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RE: BAY MILLS INDIAN COMMUNITY'S COMMENTS ON THE SCOPE OF THE ENVIRONMENTAL IMPACT STATEMENT FOR THE ENBRIDGE LINE 5 TUNNEL PROJECT

Gnoozhekaaning, "Place of the Pike," or Bay Mills Indian Community ("Bay Mills") provides the enclosed comments on the scope of the Environmental Impact Statement ("EIS") that the U.S. Army Corps of Engineers is preparing as it evaluates Enbridge Energy, Limited Partnership's ("Enbridge") application for a permit pursuant to Section 404 of the Clean Water Act ("CWA"), 33 U.S.C. § 1344, and Section 10 of the River and Harbors Act, 33 U.S.C. § 403. Enbridge seeks to construct a tunnel beneath the lakebed of the Straits of Mackinac and route a pipeline through it so that it may operate the Line 5 pipeline. Bay Mills submits these comments as a sovereign tribal nation, a consulting tribal nation, and a cooperating agency.

The proposed construction and the Line 5 pipeline are in an area of abundant resources and enormous cultural, spiritual, and economic importance to Bay Mills. The gravity of this proposal must be reflected in the scope of the EIS.

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Whitney B. Gravelle
President, Executive Council

Environmental Impact Statement Scoping Comments of Bay Mills Indian Community Addressing the Proposed Line 5 Tunnel Project

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I. INTRODUCTION

Gnoozhekaaning, "Place of the Pike," or Bay Mills Indian Community ("Bay Mills") provides these comments on the scope of the Environmental Impact Statement ("EIS") that the U.S. Army Corps of Engineers (the "Corps") is preparing as it evaluates Enbridge Energy, Limited Partnership's ("Enbridge" or the "applicant") application for a permit pursuant to Section 404 of the Clean Water Act ("CWA"), 33 U.S.C. § 1344, and Section 10 of the River and Harbors Act, 33 U.S.C. § 403. Enbridge seeks to construct a tunnel beneath the lakebed of the Straits of Mackinac ("the Straits") and route a pipeline through it so that it may operate the Line 5 pipeline (the "Project" or "Proposed Project"). Enbridge proposes this Project in an area of abundant resources and enormous cultural, spiritual, and economic importance to Bay Mills, and the gravity of this proposal must be reflected in the scope of the EIS.

Bay Mills previously has expressed concerns about deficiencies in Enbridge's application materials, including missing information about the purported need for this Project, decommissioning the dual pipelines, and cumulative environmental impacts, among other things. Those information gaps about this Project persist and must be corrected—and Bay Mills, other tribal nations, and the broader public must be provided an opportunity to comment on any new information.

It is critical that the Corps prepare a comprehensive EIS that respects tribal nations and resources. Bay Mills' comments highlight the following essential topics that must be included in the scope of the EIS:

- the relationship between the EIS and the review of this Project pursuant to Section 106 of the National Historic Preservation Act ("NHPA"), and how the Section 106 review informs an alternatives analysis in the EIS;

- appropriate alternatives for this EIS, including alternatives in which there is no oil pipeline crossing the Straits;

- related and connected actions on the Line 5 pipeline;

- the environmental effects of an oil spill in the Great Lakes Basin as a consequence of this Project;

- the Project's contributions to climate change and the way that the effects of climate change may impact the Project; and

- the environmental effects of Project construction and operation, including the risk of catastrophic failure, explosion, or oil spill based on engineering design for this first-of-its-kind tunnel, as well as construction impacts to species, wetlands, water quality, and air quality.

Bay Mills' comments are informed by tribal teachings and experiences, tribal leadership, scientists with the Bay Mills Biological Services Department, and support from Great Lakes Indian Fish and Wildlife Commission ("GLIFWC"), consulting engineers,[1] and counsel. Bay Mills is a federally recognized Tribal Nation[2] and a sovereign nation with an inherent right to self-governance and self-determination, and it has a government-to-government relationship with both the United States and the State of Michigan. Bay Mills submits these comments as a sovereign tribal nation, a consulting tribal nation, and a cooperating agency.[3]

II. THE EIS SHOULD HONOR THE DEEP CONNECTION AND PROTECTED INTERESTS OF BAY MILLS AND OTHER TRIBAL NATIONS IN THE AREA OF LINE 5 AND THE PROPOSED PROJECT.

Bay Mills is one of several Tribal Nations of Anishinaabe people (Ojibwe, Odawa, and Potawatomi) with a deep connection to the lands and waters of the Upper Great Lakes. Enbridge proposed the Project in an area of enormous importance to these Tribal Nations. Bay Mills recognizes the Straits of Mackinac as the center of creation. The Straits of Mackinac are more than a waterway; they are a place of ongoing spiritual significance to the way of life of Bay Mills since time immemorial. The Straits are also home to many species, natural resources, treaty resources, and cultural resources that are important to Bay Mills. The Project and the Line 5 pipeline thus pose serious threats to the exercise of Bay Mills' reserved treaty rights, ability to preserve cultural resources, cultural and religious interests in the Great Lakes, and economy, as well as the health and welfare of tribal citizens.

Every aspect of the Corps' EIS process must be conducted in a way that ensures and maintains respect towards Tribal Nations and protection of tribal resources. The potential impacts from the Proposed Project's construction on cultural and natural resources must be evaluated in the EIS. This assessment must begin with the identification and recognition of these resources, including not only specific land and water areas, sites and structures, but also plants and animals, fish and water, and human relationships with nature and the environment, including cultural and spiritual relationships. It must include economic and social effects, which are interrelated with the natural or physical environmental effects.[4]

A. The Straits Are At The Center Of Bay Mills' Creation Story.

As President Gravelle has recounted in testimony to the Michigan Public Service Commission, the Straits are central to Bay Mills' creation:

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[1] Pre-Filed Rebuttal Testimony of Richard B. Kuprewicz, Exh. BMC-37, Appl. for Auth. to Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763). Curriculum Vitae of Brian O'Mara (included as Attachment A).

[2] 87 Fed. Reg. 4636 (Jan. 28, 2022). Bay Mills was first recognized by Congress in the Treaty of Sault Ste. Marie in 1820 and was officially recognized by an Act of Congress on June 19, 1860.

[3] Bay Mills also refers to and incorporates fully herein the comments on this Project that it provided the Corps on July 14, 2020, and December 14, 2020.

[4] 40 CFR § 1502.16(b).

> According to our oral histories, the creation of North America began with a flooded Earth. The animals received instructions from the Creator to swim deep beneath the water and collect soil that would be used to recreate the world. All of the animals failed, but the body of the muskrat, the last animal that tried, resurfaced carrying a small handful of wet soil in its paws. It is believed that the Creator used the soil collected and rubbed it on the Great Turtle's back, forming the land that became known as Turtle Island, the center of creation for all of North America. According to history, the Great Turtle emerged from the flood in the Straits of Mackinac. The word "Mackinac" is derived from the original name of the Great Turtle from the Ojibwe story of Creation. The Straits are more than a waterway; they are a place of ongoing spiritual significance to the way of life of Bay Mills since time immemorial.[5]

The Straits of Mackinac are not only the center of Bay Mills' creation story, but, as addressed throughout these comments, the Straits play an ongoing central role in the lives of Bay Mills' citizens through ongoing reliance on the area for their livelihood, ceremony and tradition, and identity.

B. Bay Mills' Identity Is Tied To The Water And Fisheries.

Water is critical to Bay Mills' identity. Women are water keepers in Anishinaabe culture; they maintain and protect water for their people, pray and care for the water during ceremonies. They also pass on water teachings to the next generation.[6] If the water is contaminated by tunnel construction, spills, or other possible outcomes, it directly affects the ability of Anishinaabe tribal nations to maintain their historic traditions.

