessary for the replacement of the St. Clair River Crossing, excluding those State of Michigan applications that are filed jointly with US federal agencies, including but not limited to the U.S. Army Corps of Engineers. No later than 240 days of the date on which this Agreement is fully executed, Enbridge will file

applications to seek all US federal and Canadian authorizations and approvals necessary for the replacement of the St. Clair River Crossing. No later than 180 days after obtaining all authorizations and approvals necessary to replace Line 5's crossing of the St. Clair River by the use of a HDD method, Enbridge will initiate the work necessary to replace that segment of Line 5.

C. Discontinuation of Line 5 Operations in the Straits During Sustained Adverse Weather Conditions: Enbridge will temporarily shut-down the operation of the Dual Pipelines while "Sustained Adverse Weather Conditions," as that term is defined in Appendix 1 to this Agreement, remain in effect in the Straits. The procedure that Enbridge is to employ during the presence of Sustained Adverse Weather Conditions is set forth in Appendix 1.

D. Evaluation of Underwater Technologies to Enhance Leak Detection and Technologies to Assess Coating Condition of the Dual Pipelines: Enbridge will provide the State with a copy of the report that is required to be prepared and submitted to the United States in accordance with Paragraphs 81-83 of the federal consent decree to assess the feasibility of installing an alternative leak detection system at the Straits (the "Consent Decree Report"). In accordance with Paragraph I.A.3 of this Agreement, Enbridge will provide the State's representative with the data used to generate the Consent Decree Report, and Enbridge will make the authors of that Consent Decree Report available to discuss its contents with the State's representative. Further, by June 30, 2018, Enbridge will review and assess any additional technologies that are not assessed in the Consent Decree Report to determine whether such other technologies would provide a viable additional benefit over and above the technologies that are already in place on the Dual Pipelines or those that Enbridge plans to implement to detect leaks as a result of the Consent Decree Report. Enbridge will also assess at the same time any technologies not currently in place that would allow it to detect damage to the coating of the Dual Pipelines. To the extent that Enbridge identifies any studied technologies that provide a viable additional benefit to detect leaks or damage to the coating of the Dual Pipelines, Enbridge will: (i) by August 30, 2018, file the necessary applications to seek all authorizations and approvals necessary to install or apply such technologies; (ii) proceed with the installation or application of such technologies no later than 365 days after receiving all approvals and authorizations necessary for their installation, or, to the extent that no approvals or authorizations are required, as expeditiously as practicable following the identification of the technologies.

E. Evaluation and Implementation of Measures to Mitigate Potential Vessel Anchor Strike: No later than June 30, 2018, Enbridge will complete a report that assesses options to mitigate the risk of a vessel's anchor puncturing, dragging, or otherwise damaging the Dual Pipelines. That report will, at a minimum, assess the following options: (i) measures to enhance shipping communication and warning technologies; and (ii) the use of protective barriers to further protect the Dual Pipelines from any risks posed by a vessel anchor coming into direct

contact with the Dual Pipelines. The report will assess the costs and engineering considerations associated with each alternative, as well as the potential environmental impacts that may result from the construction, operation, and maintenance of the alternatives. The report shall also identify a proposed timeline for seeking all regulatory approvals. Enbridge shall proceed with detailed design and installation of the most appropriate option within 180 days of receiving all authorizations and approvals necessary for the construction of that option.

F. Evaluation of Alternatives to Replace the Dual Pipelines: No later than June 15, 2018, Enbridge will prepare a report assessing the replacement of the Dual Pipelines across the Straits. That report will, at a minimum, include an assessment of the following alternatives: (i) placing a new pipeline or pipelines in a tunnel under the Straits; (ii) installing a new pipeline or pipelines under and across the Straits by the use of an HDD method; and (iii) installing a new pipeline or pipelines across the Straits with an open-cut method that includes secondary containment. The report will assess the costs and engineering considerations associated with each alternative, as well as the potential environmental impacts that may result from the construction, operation, and maintenance of the alternatives. The report will further identify the approvals or authorizations that would be necessary to construct, operate, and/or maintain each studied alternative.

