FLOW
FOR LOVE OF WATER

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

August 4, 2017

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VIA ELECTRONIC SUBMISSION

FLOW (FOR LOVE OF WATER) SUPPLEMENTAL PUBLIC COMMENTS AND REPORT ON THE JOINT APPLICATION OF ENBRIDGE ENERGY TO OCCUPY GREAT LAKES BOTTOMLANDS FOR ANCHORING SUPPORT STRUCTURES AND IMPROVEMENTS FOR LINE 5 PIPELINES IN THE STRAITS OF MACKINAC AND LAKE MICHIGAN [2RD-DFDK-Y35G]

Dear Michigan Department of Environmental Quality Director Grether; GLSL Unit Chief Milne; and GLSL Unit Specialist Graf; Acting Chief Fish; Analyst Rasmusson; other State Officials; and staffs:

For Love of Water (FLOW) submitted formal comments, together with technical reports and other attachments, during the public comment period on the above matter ending June 29, 2017. Those comments and reports, together with previous reports, are incorporated by reference as part of the public record. As a result of a large number of requests by interested persons and organizations, the Michigan Department of Environmental Equality ("DEQ") noticed and scheduled a public hearing and extended public comment pursuant to Section 32504 of the Great Lakes Submerged Lands Act ("GLSLA"), MCL 324.32514(1). FLOW submits the following Supplemental Legal and Technical Comments, together with attached supplemental technical reports and information, as part of the public record, and in support of its comments at the public hearing.

I. SUPPLEMENTAL LEGAL AND TECHNICAL COMMENTS

A. The 1953 "Easement" by Its Nature Is Revocable

As previously concluded, the nature of the 1953 Easement authorized by Act 10[1] is only a license or easement-in-gross; that is, the easement is personal property.[2] The Easement is revocable because of the nature of the easement and the legal conclusion that it is subordinate to the paramount public trust interest in the Great Lakes and the state's perpetual duty to protect the public trust. This inherent state power to revoke the easement because of harm or unacceptable risk to the public trust is separate from and in addition to the rights of the state to terminate under the terms of the Easement.[3]

Further, while Act 10 delegated the authority to the Department of Conservation to grant an "easement" on public trust bottomlands, it did not and could not waive the due recorded findings required of the Department to comply with the narrow exception to the prohibition of grants of occupancy or use of the bottomlands and waters of the public trust directed by *Illinois Central Railroad v Illinois*.[4] "The control over public trust bottomlands and waters can never be lost" except where (1) such parcels are to be used to promote the public interest in the lands and water remaining (i.e., a public trust interest or protected use), or (2) such interest can be granted that will "impair or substantially interfere" with the public trust interests and uses in such land and waters.[5] To date, the state has never made any "due finding" that comply with these exceptions to authorize the Easement under *Illinois Central Railroad*, the Great Lakes Submerged Lands Act ("GLSLA") of 1955, and the Michigan Supreme Court decision in *Obrecht v National Gypsum Company*.[6]

The 1953 Easement was and is subject to the public trust, which continues and is binding on the state and any party dealing with the state under public trust law. The public trust in these waters and bottomlands is reserved to the State of Michigan, and the state can exercise this continuing power to protect the public trust by modifying, revoking, or terminating the 1953 Easement. Specifically, the state reserved "all rights no specifically conveyed.[7] Moreover, the Easement" was granted "without warranty express or implied,"[8] was "subject to the terms and conditions herein set forth," and the Easement is confined to and limited by

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[1] Public Act 10, 1953.

[2] E.g. Some of Enbridge's pipeline easements are recorded as "personal" in the register of deeds office, Mackinac County. It is not known whether Enbridge has paid taxes on the Easement to State or to the local taxing authorities. See e.g. Section 32508, GLSLA, MCL 324.32508.

[3] 1953 Easement, Sec. C. at pp. 7-8. The Easement is subject to the contractual covenant by Lakehead Pipe Line Company (Enbridge) "at all times to exercise the due care of a reasonably prudent person" to protect public property (like public trust and public drinking water interests) and private riparian property and businesses from harm or injury constitute a basis for termination or revocation. Easement, Sec. A., pp. 3-4.

[4] 146 US 387, 453 (1892).

[5] *Id*; Great Lakes Submerged Lands Act, MCL 324.32502 and 32503; *Obrecht v. National Gypsum*, 361 Mich 399 (1960). The Michigan Supreme court affirmed the common law standards in Illinois Central and the standards contained in the Great Lakes Submerged Lands Act, and found the agreement for use of Lake Huron bottomlands for a commercial dock lacked the "due findings" of the public trust standards of the GLSLA and Illinois Central.

[6] *Id*. *Obrecht*, 361 Mich at 415-416.

[7] "All rights not specifically conveyed herein are reserved to the State of Michigan." 1953 Easement, Section M, p. 11.

[8] *Id*., p. 2.

the "detailed plans and specifications" filed with the Department.[9] Further, there is no provision authorizing an amendment or modification of the Easement.[10]

B. A Plain Reading of the Great Lakes Submerged Lands Act Requires Enbridge to Obtain a Permit for Conveyance or Occupancy Agreement for Structures and Improvements, Including the New Anchor and Pipeline Supports Design and Specifications That Are Not Part of the Specifications and Design Approved in 1953.

As noted above, the state reserved and granted the Easement subject to public trust doctrine and authorized the use of bottomlands for the twin pipelines only as specified and designed and approved by the Department. The design and specifications required the pipeline to anchor or rest on the bottomland with the limitation that no length of the pipeline or span could be unsupported by bottomlands that exceeded 75 feet.[11] The recent addition of the new screw-anchor and bracket design structures for the pipeline was not contemplated or authorized by the 1953 Easement. Rather this new or modified pipeline design is directly connected to the failure in design and specifications of the pipeline that has resulted in constant erosion of bottomlands beneath the lines, causing bending, pealing, and compromise of the lines integrity, and consequently serious risks of rupture or leak. This new or change in design for screw anchor brackets along the lines is also related to the increase in the flow rates of crude oil or NGL-- 300,000 barrels per day ("bbl") as originally approved to 490,000, and in the last few years from 490,000 bbl to 540,000 bbl.

Section 32502 of the Great Lakes Submerged Lands Act states in part:

> This part shall be *construed so as …* to *provide for the sale, lease, exchange, or other disposition of unpatented lands* and *to permit the filling* in of patented submerged lands whenever lands and waters…[12]

Section 32503(1) states in part:

> … [T]he department, after finding that the public trust will not be impaired or substantially affected, *may enter into agreements pertaining to* waters over and *the filling in* of submerged patented lands, or to lease or deed unpatented lands, after approval of state administrative board.[13]

Section 32505(2) states:

> The department may *permit* <u>*by lease or agreement*</u>, *the filling in* and *permanent improvements and structures*, after finding that the public trust will not be impaired or substantially injured.[14]

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[9] *Id*., pp. 4, 6.
[10] While the "Easement" allows for subsequent modifications, it can only be done by written approval by the State. *Id*., p. 4. Any such approval involving improvements or structures would require authorization in full compliance with Sections 32503 and 32505 and other parts of the GLSLA and its rules.
[11] Easement, C. (10), p. 5.
[12] MCL 324.32502.
[13] MCL 324.32503(1).
[14] MCL 324.32505(2).

Read together, Sections 32502, 32503, and 32505 plainly require agreements for conveyances or occupancy agreements for the *filling in* and *improvements* and *structures* on or in bottomlands and waters.

Enbridge has never obtained any agreement or other disposition for this new and/or modified design and expanded use of the pipelines in the Straits as the Great Lakes Submerged Lands Act. Accordingly, the state must require Enbridge to obtain authorization for occupancy and use of the bottomlands and waters of the Straits for the pipeline with this new screw-anchor and bracketed pipeline structure.

C. Enbridge Must Obtain an Agreement Authorizing Occupancy of These New "Structures" and "Filling in" and an "Activities" Permit.

1. Sections 32502, 32503(1), and 32505(2) Require Authorization and an Agreement for "Improvements," "Structures," and "Filling in."

Enbridge's significant modifications of its pipelines and screw-anchor support system constitute permanent "improvements," "structures" and "filling in" of bottomlands.

The GLSLA brought Michigan into compliance with the narrow exceptions for allowing private use of public trust waters and bottomlands set forth in *Illinois Central*.[15] Section 32502 through 32505(2) make it clear that the GLSLA is intended to require *leases or agreements to permit any new filling-in and improvements or structures.* The 22 screw-anchor supports are undisputedly new improvements and structures for the pipeline on bottomlands. They are necessary to shore up an unstable pipeline caused by mismanagement, neglect, and changing conditions that have increased the risk of excessive impairment or harm to the public trust, health, and safety. Enbridge's twin-pipelines in the open waters of the Straits are necessary and related to the increase to 540,000 bbl. of Line 5's entire flow rate of crude oil. The 1953 Easement and plans did not intend or contemplate screw-anchor supports.

Accordingly, in addition to the current request for an activity permit for placing spoils or other materials on bottomland under Section 32512(1)(c), Enbridge must apply for authorization for the screw-anchor and pipeline design structures and improvements. To date, Enbridge has not done so. As a result, Enbridge is in violation of the GLSLA, and is not in compliance with the standards for authorizing such improvements and structures within the narrow exceptions of the GLSLA, *Obrecht*, and *Illinois Central.*

Therefore, the Enbridge application for a permit under Section 32512(1) and Rule 1015 must also demonstrate that it is entitled to occupancy or other use agreement for authorization of these improvements, structures and/or filling in by this new or modified pipeline and screw-anchor support system.

2. Enbridge Must Also Obtain a Permit for Its Activity to Construct These Improvements, Structures, and Filling in as Required by Section 32512(1) (c) of the GLSLA.

Section 32512(1) prohibits certain construction activities, such as canals, connecting waterways, dredging or placing spoils, and marinas unless the activity is permitted under Section 32512(1)(c) states:

"Unless a permit has been granted…. a person shall not do any of the following:

(c) Dredge or place spoil *or other materials* on bottomland."[16]

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[15] *Illinois Central R.R.* 146 US 387 (1892); *Obrecht v. Nat'l Gypsum*, 361 Mich at 412-414 (1961).
[16] MCL 324.32512(1) (c).

The activities covered by Section 32512(1)(c) involve dredging or placement of materials such as spoils from dredging on bottomlands. However, in the 1980s, the Department adopted a definition of "materials" in Rule 1001(k) that added the word "structures." As a result, structures that require authorization or an agreement or conveyance permitting them to occupy bottomlands and waters must also comply with the activities permit required by Section 32512(1)(c). The inclusion of "structures" in the meaning of "other materials" in Section 32512 cannot be read to and does not replace or supplant the requirement for authorization of structures and improvements under Sections 32503 and 32505. The only way these sections can be reconciled is to read them together; that is, there is a requirement for both authorization by an occupancy agreement or conveyance under Sections 32503 and 32505 and for the activity of actually placing the structure under Section 32512(1)(c).

Therefore, the current application for a permit for construction activity to "place spoils or other materials" under Rule 1008 and 1015 does not satisfy this additional mandatory requirement for a lease or agreement to permit improvements and structures. For the reasons stated in FLOW's previous June 29, 2017 comments and these supplemental comments, the application requirements and standards for authorization of conveyance (or occupancy) for the screw-anchor brackets and pipelines improvements or structures and the activity of placing these "structures" on bottomlands have not been satisfied.

Parenthetically, it should be noted that this does not mean the state cannot take interim or permanent measures to halt the flow of crude oil within a reasonable period of time under the Easement or the GLSLA application, pending additional filings to comply with the requirements of the Act. The FLOW technical team has raised a number of risks concerning the current pipeline and the proposed screw-anchors in previously filed reports, as well as the attached supplemental reports by Ed Timm, Ph.D[17] and by Rick Kane,[18] a hazardous risk expert.

D. Enbridge Has Not Submitted a Comprehensive Environmental Assessment or Alternatives Study Showing the Full Potential Adverse Environmental Effects, No Impairment of the Public Trust, and That There Exists No Feasible and Prudent Alternative as Required by Sections 32502, 32503, 32505, and 32512 of the GLSLA and Rule 1015 and 1015(a), Section 1705(2) of the Michigan Environmental Protection Act ("MEPA"), *Vanderkloot,* and the Duty to Consider Impacts Under Public Trust Law.

As established above, Enbridge must submit a full, comprehensive environmental assessment of the overall threatened risks and potential adverse impacts and impairment to the public trust required by the GLSLA, and its Rules 1015, 105(a). Moreover, Michigan Constitution Art 4, Sec. 52 and the MEPA require a full and sufficient environmental evaluation or impact statement for the state to consider and determine likely effects on the state's paramount interests in the water, aquatic resources, such as fish and fish habitat, and the public trust in those resources.

As demonstrated by FLOW's June 29, 2017 comments, Enbridge's application does not address potential adverse impacts or demonstrate no impairment. Moreover, it fails to prove that there are no feasible and prudent alternatives to the high risk, failures, and lack of approvals for the continued use of these lines in the Straits, including the increases in flow rate of crude to 540,000 bbl as part of Enbridge's massive $2.6

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[17] Ed Timm, Ph.D., Technical Note: *An Analysis of Errors and Omissions in the Dynamic Risk Inc. Line 5 Alternative Analysis Option 5,* July 24, 2017, attached as Appendix A.
[18] Rick Kane, *Defining a Worst-Case Release Scenario for the Enbridge Crude Oil Pipelines Crossing the Straits of Mackinac,* Aug. 2, 2017, attached as Appendix B.

billion expansion of its overall Lakehead System into and through the Great Lakes, including Line 6b (now Line78) across southern Michigan.[19]

Apparently, it is the position of Enbridge, and possibly the DEQ, that Enbridge needs only to submit a bare-bones application for placement of "structures" as "other materials" under Section 32512(1) (c) and Rule 1015. Reportedly, in a tribal consultation meeting on July 14, 2017, state DEQ officials stated that they would confine the assessment of potential adverse impacts and any alternatives study and review to the small area of bottomlands surrounding the footprint of each screw-anchor pipeline support.[20]

This position is untenable and calculated to evade the law and facts that call for full impact and alternative analysis and review. The anchor supports are necessarily and related to the entire Straits pipelines segments to shore up these pipelines risks, failures, and the stress and bending that have compromised the integrity of these lines. As a matter of law, the DEQ has a legal duty to require Enbridge to prove no adverse impacts or impairment, and a legal duty to consider and determine the potential of such likely impacts under the GLSLA, public trust law, and MEPA. The plain meaning of the GLSLA and Rules 1015 and 1015(a) requires Enbridge to submit and demonstrate by a full environmental assessment of all "existing and potential adverse effects" that impacts will have only minimal likely adverse effects or impairment of the public trust applies to "any permit." Moreover, permits for the anchor structures to occupy bottomlands of the state are required in addition to the construction activity itself under Rule 1015. The DEQ, and presumably Attorney General's narrow interpretation of the scope of the assessment is contrary to law.

Further, for the reasons described in Sections A through C above, Enbridge must obtain authorization for any "structure" or "improvement" under Sections 32503 and 32505. The plain meaning of Section 32512(1)(c) and Rule 1015 prohibit any permit without a report on potential adverse impacts and a showing that there will be no impairment or interference, and that there exists no alternative to the screw-anchor bracket "improvement" or "structure" to the pipelines. Because these anchor supports are new, fall outside the Easement and its requirements, and are inseparable from the pipeline for its to operate, Enbridge must submit a full, comprehensive environmental assessment of the overall threatened risks and potential adverse impacts and impairment to the public trust required by the GLSLA and Rules 1015, 1015(a). Finally, as discussed above and in previous reports, Enbridge must submit a comprehensive report showing that there exists no alternative.

After consideration of the twin lines in the Straits, the Michigan Petroleum Pipeline Task Force and the Request for Proposal signed by the consultant with the state in the Pipeline Advisory Process identified the specific lack of and need for a comprehensive " independent assessment of risks and impacts" and alternatives.[21] Moreover, the Michigan Constitution Art 4, Sec. 52 and MEPA require a full and sufficient environmental evaluation or impact statement for the state to consider and determine likely effects on the state's paramount interests in the water, aquatic resources, such as fish and fish habitat, and the public trust in those resources.[22]

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[19] E.g. Enbridge Line 3 Replacement Underway in Wisconsin. http://www.superiortelegram.com/news/superior/4305512-enbridges-line-3-replacement-underway. Like it did before the MPSC and DEQ here in Michigan, Enbridge continues to segment this massive expansion project by pawning these segments as "maintenance" or "repair."

[20] See also July 20, 2017 letter to Director Grether, DEQ, from William Rastetter, Tribal Attorney, Grand Traverse Band of Ottawa and Chippewa Indians, at p. 2.

[21] Michigan Petroleum Pipeline Task Force Report, pp. 46-47; Independent Risk Analysis for Straits Pipeline, Draft Scope of Work, Michigan Pipeline Safety Advisory Board, Oct. 28, 2015, p. 1.

[22] See FLOW June 29, 2017 Comments, Sec. D., p. 11, footnotes 36-39, and accompanying text.

1. The Need for a Comprehensive Environmental Assessment Showing Potential Adverse Impacts, Magnitude of Harm and Risks, and No Impairment Is Even Greater.

FLOW's public comments filed June 29, 2017 established the requirement for and lack of a comprehensive environmental assessment of impacts. Since that time, the state scrapped the Det Norske Veritas Inc. ("DNV") draft risk report because of a conflict of interest created by Enbridge and the consultant who had contracted with the state. Moreover, the Dynamic Risk ("DR") "Draft Alternatives Analysis for the Straits Pipeline" acknowledges that DR's risk assessments of various threats to alternatives it considered "are not intended to represent a 'worst-case spill.'"[23] The lack of risk report creates a substantial void, which makes it difficult for the DEQ to consider or determine potential adverse impacts associated with the continued operation of Line 5 in the Straits with the screw-anchor support design and structures. As a result, there is no credible risk report showing the magnitude of potential impacts, harm and probability of failure, and there is no report showing that there will be no or only minor impairment or interference with the waters and related biota, public trust and riparian uses. High risk is a function of both likelihood and harm; the higher the magnitude of harm, the lower the corresponding threshold for establishing a probability or likelihood of such harm or impairment.[24]

Without the state's risk report, Enbridge has failed to show through a comprehensive environmental and risk assessment that it has satisfied the standards and requirements of the GLSLA and its rules, the MEPA, as wells as the duty to protect and preserve the public trust and specific public trust rights and uses, such as swimming, boating, fishing, and drinking water under the public trust doctrine.[25]

In order to address the lack of a credible risk assessment and better identify risks of potential adverse impacts, FLOW's technical experts have continued to evaluate magnitude of harm and risks since FLOW's June 29, 2017 comments. These assessments provide the Department and state officials with additional information on the compromised integrity and uncertain dangers of the Straits pipelines, and a credible worst-case scenario of impacts and harm.

(a) Dr. Ed Timm has submitted a submitted a supplemental technical report to the state.[26] This report, along with his previous analyses and documents filed with the state by Enbridge, shows that the integrity of the pipeline has been seriously compromised, the line is damaged, and the risk of a pipeline failure and serious harm and impairment to the Straits, environment, and public trust is high.

Dr. Timm's recent supplemental report on the DR Draft Alternatives Analysis for the Line 5 pipelines in the Straits concludes that the DR report is flawed and not credible.[27] However, in order to properly evaluate the DR Analysis, Dr. Timm conducted a careful examination of the

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[23] Dynamic Risk Draft Alternatives Analysis, June 27, 2017, p. 60 ("DR Draft Alternatives Report").
[24] E.g. *Ethyl Corp v. EPA*, 541 F2d 1, 18-20 (D.C. Cir. 1976)
[25] GLSLA Sections 23102-32505, 32512, GLSLA Rule 322.1001(m) ("public trust" means the perpetual duty of the state to secure to its people the prevention of pollution, impairment or destruction of its natural resources, and rights of navigation, fishing, hunting, and use of its lands and waters for other public purposes."). *Collins v Gerhardt,* 236 Mich 38 (1926); *Glass v Goeckel*, 473 Mich667, 694 (2005).
[26] Ed Timm, Ph.D., Technical Note: *An Analysis of Errors and Omissions in the Dynamic Risk Inc. Line 5 Alternative Analysis Option 5,* July 24, 2017, attached as Appendix A ("Timm July 24 Analysis of Errors and Omissions Report"), Risks, at pp. 1-8, Unsupported Spans, pp. 9-14, Span History of West (W 11) Line Dating from 2005, at pp. 19., Evidence of Damage to Line 5 under the Straits, at pp. 15-19, Other Pipeline Integrity Concerns, pp. 19-21.
[27] Id., Appendix A, p. 23.

risk analysis for these twin pipelines, including evidence of their damaged condition. The operating condition and risk of these twin-lines are constantly threatened from ship anchors, errors in operations, vortex-induced vibration, and spanning stress.[28] Currents, turbulence and gravity cause vibrations and bending, scouring and erosion underneath these lines where they were placed along the bottom of the Straits; this demonstrates a significant risk of failure; these currents and gravity have in turn caused erosion and resulted in long spans (as much as 286 feet)[29] of the pipeline that are unsupported by these bottomlands. Recently disclosed evidence from the Kiefner report documented long unsupported spans of pipeline and calculations about these structures.

Dr. Timm determined that these spans which have been a continuing problem over the years have compromised the integrity of these twin-lines from bending or plastic deformation beyond elastic limits.[30] Knowledge of "peak currents" is essential to determine the degree of deformation and bending, as well as scouring and erosion. This requires proper calculations in inputs into probability distributions, which is a function of fluid mechanics. The DR analysis failed to take current velocities and the effect on erosion and bending or deformation, and on closer examination Dr. Timm observed that the longer spans are affected by velocities that exceed the pipelines' original design velocity (2.25 mpg).[31] This means the pipeline's integrity has been compromised, and more importantly, that the original design of placing the lines along the bottom was compromised because of these higher-end velocities. In addition, DR notes its analysis that these stresses overtime increased the probability of failure; yet DR started its Monte Carlo probability analysis in the year 2018 (next year), not 1953 when these stresses actually began to occur and cause erosion, long unsupported spans, and likely deformation or bending.[32] In effect, DR ignored over 60 years of historical conditions and stresses of the underwater pipeline. Dr. Timm chronicles Enbridge's five historical periods of unsupported spans from currents and turbulence.[33]

When Dr. Timm sought to correct the errors in the DR report, he found that the DR model underpredicted most currents because it was based on data taken from periods of moderate weather. Moreover, it did not predict peak currents during severe weather combined with long unsupported spans of pipelines (despite Enbridge's efforts to reduce the spans by filling clay under and around the lines). Enbridge more recently has added screw-anchor supports with brackets, a completely new design for the pipeline that has never been tested.[34] The current Enbridge application for 22 more screw-anchor supports with brackets around the lines shows a continuing problem and risk of failure, and an admittedly new, significantly modified design from the one approved and constructed in 1953. This reality and numerous flaws in DR's probabilistic risk evaluation demands a full and careful reanalysis of these twin-lines in the Great Lakes, because of the increased, although unknown, probability of pipeline failure or rupture.[35]

[28] Appendix A, p. 1.
[29] Appendix A, Tables 2 and 3, p. 11.
[30] Appendix A, pp. 2-3.
[31] Appendix A, p. 3.
[32] Appendix A p. 3. See also Fig. 3, p. 6.
[33] Appendix A, Table 4, p. 12.
[34] Appendix A, Table 4.
[35] Appendix A, pp. 5-7.