Fish and fishing are also critical to Bay Mills' identity. Lake Whitefish, Lake Trout, and other fish are used in cultural traditions for naming and for feasting in celebration of children, ghost suppers, burial ceremonies, and other cultural traditions, and Lake Whitefish are sacred to the Anishinaabe.[7]

Fishing is a traditional and cultural practice for Michigan Tribal Nations, including Bay Mills.[8] Over half of the Bay Mills' citizen households rely on fishing for some or all of their income. In addition, traditional fishing knowledge is passed down from each generation, and fish are an important food used in ceremonies.

Within the Straits of Mackinac are numerous spawning grounds for different fish species, including walleye and Lake Whitefish. If Lake Whitefish, Lake Trout, and other fish are

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[5] Pre-Filed Direct Testimony of Pres. Whitney Gravelle at 7, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763) (hereinafter "Gravelle Testimony").
[6] *Id.* at 1.
[7] *Id.* at 8.
[8] Pre-Filed Direct Testimony of Jacques LeBlanc Jr. at 4, Appl. Pre-Filed Direct Testimony of Pres. Whitney Gravelle at 7, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763) ("[Fishing] is not just part of my history; it is who I am.")

harmed by tunnel construction, the ongoing operation of the dual pipelines until the tunnel is constructed, or an oil spill from Line 5, a critical component of the tribal livelihood and tribal community would be impacted. The EIS needs to address this potential loss in the EIS, and it must do so in consultation with Bay Mills and other Tribal Nations.

C. Bay Mills Retains Tribal Treaty Rights In The Great Lakes Basin And Has Fiercely Fought To Protect Treaty Rights And Resources.

Bay Mills is the modern-day successor in interest to the bands of Ojibwe people who were identified by the negotiators for the United States as living near Sault Ste. Marie in the Treaty of Sault Ste. Marie of June 16, 1820; the Treaty of Washington of March 28, 1836, 7 Stat. 491; the Treaty of Detroit of July 30, 1855; and the Treaty of Detroit of August 2, 1855.[9] Through these treaties, Tribal Nations retain all rights not expressly granted.[10]

Specifically, as signatories to the 1836 Treaty of Washington, the Ojibwe and Ottawa ceded to the federal government over 14 million acres of land and, in addition, the waters of Lake Superior lying eastward of the Chocolay River, the northern portion of Lake Huron to the mouth of the Thunder Bay River, the waters of Lake Michigan from Ford River south of Escanaba to Grand Haven on Lake Michigan's southeastern shore, and all the waters connecting the three lakes.[11] This area, known as the ceded territory, includes a large part of the upper and lower peninsulas and the Straits of Mackinac, and paved the way for Michigan's statehood.[12]

The Tribal Nations only agreed to this vast cession of their ancestral home upon assurance that they would have the continued ability to exercise their inherent rights, reserved by the Treaty, to hunt, fish, and gather throughout the ceded territory.[13] The Tribal Nations carefully protected their traditional lifeway and its reliance on the environment's natural resources for food, shelter, medicines, and trade.[14] If permitted, the Project would be constructed and would operate in the ceded territory.

Bay Mills has fought to protect its treaty rights through litigation, obtaining decisions from the Michigan Supreme Court and a federal district court recognizing the treaty-protected rights and limitations on the state's power to regulate treaty-protected fishermen.[15]

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[9] Gravelle Testimony at 8.
[10] *United States v. Winans*, 198 U.S. 371, 381 (1905) (explaining that treaties are "not a grant of rights to the Indians, but a grant of right from them, a reservation of those not granted").
[11] Gravelle Testimony at 9-10.
[12] *Id*.
[13] *Id.*
[14] *Id.*
[15] *United States v. Michigan*, 471 F. Supp. 192 (W.D. Mich. 1979); *People v. LeBlanc*, 399 Mich. 31; 248 NW2d 199 (1976).