G. Evaluation of Line 5 Water Crossings Other Than the Straits: Enbridge will work in coordination with a representative to be designated by the State to identify and evaluate water crossings by Line 5, other than the Straits, to assess measures to minimize the likelihood and/or consequences of a release at each water crossing location. No later than June 30, 2018, Enbridge will prepare and submit to the State plans that prioritize water crossings jointly identified by Enbridge and the State and that specify measures to minimize the likelihood and/or consequences of a release from Line 5 into such prioritized water crossings. The plans will include a schedule for implementing the measures described therein following Enbridge's receipt of all necessary authorizations and approvals.

H. Potential Further Agreement Concerning Pipelines Across the Straits: The State and Enbridge agree to initiate discussions, as soon as practicable following the completion of the evaluations required under Paragraphs D-G above, regarding a potential further agreement to address issues concerning actions related to pipelines across the Straits, with a goal of executing such an agreement by August 15, 2018.

II. AMENDMENT

The State or Enbridge may propose in writing that this Agreement be amended. The State and Enbridge agree to consult in good faith in an effort to reach agreement on any proposed amendment. Any amendment agreed to by the State and Enbridge shall be effective on the date that any written amendment is executed by the State and Enbridge.

III. DISPUTE RESOLUTION

The State and Enbridge agree that, should any dispute arise under this Agreement, the State and Enbridge shall in good faith attempt to resolve the dispute through informal negotiations. If the parties are unable to informally resolve such a dispute, either party may initiate proceedings in a court of competent jurisdiction to resolve the dispute.

IV. TERM AND TERMINATION

The terms of this Agreement shall remain in effect until the commitments in Paragraphs I. B and I.D.-G above are fulfilled, except that the obligations in Paragraphs I.A and I.C shall continue unless and until the Agreement terminates automatically. This Agreement shall terminate automatically upon: (i) the permanent discontinuation of service by Enbridge on the Dual Pipelines; or (ii) placing into operation a replacement pipeline or pipelines across the Straits that has been approved by the State pursuant to applicable permitting procedures.

V. COMPLIANCE WITH APPLICABLE LAW

The State and Enbridge acknowledge and agree that Enbridge's operation of Line 5 remains subject to the requirements of all applicable state and federal law, the Easement, the September 3, 2015 Agreement with the State that prohibits Enbridge from transporting heavy crude oil on Line 5 within the State of Michigan, and the terms of any easement granted by the State for Line 5 and agree that nothing in this Agreement is intended to relieve Enbridge of its obligation to comply with or waive any rights that Enbridge and the State may have under such laws or to supersede or displace applicable state law, regulation or requirement, or any federal law, regulation, or requirement that is applicable to the operation or maintenance of Line 5, including but not limited to the Pipeline Safety Act (including its preemption provisions); the Protecting Our Infrastructure of Pipelines and Enhancing Safety Act of 2016 (Public Law 114-183); any regulation or order issued by PHMSA or any other federal agency; or the Consent Decree entered into between Enbridge and the United States, in *United States v. Enbridge Energy, Limited Partnership, et al.*, No. 1:16-cv-914, ECF No. 14 (E.D. Mich., entered May 23, 2017), which specifies certain investigation, integrity management, leak detection, valve

placement, and emergency response measures to prevent discharges of oil or hazardous substances into or upon the waters of the United States or adjoining shorelines.

VI. ENTIRE AGREEMENT

This Agreement constitutes the whole of the agreement between the parties concerning the matters addressed in this Agreement.

VI. EXECUTION

This Agreement may be executed in counterparts without the necessity that the Parties execute the same counterpart, each of which will be deemed an original but which together will constitute one and the same agreement. The exchange of copies of this Agreement by electronic or hard-copy means shall constitute effective execution and delivery thereof and may be used in lieu of the original for all purposes.

FOR THE STATE OF MICHIGAN



Name: Rick Snyder

Title: Governor

Dated: 11/27/2017

FOR ENBRIDGE ENERGY, LIMITED
PARTNERSHIP

BY: ENBRIDGE PIPELINES (LAKEHEAD)
L.L.C. AS GENERAL PARTNER



Name: Bradley F. Shamla

Title: Vice President, U.S. Operations

Dated: 11/27/2017

FOR ENBRIDGE ENERGY COMPANY,
INC.