Given the evidence of these stresses, forces, unsupported spans and bending, pipeline fatigue risks, the current application must be treated as a new, increased and significantly modified design that requires full evaluation as the law requires.

Moreover, when DR performed its Monte Carlo probability analysis, it looked at and calculated a result for each span location separately over time, and not both lines and all spans simultaneously, which represents more accurately real world conditions; as a result, DR made a mathematical error.[36] If the Straits sections of Line 5 are treated as a typical buried pipeline, Dr. Timm calculated the probability of pipeline failure in 2017 at 46.4 percent, and in 2053 at 72.5 percent.[37] As noted by Dr. Timm, quoting from DR's own report, "In a dynamic environment, characterized by changing water currents, span lengths and gap ratios, there is potential for maximum combined effective stress to vary with time… Under such conditions, the potential for plasticity (bending) creates potential for fatigue, under which conditions, progression to failure can occur after relatively few cycles." [38]

It is not surprising that there is documented evidence of damage to Line 5, including bends 10 and 11, east leg pipeline, and bends 9 through 13 along the west leg line.[39]

Dr. Timm also identified problems with girth welds and welding practices, coating integrity and compromised cathodic protection, thermal expansion and pipeline movement.

In short, the conditions of the Straits lines are already compromised, and the gravitational forces and currents will continue to cause damage. Moreover, in its application for a new and modified design, Enbridge has provided the DEQ no evaluation of the condition of the pipeline and the potential risks to environment, public health and safety, or the public trust in the Great Lakes. Critically, there is a high probability that this line will fail, this year or during the next few years. Even the erroneous 1:60 probability of failure in the DR analysis by 2053 is serious when combined with the high degree or magnitude of harm and damage.

(b) Rick Kane, hazardous risk management expert, has submitted technical reports showing that Enbridge and the consultants for the state as part of the Pipeline Safety Advisory Board ("PSAB") process have not submitted a valid or credible worst-case scenario.[40] Identifying the worst-case scenario is the starting point for risk assessment. To assist the DEQ, Mr. Kane in consultation with Gary Street analyzed and identified the proper approaches for a worst-case scenario and risks assessment, including identifying the potential or likely magnitude of harm in the event of a rupture, release, or slow, undetected leak from a failure of one or both of the lines in the Straits.[41]

The size of a spill is crucial to identifying risk, including magnitude of harm. To calculate a valid worst-case scenario, only "passive controls" should be considered. Passive controls are such things as secondary containment, but do not include sensors, shut-down or other mechanical and

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[36] Appendix A, pp. 13, Fig. 6.
[37] Appendix A, pp. 14-15.
[38] Appendix A, p. 15; DR Alternative Analysis Report, Ref1, p. TS-13.
[39] Id., p. 16-17, text and Fig. 7. Fig. 8 on page 18 shows significant deformation and bending from 1979 to 2016.
[40] Rick Kane, *Defining a Worst-Case Release Scenario for the Enbridge Crude Oil Pipelines Crossing the Straits of Mackinac*, Aug. 2, 2017, attached as Appendix B ("Kane Worst-Case Scenario Report").
[41] See Appendix B, Appendix D.

electrical and control systems, or procedures and emergency response actions. These active controls can be used for alternative scenarios, but they are not worst-case.

Under PHMSA worst-case scenario regulations, the pipeline operator need only calculate the size of a spill based on the understanding that the size of the spill would not exceed the largest release that the company's emergency response plan filed with PHMSA.[42] For Line 5, DR only analyzed the various threats and likelihood that such threats would occur, and as noted above did not conduct a worst-case scenario analysis. DR then evaluated a rupture from a 3-inch diameter hole in one of the 20-inch lines, releasing 2,600 barrels during a 10-minute detection by sensors, 30 seconds for shut-down detection, and 3 minutes for valve closure and response time ranging from 1.8 to 5.8 hours. DR calculated that a "reasonable" scenario would impact 20 miles of shoreline, with a 1:60 probability of occurrence within the next 35 years.[43] This is similar to Enbridge's assumptions in filing its "worst-case discharge" based on its "operator's best estimate" as "adjusted for any subsequent corrective or preventive action taken."[44] In both instances, the worst-case represents an estimate with adjusted discharge determined by the operator Enbridge.

Enbridge's actual emergency response plan filed with PHMSA is not available because it is claimed to be protected from disclosure based on a sensitive security matter. However, enough of the response plan is available through public record channels, that the Enbridge worst-case discharge scenario can be understood. Enbridge assumes a release of 4,500 barrels (189,000 gallons) from a cut to one of its lines, with 10-minute response time, 3-minute valve closure, or 13 minutes from discovery to shut-down. Further, the amount of crude oil released was reduced because of the water pressure related to the specific gravity of crude oil (lighter) would keep oil in the ruptured line; the crew would then insert a tube and pump the oil out of the pipeline.[45]

In short, the DR and Enbridge worst-case approaches are closer to all things working as planned, which is closer to an ideal or optimal case. Other Enbridge pipeline ruptures like Line 6B have taken many hours or days for response and shut-down of the release, and years to clean up.[46] By contrast, other federal agencies, including EPA, OSHA, Homeland Security and NRC, demand worst-case scenario determinations.[47] For example, the federal Council of Environmental Quality requires worst-case scenarios as part of the environmental impact statement process imposed on agencies by NEPA.[48]

As previously established and incorporated into FLOW's reports on file in this matter, under Michigan public trust law, the GLSLA and its Rules, and the MEPA, the state has a duty to protect public trust lands and waters, aquatic habitat and species, and public trust uses such as fishing, boating, drinking water, sustenance, and swimming or other recreation. This also includes a duty to prevent and minimize likely environmental degradation, and a duty to fully

[42] 49 CFR 194.105.
[43] DR Draft Alternatives Report, pp. MS-2 and TS-10.
[44] 49 CFR 105(b)(1).
[45] Appendix B, p. 8.
[46] Appendix B, pp. 8-9.
[47] Appendix B, p. 6.
[48] 40 CFR 15022.22; NEPA, 42 U.S.C. 4332(C); *Sierra Club v Sigler*, 695 F 2d 957, 967-974 (Just because probability of a threat is considered low, doesn't mean a worst-case scenario can be ignored as part of ascertaining uncertain risks of fairly or reasonably certain harm if a large release occurs).

consider effects and alternatives.[49] The failure of Enbridge to submit or demonstrate potential environmental impacts and no impairment through an environmental assessment, including a credible and proper worst-case scenario violates the GLSLA, its Rules, MEPA and the public trust duties and standards.[50]

Mr. Kane, in consultation with technical advisor Gary Street, concluded that the DR and Enbridge worst-case approach is not a true worst-case. He then followed a proper approach for worst-case scenario to calculate a credible worst-case scenario for a spill, release, and slow leak from the Strait's pipelines. To do so, he removed the active controls and optimal response times, and applied standard industrial and hazardous materials approaches for determining worst-case scenario.

In hazardous risk management, RISK is a function of CONSEQUENCE times PROBABILITY. Risk is a measure of the degree of human injury, environmental damage or economic loss in terms of likelihood (probability) and the magnitude of loss or injury, which is consequence. Probability is a function of vulnerability and threat.[51] Vulnerability is any weakness in a system that can be affected by accidental, natural or man-made causes resulting in harm. Threat is any indication, circumstance, or event with the potential to cause the loss of or damage to a system or asset or person, also of man-made or natural origin. As a result, actual conditions of the twin pipelines in the Straits, the range of potential threats and vulnerabilities to the pipeline, including those that have already been identified in the Enbridge system and elsewhere, must be considered. Moreover, given these vulnerabilities and threats, the range of size and magnitude of the harm or consequence from a release or leak must be considered. Where the magnitude of harm is massive or high, RISK remains high because the higher the degree of harm the less important is probability; in other words, high vulnerability and threats that result in a high degree of harm are likely in the context of avoiding or preventing unacceptable risk.

Based on this approach, Kane and Street calculated a credible worst-case scenario for the pipelines in the Straits. Assuming operation capacity of 540,000 bbl, major breach or rupture with a 2-hour release would release 45,000 barrels of oil; if two lines ruptured at or about the same time, it could be as high as 61,000 barrels of oil.[52] While the exact numbers can be debated, the factual conclusion is that the worst-case scenario for these pipelines are as much as 10 times the optimal worst-case discharge for Enbridge's emergency response plan.

An undetected, slow leak could actually be much worse. A leak could go undetected for a week. In winter months, with agglomeration of particulates and dispersions, it could go undetected for a much longer time period, or be more difficult to ever clean up or remediate.[53] The worst-case calculated by dispersion modeling done by Dr. David Schwab at the University of Michigan concluded a spill would release 25,000 barrels (1,050,000 gallons) If you consider the "Black Swan" or "perfect storm" scenario (think Fukushima and human-error design assumptions), a

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[49] MCL 324.1705; *Ray v Mason Co Drain Comm'r*, 393 Mich 294; 224 NW2d 883 (1975); *State Hwy Comm'n v Vanderkloot*, 392 Mich 159; 220 NW2d 416 (1974).
[50] The failure to submit a proper "worst-case scenario" also undermines the reliability of any evaluation in an alternative analysis. See Section D, 2, below.
[51] See references at end of Appendix B, including Fidler, et al., Crowl, et al., Center for Chemical Process Safety, and US EPA, "Risk Management Program Guidance for Offsite Consequence Analysis."
[52] Appendix B, p. 9.
[53] Appendix B, p. 10.

spill and damage would be higher and more widespread than these catastrophic worst-case scenarios.[54]

In summary, the pipelines under the Straits have been compromised by erosion, currents, and other forces, which will continue. The screw-anchor supports design implemented more recently has not been evaluated and some anchors have been pulled from the bottomland. The risk is high and imminent; according to Dr. Timm, the probability is as high as 46 percent at this time. Even the DR prediction of 1:60 is high and probable given the estimated high degree of harm and damage.

There are two credible worst-case scenarios: (1) rupture and release of oil from 45,000 barrels to 61,000 barrels; (2) slow or undetected leak for a week or months, from 23,450 barrels to far more than that. In either case, the disruption and permanent irreparable losses and damages would be monumental, covering hundreds of miles of shoreline, loss of wildlife, fishery, recreation, drinking water, boating services, tourism, private property and regional economy. In addition, because of this magnitude of harm, there is likely impairment of the public trust and water and natural resources of the state, contrary to the GLSLA, its Rules, common law public trust, and MEPA.

2. Enbridge Has Not Submitted a Reliable Comprehensive Alternatives Report That Demonstrates That There Is No Feasible and Prudent Alternative to the Screw-Adrnchor Anchor Support Structures and Pipelines.

Enbridge's application does not address or demonstrate that "there is no feasible and prudent alternative" to the anchor support structures or the construction activity necessary to shore up the twin lines under in the Straits. Moreover, as described in detail in previous reports, the anchor supports are part of a new or modification and systematic upgrade of Line 5 to increase design or operating capacity from 300,000 bbl to 540,000 bbl.[55] Neither the MPSC nor the DEQ, nor any other office of the state to date has independently considered and/or determined the question of whether "feasible and prudent alternatives" to the lines in the Straits directly related anchor supports exist.[56] In addition, Enbridge must submit a comprehensive alternatives report that demonstrates that there is no feasible and prudent alternative to the Straits Pipelines consistent with the requirements of the public health, safety and welfare.[57] Enbridge has not done so.

The recently released "Draft Alternatives Report" by DR for the state on the pipelines under the Straits was contracted for by the state in conjunction with the PSAB voluntary process. While the DR report purports to evaluate six (6) alternatives identified by the state and the PSAB, the draft report is not reliable or credible because of serious flaws, described by Dr. Timm in his supplemental Technical

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[54] Appendix B, p. 10.

[55] FLOW June 29 2017 Comments, Sec. II, at pp. 12-13, Sec. III, at pp. 13-15 http://flowforwater.org/wp-content/uploads/2017/06/FINAL-2017-06-29-17-Comments-to-DEQ-USCOE-Joint-App-Enbridge-for-Supports.pdf; FLOW Alternatives Report to Michigan Pipeline Safety Advisory Board: Eliminating the Line 5 Oil Pipelines' Unacceptable Risk to the Great Lakes Through A Comprehensive Alternatives Analysis and Systems Approach, December 14, 2015 http://flowforwater.org/wp-content/uploads/2015/12/FLOW-Composite-Report-12-14-15-FINAL-1.pdf ; FLOW Report, September 7, 2015, Appendix A and Appendix B, 2-3.

[56] FLOW June 29, 2017 Comments, Sec. D., p. 11, footnotes 36-39, and accompanying text.

[57] See FLOW Alternatives Report to Michigan Pipeline Safety Advisory Board: Eliminating the Line 5 Oil Pipelines' Unacceptable Risk to the Great Lakes Through A Comprehensive Alternatives Analysis and Systems Approach, Part I, pp. 7-12. December 14, 2015 http://flowforwater.org/wp-content/uploads/2015/12/FLOW-Composite-Report-12-14-15-FINAL-1.pdf.

Report discussed above,[58] and by experts Rick Kane and Gary Street in their supplemental reports attached to this Legal and Technical Supplemental Comment, discussed immediately below.[59] These flaws and errors include a myopic view of the reports objective, false assumptions, skewing the application of models by erroneous inputs, a failure to evaluate the risks of the six (6) alternatives based on a credible worst-case scenario, failure to accurately address the risk and relative costs and damages or impairment to fishing rights, public trust rights and interests in the Straits; they also fail to adequately incorporate the age, evident damage, bends or deformations, and historically and long spans unsupported by bottomlands.

Technical experts, Rick Kane and Gary Street, have continued to investigate the existence of alternatives to Line 5, including the twin-lines under the Straits. They previously concluded that Line 5 is not essential and can be eliminated based on a comprehensive alternative adjustment of existing pipelines within the Lakehead System.[60] Their supplemental conclusions are: (1) there exists a combination of existing alternative pipeline infrastructure and capacity, or easily modified infrastructure and capacity, that can handle all of the light crude oil now transported by Line 5 and meet all Canadian and Michigan needs; (2) such infrastructure and capacity would be less costly than other alternatives, and would be part of Enbridge's continuing $2.6 billion expansion of its Lakehead System; (3) the NGLs for Enbridge's propane customers in the UP, should they stay with Enbridge and not buy from the supplier in Sault Ste. Marie, is overstated, and NGLs can be transported through a 4-inch replacement Line within the Line 5 easement to Rapid River; this would remove the risk of continuing failures and releases from the 64-year old Line 5; (4) the continuation of Line 5 in the Straits would pose continued high risks, because of indisputably powerful currents, and constant erosion of bottomlands support and anchor supports; (5) the consideration of a tunnel option or alternative is unrealistic and imprudent because the cost would be prohibitive compared to existing pipeline infrastructure alternatives.[61]

[58] See Appendix A.
[59] See Appendices B, C, and D.
[60] FLOW Line 5 Comprehensive Alternatives and Systems Report.
[61] It should also be noted that a tunnel option would be most likely infeasible, because it would have to obtain approvals under the GLSLA and public trust; most everyone agrees, including Attorney General William Schuette, that any new crude oil pipelines and related design infrastructure would not be authorized today.

II. Supplemental Comment on DEQ Action on the Application and Immediate Measures and Conditions

Based on FLOW's comments and appendices submitted to the Department on June 29, 2017 and the foregoing supplemental comment and attached appendices, the Department is requested to take the following immediate actions and measures:

1. Continue this proceeding and maintain jurisdiction to assure protection of the public trust and compliance with the requirements and standards of the Great Lakes Submerged Lands Act ("GLSLA") and its Rules, the common law of public trust, and the MEPA and Michigan Constitution 1963, art. 4, sec. 52;
2. Require Enbridge to submit an application on the 22 proposed screw-anchor and brackets occupying the bottomlands in accordance with the GLSLA and its Rules and public trust for "structures" and "improvements under GLSLA Sections 32503, 352505(2), 32512 and its Rules, MEPA, Michigan Constitution 1963, art. 4, sec. 52, and public trust law;
3. Require Enbridge to submit a comprehensive environmental assessment on the entire lines in the Straits with a determination of the "existing and potential adverse effects," including a credible worst-case scenario;
4. Require Enbridge to submit a comprehensive alternative analysis that demonstrates that there are no feasible and prudent alternatives; including but not limited to a decommissioning Line 5 in the Straits and elsewhere because of its age, condition, and risks;
5. Make available the supplemental application and additionally required information submitted pursuant to the above to the public and interested persons and organizations;
6. Provide a reasonable new time period for the public, interested persons, and organizations to comment and schedule an additional public hearing;

This supplement comment also provides critical supplemental technical evaluations and conclusions from Dr. Timm and Kane and Street that document (a) the compromised integrity and evidence of historical damage of the twin-lines in the Straits, (b) the significant probability of imminent danger and harm to the public trust waters, bottomlands, aquatic resources, environment, and public trust uses, and health, safety and welfare from a rupture, failure or release of or from one or both lines, and in relation to (c) the high degree and magnitude of harm and damage to the environment, public trust, waters, biota, public and private property, and public health and safety. Because of this, the Department is requested to take the following immediate and interim measure and action:

Temporarily order Enbridge to halt the flow of crude oil and other petroleum products through the Straits pipelines pending implementation of the previously stated recommendations.

Once more FLOW appreciates every effort moving forward the state makes to assure to the highest duties and standards to comply with the laws and public trust duties and principles that apply to this matter. Should you have any questions or desire further information, we are willing to meet with you and technical experts to discuss the above.

Thank you.

Sincerely yours,

James Olson
President

Elizabeth R. Kirkwood
Executive Director

CC: Charles Simon, Chief, Regulatory Office, Corps Detroit District
Kerrie Kuhn, Chief, Permits, Corps Detroit District
Michigan Governor Rick Snyder Michigan
Attorney General Bill Schuette
MDNR Director Keith Creagh
U.S. Senator and Hon. Gary Peters
U.S. Senator and Hon. Debbie Stabenow

Appendix A

Technical Note

An Analysis of Errors and Omissions in the Dynamic Risk, Inc. Line 5 Alternatives Analysis, Option 5

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Introduction

The potential for an ecologically and economically disastrous rupture of Enbridge Energy Partners Line 5 under the Straits of Mackinac has resulted in an Alternatives Analysis commissioned by the State of Michigan and conducted by Dynamic Risk, Inc. The release of a draft[1] for comment of this analysis by the State's Pipeline Safety Advisory Board on June 29, 2017 started the clock on a public comment period concerning the substance of the Alternatives Analysis; this Technical Note addresses errors and omissions in the analysis of Option 5 therein. Option 5 in the Alternatives Analysis is the base case in the analysis to which other alternatives can be compared. This option is a "status quo" option intended to quantify the probability of a rupture and its consequences if the Straits sections of Line 5 are operated "as is" for an extended period into the future. It is critical for the purposes of the Alternatives Analysis that the probability of a rupture is determined through unimpeachable methodology since, if the rupture risk is incorrectly determined, comparisons to other options will be flawed
and the conclusions of the study will be questionable.

The twinned 20' pipelines on the bottom of the Straits of Mackinac were a pioneering effort in the construction of underwater pipelines. Constructed in 1953 by Bechtel, Inc., the two thick walled pipes were laid directly on the partially graded lake bottom without discrete support. The Alternatives Analysis attempts to quantify the risk of rupture or leakage into this critical waterway from several threats. Twelve different threat categories were considered in the Alternatives Analysis. Of these, four were found to be significant. Quoting[2] from this document:

"Operating Risk Analysis
In the risk assessment of the existing Straits Crossing segments, the principal threats that were found to contribute to the operating risk on the existing 20-in. Straits Crossing segments are, in order of decreasing contribution, anchor hooking, incorrect operations, vortex-induced vibration (VIV), and spanning stress."

The threats to Line 5 due to vortex-induced vibration and spanning stress result from the decision to lay the pipe directly on the partially graded lake bottom leaving unsupported spans of pipe subject to the forces of gravity and currents. Over time, currents have scoured the lake bottom from underneath the pipe causing unsupported pipe spans that may fail from bending stress and fatigue. This problem was recognized by both the designers of the pipe and the State of Michigan who granted an easement[3] for the pipe over state owned bottomlands. A recent review of what is publically known about the design and construction of Line 5 under the Straits as well as the threats to the pipe due to gravity and currents was released by Timm[4].

Following Timm's report, a report by Kiefner and Associates[5] was discovered that detailed the existence of very long unsupported spans and calculations about the structural stability of those spans. The Kiefner report revealed that Enbridge allowed unsupported spans to develop during the first 50 years of Line 5's operation that were much longer than those allowed under the easement (<75') or within the elastic limit of the pipe (~140'). This information necessitated an addendum[6] to the Timm report because these spans which were well beyond its elastic limit certainly resulted in plastic deformation of the pipe.