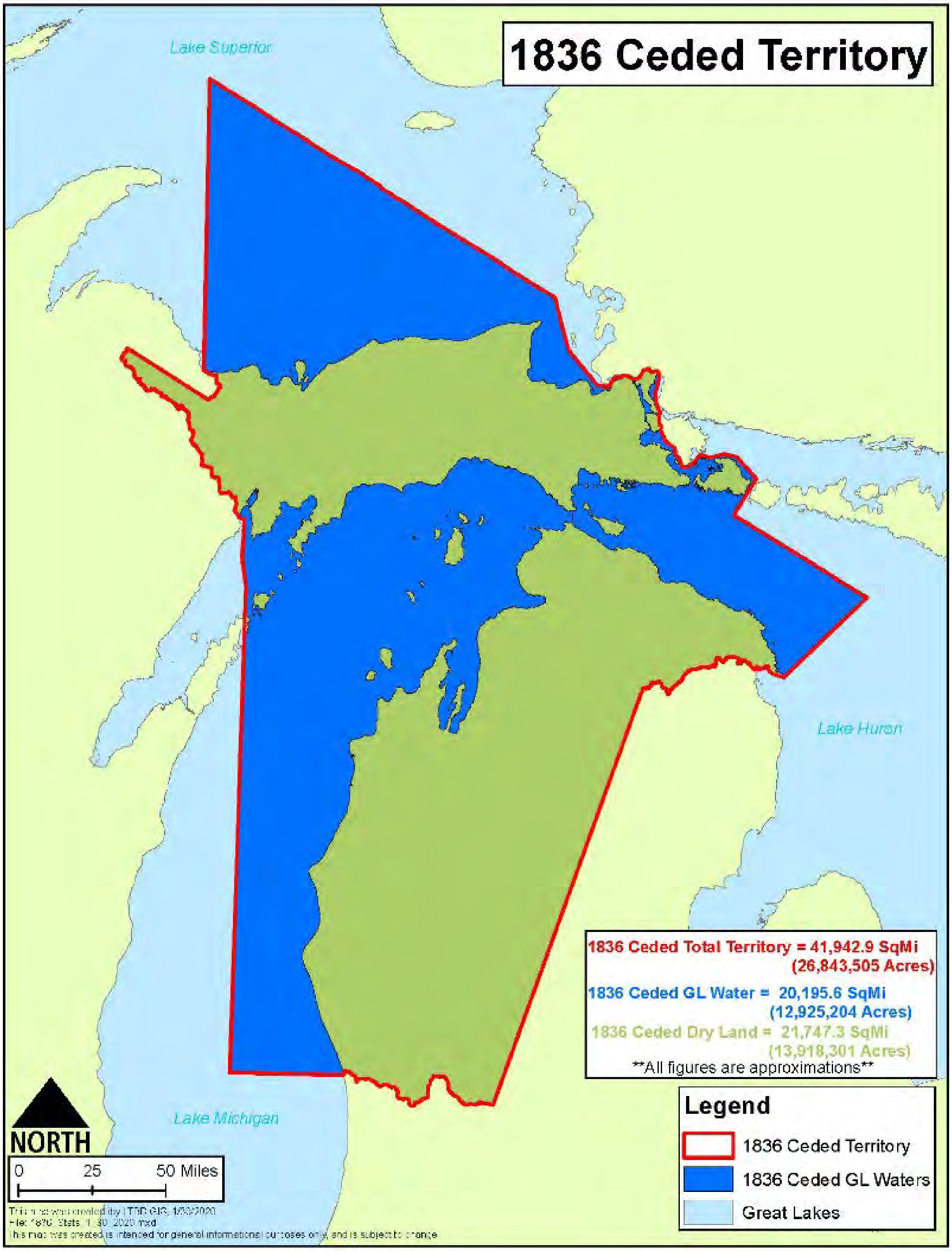

Figure 1: 1836 Ceded Territory Map

Treaties are the supreme law of the land.[16] Federal agencies, including the Corps, have a trust responsibility to tribal nations.[17] Agencies cannot act to render treaties meaningless; only an act of Congress can diminish a treaty.[18] If the resources that a treaty right depends upon are destroyed, the right is violated.[19] A recognition of the supremacy of tribal treaty rights is apparent in Executive Order 13175 and the Memorandum of Understanding Regarding Interagency Coordination and Collaboration for the Protection of Tribal Treaty Rights and Reserved Rights ("MOU"), to which the Department of Defense is a signatory. Section 3(a) of Executive Order 13175 provides in relevant part: "Agencies shall respect Indian tribal self-government and sovereignty, (and) honor tribal treaty and other rights."[20] The MOU recognized that "integrating consideration of tribal treaty and reserved rights into agency decision-making and regulatory processes is consistent with the federal government's trust responsibility to federally recognized tribes and to fundamental principles of good government." Treaties themselves are "the source of legal authority to ensure that agency processes account for reserved treaty rights." [21] Thus, the Corps must not permit any project that will diminish Bay Mills' tribal treaty rights. As emphasized throughout these comments, that includes direct and indirect harm to the Tribal Nations' resources in the Great Lakes from Project construction or operation, including oil spills and climate change.

Notably, Bay Mills has recognized that the Line 5 pipeline poses an existential threat to treaty-protected rights and resources. On March 16, 2015, the Bay Mills Executive Council adopted and approved Resolution No. 15-3-16-B, requesting that "any regulatory body with oversight authority over the subject matter and/or geographic area to take any and all actions reasonable and necessary to mandate and enforce the decommissioning of Line 5 at the Straits of Mackinac."[22] The Resolution explains its support for the decommissioning of Line 5 because of Bay Mills' concern about discharge of petroleum products into the Straits, as any discharge would adversely affect fish shoaling, spawning and nursery areas in both Lakes Michigan and Huron which encompass the most productive fishing areas in the 1836 Treaty ceded waters.

[16] *People v. Jondreau*, 384 Mich 539 (1971) (interpreting U.S. Const., Art. VI, cl.2. and the Treaty of 1836).

[17] *See* https://www.usace.army.mil/Missions/Civil-Works/Tribal-Nations (outlining the Corps' Trust Responsibility and referring to: *Cherokee Nation v. Georgia*, 30 U.S. (5 Pet.) 1 (1831); Presidential Memorandum (29 Apr. 1994) Government-to-Government Relations With Native American Tribal Governments; Executive Order 13175 on Consultation and Coordination with Indian Tribal Governments (06 Nov. 2000); and, the Office of the Secretary of Defense, Trust Responsibility and Consultation Matrix.) In carrying out its federal trust responsibility, it is the Corps' responsibility to ensure that tribal "treaty rights are given full effect," including denying a permit for a project that would impair treaty rights. *Nw. Sea Farms, Inc. v. U.S. Army Corps of Eng'rs*, 931 F. Supp. 1515 (W.D. Wash. 1996).

[18] *People v. LeBlanc*, 399 Mich. 31, 58 (1976) (citing *Menominee Tribe v. United States*, 391 US 404, 413 (1968)).

[19] *See United States v. Washington*, 853 F 3d 946 (9th Cir 2017), *aff'd by Washington v. United States*, 138 S. Ct. 1832. (2018) (holding that where state-owned culverts located under state roads obstructed fish passage, diminishing the supply of fish, the state had violated its duty owed to tribes under treaties that guaranteed fishing rights).

[20] Executive Order 13175. Section 3(a).

[21] Memorandum of Understanding Regarding Interagency Coordination and Collaboration for the Protection of Tribal Treaty Rights and Reserved Rights (Nov. 9, 2021).

[22] Resolution No. 15-3-16-B, Support for Decommission of Enbridge Line 5 Oil Pipeline Under the Straits of Mackinac (March 16, 2015). Notably, Bay Mills was not consulted when the dual pipelines were initially constructed in 1953.

Moreover, a catastrophic oil spill into the Straits would devastate the aquatic ecosystem, damage the shorelines, and disrupt, degrade, and diminish the tribal fishery reserved by treaty. This Resolution recognized that "*the human and natural ecosystems of the Straits of Mackinac are both too complex and too fragile for a replacement pipeline for Line 5 to be successfully sited and constructed within the reasonably foreseeable future*."[23]

More recently, on May 10, 2021, the Bay Mills Executive Council adopted and approved Resolution No. 21-05-10A, banishing Enbridge's dual pipelines from the Bay Mills Indian Community reservation and the lands and waters of the ceded territory, including the Straits of Mackinac.[24] Banishment is a traditional, historical, and customary form of tribal law that has existed since time immemorial and is only exercised by Bay Mills when egregious acts and misconduct have harmed tribal citizens, treaty rights, territories, and resources. Banishment is a permanent and final action.

Banishment was based, in relevant part, on Enbridge's demonstrated actions that it does not honor the rights and interests of Tribal Nations. These actions include: altering underwater archeological reports; utilizing traditional cultural practices against Tribal Nations; and, attempting to initiate non-expert cultural survey work in the Straits of Mackinac without informing or engaging permitting authorities. Banishment further recognized that continued operation of the Line 5 Dual Pipelines will result in a rupture of the pipeline, causing catastrophic damage to the lands and waters near the Straits of Mackinac, destruction of tribal treaty rights, and harm the people who depend on the Great Lakes for their economic livelihood, their quality of life, their cultural wellbeing, and their very existence.

D. The Straits of Mackinac Are A Traditional Cultural Property That Merits Special Consideration In The EIS Process.

The Straits of Mackinac are a place of deep spiritual and cultural meaning to Bay Mills, where there are important cultural and historic resources, some of which are still being discovered and studied. Bay Mills, the Corps and SHPO[25] all agree that the Straits of Mackinac are a Traditional Cultural Property (or Traditional Cultural Landscape).[26] Accordingly, it is essential that the EIS evaluate the impacts of tunnel construction on this special place and identify ways to avoid (or mitigate) those impacts. The EIS must recognize and identify the

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[23] *Id.* (emphasis added)

[24] Resolution No. 21-05-10A, Banishment of Enbridge Energy, Inc. Line 5 Dual Pipelines from the 1836 Treaty of Washington Ceded Territory, waters of the Great Lakes, and the Straits of Mackinac (May 10, 2021).

[25] Letter from Stacy Tchorzynski, Michigan State Historic Preservation Office Senior Archaeologist to Joseph Haas, Michigan Department of Environment, Great Lakes and Energy ("EGLE") Gaylord District Supervisor, (November 2020) (included as Attachment B); *see also* Letter from Whitney Gravelle, President of Bay Mills Indian Community, to Martha MacFarlane-Faes, Deputy State Historic Preservation Officer (Oct. 12, 2022) (included as Attachment C).