Name: Bradley F. Shamla

Title: Vice President, U.S. Operations

Dated: 11/27/2017

Appendix 1

Enbridge Line 5 – Sustained Adverse Weather Conditions Procedure

This Appendix is designed to facilitate an effective emergency response to a potential release incident by specifying procedures for a systematic approach by Enbridge to temporarily shut down Line 5 in the Straits of Mackinac during Sustained Adverse Weather Conditions. Enbridge shall maintain a record of its use of the procedure and make it available to the State. If an alternate near-real time data point becomes available following the execution of this agreement, Enbridge shall notify the State in writing of Enbridge's intent to use alternate data sources and the parties will work cooperatively to revise this Appendix to account for the alternative data source.

Definitions:

Sustained Adverse Weather Conditions: Conditions in which median wave heights in the Straits of Mackinac over a continuous 60-minute period are greater than 8 feet based on "Near-real Time Data," or in its absence "Modeled Data."

Near-real Time Data: The wave height data derived from Buoy 45175 (Mackinac Straits West) of the Great Lakes Research Center of Michigan Technological University's Upper-Great Lakes Observing System (UGLOS).

Modeled Data: Modeled wave height data based on real-time data inputs that is available on the NOAA Great Lakes Coastal Forecasting System (GLCFS) Nowcast model at a representative point in the Straits.

Forecasted Data: Data available on the NOAA Great Lakes Coastal Forecasting System Forecast model at a representative point in the Straits.

Enbridge Line 5 Procedures – Sustained Adverse Weather Conditions

Step #	Action
1	Enbridge or Enbridge Consultant (collectively "Enbridge Monitor") will continuously monitor Near-real Time Data, or in its absence Modeled Data, to identify Sustained Adverse Weather Conditions at the Straits.
2	When Sustained Adverse Weather Conditions are forecasted based on Forecasted Data, the Enbridge Monitor will inform the Control Center Operations Shift Supervisor, at which point the Control Center Operations will prepare for the potential that an unplanned shut down of Line 5 at the Straits may be required.
3	When Near-real Time Data, or in its absence Modeled Data, indicate that Sustained Adverse Weather Conditions are occurring at the Straits, the Enbridge Monitor will immediately contact the Control Center Operations Shift Supervisor.
4	The Control Center Operations Shift Supervisor will promptly call the Enbridge Great Lakes On-Call Manager to advise them that Sustained Adverse Weather Conditions exist at the Straits.

5	The Enbridge Great Lakes On-Call Manager will request, no later than 15 minutes after being notified in Step #4 above, that the Control Center Operations shutdown Line 5. If real time conditions in the Straits determined by the Enbridge Great Lakes On-Call Manager indicate Sustained Adverse Weather Conditions do not exist, the Great Lakes On-Call Manager will advise the Control Center Operations Shift Supervisor that Line 5 should not be shutdown. In that event, the Enbridge Monitor will continue to monitor conditions as per Step 1 for changes that indicate that Sustained Adverse Weather conditions may be present and the other Steps in this Appendix shall be followed should the Enbridge Monitor determine that such conditions are present.
6	Unless advised otherwise by the Enbridge Great Lakes On-Call Manager as per step 5 above, Control Center Operations will perform a controlled emergency shut down of Line 5 and isolate the segment across the Straits.
7	While shut down, the Enbridge Monitor will continuously monitor Near-real Time Data, or in its absence Modeled Data, to identify the continuance of Sustained Adverse Weather Conditions at the Straits.
8	When Near-real Time Data, or in its absence Modeled Data, indicates the Sustained Adverse Weather Conditions no longer exist at the Straits, the Enbridge Great Lakes On Call Manager and Control Center Operations Admin On Call will authorize the restart of Line 5.
9	Control Center Operations will safely restart Line 5.

Questions and Answers

Agreement with Enbridge Energy, Inc., regarding Line 5

Nov. 27, 2017

Q: Why did the state demand this agreement from Enbridge Energy, Inc.?