The Dynamic Risk Alternatives Report uses a Monte Carlo[7] simulation to calculate the probability of the pipe meeting a failure criterion. The necessary inputs to this simulation are a distribution of current velocities that impact the pipe and a distribution of unsupported span lengths that have occurred over the life to date of the pipe. Through numerous trials, the simulation repeatedly subjects a randomly chosen unsupported span to a randomly chosen mix of gravitational and drag forces then calculates the maximum principal stress resulting from this situation. If this stress exceeds the yield strength of the pipeline steel the trial is scored as failure and the process is repeated for a large (10^8) number of trials and the results are analyzed to give a "failure" probability". Quoting from the Alternatives Analysis:

"Spanning Assessment
The evaluation of threat attributes indicated that the Straits Crossing segments are potentially vulnerable to two separate failure mechanisms related to spanning:

i) fatigue caused by vortex-induced vibration (VIV) at span locations, resulting from near-lake-bottom water currents; and,
ii) over-strain caused by stresses due to unsupported span length (gravity and water current drag forces)

With respect to the threat of VIV, depending on pipeline design attributes and span lengths, even moderate currents can induce vortex shedding, at a rate determined by the velocity of water flowing around the pipe. Each time a vortex sheds, a force is generated, causing an oscillatory multi-mode vibration. Under some circumstances, this vortex-induced vibration can give rise to fatigue damage and failure of submarine pipeline spans. The threat of VIV was analyzed utilizing an amplitude response model in which input parameters of span length and upper-bound bottom-layer water currents along both the east and west Straits Crossing segments were represented as probability distributions. The span length distributions reflect observations that actual span lengths have exceeded (in some cases, by significant margins), the 75 ft. maximum stipulated in the Line 5 easement agreement. Using a total of 100,000,000 simulations in a Monte Carlo analysis, the probability that fatigue life would be exceeded for each of several future time periods was determined up to the year 2053.
As a separate analysis, a stress analysis was conducted that considered stresses arising from both gravity and drag forces in addition to those arising from operating pressure and temperature. As was done for the VIV analysis, input parameters of span length and upper-bound bottom-layer water currents along both the east and west Straits Crossing segments were represented as probability distributions. For the purposes of the spanning stress analysis, the probability of failure was defined as the fraction of simulations in which the maximum combined effective stress exceeded yield stress. Using a total of 100,000,000 simulations in a Monte Carlo analysis, the probability that

the pipe's yield strength would be exceeded by the maximum combined effective stress would be exceeded was determined. Although there is ample strain capacity beyond yield (and therefore, failure does not occur when the maximum combined effective stress reaches yield stress), yielding was selected as a failure criterion because it defines the onset of plasticity, which in a dynamic environment could give rise to high amplitude fatigue.
The analysis determined that the annual probability of failure associated with spanning-related threats was time-dependent, rising from 1.42x10-05 (3.1% of total, all-threat annual failure probability) in the year 2018 to 1.65x10-05 (3.5% of total, all-threat annual failure probability) in the year 2053."

As with any such analysis, if the input probability distributions are unrealistic, the output failure probabilities are not a true appraisal of the actual risk. This appears to be the case with the appraisal of both spanning and VIV failure mechanisms found in the Alternatives Analysis. With neither the Kiefner and Associates[5] report or both of the Timm[4,6] reports referenced or examined in Dynamic Risk's analysis, it appears as if there are both errors and omissions in the Alternatives Analysis which make its conclusions highly suspect. The following sections of this report will focus on these errors and omissions with the intent of providing guidance for a more realistic set of inputs for a robust Monte Carlo simulation of the risk of rupture of Line 5 under the Straits due to unsupported spans and vortex induced vibration.

Current Velocity Probability Distribution Discussion

When Bechtel's engineers were presented with the task of designing the segments of Line 5 under the Straits of Mackinac one of the first problems they faced was determining a realistic value for the maximum current velocity in the proposed location of the twin pipes. Based on unreported measurements, the Bechtel engineers concluded that the maximum current their design would have to withstand was 1.96 knots (~2.25 mph, 1.01 m/s). This value was used in the calculations of the maximum stress the design would have to withstand from many mechanisms. A review of these calculations can be found in the analysis by the famed structural engineer Mario Salvadori[8] in 1953. Foremost among the conclusions of this work is that an unsupported span of 140 feet is very close to the elastic limit of the pipe and this span should never be exceeded. This 140' span limit is supported by calculations made by Timm[9] at current velocities up to 2.25 mph. At current velocities above 2.25 mph the hydrodynamic drag from the current becomes a significant contributor to the bending force on the pipe as illustrated in Figure 1, taken from the Timm[9] report. Figure 1 shows that at the recommended span limit of 140' there is still some safety margin between the maximum combined stress and the elastic limit of the ASME Grade B (X35) steel used in the pipe which is given as 35,000 psi. Figure 1 also shows that the combined stress reaches the elastic limit at a 160' span impacted with a 3.6 mph current. Consequently, since it is known that spans of 160' and much longer developed over the 50 year period of 1953 to 2003 when Enbridge began significant efforts to add supports to the pipe, knowledge of the peak currents impacting these very long spans is critical to assessing the amount of plastic deformation accumulated over the years.

For these reasons, an accurate assessment of the rupture probability of the Straits sections of Line 5 depends on developing a good understanding of the fluid mechanical phenomena that characterize flow in the Straits. As thoroughly discussed in the Timm[4] report, flow in the Straits at any velocity beyond creeping flow is characterized as a developing mesoscale turbulent flow similar to the flow fields found in the Gulf Stream or the Straits of Gibraltar. The flow is further complicated by the fact it is driven by weather systems that cross the Great Lakes basin in unpredictable ways. Since drag forces on the pipe respond to variations in flow velocity on the millisecond time scale, it is important to characterize maximum instantaneous flow velocities during extreme weather events to develop a realistic current velocity probability distribution for use in a Monte Carlo simulation of pipeline rupture risk. This task is yet further complicated by the fact that the turbulent flow in the Straits is far from homogeneous. Buoy ADCP data taken at differing locations in the Straits shows significant current velocity variation based on location as would be expected. Characterizing the flow field in the Straits using a single probability distribution for current velocity can only give an estimate of rupture risk that is biased low unless that distribution accurately includes the highest instantaneous velocities anywhere along the span of the pipeline.

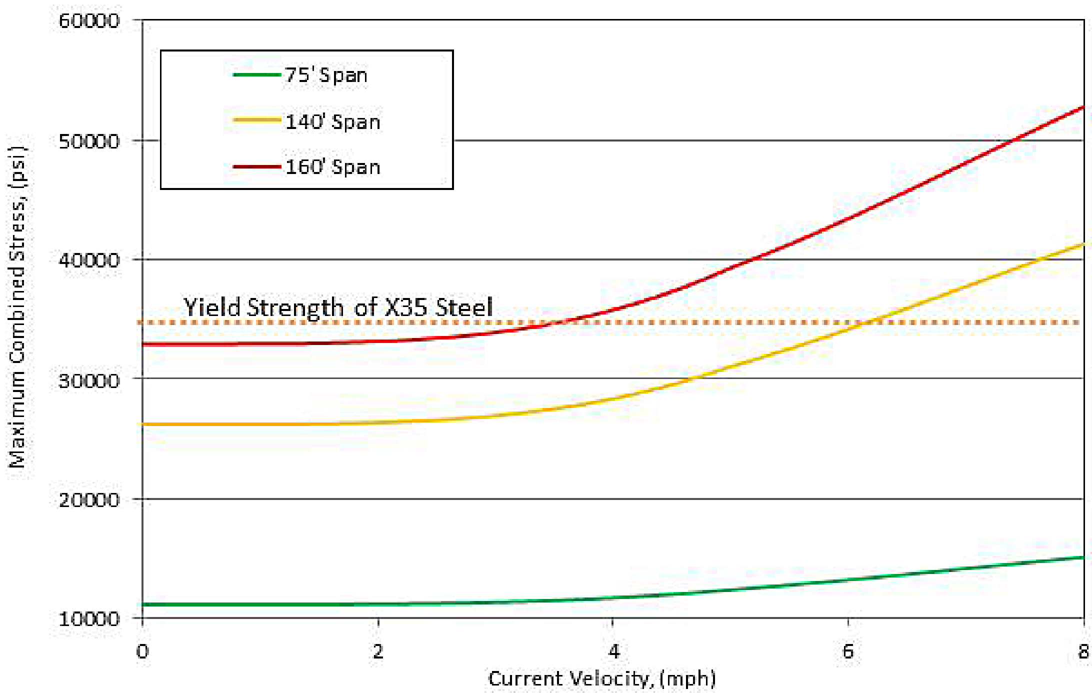

Figure 1. Maximum Combined Stress for Line 5 as a Function of Current Velocity

The Alternatives Analysis requires modeling of the flow in the Straits to explore the issues associated with hydrodynamic forces on Line 5 under the Straits of Mackinac and modeling the whole of the Lake Michigan/Lake Huron basin to explore the issues associated with oil dispersion in the event of a rupture. Dynamic Risk contracted with DHI, Inc.[10]. to develop these hydrodynamic models using their well-known MIKE 2 and MIKE 3 hydrodynamic modeling packages[11]. Appendix 5[12] of the Alternatives Analysis details this effort. The MIKE 3 hydrodynamic model of flow in the Straits used a variable mesh grid and a maximum 10 minute step time to model flow in the Straits based on a given set of meteorological forcing functions. After making an attempt to calibrate the model against existing buoy ADCP data sets, the model was run in monthly increments for a year to develop a velocity field data set representing velocities expected to be experienced in the vicinity of Line 5. Velocity probability distributions were then fitted to this synthetic data from several locations along the pipe and generalized into two probability distributions representing the east and west legs of the pipeline. Ignoring for a moment the fact that the ten minute step time of the model makes it impossible to accurately model the mesoscale turbulence characteristics of flow in the Straits, there are several reasons to question the accuracy of this effort.

Figure 2 is an annotated comparison of velocity data taken over a twelve day period beginning October 15, 2015 at the -20 m level from NOAA Buoy 45175 with the predictions of the MIKE 3 model. On a separate plot, the wind speed and barometric pressure measured by Buoy 45175 during this period is depicted.

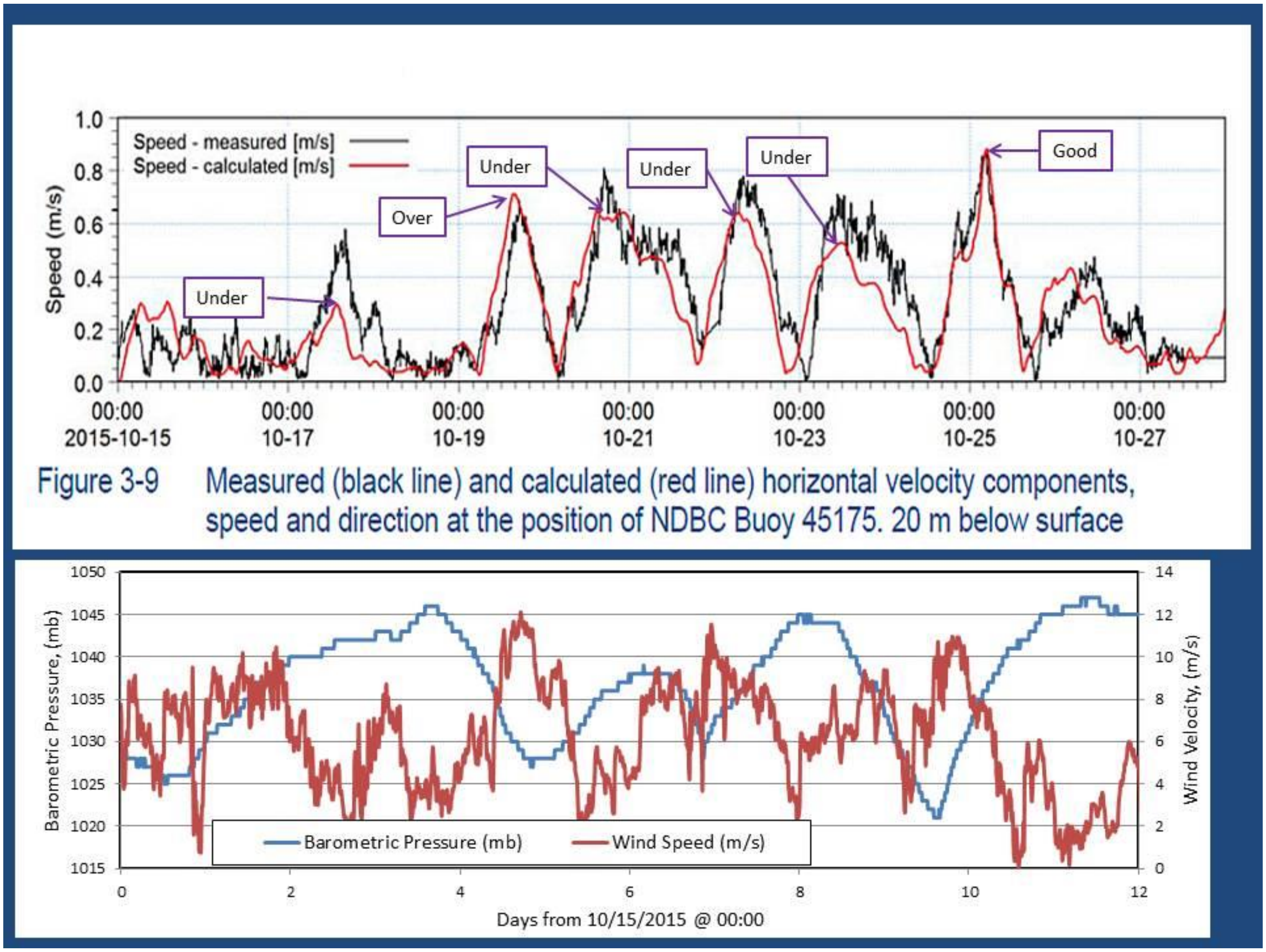

Figure 3-9 Measured (black line) and calculated (red line) horizontal velocity components, speed and direction at the position of NDBC Buoy 45175. 20 m below surface

Figure 2. Comparison of Measured and Predicted Current Velocity at NOAA Buoy 45175 along with Corresponding Meteorological Conditions

Figure 6 shows that while the MIKE 3 model predicts currents that generally correspond with the measured velocities, it fails to predict the critical peak current velocities necessary to predict maximum stresses on the pipe. Of the six current excursions depicted in Figure 2, one is correctly predicted, one is over-predicted by ~15%, three are under-predicted by ~20% and one is under-predicted by ~50%. The meteorological information shown on Figure 2 describes a period of generally moderate weather for October on the Great Lakes with high pressure and winds not exceeding 24 mph. Given that hydrodynamic forces on Line 5 generally scale with the square of current velocity, these predictions of peak current velocity are insufficiently robust to be the basis for examining the rupture risk of the single most critical oil pipeline in the

Great Lakes Basin. A further complication with this modeling effort can be found in the following paragraph[13]:

"4.1 Selection of Production Period
Following consultation with the project team, the 1 year time period of time extending from 1st of July 2014 to 30th of June 2015 was adopted for the model production runs. The following considerations were put forward when selecting this timeframe:
• Advantageous to start the model simulation in summer to allow a well-developed model solution (in terms of flow and water levels) prior to any ice effects influencing the model results
• Ice cover: the winter of 2014/2015 is a winter with fairly high ice coverage in Lakes Michigan and Huron; however, the period with significant ice cover is brief (not like in winter 2013/14, for example, with a prolonged period of ice cover)
• Wind conditions are fairly average compared to other years, without any particular high wind events or extreme situations.
• The selection of the simulation period has been based on the last 10 years, rather than further in the past"

This decision by the unidentified "project team" (Dynamic Risk ?, DHI ?, Enbridge ?) to use meteorological forcing data from a period where "Wind conditions are fairly average compared to other years, without any particular high wind events or extreme situations." defies common sense. Even laity certainly understand that structures don't fail during nice weather! To exclude the very conditions that would be expected to lead to a rupture of Line 5 and then using the model output to attempt to predict rupture risk is a decision by the "project team" that is neither explained in the Alternatives Analysis nor realistic. The only explanation for this decision that occurs to this author is that the MIKE 3 model cannot be reasonably converged when faced with extreme but historical meteorological forcing conditions as would have been found with years like 1913, 1975 or other years memorable for very severe weather[14]. Regardless of the reasons for the decision to base the Alternatives Analysis on a year with only mild weather conditions, this decision alone makes the risk estimates for spanning and vortex induced vibration based failures extremely suspect.

Similarly, it can be seen that the MIKE 2 hydrodynamic model, used to predict wave heights for the purpose of oil dispersion modeling, under-predicts wave heights during relatively benign October weather conditions. Figure 3 is reproduced from Appendix 5 of the Alternatives Analysis[15]. It too shows that the MIKE 2 model does a very poor job of predicting peak significant wave heights in conditions where the largest measured significant wave height is under two meters. Reference to the data available online from NOAA Buoy 45175[16] for October 10, 2015 at 19:40 shows a significant wave height of 2.509 m. This value is not reflected in Figure 3 which shows a predicted significant wave height of 1.3 m or about half of the actual value. This kind of disagreement between the model and actual measurement of peak wave heights makes relying on model predicted values instead of actual data likely to result in under-prediction of dispersion phenomena related to oil spill modeling. A likely cause of this misleading information from the MIKE 2 hydrodynamic model is the model is run with a maximum time step of 30 minutes while Buoy 45175 takes data every ten minutes. Once again, awareness of the averaging time used in model simulation and buoy measurements is necessary to prevent incorrect conclusions about the severity of extreme peak events from being drawn based on information that does not have the time resolution necessary to expose extreme peaks.

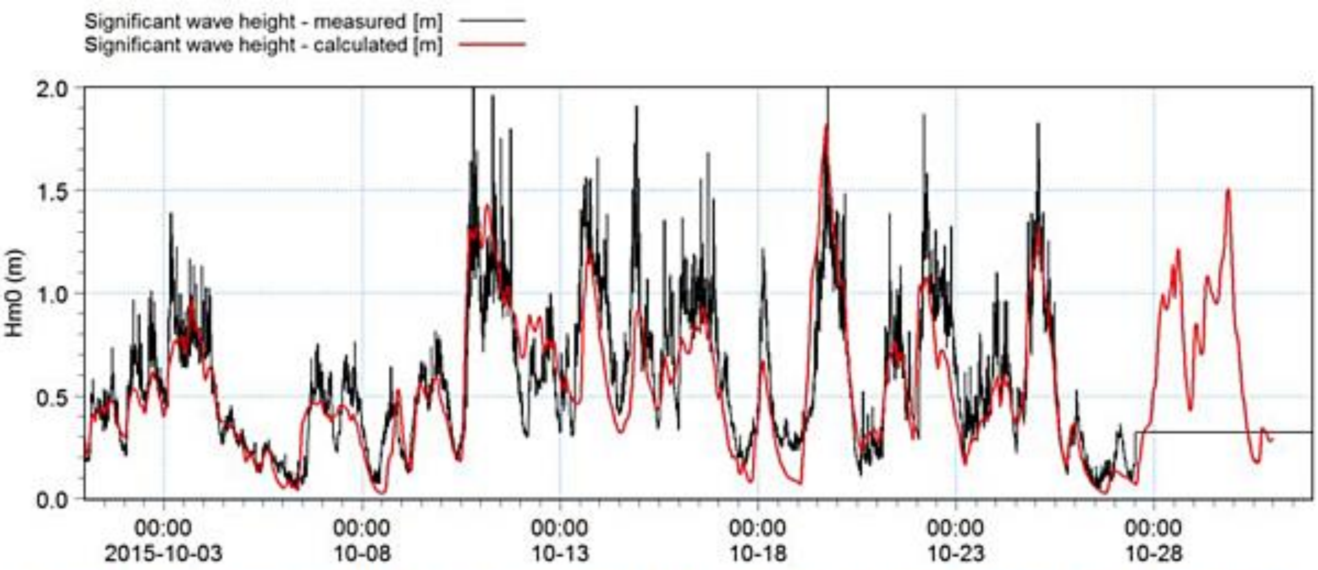

Figure 3-32 Measured (black line) and calculated (red line) significant wave height, peak wave period and mean wave direction at the position of NDBC Buoy 45175. October 2015

Figure 3. Comparison of Measured and Predicted Significant Wave Height at NOAA Buoy 45175

The current velocity probability distributions used in the Monte Carlo simulation intended to calculate the risk of rupture from both spanning and vortex induced vibration are described in the Alternatives Analysis report[17]. Following is a description of these distributions:

Accordingly, an extract of modeled hourly current velocity values over a one-year period was obtained from the bottom layer that corresponded to the position along both the East and West Straits crossing segments with the highest current velocity. These data extracts were used to fit probability density functions describing upper-bound temporal bottom-layer current velocity for both the East and West Straits Crossing segments. For the East segment, a Gamma distribution, having a Shape Parameter of 1.6861 and a Scale Parameter of 0.1051 was obtained, while for the West segment, a Lognormal distribution, having a mean of -2.1623 and a standard deviation of 0.7708 was obtained.

Since it is extreme values of the current velocity that will apply potentially damaging forces to the Straits segments of Line 5, a comparison of actual data with these calculated distributions in the upper tail region is warranted. Figure 4 is a cumulative probability plot of data taken from buoys 45175, LM 01 and the unreported measurements revealed in the Kiefner report with the current velocity fits resulting from the one year duration run of the MIKE 3 model. This figure shows that the tail risk for current velocity between data taken from Buoys 45175 and LM 01 is similar to the risk calculated from the MIKE 3 model for the West Leg of Line 5. The agreement between the buoy data and the MIKE 3 model for the East Leg as well as the Kiefner data is not nearly so impressive. Given that Buoys 45175 and LM 01 straddle the location of the pipeline, are placed in water of similar depths and give quite similar risk results;

the fact that the MIKE3 model gives very different tail risk for these two locations is puzzling. The Kiefner measurements are expected to predict lower velocities because they are apparently three hour average data as opposed to LM 01 which has a one hour averaging period and 45175 which has a ten minute averaging time.

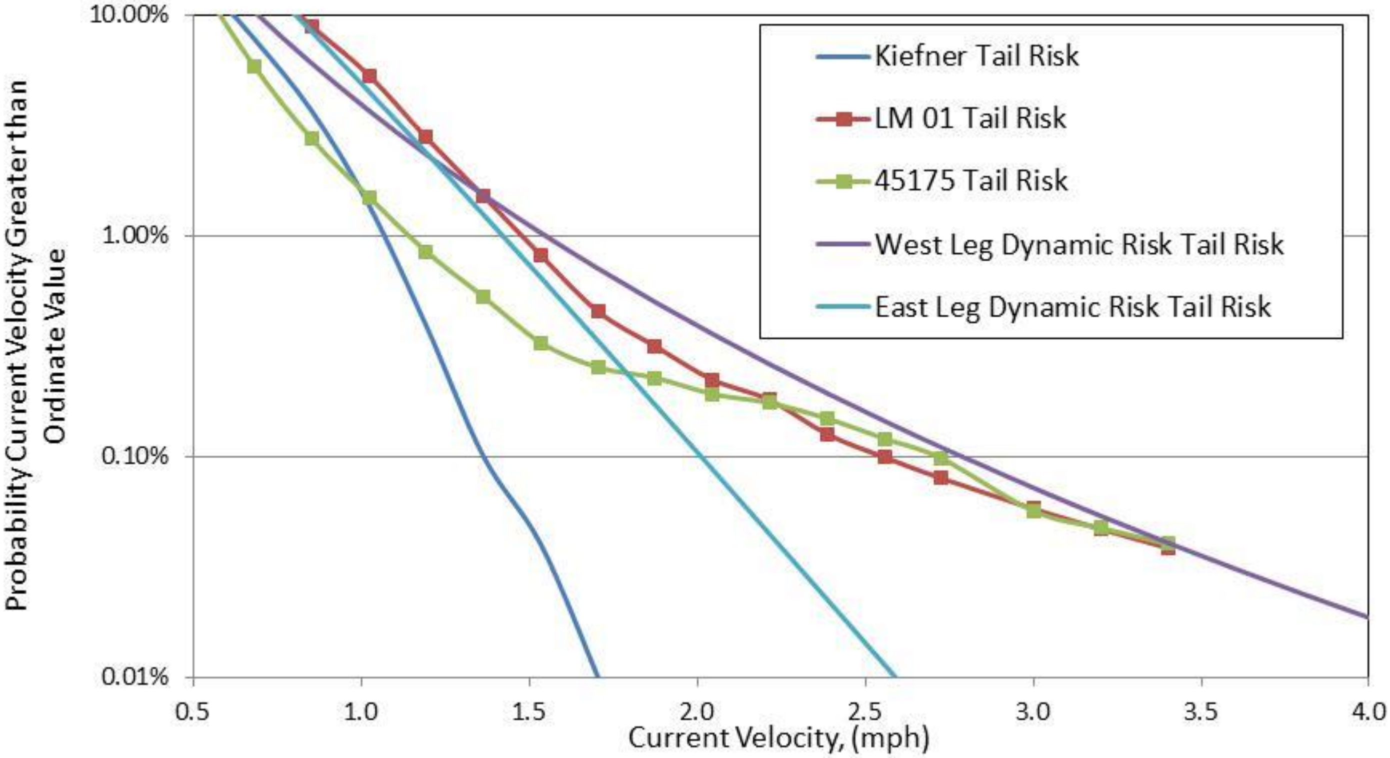

Figure 4. Comparison of the Tail Risk as a Function of Current Velocity

Conversion of the information displayed in Figure 4 into the expected amount of time the current velocity exceeds the Bechtel design basis for Line 5 under the Straits gives a more obvious indication of how the design basis compares with measurement and modeling based results. It should be noted that none of the measured data comes from a particularly stormy year and the model output was specifically restricted to quiescent conditions due to the choice of meteorological forcing conditions.