[26] *See* 54 U.S.C. § 302706; *see also* National Register Bulletin 38, *Guidelines for Evaluating and Documenting Traditional Cultural Properties* (1990) (discussing Traditional Cultural Properties and defining "traditional cultural significance").

existence of sacred sites, culturally identified as places where significant events occurred as well as burial or cremation places.[27]

Ethnohistorian Dr. Charles Cleland described the rich history of the Straits of Mackinac in his testimony presented to the Michigan Public Service Commission:

> In the case at hand, the Straits of Mackinac area was occupied in the past by people of several native societies, particularly the Ojibwa (Chippewa) and the Odawa (Ottawa) and more recently by modern Euro-Americans. In the case of Native American occupation sites, they collectively contain a record of thousands of years of tribal history. This very ancient history is preserved only in archaeological context. Such sites are non-renewable, so that once they are damaged or destroyed, there are no alternative means of learning about the lives of the native people who first settled and developed unique adaptations to the natural environment in what is today northern Michigan.
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> In more recent times, the Straits area was also the scene of Euro-American settlement during the eighteenth and nineteenth centuries; sites such as Fort Michilimackinac and Fort Mackinac on Mackinac Island and the Pere Marquette Mission at St. Ignace as well as their associated settlements are very valuable in Native American, American, Canadian, French and British history as well as to the modern historic tourism industry.
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> Regretfully, the archaeological sites which incorporate so many details about the lives and cultures of previous occupants of the Straits area have long been under dire threat of destruction due to modern development, rendering those that remain intact of much greater importance. Fortunately, many have been recognized by their listing on the National Register of Historic Places and Sites which signifies their importance for our national patrimony. It would be difficult, perhaps impossible, to find any other small area of North America that has such a huge concentration of important historic sites.[28]

Further, Dr. Cleland testified that there are 141 terrestrial archaeological sites included in the State of Michigan's SHPO files in close proximity to the Straits of Mackinac, including nineteen that are listed on the National Register of Historic Places, three that are part of Historic Archaeological Districts, and one site that has been designated as a National Historic Landmark. These sites may be endangered by the continued operation of the Line 5 dual pipelines and the tunnel construction.[29]

[27] As a way to protect tribal interests and the integrity of these sites, the Corps should not identify in public materials the exact location of culturally significant sites.
[28] Pre-Filed Testimony of Charles E. Cleland at 10-11, Appl. for Auth. to Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763).
[29] Id at 18-19.

More information is needed to fully understand the cultural and archaeological sites in the Straits. SHPO characterized the discovery of significant cultural resources as a likelihood, stating "we *expect* numerous additional resources to be present that have yet to be reported, documented, and evaluated."[30] As discussed further in the Section 106 discussion, *infra* at III.C, archaeological sites within the project area, surrounding area, and downstream areas must be identified and addressed in the EIS. The EIS must also acknowledge and describe sacred sites, burial sites, and cremation within the project area and surrounding areas potentially affected by the proposed project.

For the NEPA and permit evaluation processes, care must be taken to protect the cultural sites from damage during surveys and to keep locational information confidential for spiritual reasons, and to prevent looting and vandalism. Identification needs to be done in consultation with and at the direction of appropriate tribal entities.

Historic and cultural resources are not simply about a moment in history; they are part of a continuum of living knowledge. Bay Mills and its tribal citizens carry cultural practices today and continue to honor their ancestors.

III. THE NATIONAL ENVIRONMENTAL POLICY ACT, EXECUTIVE ORDERS ON ENVIRONMENTAL JUSTICE, AND THE NATIONAL HISTORIC PRESERVATION ACT SUPPORT A COMPREHENSIVE EIS.

A. Under NEPA, An EIS Should Be More Extensive Than The Proposed Project.

The National Environmental Policy Act ("NEPA") and its implementing regulations[31] support a comprehensive EIS. NEPA requires agencies to analyze the environmental impacts of their actions. NEPA's implementing regulations demand that federal agencies, "to the fullest extent possible . . . [u]se all practicable means, consistent with the requirements of [NEPA] and other essential considerations of national policy, to restore and enhance the quality of the human environment and avoid or minimize any possible adverse effects of their actions upon the quality of the human environment."[32]

To achieve these objectives, NEPA requires all federal agencies—including the Corps—to prepare an EIS for all "major Federal actions"—such as the Proposed Project—"significantly affecting the quality of the human environment,"[33] and these rules set the broad contours for the scope of an EIS.[34] The scope of an EIS consists of actions, including connected, cumulative,

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[30] Attachment B at 2.
[31] The 1978 Council on Environmental Quality ("CEQ") regulations implementing NEPA apply to this EIS. The CEQ regulations were revised in 2020, then revised again in 2022. The Corps has acknowledged that the 1978 regulations apply here, consistent with 40 C.F.R. § 1506.13 (2022).
[32] 40 C.F.R. § 1500.2(f) (1978).
[33] 42 U.S.C. § 4332 (C).
[34] 40 C.F.R. § 1508.25 (1978). An EIS "should be 'more extensive than the proposed project,'" as environmental effects would be experienced beyond an immediate construction site. Congress enacted NEPA "to reduce or

and similar actions; alternatives, including the no action alternative, other reasonable courses of actions, and mitigation measures; and impacts, which may be direct, indirect, or cumulative.[35]

While the Corps' permitting authority under the Clean Water Act and Rivers and Harbors Act may be limited to jurisdictional waters, its NEPA responsibility is not. The Corps has "responsibility under NEPA to analyze all of the environmental consequences of a project," and the scope of an EIS extends beyond jurisdictional waters.[36] The agency must look to the future. A critical part "of an agency's responsibilities under NEPA is to predict the environmental effects of [a] proposed action before the action is taken and those effects fully known,"[37] thus, "reasonable forecasting and speculation is…implicit in NEPA."[38] Throughout the process, the agency cannot simply accept an applicant's information or conclusions; an agency must verify the accuracy of information supplied by the applicant.[39]

B. The Corps Must Review The Proposed Project Through A Lens of Environmental Justice And The Federal Government's Commitment To Protect Tribal Treaty Rights.

The Corps must incorporate environmental justice[40] and the federal government's commitment to respect tribal knowledge and rights throughout the entire EIS process. Both Executive Orders and Council on Environmental Quality ("CEQ") guidance require consideration

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eliminate environmental damage." *Appalachian Mountain Club v. Brinegar*, 394 F. Supp. 105, 117 (D.N.H. 1975) (citing *Indian Lookout Alliance v. Volpe*, 484 F.2d 11, 19 (8th Cir. 1973) (finding that it was unreasonable for an EIS to ignore possible environmental effects that could occur in an environmentally fragile area thirteen miles south of the project).

[35] 40 C.F.R. § 1508.25(a)-(c) (1978).

[36] *See Save Our Sonoran, Inc. v. Flowers*, 408 F.3d 1113, 1122 (9th Cir. 2005) (affirming a district court conclusion that the Corps had improperly constrained its NEPA analysis).

[37] *Scientists' Inst. For Pub. Info., Inc., v. Atomic Energy Comm'n*, 481 F.2d 1079, 1092 (D.C. Cir. 1973).

[38] *Delaware Riverkeeper Network v. FERC*, 753 F.3d 1304, 1310 (D.C. Cir. 2014); *see also Scientists' Inst. For Pub. Info., Inc.*, 481 F.2dat 1092 (stating that courts "must reject any attempt by agencies to shirk their responsibilities by labeling any and all discussion of future environmental effects as 'crystal ball inquiry.'").

[39] 40 C.F.R. § 1506.5 (1978); 33 C.F.R. Part 325, App. B § 8(f)(2).