Continuing disclosures by Enbridge regarding damage to the Line 5 coating beneath the Straits of Mackinac have underscored the need for improved stewardship of the pipeline by Enbridge and increased action by the State. Business as usual is no longer acceptable. This agreement demands specific actions of Enbridge with hard deadlines for each action to make certain there is the proper level of active examination, immediate safety improvements and increased transparency for Line 5. The evaluation of Line 5 being conducted by the Michigan Agency for Energy, the Michigan Department of Environmental Quality and the Michigan Department of Natural Resources will continue, ending with a final decision from the State on the future life expectancy of Line 5 on a clear timeline. The measures outlined in this agreement will provide greater safeguards while that evaluation continues.

Q: What specific State concerns does this agreement address?

Transparency: Gov. Rick Snyder has said the lack of transparency is a significant concern in the State's dealing with Enbridge. This agreement puts state-appointed experts shoulder-to-shoulder with the company during significant study and implementation milestones so the State can independently verify the findings and be assured that any and all information is made available in a timely manner.

Timeliness: C. Heidi Grether, director of the Department of Environmental Quality, has said the state will continue to evaluate thoroughly all the information Enbridge provides as the DEQ reviews the company's application to install more anchors along the pipeline. Having the latest information available in a timely manner will allow the DEQ to make the best-informed decision regarding the anchor application. It also requires Enbridge to meet regularly with the State to review operations, any changes, etc.

Truthfulness: Valerie Brader, executive director of the Michigan Agency for Energy, says the rules set in this agreement go a long way toward making sure Enbridge is giving the state the latest, most accurate information about the pipeline's condition. New monitoring techniques will provide timely, scientific data on the condition of the pipeline, its anchors and its protective exterior coating. Independent of the agreement, Enbridge is expected to give a full accounting of the status of Line 5 at the Dec. 11 meeting of the Pipeline Safety Advisory Board meeting in Lansing.

Stewardship: Keith Creagh, director of the Department of Natural Resources, has said the state has concerns about Enbridge's stewardship of the pipeline and possible effects on Michigan's natural resources. The agreement calls for Enbridge to evaluate Line 5 crossings of other bodies of water throughout the state. At the same time,

Enbridge's decision to tunnel below the St. Clair River is a first step in the right direction for protecting the Great Lakes. Also, studying how best to avoid an anchor snag of the Line 5 pipes in the Straits of Mackinac, which the independent Alternatives Analysis identified as a major threat to the twin pipes, is expected to lessen the possibility an accidental anchor drop will create a situation where oil and natural gas liquids may spill into the water of the Great Lakes.

Safety: Chris Kelenske, deputy state director of Emergency Management and Homeland Security and commander of the Michigan State Police, Emergency Management and Homeland Security Division, has stated that it's imperative Enbridge do the right thing to protect Michigan's natural resources. In addition to the many studies for improvements detailed in the agreement, it provides for a shutdown of the Straits pipeline when weather conditions would not allow for response to an oil spill. This is an immediate improvement in Line 5 safety.

Q: What portions of the pipeline in addition to the Straits are addressed in the agreement?

Every portion. The agreement mandates that Enbridge replace by means of horizontal directional drilling the portion of Line 5 that crosses beneath the St. Clair River, a location where this action can be quickly accomplished. The St. Clair River is a primary source of drinking water and an environmentally sensitive location on the pipeline. In addition, the agreement mandates that Enbridge, in partnership with the State, evaluate other Line 5 water crossings in Michigan and identify additional measures that would minimize the likelihood and consequences of an oil spill at those locations, then implement the identified measures.

Q: What does the agreement say about the portion of the pipeline that runs beneath the Straits of Mackinac?

The agreement mandates that Enbridge undertake, in partnership with the State of Michigan, a study of alternatives to the current Straits pipeline. Specifically, the study must explore: placement of pipeline (s) in a new tunnel beneath the Straits of Mackinac; installation of a new pipeline across the Straits using horizontal directional drilling; and installation of a new pipeline across the Straits with an open-cut trenching method that includes secondary containment.

Q: What other actions does the agreement require of Enbridge at the Straits of Mackinac?