Table 1. Comparison of the Expected Duration of Currents Exceeding the Design Velocity of Line 5.

Current Velocity, (mph)	Kiefner Duration (hr/yr)	LM 01 Duration (hr/yr)	45175 Duration (hr/yr)	West Leg Dynamic Risk Duration (hr/yr)	East Leg Dynamic Risk Duration (hr/yr)
2.22	0	16	15	23	4

From Table 1, it appears as if the current velocity probability distribution used in the Alternatives Analysis for the West leg Monte Carlo simulation agrees reasonably well with buoy data taken with averaging periods similar to the maximum time step used in the MIKE 3 model. The fit for the East Leg does not agree well and, since both pipes are less than 1200' feet apart, this disparity may be an indication of a violation of the continuity constraint. In either case, measurements of turbulence intensity as discussed in the Timm[4] report and detailed by Thompson[18] are necessary to truly characterize the instantaneous velocities impacting Line 5. Thompson's work indicates that peak velocities approaching 20% higher than the averaged values are likely to be found in the mesoscale turbulent fluctuations that characterize the flow field in the Straits. Any analysis that does not address this subject, as is the case with the Alternatives Analysis, is suspect as a basis for making a well-informed decision of enormous ecological and economic consequence. Real instantaneous current velocity data taken directly near both legs of Line 5 is a much more robust basis for calculating the risk of rupture of this pipe. The fact that the West Leg current velocity probability distribution derived in the Alternatives Analysis is similar to those used in Timm's analysis leads credence to Timm's thesis that currents that exceed the design basis of Line 5 under the Straits exist and are capable of affecting the integrity of the pipeline.

Unsupported Span Length Probability Distribution

Through a series of Enbridge document releases in compliance with the requests of both the Michigan Pipeline Task Force and the Federal Court negotiating the consent decree settlement over Enbridge's Line 6b rupture, the history of unsupported spans in Line 5 under the Straits has been reconstructed. When the Michigan Conservation Commission negotiated the easement allowing construction across State bottomlands in the Straits, it laid down three conditions that read on unsupported spans and construction practice. These are:

"(1) All pipe line laid in waters up to fifty (50) feet in depth shall be laid in a ditch with not less than fifteen (15) feet of cover. The cover shall taper off to zero (0) feet at an approximate depth of sixty-five (65) feet. Should it be discovered that the bottom material is hard rock, the ditch may be of a lesser depth, but still deep enough to protect the pipe lines against ice and anchor damage.
(4) The minimum curvature of any section of pipe shall be no less than two thousand and fifty (2,050) foot radius.
(10) The maximum span or length of pipe unsupported shall not exceed seventy-five (75) feet.
(13) In locations where fill is used, the top of the fill shall be no less than fifty (50) feet wide."

The history of unsupported spans on the two legs of Line 5 under the Straits can be divided into five periods as follows:

Period 1, the period starting with the beginning of dredging and construction and ending when each pipe was flooded with water to sink it into the bottom of the Straits. The date of the end of this period for each leg is immediately after the pipes were pulled across the Straits. Reference to the "as built" profile drawings of the pipe resting on the bottom of the Straits do not allow determination of the distribution of unsupported spans immediately following the pipe laying operation but Bechtel engineers realized the freshly laid pipe did not sag into final contact with the dredged bottomland to a degree they found acceptable. Remedial action was required and the evidence supports many violations of the radius of curvature requirement in the easement (4) that was intended to prevent plastic deformation of the pipe as it was placed. Remediation of these long unsupported spans was accomplished by piling clay fill on top of the pipe resulting in many clay piles along the pipe path. At least 15 spans along the West Leg and at least 10 spans on the East Leg were remediated in this fashion. Figure 5 is a photograph of a typical clay pile near the South end of the West Leg location taken from the 2012 underwater inspection video. Careful review of all of the 2012 inspection video reveals that easement requirement (13) is consistently violated by all observed clay fill piles. Some of these clay piles are quite large with lengths approaching 100’ and heights over 20’. They appear to have been placed by dumping the clay chunks onto the pipe perhaps using a hopper barge.

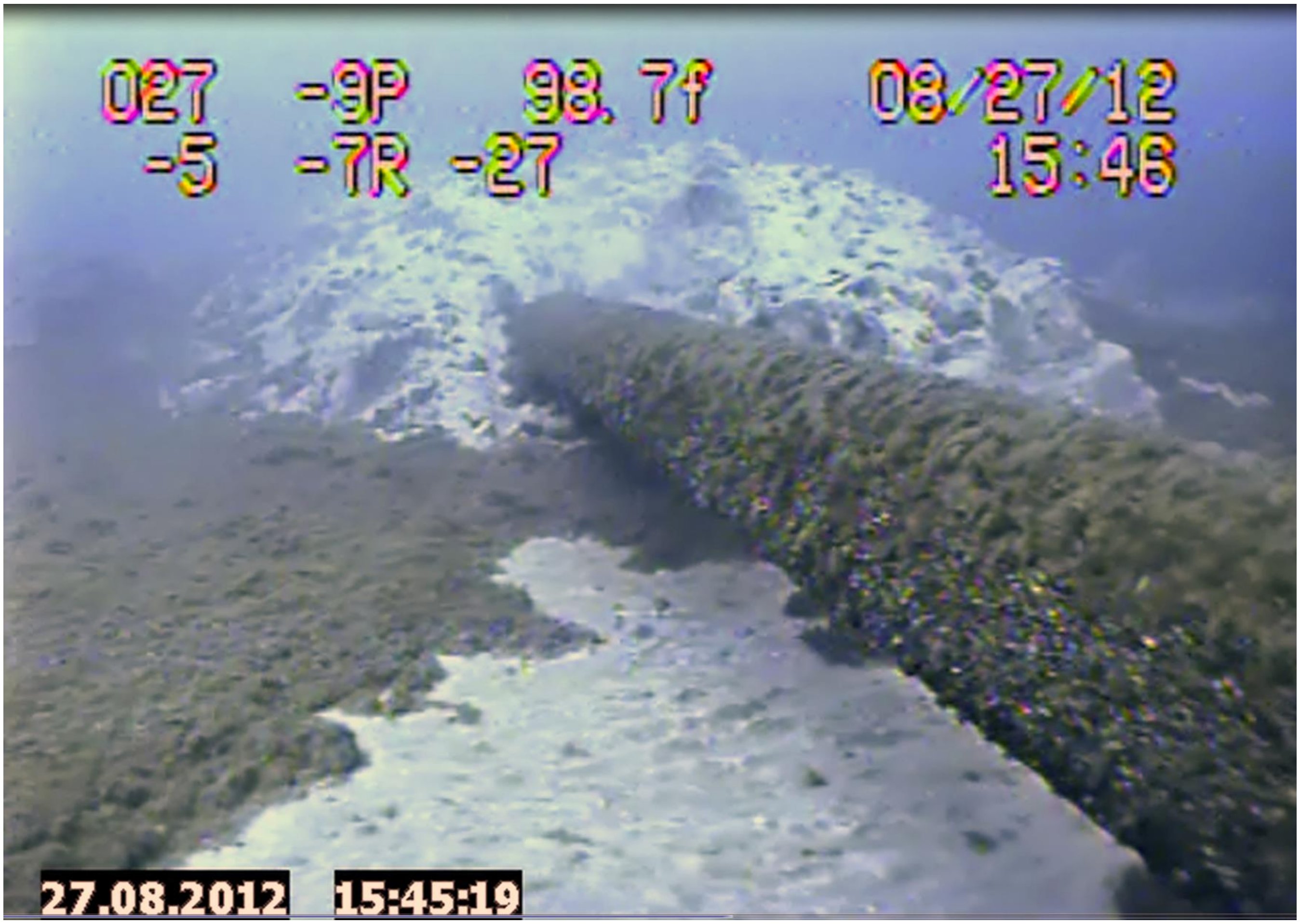

Figure 5. Typical Clay Fill Pile Placed in 1953 to Remediate an Unacceptably Long Unsupported span.

<u>Period 2</u>, the period that ends with the cessation of construction activities in November, 1953. As documented by the “as built”[19,20] drawings of the pipeline’s profile that were traced from Bechtel originals in 1964 and updated with information about span distributions and remedial actions through 1979. It can be seen in these drawings that many long unsupported spans remained after the clay dumping operation but the exact distribution of spans following the cessation of construction in 1953 cannot be reliably determined because the updating process for the drawings is not well noted.

<u>Period 3</u>, the period beginning when the as built drawing were updated through 1979 and approved on January 15, 1980. An accurate distribution of unsupported spans can be determined from these updated drawings and a review of this subject is found in the Timm report, Appendix 1[4] and the Supplemental Addendum[6] to the Timm report. As of the beginning of 1980 the unsupported span distribution in Table 2 was determined.

Table 2. Unsupported Span Distribution as of January, 1980

Location	Spans > 75 feet	Spans > 140 feet	Maximum Span
West Leg	10	3	160
East Leg	7	0	90

Period 4 is the period beginning in 1980 and ending in 2003. The Kiefner report[5,] which was issued in 2016 but originally drafted in 2003 and released in draft form to Enbridge in 2005, is the next source of the information about unsupported span distributions. The following brief summary of the number of unsupported spans is taken from this report:

"The 2003 survey identified 7 spans longer than140 feet in the east leg, with the longest being 224 feet, and 9 spans longer than 140 feet in the west leg, with the longest being 286 feet (due to a failed grout bag support)."

Table 3 summarizes this fragmentary information similarly to Table 2.

Table 3. Unsupported Span Distribution as of 2003

Location	Spans > 140 feet	Maximum Span
West Leg	9	286
East Leg	7	224

A comparison of Tables 2 and 3 shows that Enbridge's efforts at span remediation were woefully deficient during the 23 year period beginning in 1980 and ending in 2003. The shockingly long unsupported spans that were allowed to develop during this time period are far beyond the elastic limit of the pipe and permanent bending occurred. According to calculations in the Kiefner report, the 20", Schedule 60 pipe used to construct the twin legs of Line 5 under the Straits will reach full catenary mode where there is no compressive stress along the inside radius of the sagged pipe at a span length of ~190 feet. At an unsupported span length approaching 300' the pipe will sag until it either touches down on the bottom or ruptures. Exact calculation of the failure mechanisms for these very long spans cannot be done because exact information about the material properties of the steel used in the pipe and weld joint efficiency are not available. Most importantly, no data seems to exist that documents the fracture toughness of the steel and welded joints in the Straits sections of Line 5 which means detailed, accurate analysis of pipe rupture mechanics cannot be calculated.

Period 5 of the history of unsupported spans begins in 2003 when Enbridge started a major effort to shore up Line 5. The history of Enbridge's efforts to provide support is shown in Table 4. This table reveals that Enbridge switched from ineffective grout filled bags placed under the pipe to provide support to modern screw anchors in a significant way in 2003. Period 5 runs through 2016. In 2016 Enbridge added four screw anchors to the pipeline and requested a permit to place 22 more anchors in 2017 to rectify developing unsupported spans that were expected to exceed the Easement's 75' limit. At the end of 2016, underwater inspection showed no spans that exceeded the 75' easement requirement.

Table 4. History of Enbridge's Campaigns to Support Line 5 under the Straits

Year of ROV Inspection	Follow up Actions (Anchor Support Installation)	Type of Support Installed
1963	None	
1972	None	
1975	3	Grout Bags
1979	None	
1982	None	
1987	7	Grout Bags
1989	None	
1990	None	
1992	6	Grout Bags
1997	None	
2001	8	Grout Bags and mechanical support
2003	16	Mechanical Screw Anchors
2004	16	Mechanical Screw Anchors
2005	14	Mechanical Screw Anchors
2006	12	Mechanical Screw Anchors
2007	None	
2010	7	Mechanical Screw Anchors
2012	17	Mechanical Screw Anchors

Line 5 under the Straits was out of compliance with the 75' unsupported span requirement from the time the pipe was sunk to the bottom until sometime after 2003 when compliance was finally achieved using screw anchor supports. During the period from 2003 until the end of 2016 compliance was sporadic due to the ongoing problem of extreme currents scouring the bottomland from under the pipe leaving washouts. An extensive spreadsheet[21] documenting the span remediation efforts from 2005 through 2016 was released by Enbridge at the request of the State of Michigan.

The two Monte Carlo simulations used in the Alternatives Analysis to estimate the risks of rupture due to spanning and fatigue from vortex induced vibration use span length probability distributions for each leg based on data from the period 2005 through 2016 found in Reference 21. Following is a description of these distributions as taken from the Alternatives Analysis[22].

"Span Length Distribution
Based on a review of information obtained from seven underwater inspections of the East and West segments spanning the years 2005 – 2016, it was observed that the lengths of individual spans change over time. [82] While the terms and conditions of the April 23, 1953 Straits of Mackinac Pipeline Easement limit allowable span length to 75 ft., and maintenance activities have been undertaken to maintain span lengths to less than that limit, span lengths have varied both below and above that limit over time. Therefore, for modeling purposes, it would be non-conservative to assume that span

lengths will be limited to 75 ft. on a go-forward basis. Instead, the results of the seven inspections performed between 2005 – 2016 were used to generate separate span length distributions for each of the East and West segments. A total of 715 separate span length measurements were used to generate a span length distribution on the East segment, and 691 separate span length measurements were used to generate a span length distribution on the West segment. In both cases, Weibull distributions were found to provide the best fit to these data."

Figure 6 is a plot of the probability a span will be greater than a given length for both legs. At the scale of Figure 6, the fitted Weibull cumulative probability distributions appear to be identical.

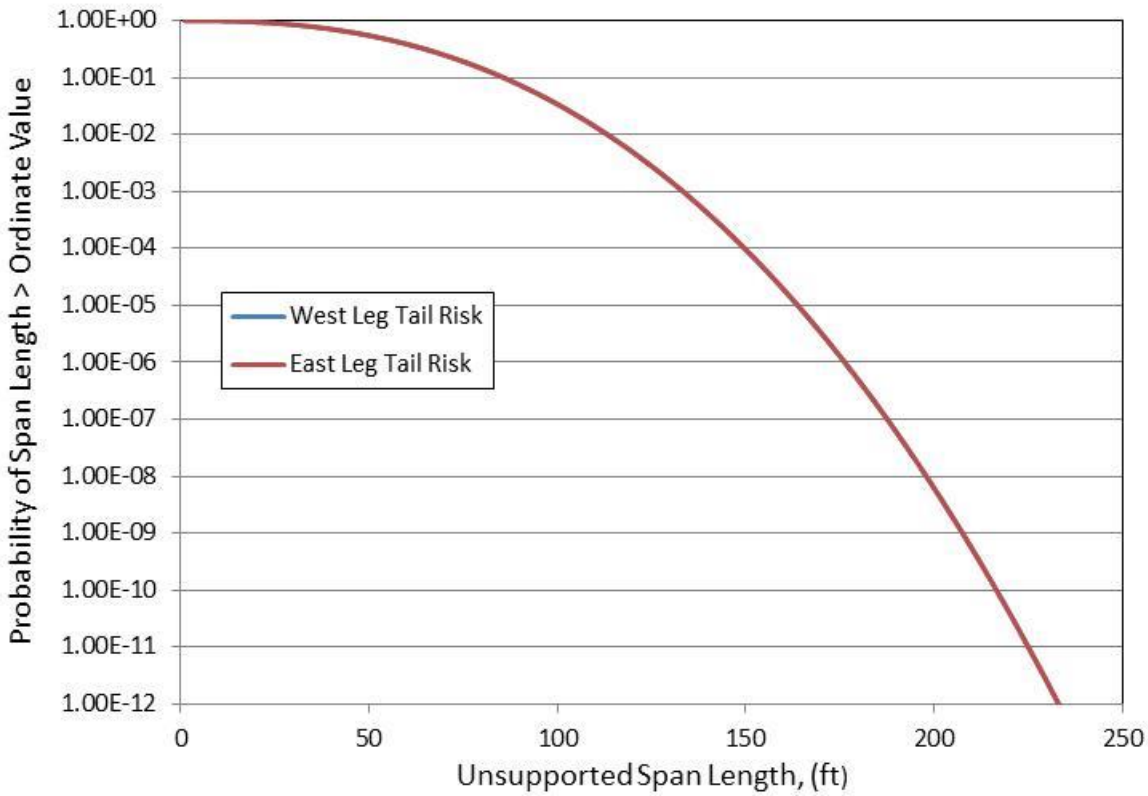

Figure 6. Probability an Unsupported Span is Longer than Ordinate Value for East and West Legs of Line 5 for the Period 2005-2016

These distributions are a very good fit to the span data revealed in Reference 21 but when used in a Monte Carlo analysis to estimate risk, the authors of the Alternatives Analysis appear to have made a serious mathematical error. The 715 East Leg span length measurements and the 691 West Leg span length measurements result from pooling data taken during inspections in 2005, 2006, 2007, 2010, 2012, 2014 and 2016. Each individual dataset contains a differing number of spans both because of new washouts and the addition of new supports. This means that while the distribution functions plotted above may be relatively time invariant over the period 2005-2016, the ensemble of spans existing during each time interval between inspections is different. Because a random selection of current velocity in the Monte Carlo impacts all the spans in an ensemble, each span in that ensemble must be tested for the failure criteria not just one randomly selected span. Because extreme current events are quite rare but each such event tests a large number of spans, multiple failures may occur for each random current velocity selection. **This physical fact results in a much larger number of failures than the Monte Carlo implementation apparently done in the Alternatives Analysis and the estimates of risk derived from this analysis are erroneously underestimated by a large margin!** This problem affects both the spanning risk Monte Carlo and the vortex induced vibration Monte Carlo analysis

Although the ensemble error mentioned previously is a disqualifying error, it is much less serious than an erroneous assumption that also greatly biases the rupture probability estimates for the Straits sections of Line 5. Assuming the ensemble error was fixed by developing representative span length ensembles for each period data is available and completing a correct Monte Carlo analysis, there is a problem with the failure criteria used in each iteration of the analysis. For both the spanning analysis and the vortex induced vibration analysis, the failure criteria requires knowledge of material properties that are affected by the fatigue history of the span of pipe being examined. Following is a short discussion of both spanning and VIV failure mechanisms.

As discussed in the Timm report, the bidirectional nature of the currents in the Straits raise the possibility that a long span may well be bent back and forth by the currents causing low cycle, high strain fatigue damage to the pipe. Therefore, it is necessary to know the stress-strain history of the pipe in order to know if the pipe is close to its fatigue limit. A heavily fatigued pipe may well fail at a stress well below the elastic limit of virgin material so the failure criteria must take into account what has gone before. Similarly, the vortex induced vibration failure criteria is based on the number and severity of vibratory cycles. Again, the analysis must start from a time when the material in the pipe has zero fatigue cycles so that cycles can be accurately counted as the fatigue failure limit is approached.

From the preceding discussions, one problem with the Monte Carlo risk estimates in the Alternatives Analysis is that they don't start from the pipeline's construction in 1953. Instead, Dynamic Risk assumes the material making up the pipe is in virgin condition when they start their analysis in 2018 and use it to predict a risk of rupture extrapolated to 2053. In fact, the pipe has endured five different periods of spanning history with each adding its quanta of damage as the years pass. Essentially, Dynamic Risk has chosen to ignore the first 50 years of Line 5 under the Straits history, a history that includes little or no span maintenance with spans growing to at least 286', and then begins its calculations starting in 2018 assuming virgin material properties. Any risk estimate based on this methodology is so erroneous an equally accurate estimate could be produced using black cat bones and fuzzy dice! A correct Monte Carlo risk estimate would require doing separate year by year analyses each featuring a realistic current velocity distribution, span length probability distribution and number of spans. This would result in over sixty different Monte Carlo risk estimates which could be added up starting in 1954 to the current date then projected forward to get a realistic estimate of risk for any year in the future.

A very simple risk estimate for the whole of the underwater section of Line 5 can be done based on the average failure rate for all DOT 195 pipelines from all causes. This risk is given as 0.89 failures/(1000 mi * yr)[23]. Using this figure, the risk of failure for the 8.15 miles of twinned lines under the Straits gives a failure rate of $7.25 * 10^{-3}$ per year. Adding up the failure probability on a yearly basis gives the 2017 failure probability at 46.4% and the 2053 failure probability at 72.5%. These figures are very different from the Alternatives Analysis estimate of 1.6% by 2053. This means that Line 5 under the Straits is 45 times safer than a typical buried DOT 195 pipeline, a conclusion that defies sense.

Evidence of Damage to Line 5 under the Straits

The Monte Carlo analysis spanning risk failure criterion is when the combined stress in the pipe reaches the elastic limit. Quoting from the Alternatives Analysis[24]:

"For the purposes of the analysis, the probability of failure was defined as the fraction of simulations in which the Von Mises maximum combined effective stress exceeded yield stress. This condition was selected as a failure criterion because although there is ample strain capacity beyond yield (and therefore, failure does not occur when the maximum combined effective stress reaches yield stress), it defines the onset of plasticity. In a dynamic environment, characterized by changing water currents, span lengths and gap ratios, there is potential for the maximum combined effective stress to vary with time in a repetitive manner, as the variables that control the stresses vary over time. Under such conditions, the potential for plasticity creates the potential for plastic fatigue, under which conditions, progression to failure can occur after relatively few cycles."