[40] There is no one preferred definition for environmental justice. In 1991, the First National People of Color Environmental Leadership Summit developed a set of environmental justice principles that still guide the environmental justice movement today. *See* Environmental Justice Principles. http://www.columbia.edu/cu/EJ/Reports_Linked_Pages/EJ_principles.pdf. According to the Corps, environmental justice is "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies, with no group bearing a disproportionate burden of environmental harms and risks." *See* https://www.army.mil/article/254935/assistant_secretary_of_the_army_for_civil_works_issues_environmental_justice_guidance_to_the_army_corps_of_engineers

of the potential impacts on "frontline communities," like tribal communities, which are likely to be disproportionately impacted by the environmental impacts of the Project.[41]

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," provides that all federal agencies must:

> make environmental justice part of [their] mission by identifying and addressing, as appropriate, disproportionately high and adverse human health and environmental effects of [their] programs, policies, and activities on minority populations and low-income populations in the United States.[42]

Its provisions apply fully to programs involving tribal nations and members.[43] Executive Order 12898 is intended to require consideration of environmental justice concerns in the NEPA process.[44] Executive Order 12898 emphasizes "the importance of research, data collection, and analysis," particularly with respect to "multiple and cumulative exposures" to environmental hazards for low-income populations, minority populations, and Indian tribes.[45] Further, it provides for agencies to collect, maintain, and analyze information on patterns of subsistence consumption of fish, vegetation, or wildlife. Where an agency action may affect fish, vegetation, or wildlife, that agency action may also affect subsistence patterns of consumption and indicate the potential for disproportionately high and adverse human health or environmental effects on low-income populations, minority populations, and Indian tribes.[46]

Accordingly, the scope of the EIS must evaluate the potential for the Project's construction or operation to pollute fish, vegetation, and wildlife that are part of the food chain for tribal members.[47]

Recent executive orders reinforce the need to pay special attention to environmental justice impacts of the Corps' decision-making processes. Executive Order 14008, "Tackling the Climate Crisis at Home and Abroad," directs federal agencies to promote environmental justice

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[41] *See Standing Rock Sioux Tribe v. U.S. Army Corps of Engineers*, 255 F. Supp. 3d 101, 140 (D.D.C. 2017) (holding that an environmental assessment failed to properly consider the environmental justice implications of a project where it did not consider the cultural, social, and economic factors that are distinct to the Tribe and that "might amplify its experience of the environmental effects of an oil spill").

[42] Exec. Order No. 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (Feb. 11, 1994).

[43] President Clinton, Memorandum for the Heads of All Departments and Agencies: Executive Order on Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (February 11, 1994), https://www.energy.gov/sites/default/files/nepapub/nepa_documents/RedDont/Req-EO12898envjustice.pdf.

[44] *See* 59 Fed. Reg. 7629 (1994).

[45] Exec. Order No. 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (Feb. 11, 1994).

[46] Council on Environmental Quality, Environmental Justice Guidance Under NEPS (Dec. 10,1997), https://www.epa.gov/sites/default/files/2015-02/documents/ej_guidance_nepa_ceq1297.pdf (hereinafter "CEQ Environmental Justice Guidance")

[47] The CEQ has oversight of the Federal government's compliance with Executive Order 12898 and NEPA. *See* CEQ Environmental Justice Guidance.

by "[d]eveloping programs, policies, and activities to address the disproportionately high and adverse human health, environmental, climate-related and other cumulative impacts on disadvantaged communities, as well as the accompanying economic challenges of such impacts."[48] Executive Order 13990, "Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis," recognizes the importance of ensuring access to clean air and water, limiting exposure to dangerous chemicals and pesticides, and holding polluters accountable.[49] The Corps should promote environmental justice through enhancing its public participation processes and evaluating the disproportionate impacts of the Line 5 tunnel project. As explained by CEQ, "[t]he participation of diverse groups in the scoping process is necessary for full consideration of the potential environmental impacts of a proposed agency action and any alternatives."[50]

The Corps' evaluation of environmental justice impacts of the Project will demonstrate that constructing a tunnel and routing a pipeline through the Straits of Mackinac will disproportionately harm Bay Mills and other Tribal Nations. The EIS should consider a full range of the potential environmental justice impacts including, but not limited to, the following:

- Threats to tribal fisheries;
- Impairment of tribal members' ability to harvest natural resources for food, medicine, and ceremony along the route of the pipeline;
- Harm to resources of cultural, economic, and spiritual importance to Bay Mills;
- Frustration of spiritual activities such as ceremonies in and around the Straits; and,
- Social, economic, and health impacts for Bay Mills and other tribal communities.

The Corps must respect the Tribal Nations' perspective and stake in the Proposed Project.

C. The National Historic Preservation Act's Section 106 Process Must Inform The EIS Process, Including The Development, Consideration, And Selection Of Alternatives.

The Corps' development, selection, and evaluation of project alternatives in the NEPA process must be informed by the National Historic Preservation Act's ("NHPA") Section 106

[48] Exec. Order No. 14008, 86 Fed. Reg. 7619, 7629. Section 220 of Exec. Order 14008 creates an interagency working group, including HUD and EPA, and calls on the group to address "current and historic environmental injustice." *Id.* at 7630. Note that although Exec. Order 14008 and the implementing memos and materials use the phrase "disadvantaged communities," there are more appropriate terms that should be used, and community members should be consulted on the preferred term.
[49] Exec. Order No. 13990, Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis (Jan. 20, 2021).
[50] *See* CEQ Environmental Justice Guidance.

process; specifically, the Corps must develop and evaluate alternatives that avoid, minimize, or mitigate adverse effects to historic properties. The Advisory Council on Historic Preservation's Section 106 implementing regulations, which are binding on all federal agencies including the Corps,[51] require the Section 106 process to be "initiated early in the undertaking's planning, so that a broad range of alternatives may be considered during the planning process for the undertaking."[52] Indeed, in order to resolve any adverse effects to historic properties that may occur because of the undertaking, the Corps must "develop and evaluate alternatives or modifications to the undertaking that could avoid, minimize, or mitigate adverse effects on historic properties."[53]

For the Corps to meet this regulatory requirement, the Section 106 process cannot be delayed, and the information gained from it must be used in developing, selecting, and evaluating project alternatives in the parallel NEPA process. If the Corps develops and selects project alternatives without the consideration of potential adverse effects to historic properties, the Corps will foreclose its ability to meaningfully consider alternatives and modifications to the Line 5 tunnel project that could avoid, minimize, or mitigate those adverse effects.[54] This would be unlawful.

The Corps was presented with a unique opportunity to initiate the Section 106 process well before the formal EIS process commenced, allowing it to engage in early and meaningful consultation with consulting parties, including Tribal Nations and Bay Mills. The Corps announced that it would develop an EIS for the Line 5 tunnel project, instead of an

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[51] *Te-Moak Tribe of W. Shoshone of Nev. v. U.S. Dep't of Interior*, 608 F.3d 592, 607 (9th Cir. 2010) ("[F]ederal agencies must comply with these regulations." (citations omitted)). The Corps purports to comply with Section 106 not by following the procedures set forth in Part 800, but those set forth in 33 C.F.R. Part 325, Appendix C. As Bay Mills has repeatedly stated, the Corps' use of Appendix C to fulfill its Section 106 obligations is unlawful, because Appendix C is not a legally valid counterpart regulation. *Sayler Park Vill. Council v. U.S. Army Corps of Eng'rs*, No. C-1-02-832, 2002 WL 32191511, at *7 (S.D. Ohio Dec. 30, 2002) ("[B]y issuing a permit to Lone Star without having complied with the regulations issued by the ACHP, the Corps violated the NHPA."). First, the ACHP never approved or concurred in the adoption and use of Appendix C. *Comm. to Save Cleveland's Huletts v. U.S. Army Corps of Eng'rs*, 163 F. Supp. 2d 776, 792 (N.D. Ohio 2001) "All parties agree that there is no record of the ACHP ever approving or concurring in the Corps' regulations."). The ACHP's approval or concurrence was, at the time Appendix C was developed and adopted, and still is, a requirement for any agency, including the Corps, to develop, adopt, and use counterpart regulations (or alternate procedures). *Accord* 36 C.F.R. § 800.14(a); 36 C.F.R. § 800.15 (1986); 36 C.F.R. 800.11(a) (1979). Second, most of the provisions in Appendix C conflict or are inconsistent with the corresponding provisions in Part 800 and the NHPA. (*Cleveland's Huletts*, 163 F.Supp.2d at 792 ("[T]he Corp's procedures are inconsistent with, and indeed, in derogation of those ACHP regulations."). The NHPA specifically requires agency-specific policies and procedures for implanting Section 106 to be consistent with the ACHP's regulations at Part 800. 54 U.S.C. § 306102(b)(5)(A); 36 C.F.R. § 800.14(a).