The agreement demands that Enbridge:

- Temporarily shut down operation of Line 5 in the Straits during periods of sustained adverse weather conditions, because those conditions do not allow watercraft and equipment to respond effectively to potential oil spills. "Sustained adverse weather conditions" are defined in an appendix of the agreement.

- Implement technologies to improve the safety of Line 5 in the Straits by allowing for a more immediate response in the event of a spill. Those technologies to be assessed include underwater cameras to monitor the pipeline.
- Evaluate and implement measures to mitigate a potential vessel anchor strike on Line 5 beneath the Straits. A vessel anchor strike was identified in the final alternatives analysis as one of the most serious threats to the safety of Line 5 in the Straits.

Q: What's to ensure that Enbridge complies with these demands?

The agreement – which can be found in full on the Pipeline Safety Advisory Board website – is legally binding and includes specific deadlines for each mandated action. Enbridge will be in legal breach of the agreement if the company fails to perform each action by its deadline. The State will hire its own experts to monitor Enbridge's actions and review and verify the company's data. The agreement requires the company to cooperatively identify and make available to the State relevant information regarding the operation of Line 5.

Q: What's next?

The state has released a final independent Alternatives Analysis. The public will have a 30-day period to review and comment on this analysis, including at three public comment sessions around the state. In addition, the State is finalizing a contract with a team of top scientists from Michigan Technological University and other colleges and universities in Michigan to undertake an independent Risk Analysis. The state will consult with Michigan's tribal governments about the pipeline. Those analyses, along with the just-signed agreement, will inform the State's decision about the future of Line 5. A date for that decision has not been set. In addition, the following deadlines are mandated in the agreement:

Nov. 27, 2017: Start date for Enbridge to temporarily shut down the operation of Line 5 in the Straits of Mackinac during periods of sustained adverse weather conditions as defined in the agreement.

Dec. 31, 2017: Deadline for Enbridge to request pre-application consultations with U.S. regulatory agencies for necessary approvals to replace Line 5 at the St. Clair River Crossing.

Feb. 28, 2018: Deadline for Enbridge to file applications to seek permits issued by the State of Michigan – and any local governments within the state -- that are necessary for replacement of the St. Clair River Crossing. This does not include applications filed jointly by state government and federal government.

June 15, 2018: Deadline for Enbridge to complete a report on alternatives to the current pipeline beneath the Straits of Mackinac.

June 30, 2018: Deadline for Enbridge to assess technologies addressed in the Consent Decree Report to determine if those technologies would provide additional benefits over and above technologies already in place at Line 5. If no authorizations are necessary, Enbridge will proceed with installation of identified technologies as soon as possible.

June 30, 2018: Deadline for Enbridge to complete a report on options to mitigate risk of a vessel anchor damaging Line 5 in the Straits. Enbridge will proceed with design and installation of the most appropriate option within 180 days of receiving all necessary authorizations and approvals.

June 30, 2018: Deadline for Enbridge to submit to the State a list of priority waters crossed by Line 5 – jointly identified by the State and Enbridge – and specific measures at each crossing to minimize the likelihood and consequences of an oil spill. The plans will include a schedule for implementing identified measures.

July 25, 2018: Deadline for Enbridge to file necessary applications to seek authorization to place new pipeline through horizontal directional drilling beneath the St. Clair River. Enbridge will proceed with replacement of Line 5 beneath the St. Clair River 180 days after obtaining all necessary permits.

Aug. 15, 2018: Goal for the State and Enbridge to execute an agreement regarding further actions on Line 5 at the Straits.

Aug. 30, 2018: Deadline for Enbridge to file all necessary applications to seek authorization to install and apply additional technologies at the Straits. Installation of those technologies must begin no later than 365 days after receiving all necessary approval and authorizations.

PIPELINE SAFETY ADVISORY BOARD



DEQ Director
Heidi Grether

MAE Executive Director
Valerie Brader

Proposed 2018 Meeting Dates

Date	Time	Location
March 12, 2018	1:30 – 3:30 PM	Location: TBA
July 9, 2018	9:00 AM – 3:30 PM	Location: TBA
October 15, 2018	1:30 – 3:30 PM	Location: TBA
December 10, 2018	1:30 – 3:30 PM	Location: TBA