The unpredictability of what happens next once a structure reaches its elastic limit is why engineers rarely design a structure where stresses approach plasticity. An example of plastic failure in Line 5 under the Straits appears to have been discovered through careful comparison of Enbridge and other documents.

If the theory proposed by Timm that extreme currents have structurally compromised Line 5 under the Straits is correct, there should be evidence of post construction plastic deformation of the pipe. This evidence would not be found in MFL or ultrasonic inspection records but should be discernable in inspection records of the physical location of the twin legs. Plastic deformation caused by currents and gravity would result in bends and in extreme cases ovaling of the pipe. Following are two statements taken from the Alternatives Analysis[25] that reveal the existence of such features.

"The analysis of inertial data identified 20 bends on the East Crossing and 23 bends on the West Crossing with an angle larger than 1.5° and a radius of curvature less than 100x diameter. There were no bends on either crossing segment that were characterized as tight (having bend radii of 5x diameter or less).
Of the 20 bends on the East Crossing, only two (BND 10 and BND 11) were located in the portion of the pipeline where the pipeline was installed on top of the lakebed; the rest were located in the trenched portions of the crossing. Of the 23 bends on the West Crossing, only 5 (BND 9 to BND 13, inclusive) were located in the portion of the pipeline where the pipeline was installed on top of the lakebed. While it was not possible to determine the origin of each bend, it is likely that bends located on the onshore portions of the crossing are field or factory bends that are part of the design. The remainder of the bends may have been intentionally or unintentionally created as part of the installation process."

"In the West Straits Crossing segment, two features (both ovalities) were identified that exceeded the reporting criteria. One ovality had a maximum deflection of 8.75% nominal

OD, and the other had a maximum deflection of 5.45% nominal OD. While significant ovalities can, under certain circumstances impair the passage of in-line inspection tools, the strain associated with these features is normally broadly distributed around the pipe circumference, and thus, ovality is not generally considered to be a feature that poses an integrity threat."

The Alternatives Analysis states that the bends found in the exposed underwater sections of the pipe (Bends 10 and 11 in the East Leg, Bends 9 through 13 on the West Leg) are of unknown origin but "may have been intentionally or unintentionally created as part of the installation process." This statement is speculation on the part of the authors of the Alternatives Analysis and potential evidence of damage should not be dismissed without a full examination of the evidence.

Information from three sources has been pooled in order to investigate the cause of damage to the exposed lakebed portion of the West Leg of Line 5. Figure 7 is a composite drawing of the area where Bends 9-13 are located. The 2016 profile view of this section of the pipe is taken from Figure 5 in the Biota[26] report, the 1979 profile view[20] was released by the Michigan Pipeline Task Force and the geometric inspection information is taken from the 2013 Baker-Hughes Geopig[27] geometry inspection report. Figure 7 shows the locations of the five bends and two ovals found by Baker-Hughes on the bottom profile view taken from the Biota report. Four of these bends are within a 250' section of pipe and the two ovals are both the result of bending as shown by their coincidence with Bends 11 and 12. Both ovals have primary axes that do not coincide with the vertical direction and all bends have a lateral component as well as a vertical component. These features are not consistent with "sag bends" that form as a pipeline is sagged into place along a poorly graded path but rather appear to have been bent both vertically and laterally which is what would be expected if they had been formed by the combined forces of gravity and currents. It is exceedingly unlikely that these bends were formed during construction since the pipe was pulled along the bottom of the Straits using great force, a process that would insure a straight path. These bends are not mentioned on the 1979 profile drawing of the pipe which includes many notes about the condition of the pipe at that date.

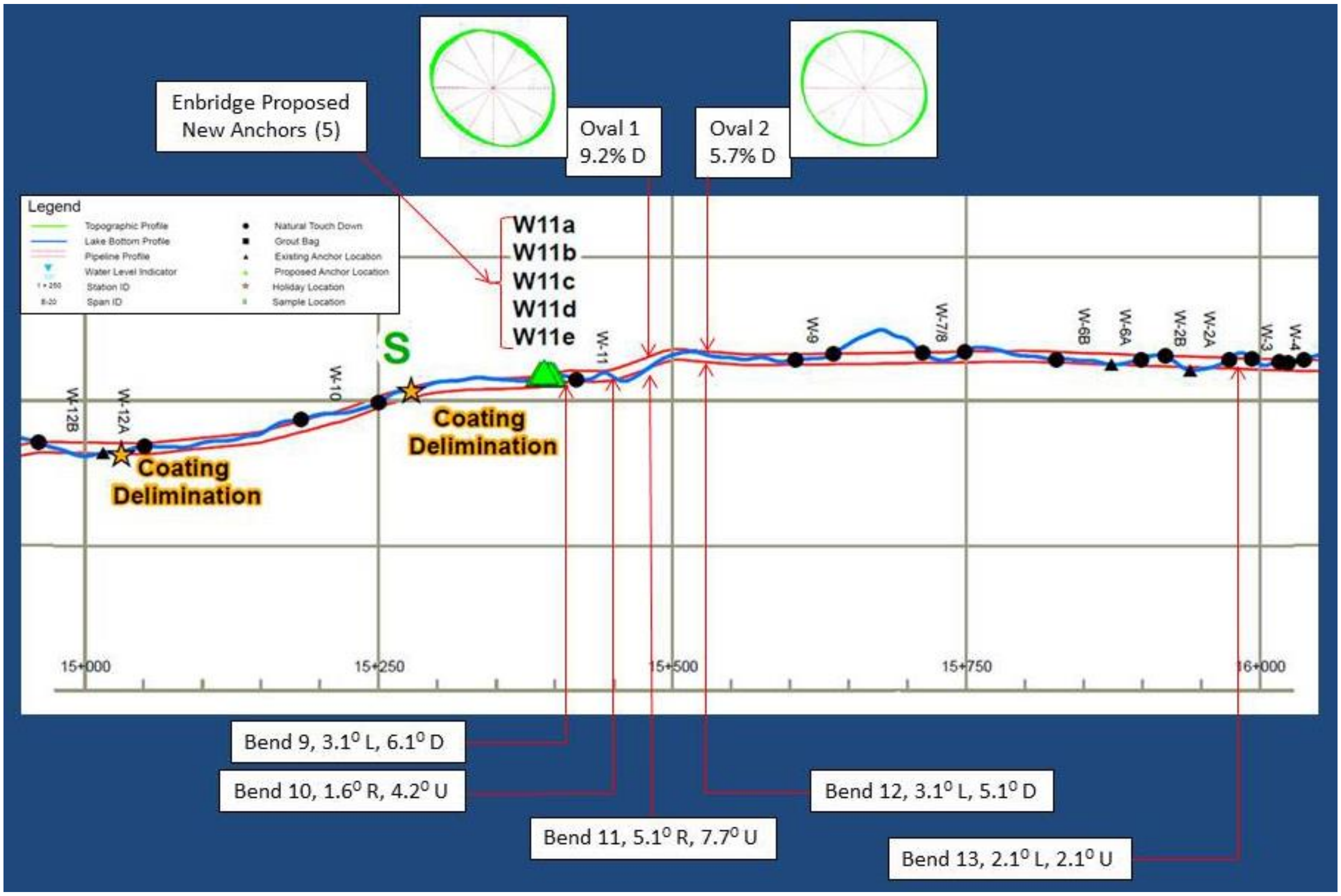

Figure 7. Overlay of Pipe Deformation Information from the 2016 Baker-Hughes Geopig Inspection on Figure 5 from the Biota Report.

A more probable explanation than the one given in the Alternatives Analysis for the existence of these features can be found in Figure 8. In Figure 8, the top drawing is the 2016 bottom profile which has been flipped end to end so that south side of the Straits is oriented to the left similarly to the 1979 profile drawing. Both profile drawings have been stretched horizontally and vertically so that they are scaled similarly. Additionally, using the 1953 Lake Michigan water level datum of 581 feet elevation allows depths to be compared and the 70' depth level is plotted on both profiles. The profile drawings have been offset to compensate for the differences between the Bechtel chainage length scale used in 1979 and the absolute length scale used in 2016.

The green dotted line on the 2016 profile drawing labelled "2016 Average Grade" has been carefully transferred to the 1979 profile drawing. The light blue area marked "Scour" on the 1979 drawing shows the volume of bottomland that appears to have been scoured away between 1979 and 2016. The obvious interpretation of Figure 8 is that the washouts noted in the 1979 drawing appear to have merged into one long span (~300 feet) sufficiently long to have caused the pipe to collapse to the bottom profile shown in 2016 bending it and ovaling it in the process.

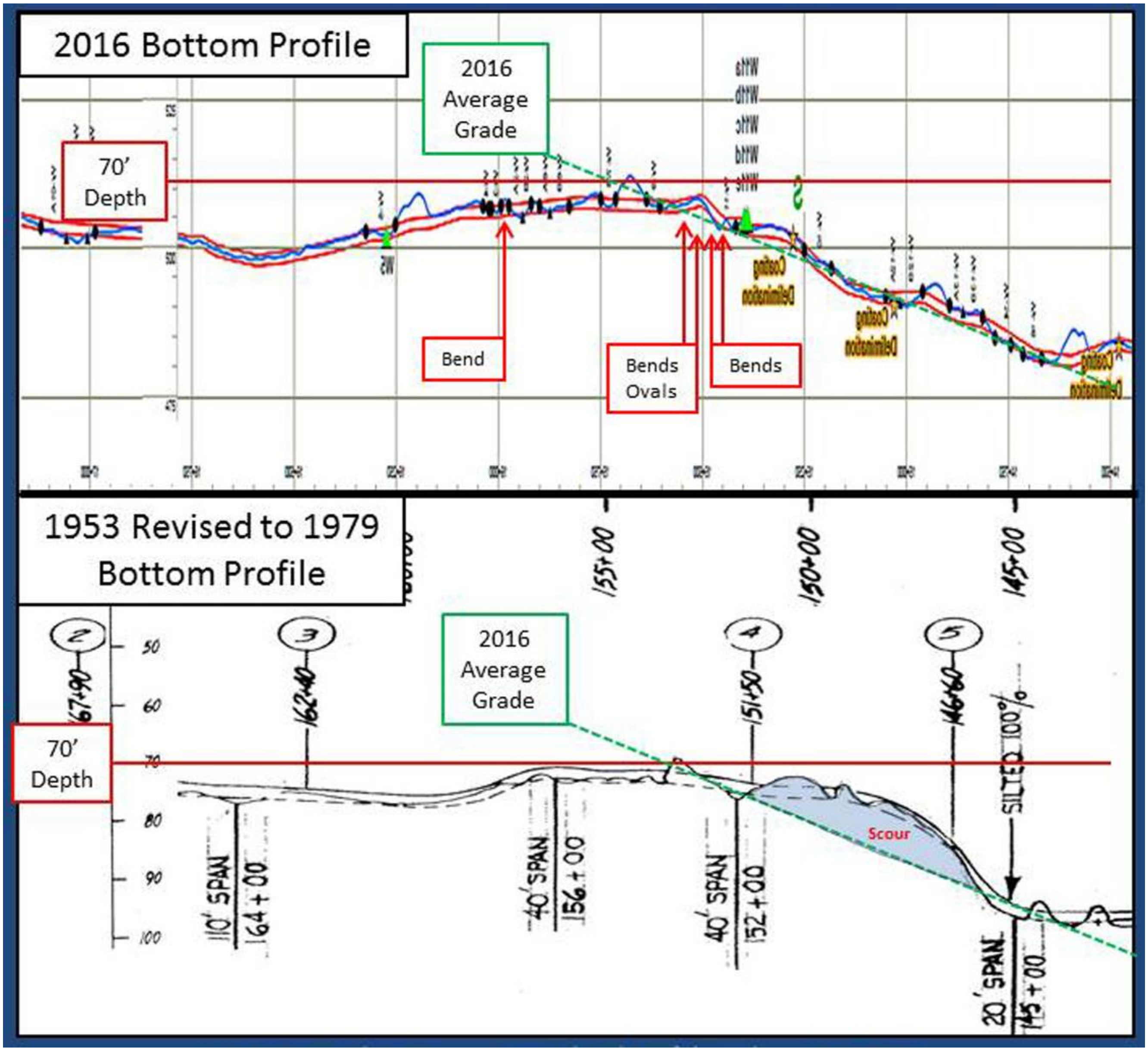

Figure 8. Comparison of West Leg, South End Lake Bottom Profile Drawings from 1979 and 2016

Given the long geometric in line inspection history that begins in 1987 as detailed in Table 2 of the Enbridge Operational Reliability Plan[28] and access to Enbridge's archives of Bechtel's construction documentation, it should be a simple task for Dynamic Risk to prove the speculative assertion made in the Alternatives Analysis that the bends and ovals found in the West Leg are a result of construction. Lacking such proof, the alternative hypothesis put forward here, that these bends and ovals are evidence of periodic uncontrolled bending due to the forces of gravity and currents, becomes very reasonable. A further argument follows.

In 2016, Enbridge applied to the State of Michigan for a construction permit[29] to place a number of new screw anchor supports on Line 5 under the Straits because of unsupported spans detected during the 2016 underwater inspection. Of the requested 22 new screw anchor supports, four were required to remediate spans over 75' and the rest were to be placed prophylactically to prevent ongoing washouts from growing into excessive spans. As can be seen from Figure 7, five of these supports (W11a-W11e) are to be placed in the area of the pipe where bends and ovals exist. Enbridge's support permit application makes no exceptional mention of these supports in their support permit request. A clip from a recent Enbridge spreadsheet that details the span history of Line 5 provides some detail on the W11 span and is shown as Table 5.

Table 5. Span History of the W11 Span Dating from 2005

* All Measurements given in feet* Span Identifier	2016 Length	2016 Span Height (Approximate)	2016 Support Length	2014 Length	2012 Length	2010 Length	2007 Length	2006 Length	2005 Length
W-11	52	2.5	107 to W-9^	48	52	47	40	46	49

Touch Down Position and Type (Year Install)	Support Depth	Notes	Anchors Proposed in 2016 (not yet installed)
South/Sand	75	Install anchors to support deflection area just south of span W-11	5
North/Sand	80		

This information about the W11 span shows that no span over 52 feet exists and there does not seem to be progressively increasing span length warranting additional support. However, it is noted in the comments column of the spreadsheet that Table 5 is taken from: "Install anchors to support deflection area just south of span W11". That five anchors are being planned for installation in an area of the pipe suspected of damage but without excessive spans requires explanation and lends credence to the theory that Line 5 under the Straits was damaged due to the forces of gravity and currents sometime after construction. This conclusion is consistent with the findings of the Timm report[4] and the Supplemental Addendum to the Timm[6] report that incorporates the findings of the Kiefner report[5].

Other Subjects of Concern Raised by the Alternatives Analysis

Girth Welds and Welding Practice

Although the Straits sections of Line 5 had their girth welds inspected both visually and by gamma ray radiography, questions remain about the joint efficiency of the welds produced using 1950's technology. The Alternatives Analysis[30] states:

"In the February 06, 2016 tethered PipeScan / WeldScan Inspection Report for the West Straits Crossing, it was noted that the girth welds displayed significant amounts of porosity, slag and lack-of-fusion, typical of vintage manual welding. There were two indications that exceeded the above reporting thresholds."

A similar revelation is made about the East Leg. Although the Alternatives Analysis goes on to dismiss concerns about the quality of the vintage girth welds in Line 5, the lack of data concerning these welds makes these conclusions suspect. No data has been publically released about the testing procedures used to qualify welds or the mechanical properties of the welds such as tensile properties or fracture toughness. Without this information, it is impossible to accurately model the processes where a departure from elastic behavior into plastic behavior can result in tensile failures and fatigue damage. Of particular concern are the girth welds used to join the 2500' pipe strings during the operation where the line was actually pulled across the Straits. Another subject of concern is whether the pre-welding preheat procedures discussed in some of the early documentation about Line 5 were actually implemented. Given the importance of girth weld integrity and the fact that poor girth welding techniques have led to problems with many vintage pipelines, a full examination of the knowledge base concerning Line 5 welding procedures including the examination of testing data from weld qualification samples is necessary to assure the models of Line 5's structural integrity are realistic.

Coating Integrity and Cathodic Protection

Both the Timm report and the Biota report document the fact that the coating system on the Straits sections of Line 5 are deteriorating with sheets of the fiberglass wrap intended to protect the base coating from abrasion delaminating from the base coating. Enbridge has contended that the base coating on Line 5 maintains its integrity and offers as proof cathodic protection surveys from Baker-Hughes that show very little current is flowing through the cathodic protection system that applies electrical polarization to the pipe. A review of Baker-Hughes literature offers no insight into the sensitivity of the Baker-Hughes CPCM™ inspection tool or this unique use of the tool to inspect an underwater pipeline submerged in low conductivity fresh water. An investigation into the sensitivity and limits of detection for a coating holiday using this inspection tool is necessary before drawing the conclusion that a newly developed inspection methodology used on a unique pipeline in an unusual environment proves anything at all about the integrity of the coating. Although numerous MFL inspections of the Straits sections of Line 5 have been conducted that show little metal loss corrosion it should be noted that MFL technology has a limit of detection for metal loss of about 10% of the wall thickness of the pipe. Because of the extremely thick walls of Line 5 (0.812"), this limitation means that corrosion damage of 0.080" is the detection threshold in this situation and significant metal loss and pitting could exist just below the detection threshold of MFL inspection technology. Further information will be available regarding corrosion and the condition of the coating on Line 5 under the Straits following the completion of the ongoing Biota[25] report.

Thermal Expansion and Pipe Movement

The Kiefner report[31] goes into great detail in the examination of a subject that is barely addressed in the Alternatives Analysis. The oil pumped under the Straits is warmer than the surrounding underwater environment. This means the pipe expands when oil is pumped into the pipe after it has been shut down for long enough to cool and vice versa. The temperature swing that occurs is on the order of 20-30 ^{o}F and the total longitudinal expansion of the unburied sections of line 5 under the Straits is around four feet. In its original conception, this thermal expansion was accommodated by the bends that naturally occurred during the pipe laying process which prevents the buildup of compressive stress and buckling. Now that the pipe is rigidly supported by screw anchor supports for long distances, the question of how thermal expansion stress will be accommodated in this new configuration becomes relevant. Quoting from the Kiefner report:

"An analysis of the deflection and stresses in the spans considered that the pipes are in a state

of compression caused by differential thermal expansion due to the crude oil product in the pipe being warmer than the water temperature of 40 F. This led to the finding that spans must exceed 120 ft in length in order to fully relieve the thermal compression. Longer spans develop catenary behavior from the thermally relieved sag configuration, with resistance to additional vertical sag developed through increased axial tension rather than additional bending stress. In fact, recognition of this phenomenon led to greater allowable spans than would be the case without any initial thermal compression on the pipeline. It follows that if the flow is shut-in for a sufficiently long period of time prior to the span correction, the lines would cool to the ambient water temperature and the thermal compressive stress would be lost. This would result in more tension in the spans and reduced sag. If the supports were to be installed with the line in this condition, then when product flow is restored and the pipe warms to the product temperature, the supports would become loaded by the additional sag induced by thermal expansion of the pipe.

It should be noted that the analysis also showed that without thermal expansion, spans of 140 ft are at the limit of acceptable lengths based on traditional Code stress criteria. This means that after cooling down, the existing long spans that are currently safe but longer than the 140-ft service lengths Enbridge plans to allow, would then be in excess of acceptable stress limits for the period of time between when the line cools down and when the supports are installed. It is likely that the longest spans could experience longitudinal stresses in excess of the yield strength. There are a number of reasons why this is probably not a real structural integrity concern but the safety margins are difficult to quantify with the information available. Thus shutting in the lines while they are full of product is not recommended even though doing so would lead to more effective span support."

Clearly, thermal expansion accommodation in Line 5's new, supported configuration becomes a problem as the number of supports is increased. The Kiefner report suggests that the pipe sag between supports may help accommodate thermal expansion stress but it assumes the supports are perfectly rigid. In fact, the supports which are adequately strong to support the weight of the pipe are quite flexible laterally compared to the forces that can develop due to thermal expansion. Since the supports are clamped rigidly to the pipe it is also possible that the supports could be bending laterally due to thermal or other forces. Figure 9 shows images clipped from the 2012 and 2016 underwater inspection videos that appear to prove that lateral flexion of the pipe supports is occurring.

The images in Figure 9 raise serious concern about the long term prospects for screw anchor supports that are flexed laterally, a condition they were not designed to accommodate. Insufficient information exists to properly assess the magnitude of this threat but the fact that the Alternatives Analysis does not recognize this phenomena as a potential cause of excessive stress on Line 5 under the Straits is a serious omission.

Also omitted from consideration in the Alternatives Analysis is a previously undiscussed mechanism affecting the integrity of the pipe. As significant lengths of pipe are supported off the bottom in a long assemblage, current forces induce an overturning moment on the whole structure. This moment must be resisted by a combination of lateral forces from the pipeline supports plus and increase in tension in the pipe as the whole assemblage tilts out of plumb in response to current drag force. How serious this problem becomes, with the result of uprooted/bent pipe supports and unknown tensile forces in the pipe, as more and more supports are added requires analysis. Failure to address this unanalyzed integrity threat as well as the difficult subject of thermal expansion stress accommodation are further reasons to suspect the conclusions of the Alternatives Analysis.

Looking West Looking East

Figure 9. Images of Laterally Deflected Screw Anchor Supports from 2012 (left) and 2016 (right) Underwater Inspection Videos. Images are believed to be of two different anchors.

<u>Conclusions and Recommendations</u>

The Alternatives Analysis authored by Dynamic Risk, Inc. is a complex work that incorporates risk modeling, oil spill dispersion modeling and economic analysis in an effort to provide insight into alternatives to Line 5 under the Straits as well as estimate the risk of operating Line 5 as is. My Technical Note, “An Analysis of Errors and Omissions in the Dynamic Risk, Inc. Line 5 Alternatives Analysis, Option 5”, attempts to address some of the shortcomings that make sections of the Alternatives Analysis incorrect. Errors and omissions in the analysis of the rupture risk associated with Line 5 under the Straits affect conclusions drawn about the condition of this critical pipe and in the comparison of Option 5 to other options. Among the errors and omissions discussed here are:

1. A conceptual mathematical error in the construction of the Monte Carlo risk analyses that results in risk estimates orders of magnitude less than would be estimated using a properly constructed analysis.