[52] 36 C.F.R. § 800.1(c); *see Safeguarding the Historic Hanscom Area's Irreplaceable Res. v. Fed. Aviation Admin.*, 651 F.2d 202, 214 (1st Cir. 2011) ("This directive makes it pellucid that agencies are not expected to delay NHPA review until all details of the proposal are set in cement.").

[53] 36 C.F.R. § 800.6(a).

[54] *Id.* § 800.1(c) ("The agency official must complete the section 106 process 'prior to . . . the issuance of any license.' This does not prohibit [the] agency official from conducting or authorizing nondestructive project planning activities before completing compliance with section 106, provided that such actions do not restrict the subsequent consideration of alternatives to avoid, minimize or mitigate the undertaking's adverse effects on historic properties.").

Environmental Assessment ("EA"), in June 2021. The Corps published its NOI in August 2022. Over that 14-month period, the Corps suspended the Section 106 process, refusing to engage in any consultation with consulting parties, including Tribal Nations and Bay Mills. Bay Mills objected to this suspension and urged the Corps to reinitiate the Section 106 process. [55]

Had the Corps not suspended the Section 106 process, or had it reinitiated the process upon Bay Mills' request, the Corps could have spent the last 14 months consulting with Bay Mills, other Tribal Nations, and consulting parties about the historic properties that may be affected by the undertaking and what the potential adverse effects could be. The information gained from these consultations could have informed the Corps' development and selection of project alternatives in the NEPA process, as is required by the regulations. Instead, the Corps chose to ignore Tribal Nations and its Section 106 obligations and refused to engage in Section 106 consultation during that 14-month period. Now that the EIS process is underway, the Corps still has not reinitiated the Section 106 process. This is unacceptable and unlawful. Bay Mills is deeply concerned that the Corps will not engage in meaningful consultation with consulting parties early enough so that the Section 106 process can have a meaningful impact on the permitting process, including the development, selection, and evaluation of project alternatives, as well as the Corps' final decision on whether to issue Enbridge a 404 permit.

The Section 106 process is not a post-decision mitigation measure meant to offset the undertaking's adverse effects; instead, it is meant to inform agency's decision making to avoid, minimize, and mitigate those potential adverse effects in the first place through the development of project alternatives and modifications. Therefore, it is imperative that the Corps initiate the Section 106 process early in its permitting process and meaningfully integrate it with the on-going NEPA process. If the Corps proceeds with developing and selecting project alternatives in the NEPA process, without input from the Section 106 process, it runs the risk of being too invested in its analysis of those alternatives to be willing or able to seriously consider different alternatives and project modifications that could resolve adverse effects to historic properties. Further, as discussed below, because serious concerns have arisen related to the Section 106 pre-construction surveys, the entire EIS process should be paused now because the Corps will not be able to meaningfully consider alternatives or modifications developed with the benefit of the Section 106 process.

The Corps' failure to meaningfully consider such alternatives or modifications would be unlawful.

IV. THE SCOPE OF THE EIS SHOULD ADDRESS THE DEFICIENCIES IN THE APPLICANT'S PERMIT.

Enbridge's permit application was jointly submitted to the Corps and the Michigan Department of Environment, Great Lakes, and Energy ("EGLE") in April of 2020.[56] At the time of

[55] Bay Mills Indian Community Request for the U.S. Army Corps of Engineers to Reinitiate the National Historic Preservation Act Section 106 Process (included as Attachment D).

[56] *See* Enbridge's Joint Permit Application for a Permit for the Line 5 Tunnel and Pipeline Project Under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, Application Number LRE-2010-004653-56-A19.

submission, the Corps notified Enbridge that additional information was necessary in order to continue processing its application.[57] Despite Enbridge's submission of incomplete application materials, however, the Corps moved forward with publishing a public notice about the Proposed Project in May of 2020.[58] Because the public notice was required to "include sufficient information to give a clear understanding of the nature and magnitude of the activity to generate meaningful comment," the Corps was in error for publishing the notice in May of 2020 based on Enbridge's incomplete application materials.[59]

Following public notice, Bay Mills commented that Enbridge's rushed, chaotic, and incomplete submission of its permit materials and the ongoing safety problems with its Line 5 pipeline operation did not instill confidence in Enbridge's ability to proceed with this Project in a way that protects precious Great Lakes resources.[60] That lack of confidence has only been amplified as the NEPA process unfolded. To date, Enbridge's plans remain inadequate, incomplete, and demonstrate an overall lack of understanding about the complexities of tunneling through the Straits and little awareness about the effects its Project will have on Tribal Nations.

An application for a permit must include, among other things, a complete description of the proposed activity; the location, purpose, and need for the proposed activity; all activities that the applicant plans to take which are reasonably related to the same project; a description of any dredging in navigable waters that the activity would entail; a description of the discharge of any dredged or fill material into the waters of the United States that the activity would entail, including the source of the material, purpose of the discharge, description of the material, the method of transportation and disposal, and the location of the disposal site; and a statement of how impacts to waters of the United States are to be avoided or minimized for activities involving discharges of dredged or fill materials.[61] A permit application is complete only "when sufficient information is received to issue a public notice."[62] Enbridge's application

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[57] *See* Comments of Bay Mills Indian Community Seeking the Denial of Enbridge's Application for a Permit for the Line 5 Tunnel and Pipeline Project Under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, Application Number LRE-2010-004653-56-A19, dated July 2020 at Exhibit F; *See* also *Id.* at Exhibit E (EGLE letter noting deficiencies in Enbridge's permit application)

[58] Army Corps of Engineers, Public Notice Re Enbridge Energy, LP No. LRE-2010-00463-56-A19, at 2 ("Public Notice") (May 15, 2020)

[59] 33 C.F.R. Sec. 325.3(a) ("The notice must, therefore, include sufficient information to give a clear understanding of the nature and magnitude of the activity to generate meaningful comment."); *see also Ohio Valley Envtl. Coal. v. U.S. Army Corps of Eng'rs*, 674 F.Supp.2d 783, 804 (S.D.W.Va.2009) (holding that Corps erred by issuing public notice that "contained no substantive information on mitigation"); *Friends of the Earth v. Hall*, 693 F. Supp. 904, 948 (W.D.Wash.1988) (holding that Corps erred by failing to give notice of a monitoring plan because it was "the single most important feature" of the project); *Nat'l Wildlife Fed'n v. Marsh*, 568 F. Supp. 985, 991, 994–95 (D.D.C.1983) (holding that Corps erred by failing to issue notice of a "staff evaluation," which evaluated benefits and rated alternative sites, because it was "the most important document influencing the [Corps'] decision" and differed substantially from information Sec. included in the public notice).

[60] *See* July 2020 Comments of Bay Mills Indian Community at 2.

[61] 33 C.F.R. § 325.1(d).

[62] 33 C.F.R. § 325.1(d) and 325.3(a)

was incomplete at the time it was submitted, and remains substantially incomplete today, for the following reasons:

- The application lacks an explanation for the need for the Project.[63]
- The application lacks an adequate description of the decommissioning options for the dual pipelines.[64]
- The application does not address cumulative impacts to the affected watersheds.[65] Enbridge's application is silent about the cumulative impacts that its Project will cause, and Enbridge has failed to adequately address cumulative impacts in its supplemental materials.
- The application and supplemental materials fail to include a complete description of the type, composition, and quantity of the material to be dredged, the method of dredging, and the site and plans for disposal of the dredged material.
- The application and supplemental materials fail to include an adequate statement describing how impacts to waters of the United States are to be avoided and minimized, as required by section 325.1(d)(7)(1).
- The application fails to include any financial assurances, or an adequate statement that either describes "how impacts to waters of the United States are to be compensated for" or "explain[s] why compensatory mitigation should not be required for the proposed impacts."[66]

It is unacceptable that, more than two years after submitting its application, Enbridge's application materials and supplemental submissions remain incomplete. At present, Bay Mills and the public are missing information that they should be able to comment on, and the Corps is missing out on the benefits of those public comments.

Moreover, an issuance of the permit based on Enbridge's incomplete application would run afoul of the "hard look" of the Project that is required by NEPA.[67] Indeed, "[a]ccurate scientific analysis, expert agency comments, and public scrutiny are essential to implementing

[63] *See* Section V.A, *infra*.
[64] *See* Section VI.B, *infra*.
[65] *See* Sections VII, VIII (discussing impacts from the Project's contributions to oil spills and climate change); IX.B, IX.C, IX.D (discussing impacts to species, wetlands, and water quality); IX.A (discussing releases into the Straits from a tunnel boring failure or an explosion), *infra*.
[66] 33 CFR § 325.1(d)(7); *see also* Section VII.D, *infra*.
[67] The court will overturn an agency's decision as arbitrary and capricious under 'hard look' review if […] the agency failed entirely to consider an important aspect of the problem…" *Sierra Club v. Flowers*, 423 F. Supp. 2d 1273, 1310–11 (S.D. Fla. 2006), *supplemented sub nom. Sierra Club v. Strock*, 495 F. Supp. 2d 1188 (S.D. Fla. 2007), *vacated sub nom. Sierra Club v. Van Antwerp*, 526 F.3d 1353 (11th Cir. 2008), and *vacated in part sub nom. Sierra Club v. Van Antwerp*, 526 F.3d 1353 (11th Cir. 2008)

NEPA."[68] "NEPA procedures must insure that environmental information is available to public officials and citizens before decisions are made and before actions are taken" and that the information must be of "high quality."[69] As part of the EIS process, these deficiencies in the permit application must be corrected immediately. Once the information is provided by Enbridge, the Corps should issue a supplemental, revised, or corrected public notice based on the change in the application data that would affect the public's review of the proposal.[70]

V. THE EIS SHOULD ADDRESS WHETHER THERE IS A NEED FOR THIS PROJECT AND EVALUATE A WIDE RANGE OF ALTERNATIVES.

In the NOI, the Corps' statement of purpose and need is so narrow that it seems to leave room for just one result: the construction of the Project.[71] But "a statement of purpose and need 'will fail if it unreasonably narrows the agency's consideration of alternatives so that the outcome is preordained.'"[72] The EIS must not be so limited. Consideration of such a narrow range of alternatives is inconsistent with the Corps' obligations under the implementing regulations of Section 106 of the NHPA. The EIS should address whether there is a need for the Project and consider a full range of alternatives, including alternatives in which there would be no pipeline crossing the Straits. A tunnel in the straits is not a foregone conclusion.

A. There Is No Established Need For The Continued Transportation Of Oil And Propane Products Through The Line 5 Pipeline.

The scope of the EIS should include an evaluation of the purported need for this Project.[73] Moreover, the Corps should address the needs and welfare of the people and the relative need for the proposed project before issuing any permit under Section 404 of the Clean

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[68] *See* 40 C.F.R. § 1500.1(b) (1978) ("NEPA procedures must insure that environmental information is available to public officials and citizens before decisions are made and actions are taken.")

[69] 40 C.F.R. § 1500.1(b) (1978).

[70] *Citizens of Karst, Inc. v. United States Army Corps of Eng'rs*, 160 F. Supp. 3d 451, 459 (D.P.R. 2016) (citing Sec. 325.2(a)(2)).

[71] Other sections of the NOI are also unduly narrow. Both the "Purpose and Need" and the "Location" sections of the NOI suggest that connecting the North Straits Facility and Mackinaw Station, in Mackinac County and Emmet County, respectively, is part of the purpose of the Project and a foregone conclusion. Notice of Intent To Prepare a Draft Environmental Impact Statement for the Line 5 Tunnel Project, Mackinac and Emmet Counties, Michigan, 87 Fed. Reg. 50,075 (Aug. 15, 2022). As written, the underlying need for a pipeline in or under the Straits is assumed—*and there is no basis for that assumption*.

[72] *Protect Our Communities Found. v. Jewell*, 825 F.3d 571, 579–80 (9th Cir. 2016); *see also Simmons v. U.S. Army Corps of Engineers*, 120 F.3d 664, 666 (7th Cir. 1997) (stating that it is contrary to NEPA for agencies "to contrive a purpose so slender as to define competing 'reasonable alternatives' out of consideration (and even out of existence)."); *Coal. for Advancement of Reg'l Transp. v. Fed. Highway Admin*., 576 F. App. 477, 487 (6th Cir. 2014) (stating that an agency "cannot define a project's purpose and need so narrowly that it contravenes NEPA's mandate to evaluate reasonable alternatives.") (citing *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 196 (D.C. Cir. 1991)).

[73] *See* 40 C.F.R. § 1502.13 (1978); *see also* 33 C.F.R. § 325.1(d)(1).

Water Act.[74] The published NOI has a one sentence "Purpose and Need" section that is overly narrow as to the purpose and silent as to the need for the Project:

> Purpose and Need: The purpose of the project is to provide transportation of light crude oil, light synthetic crude oil, light sweet crude oil, and natural gas liquids between Enbridge's existing North Straits Facility and Mackinaw Station, and to approximately maintain the existing capacity of the Line 5 pipeline while minimizing environmental risks.[75]

Limiting the purpose of the project to transportation of fuels "between Enbridge's existing North Straits Facility and Mackinaw Station" defines reasonable alternatives out of existence, which federal agencies are prohibited from doing.[76] This unreasonably narrow geographic definition of the Project's purpose must not be used to limit the scope of the EIS.