2. A non-existent understanding of the bidirectional mesoscale turbulent flow field in the Straits and how averaged current data under-predicts the peak current velocities,

3. Failure to take into consideration the very long unsupported spans that evolved over the first fifty years of the line’s lifetime and the possibility that these spans were fatigued and otherwise damaged by the combination of bidirectional currents and gravity,

4. The use of an unproven hydrodynamic model with an inappropriate choice of input meteorological forcing data to derive current velocity extremes impacting the unsupported spans of the pipeline,

5. The use of material property information appropriate for virgin pipeline steel in the simulations of spanning and vortex induced vibration risk even though evidence shows the pipe has experienced fifty years of neglect and abuse,

6. Failure to consider integrity threats that result from the addition of supports to a pipeline designed without support. Thermal expansion stresses and assemblage overturning moment forces resulting from the pipelines new configuration require consideration, analysis and quantification before they can be dismissed as insignificant threats to the integrity of Line 5 under the Straits.

The Alternatives Analysis is a very complex work that incorporates a great deal of good information and calculation concerning the alternatives to Line 5 as it exists today. Unfortunately the errors and omissions in the analysis of the risk associated with the “do nothing” Option 5 compromise many of the conclusions of the Alternatives Analysis making the document as a whole a very flawed work. In general, the plethora of questionable assumptions and unsupported conclusions found in the sections of the Alternatives Analysis intended to support the fitness for service of Line 5 under the Straits, raise questions about the lack of intellectual curiosity and objectiveness necessary for this kind of work to be credible. As a result of these errors and omissions, at a minimum, it is recommended that an interdisciplinary group of technical experts drawn from a range of industry and non-industry sources be assembled to recommend a path towards a robust examination of the future fitness for service of Line 5 under the Straits.

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FOR LOVE OF WATER

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

DEFINING A WORST-CASE RELEASE SCENARIO FOR THE ENBRIDGE CRUDE OIL PIPELINES CROSSING THE STRAITS OF MACKINAC – LINE 5

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Background

The basic objectives of the MPSAB in commissioning the studies were to obtain: 1) an expert risk analysis on the Enbridge Line 5 pipeline crossing the Straits of Mackinac (Straits) and 2) an analysis of alternatives for NGL/crude oil transportation. The risk analysis was to include identification of worst-case and alternative scenarios based on different pipeline failures, materials being transported, seasons of the year and etc. The alternatives analysis was to include: construction of new pipelines, use of alternative pipelines and other transportation methods, replacement of the existing pipelines across the Straits, maintaining existing pipeline operations and decommissioning the Straits crossing with continued use of upstream and downstream segments.

The Risk Analysis - The State of Michigan (State) terminated the contract with Det Norske Veritas, Inc. (DNV GL), the contractor developing the risk analysis study on June 21, 2017, due to violation of conflict of interest prohibitions contained in the contract. The draft report was not received by the State and is not available for public review. The failure to deliver this report creates a huge void in identifying and understanding the risks of Line 5 operations in the Straits, especially the worst-case scenario (WCS).

The Alternatives Analysis – the "Draft Final Report - Alternatives Analysis for the Straits Crossing" developed by Dynamic Risk Assessment Systems, Inc. was submitted to the State on June 27, 2017 and then released for public review and comment. (1) Comments on this report are provided in a separate paper.

This report addresses the worst-case release scenario for a failure of Line 5 at the Straits, filling part of the void left by the DNV GL contract termination. This report provides an overview of the current confusion in understanding WCS's, alternative scenarios and conflicting risk management and regulatory definitions for "WCS". For the State of Michigan and communications to the citizens and stakeholders, it is important to use a common sense and professional risk management approach, not so-called worst cases reduced and restrained by numerous assumptions that can fail or not correctly defined for the issue under study. The release quantities in this report can be used to model spill dispersion and human health, environmental and economic impacts. The assumptions are also defined, transparent and can be debated and adjusted.

FLOW provides an analysis in this report on WCS releases and potential quantities that could be released in the Straits from a Line 5 failure. In other words, it answers the question; how big could the spill be? The report does not provide information on crude oil spill dispersion, fate and consequences after release to the waters of the Straits. Other organizations are working on fate and consequence assessments. It is vital that these assessments include realistic crude oil WCS release quantities; concentrations and dispersion ranges drive the magnitude of consequences.

Executive Summary

Identification of the worst-case and alternate scenarios is the key starting point in conducting a risk assessment. On June 21, 2017, the State terminated the contract with DNV GL, the consultant who was to provide the worst-case and risk analysis. The failure to deliver this report creates a huge void in identifying and understanding Line 5 risk in the Straits. This study provides a worst-case release scenario for consideration.

There is considerable confusion and misunderstanding on a worst-case release scenario for the Straits as different organizations use different definitions, leading to public misunderstanding. This report provides a credible worst-case release based on risk management principles that allow consideration of passive controls - fixed systems but not active controls (mechanical, electrical and control systems, procedures and emergency response) to identify the worst-case.

Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) regulations require the calculation of a scenario for emergency response planning. Pipeline operators can assume credits in their scenarios for passive and active controls (alarms, SCADA / material balance systems, remote valves, water back pressure, emergency response) and 100% reliability. Although noted as a "worst-case discharge", in the regulations and application as the largest release that the Emergency Response Plan submitted to PHMSA for approval is theoretically able to handle; it is not **how big a spill could really be. In other words, the worst-case discharge submitted by Enbridge to meet PHMSA requirements is not a Worst-Case Scenario. (2,3,4)**

The scenario for a catastrophic release submitted to PHMSA by Enbridge is approximately 4,500 bbl. The WCS release calculated by FLOW is 61,000 bbl. for a catastrophic release. For a slow leak release scenario, 24,000 bbl. per week was calculated; however, a 20-day undetected leak could exceed the size of a catastrophic failure. Dispersion modeling to determine shoreline impact was beyond the scope of this report; however, for comparison, Dr. David Schwab at the University of Michigan modeled several release scenarios. The largest release modeled was 25,000 bbl. (1,050,000 gallons) which is approximately the quantity released in 2010 from the Enbridge Line 6B failure in the Kalamazoo River watershed. Dr. Schwab's model indicated that a 25,000 bbl. release in the Straits could impact approximately 720 miles of Lake Michigan and Lake Huron shorelines.

The report prepared by Dynamic Risk Assessment Systems, Inc. (Dynamic Risk) does not contain a worst-case scenario and impact analysis. It is a comparative analysis of possible alternatives. Do not interpret findings in this report as representative of a worst-case. The release quantities in the Dynamic Risk alternative scenarios are orders of magnitude lower than a possible WCS.

Overview

This report provides background information on risk management and worst-case scenario (WCS) information that should be communicated to stakeholders concerned with the risks posed by the Enbridge Line 5 pipeline at the Straits. This information is not available from the MPSAB consultant studies as the contract with DNV GL was terminated and the analysis by Dynamic Risk did not include a WCS, as it was not within the scope of their work.

The identification of a WCS in most cases does not require complex mathematical modeling. The most important aspects of WCS identification are proper definition of the system scope or boundaries and appropriate application of protective measures to prevent a release from occurring. Inappropriate assumptions that reduce release quantities can result in gross under estimations of potential consequences. There is a history of events in several industries where real events exceeded WCS's submitted to meet regulatory requirements. (9)

Hazardous Materials Risk Management (5,6,7,8)

Risk is a function of ***consequence*** and ***probability***. ***Probability*** is a function of ***vulnerability*** and ***threat***. It is important to define and understand basic definitions for risk management upfront as the terms are often used loosely resulting in confusion to stakeholders and leading to a misunderstanding of real risk.

Risk is a function of ***consequence*** and ***probability***.

Risk = Consequence X Probability

> ***Risk*** – a measure of human injury, environmental damage or economic loss in terms of incident likelihood (probability) and the magnitude of loss or injury (consequence).

Consequence – the direct undesirable result of an incident outcome, specifically the impacts resulting from the release of a hazardous material. Consequence is generally a function of the hazards of the material released, the extent of the release and the presence of receptors (people, ecosystems, property, etc.).

Probability – the expression for the likelihood of occurrence of an event or an event sequence during an interval of time or the likelihood of the success or failure of an event on test or demand.

Probability is considered to be a function of ***vulnerability*** of hazardous materials operations to various ***threats.***

Probability = Vulnerability X Threat

Vulnerability – any weakness in a system or asset that can be affected or exploited by accidental, natural or man-made causes resulting in harm.

Threat – any indication, circumstance, or event with the potential to cause the loss of, or damage to, a system or asset. Threats can be of natural or man-made origin.

For example, the risk posed by a crude oil pipeline is a function of consequences resulting from a crude oil release to the environment and the vulnerabilities of the pipeline to the various threats in its operating environment.

Worst–Case Scenario (WCS) and Alternative Release Scenarios (ARS)

In risk management for existing and proposed operations and transportation systems, a starting point is to identify the WCS and understand the possible consequences. For a WCS where the consequences are intolerable, even with an extremely low likelihood of occurrence, alternative options are required. Failure to identify the WCS misinforms the public and can lead to decisions that later lead to disaster. Unfortunately, the phrase "worst-case scenario" is used loosely with different definitions causing confusion and surprises when emergency response is inadequate.

Fundamentally, a WCS analysis in managing hazardous materials is the identification of the largest quantity release and consequences mitigated by permanent, fixed infrastructure and natural features. For example, a facility built in a natural basin or surrounded by permanent secondary containment (dike, basin) is considered to have "passive protective control measures" and these features can be counted upon to reduce release quantities to the environment. Other release scenarios that include valves, alarms, supervisory control and data acquisition (SCADA) systems and etc. that act to reduce release quantities are "active protective control measures" and the scenarios developed are called Alternate Release Scenarios (ARS). Release quantities from an ARS are less than a WCS. (10,11)

The overall risk management approach is to identify: the WCS for existing or proposed operations and ARS's and opportunities to eliminate entirely or reduce risks. In the case of an intolerable WCS, current operations are halted and an acceptable alternative implemented.

Risk management is trying to address failures of risk identification approaches to identify possible scenarios that are beyond worst-case. Disasters such as Deep Water Horizon, Enbridge Line 6B, the Fukishima nuclear reactor disaster and so on are often considered to be "Black Swan" or "Perfect Storm" scenarios. A key issue is that these types of incidents are continuing to occur as well as the reoccurrence of incidents that were to "never happen again." (12, 13,14, 15)

> **Black Swan** - as outlined by N. Taleb (12), it is 1) an outlier, as it lies outside the realm of regular expectations, because nothing in the past can convincingly point to its possibility; 2) it carries an extreme impact; 3) in spite of its outlier status, human nature makes us concoct explanations for its occurrence after the fact, making it explainable and predictable.
>
> **Perfect Storm** – can be considered to be a sub-case of the Black Swan but importantly the events and possibilities are better known, in some cases well-known but decisions are made to not consider them because they lie outside regular expectations. (15)

Risk managers are working to improve assessment and auditing practices to root-out and prevent black swans and perfect storms. A controversy is the question; can these events really be identified? In practice, often the answer is yes but they were not considered due to incorrect system and scope definitions, incorrect assumptions, over-confidence in the functioning of protective systems, poor threat assessment, management failing to address an obvious issue and so on.

A WCS is a concept in risk management wherein the planner, in planning for potential disasters considers the most severe possible outcome that can reasonably be projected to occur in a given situation. For hazardous materials operations and transportation the definition is more refined.

Worst-Case Scenario (WCS) – also called a "credible worst-case scenario" is the potential release quantity based on system capacity <u>with</u> the consideration of mechanical, control system, operational and human factors <u>failures</u>. Credits for mitigation of potential release volume are allowed for ***passive controls*** that are permanently in place and in very limited cases for active controls.

> ***Passive controls*** are equipment, devices, or technologies that function without human, mechanical, or other energy input. Passive mitigation systems include dikes, containment walls and natural barriers such a valleys and berms.
>
> ***Active controls*** are measures such as remote shutdown valves, computer control and material balancing systems, alarms, operating procedures and training. Active controls require mechanical, energy or human input to function.

The scope of the <u>system</u> must also be correctly and consistently defined as changing simple assumptions can drastically change release quantities. A recognized definition is provided by the Occupational Health & Safety Administration (OSHA) Process Safety Management (PSM) Program and used by other regulatory agencies [x].

> ***Process and Interconnected System*** - Any activity involving a regulated substance, including any use, storage, manufacturing, handling, or on-site movement of such substances, or combination of these activities. For the purposes of this definition, any group of vessels that are interconnected, or separate vessels that are located such that a regulated substance could be involved in a potential release, shall be considered a single process."

Thus, to calculate a WCS, the system would be defined as connected tanks and pipes, connected storage tanks and credit given for the presence of passive control measures. In the case of crude oil pipelines and facilities, passive control measures are typically permanent secondary containment structures.

Common cause failures and ***cascading events*** are also important considerations in identifying the WCS. A “common cause” failure example would be a severe weather event that leads to power failures affecting equipment and delays response by operating personnel. A “cascading failure” example is a mechanical failure that triggers a “hydraulic hammer” to propagate down a pipeline and cause a rupture at a weak point.

Alternative Scenarios are calculated in addition to the WCS based on assumptions required in regulations or defined by the owner/operator. For example, company management or insurers may define an alternative or “most-likely accident scenario” or an “emergency response-planning scenario” required for insurance certification or regulatory permit approval. Planning scenarios have much lower release and consequence levels than the WCS.

The PHMSA WCS – PHMSA defines a WCS as shown below. This definition is used by owner/operators to develop emergency response plans for regulatory approval. ***The approach defined by PHMSA is does not follow the hazardous industry approach for WCS, but it is consistent with an ARS for emergency response planning. Unfortunately, government officials, 1^st^ responders and the general public often assume that the PHMSA definition identifies the WCS; it does not. It is the largest spill that the Emergency Response Plan should be capable of handling.***

The PHMSA definition also leaves a lot of discretion to the pipeline owner/operator. An owner/operator must determine the quantity escaping based on release time, shutdown time plus the amount of material that drains from the pipeline after shutdown. Contrary to industry practices for WCS identification, pipeline owner/operators take credit for active controls, SCADA control and material balancing systems, operator training, management procedures and even emergency response measures, such as vacuuming materials calculated to be remaining in the pipeline. This approach is unacceptable in EPA, OSHA, DHS and NRC worst-case scenario determinations, but it is not for determining an ARS. The PHMSA Worst-Case Discharge is an alternate planning scenario and not a WCS as practiced by risk management professionals.

PHMSA WCS - Department of Transportation (DOT) and their Pipeline and Hazardous Materials Safety Administration (PHMSA)

Response Plans for Onshore Oil Pipelines 49 CFR 194 - Department of Transportation (DOT) and their Pipeline and Hazardous Materials Safety Administration (PHMSA) -

49 CFRR 194.105 Worst-Case Discharge

(a) Each operator shall determine the worst-case discharge for each of its response zones and provide the methodology, including calculations, used to arrive at the volume.

(b) The worst-case discharge is the largest volume, in barrels (cubic meters), of the following:

(1) The pipeline's maximum release time in hours, plus the maximum shut-down response time in hours (based on historic discharge data or in the absence of such historic data, **the operator's best estimate)**, multiplied by the maximum flow rate expressed in barrels per hour (based on the maximum daily capacity of the pipeline), plus the largest line drainage volume after shutdown of the line section(s) in the response zone expressed in barrels (cubic meters); or

(2) The largest foreseeable discharge for the line section(s) within a response zone, expressed in barrels (cubic meters), based on the maximum historic discharge, if one exists, **adjusted for any subsequent corrective or preventive action taken**; or

(3) If the response zone contains one or more breakout tanks, the capacity of the single largest tank or battery of tanks within a single secondary containment system, adjusted for the capacity or size of the secondary containment system, expressed in barrels (cubic meters).

(4) Operators may claim prevention credits for breakout tank secondary containment and other specific spill prevention measures as follows:

Prevention measure	Standard	Credit (percent)
Secondary containment > 100%	NFPA 30	50
Built/repaired to API standards	API STD 620/650/653.	10
Overfill protection standards	API RP 2350	5
Testing/cathodic protection	API STD 650/651/653.	5
Tertiary containment/drainage/treatment	NFPA 30	5
Maximum allowable credit		75

The Enbridge / PHMSA Scenario

The assumptions and approach used by Enbridge to calculate their scenario follows PHMSA regulatory requirements as outlined in the regulations, above and Enbridge's redacted emergency response plan (3). Details on the assumptions and calculations are not provided as Enbridge and PHMSA claim that the information is sensitive security information and protected from public disclosure. Under other regulatory regimes, this protection is normally not allowed for information that was publically available to the public prior to the 9-11 terrorist attack. For example, information submitted to the EPA by regulated owner/operators to meet the Clean Air Act Risk Management Rule requirements was removed from the Internet but the public can still review it by signing in at "EPA reading-rooms". This procedure maintains the citizen's right-to-know provisions and provides some level of security. However, Enbridge at public forums has disclosed enough information that the main elements of their scenario can be analyzed. (16)

Assumptions & Basis for the Enbridge Scenario – At a conference sponsored by the Tip of the Mitt Watershed Center in Petoskey Michigan on August 27, 2015 an Enbridge representative presented information on the scenario: (16).

- Size of the crude oil release 4,500 bbl

- Failure is a guillotine cut to one of the 20 inch pipelines
- Supervisory control and data acquisition (SCADA) control and material balancing systems alert control center personnel
- Personnel take action within the 10 minute procedure decision time
- Operator use remote control to close block valves
- The valves close in 3 minutes, slow to prevent hydraulic hammer
- Total operating flow time from discovery to shutdown is 13 minutes
- Amount of crude oil drain-down after shutdown per owner/operator judgment – by calculation method, the pipeline was divided into segments that would or would not leak based on the specific gravity of the crude oil being less than water and that the water pressure at depth in the Straits would prevent the crude oil from leaking from the ruptured pipeline.
- Then, emergency response crews would insert a tube from shore and pump the crude oil out of the underwater pipeline in the segments where it is held back by water pressure.

Back calculating from a release quantity or 4,500 bbl. (189,000 gal.) and assuming the pipeline is operating at capacity (540 bbl./day divided by 2 for one 20" pipeline), a 13-minute period would release 2,438 bbl. This leaves the expected drain-down to be 2062 bbl. For the scenario to achieve only a 4,500 bbl. release quantity, it assumes design performance of all active controls (alarms, SCADA, electrical, mechanical, procedural and training) and unbelievably, theoretical emergency response.

Assuming perfect performance of all systems is not allowed in other regulatory regimes for the WCS. For example, the Enbridge Line 6B failure events at their operations center in Calgary where the optimal "near instantaneous shutdown" as described in Congressional testimony by Enbridge 10 days prior to the rupture, turned out to be a PHMSA described Keystone Cops debacle of 17 hours. Similar events occurred with the Santa Barbara crude oil pipeline spill in 2015 and the Colonial gasoline pipeline leak in 2015.

Worst-Case Scenario, Are There 2, a Major Breach & Undetected Leak?

This report provides two credible WCS's: 1) a release based on a major failure that would be immediately detected and 2) a leak with a flow rate just below the detection threshold for the SCADA and material balancing systems.

Major failure – Alarms, the SCADA and material balancing systems, pump failure alarms immediately alert operating personnel to a major failure. The following assumptions are used to calculate the WCS scenario:

- Both 20" pipelines fail or are cut:

- There are identified threats that could cause a double breach
- In addition, as both lines are connected as one system, engineering principles and other regulatory regimes would count the quantity in both pipelines even if only one were breached.

- SCADA and material balancing systems immediately alert control center personnel.
- Remote operated valves and shutdown systems do not work as they are active control measures.
- Remote valves must be manually closed. A two (2) hour response time is used as noted by Enbridge represented in public information. This is an active measure; personnel live in the St. Ignace area. It can be argued that in bad weather conditions, the response time may be longer.
- Assume full flow for 2 hours.
- It can be argued that the pumps will go down. In this case if there are NGL's in the line upstream, the depressurization will result in the NGL's expanding and driving crude oil down the line to the failure point under 2-phase flow. The amount driven by this mechanism could far exceed a 2-hour shutdown flow.
- The quantity of crude oil released after manually closing the valves is the volume of both pipelines. Retention of a large quantity of crude oil within the pipelines for later recovery is not counted. This assumption is not allowed under other regulatory regimes and questionable in practice. Backpressure and specific gravity differences are NOT secondary containment **-** only permanent fixed structures are secondary containment.

Assuming operation at capacity (540 bbl./day), a 2-hour release is 45,000 bbl. The quantity that is contained in the pipelines in the Straits is 15.6 bbl. for a **WCS of 61,000 bbl.**

These assumptions can be debated and adjusted up or down but the result still is that the WCS calculated using risk management and other regulatory regime assumptions is <u>greater than 10 times larger than the Enbridge/PHMSA approved Emergency Response Planning Scenario</u> or worst-case discharge which is often mistakenly referred to as the WCS.

The "Black Swan" or "Perfect Storm" Scenario

Research and assessments continues to be done on the failures of traditional risk analysis approaches. (9) Major incidents in the nuclear, chemical, oil & gas, refining, and transportations industries have occurred and later deemed to be the result of a failure to properly identify and analyze risk (consequences, vulnerabilities, threats).

"Black Swan" and "Perfect Storm" scenarios are often discussed after a major incident and then critiques begin on how risk managers should have predicted the incident and taken action beyond the minimum regulatory requirements to protect human health, safety, the environment and economy. Too often studies quickly deep-dive into quantitative, mathematical exercises without getting the scope and assumptions correct at the start of the analysis. The results are a major failure possibly even a Black Swan or Perfect Storm event that could have been foreseen or at least considered. The State of Michigan in its request for comprehensive risk and alternatives analysis is not required to follow regulatory definitions but the public trust doctrine and the iconic nature of the Straits requires that they approach WCS analysis from recognized risk management and "black swan –perfect storm "perspectives.

A "perfect storm" for Line 5 is a major pipeline failure during a major weather event with the resultant power and system failures. It can be argued that emergency generators operate (active controls) and pumps shutdown or fail. However, the pipeline also transports large quantities of NGL's, which are liquids under transport conditions but a gas under atmospheric pressure or the pressure at the bottom of the Straits. A line failure would result in the pipeline de-pressuring and the NGL's expanding (phase transition from a liquid to a gas). The resulting expansion would push crude oil downstream to the rupture point through open or partially shut valves. Rapid two-phase (gas-liquid) flow would occur. This is analogous to shaking up a bottle of champagne and then popping the cork. Depending on the assumptions for the location of the NGL's in Line 5 and how many miles of crude oil are between the NGL's and the pipeline failure point; the amount of crude oil released could be orders of magnitude greater than the worst-case described above.

The Undetected Leak

SCADA and computer-based material balancing systems have limitations on accuracy. The limitations are the result of the inherent capabilities and the technologies and electronics of the system components. The typical accuracy for these systems in the chemical and refining industry is 1.0% to 1.5%. Enbridge has claimed that 3,350 bbl. could be leak undetected[1] by their system which is 0.62% accuracy. The lower detection limit is assumed to be "best-in-class"; however, the release quantity is still quite large.

Discovery by private citizens is historically the means of detecting slow leaks and even large ones where the SCADA and material balance systems fail to alert operators or when operators make wrong decisions. A release at the bottom of the Straits could run for many hours and days before being detected by a private citizen, for example walking on the beach. A one-week duration would result in a spill of 23,450 bbl. Spill durations of 30, 60 and even 90 days can be envisioned depending on the time of the year (winter ice cover), crude oil "weathering phenomena" (agglomeration with particulates and dispersion to Lakes Michigan and Huron in the water column, below the surface), shoreline impact in areas not frequented by the public and etc.

Dispersion Modeling

This study does not address the dispersion and shoreline impact of the WCS release quantities. However, Dr. David Schwab as the University of Michigan modeled several release scenarios.

[1] Correspondence from Enbridge (Brad Shamla) to Attorney General Bill Schuette and DEQ Director Dan Wyant, February 27, 2015, Item 14.
http://www.michigan.gov/documents/deq/Appendix_B.6_493994_7.pdf

The largest release was 25,000 bbl. (1,050,000 gallons) which is approximately the quantity released in 2010 from the Enbridge Line 6B failure in the Kalamazoo River watershed. This release impacted approximately 700 miles of lake shoreline. This report concludes that the potential release for a catastrophic failure of Line 5 could 2.5 times larger, shoreline impact is unknown and that for a slow leak potentially even larger depending on time to detection.

CONCLUSIONS

The State of Michigan does not have a worst-case release scenario in-hand to assess the consequences of a Line 5 failure.

The WCS must be based on risk analysis approaches that only allow release reduction credits for passive control measures. The WCS scenario and its communication to the citizens of the State of Michigan are vital to establish whether continued operation of Line 5 is acceptable. The Enbridge/PHMSA worst-case discharge scenario is not a true WCS analysis and should not be viewed as such.

There are two potential worst-cases, 1) catastrophic failure and release and 2) slow undetected leak for an extended period of time. For comparison:

Enbridge/PHSMA Worst-Case Discharge = 4,500 bbl

FLOW Worst-Case Scenario = 61,000 bbl

Flow Undetected Slow-Leak Scenario = would exceed the Flow WCS in 20 days

Recommended Reading

Niklas Möller and Per Wikman-Svahn , "Black Elephants and Black Swans of Nuclear Safety", *Ethics, Policy & Environment*, 14:3, 273-278, DOI: 10.1080/21550085.2011.605853, 2011. http://dx.doi.org/10.1080/21550085.2011.605853

This article is recommended reading because it provides a broad outline on risk management failures that can be applied to all high hazard industries, including pipelines. It is a short and worthwhile read.

> *This leads us to highlight another concept that we believe is important in order to understand and to prevent hazards: the 'black elephant', which is similar to a black swan, but like the 'elephant in the room' is visible but largely ignored (Gupta, 2009). We define a black elephant as: (i) a high-impact event, that (ii) lies beyond the realm of regular expectations, but (iii) is ignored despite existing evidence.*

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COMMENTS ON THE DYNAMIC RISK REPORT: "DRAFT FINAL REPORT – ALTERNATIVES ANALYSIS FOR THE STRAITS PIPELINE"

Prepared for: **FLOW – For Love of Water**
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Background

On August 24, 2016 the MDEQ, MDNR, MAE and AG's Office, collectively referred to as the State, entered into contract with Dynamic Risk Assessment Systems, Inc. (Dynamic Risk) to conduct an alternatives analysis of Enbridge's Line 5 pipelines crossing the Straits of Mackinac (Straits). The Alternatives Analysis was to be a systematic comparison of the feasibility, costs, benefits and risks of several alternatives, including a detailed base case on continued operation of the existing two 20" Straits pipelines. Dynamic Risk was not charged with recommending a preferred alternative. Instead, the overall purpose was to provide the State, Enbridge and the public with information that could be used to help guide decisions about the future of the pipelines. The "D*raft Final Report - Alternatives Analysis for the Straits Pipeline";* by Dynamic Risk, hereinafter referred to as Report, was issued for review on June 27, 2017. (1) This review addresses the approach, errors and omissions in the Dynamic Risk Report.

DNV GL was conducting a second study, a risk analysis. The risk analysis study was terminated by the State before completion due to a conflict of interest resulting in a failure to meet the terms of the contract. Not having the risk analysis creates a huge information gap for the State and private citizens on the risk and impacts of an Enbridge Line 5 failure at the Straits. However, FLOW issued a report: *Defining a Worst-Case Release Scenario for the Enbridge Crude Oil Pipelines Crossing the Straits of Mackinac – Line 5*. Flow did not develop quantitative risk and consequence assessments, but the FLOW report provides a worst-case scenario (WCS) analysis on the potential spills using recognized risk management approaches. (2)

Executive Summary

As noted in the Dynamic Risk Report but not necessarily clear to a non-technical reader, the methodology provides risk comparisons for the different alternatives to a given set of threats; it provides a comparison, not a WCS analysis for each alternative.
A FLOW WCS analysis found that there are two potential worst-cases: 1) catastrophic failure and release and 2) slow undetected leak for an extended period of time. (2)

- Enbridge/PHSMA Worst-Case Discharge = 4,500 bbl.
- FLOW Worst-Case Scenario = 61,000 bbl.
- Flow Undetected Slow-Leak Scenario = would exceed the Flow WCS in 20 days

Dynamic Risk should have provided worst-case information for each alternative studied, not just a comparison of likely failures. This is gap in the Dynamic Risk Report.

Dynamic Risk did not collect or use primary data. A key justification in hiring consultants is their ability to reach out to the business community and private citizens and gather primary data. Lack of primary data is a fatal flaw in the report as forecasts and projected evolution of the transportation system cannot be credibly analyzed.

Dynamic Risk's decision to prematurely drop the analysis of Alternative #2 - Utilize existing alternative pipeline infrastructure is a major failure in meeting the goals in the contractual agreement with the State. A forecast should have provided on the potential evolution of the pipeline network given a projected decommissioning date. This is a normal task performed by consulting companies, providing forecasts

Low probability events for Alternative #5 were not considered. These events could be catastrophic at the Straits but generally not issues with other pipeline systems (see numerous reports by Dr. Edward Timm).

Leaks under the detection threshold of the SCADA and material balancing systems were not considered. These "smaller leaks" have historically been discovered by private citizens and could occur of long extended periods in Northern Michigan.

Alternative 6 – Decommission Line 5 at the Straits Determine Viability of Continued NGL Deliveries to Rapid River and Michigan Crude Oil Shipments at Lewiston was quickly dismissed without consideration of other possible options that would require capital expenditures and a practicable time to implement. Primary research should have been conducted and a forecast provided on the system evolution 18 to 24 months into the future.

Issues Identified in the Dynamic Risk Report

State's Comments on the Draft Report

In the "*State's Statement Regarding Draft of Alternatives Analysis*", the State commented: *"The State project team indicated that the discussion of "worst case" spills in the draft report was unclear and suggested the need to explain and clarify how it had done so across the various alternatives, particularly with regard to Alternative 5, continued operation of the Straits Pipelines."* This issue is still problematic. In FLOW's discussion with private citizens, they still believe that they are reading about worst-case scenarios (WCS). A strong cautionary statement needs to be made upfront and repeated throughout the report similar to the Dynamic Risk statement on page 1-7.

> ***"Role of Risk Analysis*** *The risk analyses conducted within this study are regarded as objective assessments of credible threats to existing or new infrastructure. They are not intended to represent a worst case spill. They are intended to provide a consistent means for looking into and comparing risks of different operations."*

As noted in the Dynamic Risk Report but not necessarily clear to a non-technical reader, the methodology provides risk comparisons for the different alternatives to a given set of threats; it provides a comparison, not a WCS analysis for each alternative.

FLOW's Report on Worst-Case Scenario Analysis

The first steps in conducting a risk analysis are to define the <u>scope of the system</u> and <u>identify worst-case and alternate release scenarios</u>. If the consequences are unacceptable for the WCS, regardless of the likelihood, then implementing an acceptable alternative and termination of the existing operation is the only option. In addition, extraordinary safety and emergency response measures are normally required in the interim, until the alternative implemented and the existing operation terminated.

The FLOW WCS analysis found two potential worst-cases: 1) catastrophic failure and release and 2) slow undetected leak for an extended period of time.

Enbridge/PHSMA Worst-Case Discharge = 4,500 bbl

FLOW Worst-Case Scenario = 61,000 bbl

Flow Undetected Slow-Leak Scenario = would exceed the Flow WCS in 20 days

Worst-Case Scenarios are Not Available for Alternatives

The Dynamic Risk Report does not provide WCS scenarios for each alternative to enable a maximum risk comparison to the base case (Alternative #5). Worst-case information for each alternative is important, not just a comparison of likely failure mechanisms. This is a gap in the Dynamic Risk Report.

Lack of and Failure to Collect Primary Data

A key justification in hiring consultants is their ability to reach out to the business community and private citizens and gather **primary data.** Alternative #2 – Utilize existing alternative pipeline infrastructure, as well as the other alternatives can only be effectively analyzed through the use of primary data. Stated in the Dynamic Risk Report:

> *"1.6.2. Primary Data The Study is based on existing information with no primary data gathering or public input on social impacts. A number of the assessments should thus be*

regarded as screening exercises - . . . . . *" (1)*

Obtaining and analyzing primary data is vital for a proper analysis of Alternative #2 - Alternatives Remote to the Straits Crossing creating a major flaw in the Report.

Inadequate Systems Analysis and Failure to Forecast System Evolution

The Dynamic Risk analysis should have started with: primary research followed by a comprehensive pipeline network analysis and then a forecast on how the pipeline network would evolve over time when constraints are placed on it, such as a planned decommissioning of Line 5.Instead, the "up-front work" was limited and a "deep-dive" with quantitative risk assessment methodology was undertaken. Their analysis focused on impacts resulting from immediate actions and not a planned industry response using an "as soon as practicable approach"; that is, rapid action is needed but with reasonable time to adjust. **The failure of the Dynamic Risk analysis to forecast the evolution of the system led to the premature rejection and inadequate analysis of key alternatives.**

The above analysis failure creates a major flaw in the Dynamic Risk conclusions for Alternative # 2 - Alternatives Remote to the Straits crossing, which FLOW believes to the most feasible and lowest risk alternative. Dynamic Risk should have assumed a time constraint such as; decommission Line 5 in 18 to 24 months, then forecasted the changes to the pipeline network made by industry players to meet market goals. Unfortunately, Dynamic Risk prematurely rejected Alternative # 2, a primary alternative demanded by the State, non-government organizations and private citizens for comprehensive analysis. From the DRAS Report page, MS-2:(1)

> ***"Alternatives Remote to the Straits Crossing***
>
> *Some alternatives to the Straits Crossing were eliminated during the early stages of analysis. For example, there were limited options for using existing pipeline infrastructure (Alt 2) due to limited capacity on existing assets, whether they are owned by Enbridge or other parties. Even in cases under consideration, it was highly probable that either a new build pipeline or alternative transportation such as rail would be required to manage capacity.* ***Therefore, the option of using existing pipeline infrastructure was removed from further detailed analyses****. . .*
>
> *. . .* ***Feasibility of Alternatives -*** *All alternatives with the exception of Alternative 2 (utilization of existing pipeline infrastructure to transport Line 5 products) were found to be feasible . . . . . "*

The North American pipeline network has undergone a major evolution in the past 5 years with pipeline replacements, expansions, flow reversals, service conversions, interconnections, company acquisitions and divestments and etc. The evolution is projected to continue at a rapid pace with the new U.S. energy strategy. The Dynamic Risk analysis tries to fit Line 5 shipments into existing available capacity in other pipelines, finding that it all does not fit, Dynamic Risk drops further consideration of Alternative #2. FLOW believes that by setting a decommissioning date, 18 to 24 months in the future, industry will use this constraint to prioritize North American needs, modify routing to the Gulf and West Coasts to meet export goals and begin implementation pipeline projects currently on-hold pending a decision on Line 5's fate. In addition, new pipeline projects are underway to expand the use of Pennsylvania, Ohio and West Virginia shale crude oil and NGL's, which compete with the Western U.S. and Canada sources further reducing the justification for the use of Line 5.

Dynamic Risk's decision to prematurely drop the analysis of Alternative #2 is a major failure in meeting the goals in the contractual agreement with the State. Instead of just looking at the current situation, a forecast should have provided on the potential evolution of the pipeline network. This is a normal task performed by consulting companies, providing forecasts and feasibility studies for their clients. Perhaps the wrong consulting company was selected?

Alternatives Analysis by Chapter

As noted above, the lack of a DNV GL risk analysis report creates a major gap in identifying the risk of Line 5 at the Straits. The Dynamic Risk Report does not provide worst-case release and consequence analyses, as this work was not within the scope of Dynamic Risk's project. However, the Report should include:

- Low probability events for Alternative #5 that could be catastrophic at the Straits but not generally issues with other pipeline systems (see numerous reports by Dr. Edward Timm).

- Leaks under the detection threshold of the SCADA and material balancing systems. These leaks historically have been discovered by private citizens and could occur of long extended periods in Northern Michigan.

Alternative 5 – Maintain the Existing Straits Pipelines

From the Report:

> ***"Analysis of the Existing Straits Crossing*** *As a base case for comparison to alternatives to the Straits Crossing, an operational quantitative risk analysis, considering likelihood and consequences of failure, was completed for the existing Straits Crossing (Alternative 5). This base case forms the basis to which all other alternatives were compared. The risk analyses conducted within this study and for each alternative are regarded as objective assessments of credible threats to existing or new infrastructure, and were based on an evaluation of threats, defined as the potential causes and failure mechanisms associated with spills. Three measures of risk were presented; Health and Safety Risk, Economic Risk, and Environmental Risk. These risk analyses are intended to provide a consistent means for comparing risks of alternatives*. (Pages MS-1, 2]

FLOW recognizes this is a base case analysis for comparison purposes. Additional clarification is required at the beginning of this section as many readers interpret the findings to be a "most-likely worst-case scenarios." This base case is a detailed analysis of likely threats, failure probabilities and resulting consequences and readers need to be cautioned that the findings are not worst-case scenarios and also not directly comparable to the "Enbridge / PHMSA worst-case discharge" which is based on different assumptions. (2)

Alternatives #4a – New Pipeline and Trench
Alternative #4b – New Pipeline and Tunnel

A new pipeline and trench would reduce the risk compared to existing Line 5 operations but not entirely eliminate critical threats and the Risk of a failure to the Straits. A new pipeline in a tunnel would provide significant risk reduction.

- The capital estimate for a new pipeline and tunnel under the Straits appears to be extremely low $150M.

- The tunnel should be engineered to meet "secondary containment criteria" equivalent to onshore facility best-practice criteria as required by the EPA and oil pollution control regulations. The tunnel should also allow visual inspection.

- A tunnel does not mitigate the extreme risk posed by Line 5 upstream and downstream of the Straits, which crosses several environmentally sensitive rivers and wetlands runs adjacent to the Great Lakes and Saginaw Bay. It can be predicted that in the near future, requests for permits would be submitted to the State to replace major portions of the 30" pipeline for "maintenance" as well as actions to increase capacity and ship diluted bitumen (Dilbit, tar sands crude).

Alternative 6 – Decommission Line 5 at the Straits Determine Viability of Continued NGL Deliveries to Rapid River and Michigan Crude Oil Shipments at Lewiston

The analysis of this alternative is inadequate and falls short for the same reasons as outlined earlier for Alternative #2. Primary research should have been conducted and a forecast provided on the system evolution 18 to 24 months into the future.

FLOW recognizes that in practice, flow rates are too low to independently operate the upstream and downstream segments without flow through the Straits. The U.P. propane demand and shipments of crude oil from Lewiston are too low; Line 5 is over-sized. However, to assume that *"no alternative infrastructure is constructed* . . . . *analysis provides a qualitative first level impact assessment* . . . ." is a failure in the Report and invalidates the comparison to other Alternatives where in-depth analyses were conducted.

Propane supply sources would adjust from the western and eastern ends of the Peninsula and it is not unreasonable to assume that rail connections could be added. Propane demand will also continue to decline as natural gas takes more market share in populated areas and a system analysis would also consider alternative supply sources for propane. Newly announced studies

and projects to pipeline NGL's and light crude to Detroit and Canada from the Marcellus and Utica formations in Ohio, West Virginia and Pennsylvania could also supply the U.P with propane via rail to Kincheloe and light crude to Detroit and Ohio refineries via non-Enbridge pipelines.
Gary Street has studied this topic extensively and Dynamic Risk should have provided more analysis on these and other options.

The assessment on transporting Michigan produced crude oil was also inadequate and other options may be feasible given a practicable period of time for implementation. Assuming only trucks shipments will work is not credible. The feeder pipeline network to Lewiston crosses rail lines and is relatively close to vacant brown-field sites. The pipeline network could be modified and a rail loading station installed. Alternatively, the existing Line 5 could be used as a sleeve and a smaller pipeline inserted that would handle the reduced flow. These options obviously require feasibility and economic analyses but they are representative of the options that should have been studied, rather than a premature termination of the analysis, possibly reaching erroneous conclusions.

Alternative 2 – Use Existing Infrastructure

Dynamic Risk prematurely dropped this alternative. This creates a fatal flaw in providing a credible alternative analysis. Quoting from the report:

> *". . . . For example, there were limited options for using existing pipeline infrastructure (Alt 2) due to limited capacity on existing assets . . . . Therefore, the option of using existing pipeline infrastructure was removed from further detailed analyses."*(1)

The North American pipeline network and business objectives of the key players were only analyzed at today's point in time; the assumption was made that Line 5 shipments either fit into available capacity in other pipelines or did not. This approach is not how the real world works. Dynamic Risk should have: 1) properly defined the pipeline system and scope, 2) assumed a Line 5 decommissioning date say 18 to 24 months into the future, 3) conducted primary research by contacting relevant industry players and 4) forecasted how the system would evolve including a credible forecast on currently planned and possible new infrastructure. Assuming that only current infrastructure is available and not conducting primary research to also consider the many projects that industry players are contemplating or have on-hold pending a Line 5 decision is not a credible analysis for Alternative #2.

Alternative 1 – Construct One or More New Pipelines

A cursory study on this alternative would have been adequate but to provide the appearance of a comprehensive report, a lot of unnecessary work was done. The effort would have been better spent on the more viable alternatives such as #2. Alternative #1 covers three (3) options: 1) northern route through Canada, 2) Central route into Michigan crossing the St. Mary's River and 3) southern route following existing Enbridge assets.

Over the past several years, there have been many incremental pipeline expansions, jumper lines, flow reversals and major new projects. This activity changes as companies adjust their plans to meet market needs and economics. A credible approach, based on primary research would be to determine if export demands could be met via system changes and the use of pipelines to the Gulf and West Coasts of North America. Strategically, priority for existing capacity should go to North American customers and incremental capacity to export markets. However, Line 5 is currently an enabler for Canadian exports with the Great Lakes carrying the risk. Why does the Report apply the downside economic impact to North American customers and not to export customers purchasing heavy crude (Line 78 - Line 9) enabled by Line 5 operation.

Alternative 3 – Use Alternative Transportation Methods

This alternative reviewed the feasibility decommissioning Line 5 and moving materials by truck, rail and barges. (1)

- FLOW agrees that total replacement Line 5 using truck and rail shipments is not a viable option due the large number of shipments required and the higher safety and environmental risk. Replacement with barges is also not a viable option due to winter shutdown and the very high environmental risk. Minimal effort could have been expended on the analysis of these "non-starter" alternatives.

- However, owner/operators use truck and rail shipments integrated with pipelines as a normal industry practice to optimize the transportation network.

Alternative 5 – Maintain the Existing Straits Pipelines

This analysis assumes that abandonment costs for the pipeline would be avoided and that consumer costs would not rise. (1) The analysis does not consider the unacceptable consequences that would result from a WCS. The Dynamic Risk study did not provide a WCS, as it was not within the scope of their work. The WCS that was to have been provided by DNV GL along with an impact assessment should have defined acceptability of Alternative 5 – Maintain the Existing Straits Pipelines.

Economic Feasibility Analysis [TS-3]

From the Report:

"For this study, the alternatives described are designed to provide equivalent capacity and deliveries to that of the existing Line 5. In practical terms, this corresponds to total delivery capacity of 540,000
barrels/day (bbl/d), of which 1/6th assumed to be NGLs. The project therefore employs a cost-effectiveness analysis to permit a simpler comparison that does not rely on explicitly estimating the benefit streams or revenues from the alternatives. Such a cost-effectiveness analysis is consistent with OMB Circular No. A-4 (2003), which focuses on regulatory analysis of alternatives. It also serves as an appropriate comparative basis for performing subsequent

market impact analyses."

- The State contracted an alternatives analysis not a regulatory alternatives study and the State is not bound by OMB procedures or assumptions on geographic scope. It is vital that the State and private citizens receive credible forecasts on impacts and economic feasibility. To obtain these forecasts, primary research must be performed and assumptions properly made on the pipeline network and evolution leading to and after Line 5 decommissioning.

- The economic impacts were artificially slanted to affect the State and did not provide information on possible actual impacts and benefits occurring outside of the State. The assessment should have been based on forecasting a future state in time, say 2 years and how optimization would credibly affect Michigan citizens.

Socioeconomic Impact Analysis [0, TS-4]

From the Report:

> ". . . . . A county corridor of the Michigan counties . . . . .
> . . . . . A Prosperity Region corridor . . . . . .
> . . . . . The State of Michigan . . . . .

- The scope of this analysis was primarily limited to the State. Some of the assumptions in the alternatives would positively and negatively impact other states. These impacts should have been qualitatively assessed as they affect the feasibility to implement the specific alternative.

Market Impact Analysis

From the Report:

> *"The project made the analytical assumption that market forces would, in the near term of service interruption, rely on some combination of trucking and rail for transportation. . . . . The assessment of larger market impacts of changes in product delivery are more complicated. The project, again, assessed the maximum anticipated impact on Michigan interests. . . . "*

- As previously mentioned, the analysis should have included an analysis given a transition time of 18 to 24 months. The decommissioning can be planned and not an abrupt "emergency shutdown."

- The report also defines "maximum anticipated impact on Michigan interests" for supply disruption but elsewhere does not determine a maximum impact from a catastrophic spill on Michigan interests.

Oil Spill Release Modeling

The approach used to establish a list of set specific threats and failure assumptions for the comparison on alternatives is appropriate. A key point that also continues to need emphasis is pointed out: [1, 1-7]

> *"The risk analyses conducted within this study are regarded as objective assessments of credible threats to existing or new infrastructure. They are not intended to represent a worst case spill. They are intended to provide a consistent means for looking into and comparing risks of different operations. The risk analyses include:*
> - *threat assessments*
> - *assessments of potential spill sizes and probabilities of credible spills*
> - *detailed modeling of fates for alternatives involving the Mackinac Straits*
> - *an assessment of economic, safety and environmental consequences."*

FLOW continues to encounter individuals who interpret the information as worst-case scenarios.

Recommended Reading

Niklas Möller and Per Wikman-Svahn , "Black Elephants and Black Swans of Nuclear Safety", *Ethics, Policy & Environment*, 14:3, 273-278, DOI: 10.1080/21550085.2011.605853, 2011. http://dx.doi.org/10.1080/21550085.2011.605853

This article is recommended reading because it provides a broad outline on risk management failures that can be applied to all high hazard industries, including pipelines. It is a short and worthwhile read.

> *This leads us to highlight another concept that we believe is important in order to understand and to prevent hazards: the 'black elephant', which is similar to a black swan, but like the 'elephant in the room' is visible but largely ignored (Gupta, 2009). We define a black elephant as: (i) a high-impact event, that (ii) lies beyond the realm of regular expectations, but (iii) is ignored despite existing evidence.*

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1. State of Michigan Pipeline Safety Advisory Board, *"State of Michigan Statement Regarding Draft of Alternatives Analysis, June 29, 2017 and Dynamic Risk, Draft Final Report - Alternatives Analysis for the Straits Pipeline"*, June 27, 2017.

2. Kane, R. J., "Defining a Worst-Case Release Scenario for the Enbridge Crude Oil Pipelines Crossing the Straits of Mackinac – Line 5", Comments submitted by FLOW to the MPSAB, August 2, 2017.

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THE WORST-CASE SCENARIO FOR A RUPTURE OF ENBRIDGE LINE 5 AT THE STRAITS OF MACKINAC

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August 4, 2017

Scope

The report that follows develops what the author believes to be the Worst-Case Scenario (WCS) for a rupture of Enbridge Line 5 at the Straits of Mackinac. It is not intended that the WCS defined here applies to any other portion of Line 5, either upstream or downstream from the Straits. Development of the WCS for segments outside the Straits is a separate topic.

Table 1 – A Summary of the Several Possible Spill Scenarios

Scenario	Brief Description		Volume of Spill (barrels)	Worst-Case Scenario (Yes/No)
Enbridge	**Source of Spill Scenario size - unknown**		**4,500**	**No**
1	**Spill confined to oil in Line at the Straits**		**20,351**	**No**
2	**Spill includes 2 hours to manually shut valves**		**65,025**	**No**
3	**Spill greatly increase due to NGLs in the line**		**136,478**	**Yes**
4	**Spill results from a Small Undetected Leak**[1]		**16,750**	**No – but must be considered**

Background

In a closely related document, Rick Kane, a colleague of the author, explains the difference between a true Worst-Case Scenario (WCS) and an Alternative Release Scenario[2]. For a more complete discussion of these important two, but very different Scenarios, the reader is referred to work done by Rick Kane. The following text, ending on page 4 and in italics, is extracted from the paper by Rick Kane, with his permission.

"In general, a WCS is a concept in risk management wherein the planner, in planning for potential disasters considers the most severe possible outcome that can reasonably be projected to occur in a given situation. For hazardous materials operations and transportation the definition is more refined.

[1] It is assumed the undetected spill would go on for 5 days. It could be shorter, or much longer.
[2] Private Communication from Rick Kane, Flow for Water, July 2017

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Worst-Case Scenario WCS – also called a "credible worst-case scenario" is the potential release volume based on system capacity with consideration of mechanical, control system, operational and human factors failures. Credits for mitigation of a potential release volume are only allowed for **passive controls** that are permanently in place.

> **Passive controls** are equipment, devices, or technologies that function without human, mechanical, or other energy input. Passive mitigation systems include dikes, containment walls and natural barriers such as valleys and berms.

> **Active controls** are measures such as remote shutdown valves, computer control and material balancing systems, alarms, operating procedures and training. Active controls require mechanical, energy or human input to function.

The scope of the "system" must also be correctly and consistently defined as changing simple assumptions can drastically change release quantities. A recognized definition is provided by the Occupational Health & Safety Administration (OSHA) Process Safety Management (PSM) Program and used by other regulatory agencies...

> **Process and Interconnected System -** Any activity involving a regulated substance, including any use, storage, manufacturing, handling, or on-site movement of such substances, or combination of these activities. For the purposes of this definition, any group of vessels that are interconnected, or separate vessels that are located such that a regulated substance could be involved in a potential release, shall be considered a single process."

Thus, to calculate a WCS – the system would be defined as connected tanks and pipes, connected storage tanks and credit given for the presence of passive control measures – in the case of crude oil pipelines and facilities, passive control measures are typically permanent secondary containment structures.

Common cause failures and cascading events are also important considerations in identifying the WCS. A "common cause" failure example would be a severe weather event causes power failures affecting equipment and delays response by operating personnel.

Alternative Scenarios are also calculated in addition to the WCS based on assumptions required in regulations or defined by the owner/operator. For example, company management or insurers may define an alternative or "most probably accident scenario" or an "emergency response-planning scenario" required for regulatory or insurance purposes. Such planning scenarios typically have much lower release and consequence levels than the WCS.

The Enbridge / PHMSA Scenario

The key point that must be understood is that the WCS ……..as defined by Enbridge and PHMSA **is not a worst-case scenario as would be defined by other regulatory agencies or risk management professionals in related industries, such as the chemical industry.**

It is a scenario that defines the largest event or spill the submitted emergency response plan is theoretically designed to manage. It is not necessarily the Worst-Case Scenario.

In other words, in other regulatory regimes, the Enbridge / PHMSA scenario would be labeled an "alternative release scenario" and used as a guideline for emergency response planning.

Assumptions & Basis for the Enbridge Scenario

At a conference sponsored by the Tip of the Mitt Watershed Center in Petoskey Michigan on August 27, 2015, an Enbridge representative presented basic information on the scenario listed below.

1. Size of the crude oil release 4,500 barrels
2. Failure is a guillotine cut to one of the 20-inch pipelines
3. Supervisory control and data acquisition (SCADA) control and material balancing systems alert control center personnel
4. Personnel act within the 10-minute decision time
5. Operator uses remote control to close block valves
6. The valves close in 3 minutes, slow to prevent hydraulic hammer
7. Total operating flow time from discovery to shutdown is 13 minutes[3]
8. Amount of crude oil drain-down after shutdown per owner/operator judgment – by calculation method, the pipeline was divided into segments that would or would not leak based on the specific gravity of the crude oil being less than water and that the water pressure at depth in the Straits would prevent the crude oil from leaking from the ruptured pipeline.

   {See The Fallacy of Hydraulic Pressure Curtailing a Pipeline Leak

   for a more compete discussion of this issue.}
9. Then, emergency response crews would insert a tube from shore and pump the crude oil out of the underwater pipeline in the segments where it is held back by water pressure.

Enbridge Reduces Spill Size by over 50%

It is interesting to note that Enbridge, over the course of roughly 15 months, reduced their estimate of a Spill Size at the Straits by nearly 50%, from 8,583 barrels to 4,500 barrels. See **Table 2.**

[3] Note that Enbridge's numbers to manually shut off the pipeline on both ends of the Straits are considerably higher as revealed in a 2015 formal written exchange between Enbridge and the State of Michigan on February 27, 2015. Correspondence from Enbridge (Brad Shamla) to Attorney General Bill Schuette and DEQ Director Dan Wyant, February 27, 2015. Item 14. http://www.michigan.gov/documents/deq/Appendix_B.6_493994_7.pdf SOM: Assuming a leak takes place in the Straits pipelines, and any automatic or remote shut-off systems fail, approximately how long would it take Enbridge workers or contractors to manually close the pipeline on both ends of the Straits? Enbridge Response: "In addition, our practice is to dispatch staff to the site to control any manual valves in the area, which would include closing the valves at the Straits. Such actions would take **15 minutes to 2 hours** depending on the time of the day and the location of existing personnel." (emphasis added).

One can only speculate as to the rationale that was used to reach 4,500 barrels. Here is a possibility of their reasoning: The distance across the Straits per Enbridge[4] is roughly 4.5 miles. The volume in this 4.5-mile segment of the two 20 inch pipelines is 7,793 barrels. This number is reasonably close to the spill volume reported by Enbridge on June 27, 2014, of 8,583 barrels.

Exactly how Enbridge arrived at 8,583 barrels is known only to them.

Having arrived at a spill volume of nearly 8,600 barrels for both lines, the next step may have been to simply assume that only one line ruptures, and "round off" the resulting spill scenario to 4,500 barrels, as reported on September 24, 2015.

This amount – 4,500 barrels – remains as the estimated spill size by Enbridge.

It is important to recognize that 4,500 barrels is merely an Estimated Spill Size – it is not a worst-case scenario.

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[4] ***https://www.enbridge.com/projects-and-infrastructure/public-awareness/line-5-michigan/about-line-5***

Table 2 -- A Brief History of the "Spill Size" as Defined by Enbridge

Enbridge Downplaying the Potential Spill Size of a Catastrophic "Line 5" Straits Rupture			
Date	**Estimated Size of a Spill at the Straits of Mackinac (by Enbridge)**		**Source**
	Barrels	**Gallons**	
June 27, 2014	8,583	360,000	Enbridge
June 27, 2014	5,793	243,000	Enbridge
Feb 27, 2015	4,950	208,000	Enbridge
Sep 24, 2015	**4,500**	**189,000**	**Enbridge**

Dynamic Risk States their Spill Scenarios are not Worst-Case Scenarios
In the recent draft of the Dynamic Risk report for the State[5], section 1.6.4 entitled Role of Risk Analysis, states:

"The risk analyses conducted within this study are regarded as objective assessments of credible threats to existing or new infrastructure. They are not intended to represent a worst-case spill. They are intended to provide a consistent means for looking into and comparing risks of different operation." (Emphasis added).

Later in the same report, Dynamic Risk[6], at section 2.4.2.2.1.1 entitled Study Limitations, states:
"The objective of the study has been to establish realistic consequences of possible oil spill scenarios, and does not represent the worst-case scenarios." (Emphasis added).

Clearly, Dynamic Risk did not include Worst-Case Scenario evaluations in their work product.

How Does EPA Define Worst-Case?
EPA has stated the following regarding Modeling for Toxic Substances[7]:

> EPA has defined (§68.3) a worst-case release as the release of the largest quantity of a regulated substance from a vessel or process line (pipe) failure that results in the greatest distance to a specified endpoint. For substances in vessels, you must assume release of the largest amount in a single vessel; for substances in pipes, you must assume release of the largest amount in a pipe. The largest quantity should be determined taking into account administrative controls. Administrative controls are written procedures that limit the quantity of a substance that can be stored or processed in a vessel or pipe at any one time, or, alternatively, occasionally allow a vessel or pipe to store larger than usual quantities

[5] Dynamic Risk, Alternatives Analysis for the Straits Pipeline, Draft Final Report, Revision 1, June 27, 2017, Calgary, Alberta, Section 1.6.4.
[6] Dynamic Risk, Alternatives Analysis for the Straits Pipeline, Draft Final Report, Revision 1, June 27, 2017, Calgary, Alberta, Section 2.4.2.2.1.1.
[7] ***https://www.epa.gov/sites/production/files/2013-11/documents/chap-04-final.pdf***

(e.g., during turnaround). <u>You do not need to consider the possible causes of the worst-case release or the probability that such a release might occur; the release is simply assumed to take place.</u>

The Fallacy of Hydraulic Pressure Curtailing a Pipeline Leak

On several occasions Enbridge has claimed that hydrostatic pressure, from the water column outside of a rupture will prevent crude oil from leaving the pipeline. An examination of this claim shows that it is based on many untested assumptions.

We have found no data in the literature that supports the assumption that water pressure will have a significant deterrent impact on the rate of leakage from a rupture. While conceptually, a leak from a tiny hole may be "slowed down" due to external water pressure, it is inconceivable that a rupture of the pipeline as what occurred in Line 6B at Marshall in 2010, or a "Full Rupture" as acknowledged by Dynamic Risk[8] would be impeded by the external water pressure.

Making the hypothesis even more tenuous, factors such as the location of the leak on the circumference of the pipeline, and the depth at which the rupture occurs come into the discussion. In the past Enbridge has assumed the depth to be roughly 250 feet[9]. This is the maximum depth of the pipelines at the Straits. Obviously, there is no way that assumption can be universally valid, even it was true that external water pressure would play a significant role in curtailing a massive leak – which we have no evidence that it will.

For example, if the leak were to occur on the top of the pipeline, or on the side, gravity would take over and the lighter oil phase would more readily escape. And, the leak/rupture could occur at a depth of 50 feet rather than 250 feet. At 50 feet, the external water pressure is 21.7 psi; at 250 feet it is 108.7 psi.

If the disaster is the result of a complete severance of the pipeline (as may occur with an anchor drag from a lake freighter), it is inconceivable that external water pressure would play any role in curtailing the leak.

In short, the hypothesis is untested, and relies on several assumptions that are not realistic and/or unproven.

What is a Credible Worst-Case Scenario?

Based on the preceding discussion, we have looked at several components that contribute to a Worst-Case Scenario.

Two very different possibilities have emerged:

1. A "Full Bore" rupture referred to by Dynamic Risk.
2. A "Small Leak" that can go on for several hours or even days before being detected.

[8] Dynamic Risk, Alternatives Analysis for the Straits Pipeline, Draft Final Report, Revision 1, June 27, 2017, Calgary, Alberta, Table 2-11.
[9] Dynamic Risk, Alternatives Analysis for the Straits Pipeline, Draft Final Report, Revision 1, June 27, 2017, Calgary, Alberta, page 2-92.

Each of the above poses a severe environmental risk to the Straits. Since the circumstances leading to the rupture are quite different, each will be dealt with separately.

The Full-Bore rupture --

The basis for this Worst-Case Scenario is:

1. The total volume of crude in Line 5 between St. Ignace and Mackinaw City.
2. The amount of crude that will be discharged to this line segment in the time it takes to manually shut block valves at St. Ignace. Brad Shamla of Enbridge has stated that it may take up to 2 hours to close the valves manually.[10]
3. The amount of crude that would be discharged if –
   a. The block valve at St. Ignace cannot be manually shut and it is necessary to isolate the discharge by manually shutting the block valve(s) at Naubinway.
   b. And, since Line 5 is used 20% of the time for NGLs, a portion of the line downstream from Naubinway contains NGLs.

Item 3.b. is particularly interesting. If there are NGLs in some portion of the pipeline between Naubinway and St. Ignace, and a rupture occurs, the line pressure will rapidly drop. When this happens, the NGLs will vaporize, acting as a "driving force" to purge the pipeline of its contents, both crude oil and NGLs. The driving force that is created would cause crude oil (and NGLs) to spill from the rupture at a far greater rate than if the rate of the spill were only a function of gravity[11].

The Full-Bore release involves a massive rupture, like what happened on Enbridge Line 6B (now renamed[12] to Line 78) at Marshall, MI, in 2010. Dynamic Risk defined a "massive rupture" (the author's term) as a "full-bore opening".

The "Small Undetected Leak" ---- The amount of leakage that could go undetected due to inherent Material Balance Error

In its 2014 correspondence with the State of Michigan (SOM), Enbridge revealed that a small undetected leak due to material balance error is possible in Line 5. [13] The following section details this exchange:

State of Michigan (SOM):

For each method, procedure or device used by Enbridge to detect potential leaks or releases, please identify and document its sensitivity or limits, i.e., the smallest quantity or rate of loss that it can detect. Given the limits of Enbridge's leak detection methods, what quantity of oil or other substances could be released from the pipelines without detection each day if the pipelines were operating at (a) full capacity, and (b) the average rate of operation over the last year?

Response by Brad Shamla of Enbridge:

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[10] Correspondence from Enbridge (Brad Shamla) to Attorney General Bill Schuette and DEQ Director Dan Wyant, February 27, 2015. Item 14. http://www.michigan.gov/documents/deq/Appendix_B.6_493994_7.pdf

[11] To picture this scenario, think of what happens when a bottle of Champagne is opened. Even when carefully opened, the dissolved gas (carbon dioxide) rapidly expands, and causes the bottle to overflow. This rapid expansion of the dissolved gas is analogous to what happens to NGLs in a pipeline when the pressure is suddenly reduced.

[12] https://www.epa.gov/sites/production/files/2017-06/documents/public_copy_lakehead_system_map.pdf

[13] Correspondence from Enbridge (Brad Shamla) to Attorney General Bill Schuette and DEQ Director Dan Wyant, June 27,2014, entitled: Enbridge Lakehead Systems Line 5 Pipelines at the Straits of Mackinac, p. 16. **http://www.michigan.gov/documents/deq/Appendix_B.2_493988_7.pdf**

Enbridge employs overlapping leak detection methods to identify leaks and alert the controller. Our CPM system and our line balance calculations are the two methods with defined sensitivity limits. Leaks that fall below the thresholds for these two systems will rely on other methods of detection, including: surveillance, inline and facility inspections, aerial patrols, and third party/employee reports.

The quantity of oil that could be released without being detected by the CPM system of the line balance calculations is approximately 400m^3/day (~3350 bbls/day). This unlikely scenario assumes that the other overlapping leak detection do not alert the operator of the release. {For a Worst-Case Scenario, we cannot assume other "overlapping" methods alert the operator, especially when we don't know what they are.}

Using an undetected leak of 3,350 barrels per day, it then becomes a matter of how many hours could elapse before the leak is detected, most likely visually from a boat, plane or observers on shore. Considering severe weather, possible ice in the Straits, nighttime conditions, and high winds leading to dispersion and large waves, it seems conceivable that the leak could go on for several hours, maybe a few days, or longer.

A Summary of Possible "Worst-Case Scenarios"

Based on the above discussion, three different Release Scenarios have been developed for a massive rupture in one or both pipelines at the Straits. In addition, one other scenario was developed to cover the case of a small, undetected leak, one that could go on for several hours or even days.

Scenario 1: One or both pipelines suffer a "Full Bore" or "guillotine" release. For Example, both lines are ruptured by an anchor drag.

In this scenario, Enbridge claims it would take 10 minutes to ascertain the problem and an additional 3 minutes to close the valves at St. Ignace and Mackinaw City.

During this time, the volume of oil trapped in the two lines is 15,587 barrels. In addition, the 13 minutes of time needed to close the valves results in another 4,944 barrels that would be released. When added together the amount of the release could be **20,531 barrels** or **862,288 gallons.**

- ➔ **This is NOT the Worst-Case Scenario.**

Scenario 2: Same as Scenario 1, except the automatic block valves at St. Ignace and/or Mackinaw City do not close and must be shut manually. Enbridge claims this may take as long as 2 hours. See Appendix 1.

In this scenario[14], the volume of crude trapped in the line (15,587 barrels), the 10 minutes to ascertain the problem (3,803 barrels) and the 2 hours to manually shut the valves (45,635 barrels) adds up to **65,025 barrels** or **2,731, 038 gallons.**

- ➔ **This is NOT the Worst-Case Scenario.**

[14] This calculation ignores the 3-minute block closure time as the valve(s) did not close.

Scenario 3: In this scenario, it becomes impossible to close the block valve(s) at St. Ignace, and automated closure of a block valve at Naubinway does not work. The only way to stop the flow is to manually close the block valve at Naubinway. Compounding the problem is that Line 5 is being shifted from transporting crude oil to transporting NGLs[15]. We now have a true Worst-Case. Will it ever happen? Maybe not. Could it happen? Yes. And that is why it is the Worst-Case Scenario.

Why is this scenario so significant? If a rupture occurs, the line pressure rapidly decreases. This causes the NGLs that are in a portion of the line to begin vaporizing. Since NGL vapor occupies far more space than NGL liquid, the rapidly expanding vapor acts as a driving force to expel the contents of the line – both vapor and liquid - through the rupture. The resulting release is far more rapid than if liquid crude oil were released only by gravity.

Assume at the time of the incident there are 20% NGLs by volume in Line 5 (80% crude). The line pressure, due to a massive rupture, suddenly drops from 600 psig to 100 psig[16]. When this happens, the entrapped NGLs will expand to 753% of their liquid volume.

This sudden vapor expansion will provide the "driving force" to rapidly evacuate the pipeline, of any both crude and NGLs that are in it.

The volume of the pipeline from Naubinway to St. Ignace is 151,114 barrels. If 80% of the volume in the pipeline is crude, then 120,891 barrels of crude would be expelled from this portion of the line to the waters of the Straits. Add to this the volume of liquid in the pipeline at the time of failure between St. Ignace and Mackinac City – 15,587 barrels. The crude oil spill amount therefore is 120,891 + 15,587 = **136,478 barrels or 5,732,000 gallons.**

- ➔ **This IS the Worst-Case Scenario.**

Scenario 4: Another Possible Worst-Case Scenario --- the Small Undetected Leak
The Small Undetected Leak Scenario is far less dramatic than a scenario involving a major rupture of the pipeline, perhaps a "full bore" rupture. However, the Small Undetected Leak may be more insidious. Per Enbridge, the spill volume for this scenario could be as great as 3,350 barrels per day per line.[17]

Since it is small, and since it is less than the Enbridge lower limit of detection, it can go on for several hours, perhaps even days before detection.

As a starting point, let us assume the undetected leak goes on for 3 days before it is discovered, and is confined to one of the two 20-inch pipelines. This results in a spill of 10,050 barrels. In 5 days, the spill

[15] Enbridge has stated on several occasions that 20% of the volume of material transported in Line 5 is NGL.
[16] The reduced line pressure of 100 psig is an assumption. It is likely on the high side. The actual line pressure could be much less.
[17] Correspondence from Enbridge (Brad Shamla) to Attorney General Bill Schuette and DEQ Director Dan Wyant, June 27,2014, entitled: Enbridge Lakehead Systems Line 5 Pipelines at the Straits of Mackinac, p. 16. **http://www.michigan.gov/documents/deq/Appendix_B.2_493988_7.pdf**

becomes 16,750 barrels. Obviously, this spill scenario is far less than Scenario 3. But since it has gone on for perhaps several days before being detected, it could also be difficult to clean up.

➔ **While not likely to be the Worst Case, this Scenario is unique and must be considered.**

Conclusion (Including a Comparison to the Enbridge Spill Scenario)

The spill scenario used by Enbridge is 4,500 barrels. However, Dynamic Risk has stated this is NOT the Worst-Case Scenario, even though they did not define a Worst-Case Scenario. At this time neither Enbridge nor Dynamic Risk have defined a true Worst-Case Scenario.

Based on practices recommended by EPA, and used by major U.S. chemical companies for the development of a Worst-Case Scenario, the Worst-Case Scenario is far greater than 4,500 barrels. It is 136,578 barrels. This is the spill volume that should be used.