Similarly, a purpose of "approximately maintain[ing] the existing capacity of the Line 5 pipeline" appears to unreasonably limit the Corps' review of alternatives and must not be used to bar the review of reasonable alternatives. Transporting the fuels through other pipelines with existing capacity or transporting the fuels by truck or rail are all "reasonable alternatives" that the Corps must review.[77]

In fact, before accepting that fuels must be transported—let alone be transported at a set capacity between specific locations—a need for the fuels must be established. There is no basis to suggest that the existing capacity of Line 5 is necessary now, let alone in the future. This is especially true in light of the climate crisis and governmental goals for carbon emissions reductions.[78]

No studies or reports demonstrate that the products transported by the Line 5 pipeline (especially at its current capacity) are needed in the region. Instead, expert testimony in other Line 5 proceedings, the historical record, and independent reports demonstrate that there is no such need:

- Line 5 has been shut down with no impact on gasoline prices. In 2020, the dual pipelines in the Straits were damaged and a state court ordered the dual

[74] 33 C.F.R. § 320.4(a).
[75] Notice of Intent To Prepare a Draft Environmental Impact Statement for the Line 5 Tunnel Project, Mackinac and Emmet Counties, Michigan, 87 Fed. Reg. 50,076 (Aug. 15, 2022).
[76] *Coal. for Advancement of Reg'l Transp. v. Fed. Highway Admin.*, 959 F. Supp. 2d 982, 1001 (W.D. Ky. 2013), *aff'd* 576 F. App'x 477 (6th Cir. 2014) ("However, an agency may not define its objectives so narrow as to confine its range of alternatives since doing so would eviscerate NEPA's mandate to rigorously explore and evaluate all reasonable alternatives.") (citing *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 196 (D.C.Cir.1991)); see also *Simmons v. U.S. Army Corps of Engineers*, 120 F.3d 664, 666 (7th Cir. 1997).
[77] 40 C.F.R. §§ 1500.2(e), 1506.1(b) (1978); 40 C.F.R. §1508.1(z) (2022).
[78] *See, e.g.*, Executive Directive No. 2020-10, Building a Carbon-Neutral Michigan (Sept. 23, 2020) (committing Michigan to "economy-wide carbon neutrality no later than 2050," with an interim goal of achieving a 28% reduction below 1999 levels in greenhouse gas emissions by 2025); Exec. Order No. 13990, Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis, 86 Fed. Reg. 7037 (Jan. 25, 2021).

pipelines to shut down completely for a week and for one of the dual pipelines to be shut down for 78 days.[79] During that period of time, gas prices in Michigan and Toronto remained near the United States and Canadian averages for gas prices.[80]

- Neil Earnest, an expert hired by Enbridge, has concluded that Line 5 has little impact on fuel prices: "The estimated impact of a Line 5 shutdown on Wisconsin and Michigan gasoline, jet fuel, and diesel prices is an increase of 0.5 cents per gallon."[81]

- The Upper Peninsula Energy Task Force, an entity created by the Michigan governor, commissioned an economic analysis of propane supply alternatives to Line 5, and the analysis concluded that any shortfall in propane supply from a disruption to Line 5 could be overcome through a combination of readily available alternatives that include delivery of propane by rail, truck, and pipeline from Edmonton, Alberta, and Conway, Kansas.[82]

- There are practical and economic alternatives to propane, including electric heat pumps and electric hot water heaters.[83]

Energy demands may be satisfied by other methods that may result in fewer greenhouse gas emissions. It is imperative that any mention of a supposed need for fossil fuels account for how long those fossil fuels would be transported and burned in the future and the climate, policy, and environmental justice implications of that usage.

To date, no need for the Project is established, and if no need is established, the Corps should halt the EIS process and deny the application. At the very least, for public transparency, the Corps must state a need in the EIS so that an appropriate set of alternatives can be

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[79] Gus Burns, Enbridge Line 5 Remains Shut Down Pending Michigan Judge's Ruling, MLIVE.COM (June 30, 2020), https://www.mlive.com/public-interest/2020/06/enbridge-line-5-remains-shut-down-pending-michigan-judgesruling.html; Kelly House, Judge: Enbridge can resume full operations on Michigan Line 5 pipelines, THE BRIDGE (Sept. 9, 2020) https://www.bridgemi.com/michigan-environment-watch/judge-enbridge-can-resume-full-operationsmichigan-line-5-pipeline.
[80] Laina G. Stebbins, Study: Partial Line 5 Shutdown Has Not Impacted Gas Prices, Despite Enbridge Warnings, MICH. ADVANCE (Aug. 10, 2020)., https://michiganadvance.com/2020/08/10/study-partial-line-5-shutdown-has-notimpacted-gas-prices-despite-enbridge-warnings/.
[81] Expert Report of Neil K. Earnest at 12, Bad River Band of the Lake Superior Tribe of Chippewa Indians v. Enbridge Energy Co., et al., No. 3:19-cv-00602-wmc (W.D. Wis. May 27, 2022) ECF No. 262.
[82] *Analysis of Propane Supply Alternatives for Michigan*, PUBLIC SECTOR CONSULTANTS 67 (2020) https://www.michigan.gov/documents/egle/egle-psc-upetf-Report_Analysis_of_Propane_Supply_Alternatives_for_Michigan_683751_7.pdf.
[83] Direct Testimony of Dr. Elizabeth A. Stanton at 14-17, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763), https://mi-psc.force.com/sfc/servlet.shepherd/version/download/0688y000001qFWcAAM. .

evaluated, and because evaluating need is a component of the public interest review the Corps must conduct before issuing a permit, pursuant to Section 404 of the Clean Water Act.[84]

B. The Corps Must Consider Alternatives In Which No Pipeline Would Cross The Straits.

The EIS must include a robust consideration of alternatives in which there would be no pipeline in or beneath the Straits of Mackinac.

There are several independent reasons to include "no pipeline in the Straits" alternatives in the EIS. First, there is no established need for Line 5 to operate. As Section V.A, *supra*, explains, there is no economic or energy security need for continuing to use this pipeline, let alone building and rerouting new segments of it. Alternatives to this Project could include an electric grid more reliant on renewable energy.

Second, even if there were a need for fossil fuel products that Line 5 transports—*which there is not*—there is no reason for these products to travel through the Straits of Mackinac. The opposite is true: A fossil fuel pipeline has no place in waters of such immense cultural, spiritual, and economic significance to Bay Mills and other Tribal Nations. Alternatives to this Project could be reliance on other existing pipelines or the use of truck and rail infrastructure.

Third, the Clean Water Act requires the Corps to presume that there are "practicable alternatives that do not involve special aquatic sites," [85] such as the wetlands on either side of the Straits,[86] to this project because it is not "water dependent." Transporting fuel through a pipeline is not water dependent,[87] and Enbridge's desire to locate the pipeline in the Straits does not make this project water dependent.[88] The Corps must presume that there is a

[84] 33 C.F.R. § 320.4(a).
[85] 33 C.F.R. § 230.10(a)(3).
[86] 40 C.F.R. § 230.3(m); *id.* § 230.41.
[87] *See Delaware Riverkeeper Network v. Sec'y of Pennsylvania Dep't of Envtl. Prot.*, 870 F.3d 171, 180 (3d Cir. 2017) (recognizing that "[i]n the context of the federal regulatory scheme . . . [an] agency will presume that the applicant can select a different pipeline route or other alternative that does not affect an aquatic site"); *Bering Strait Citizens for Responsible Res. Dev. v. U.S. Army Corps of Eng'rs*, 524 F.3d 938, 947 (9th Cir. 2008) (recognizing that a proposed gold mine is not water dependent even if the applicant wishes to mine in a watershed because not all gold mining requires access or proximity to water); *City Club of New York v. U.S. Army Corps of Eng'rs*, 246 F. Supp. 3d 860, 870 (S.D.N.Y. 2017) ("A project whose fundamental goal is to provide park and performance space is not water dependent, regardless of whether the [applicant] prefers to build such space on a pier."); *see also Sierra Club v. Van Antwerp*, 709 F.Supp.2d 1254, 1261 (S.D. Fla. 2009) (noting that dams and marinas are water dependent) (quoting Army Corps of Engineers Standard Operating Procedures for the Regulatory Program (October 15, 1999)), *aff'd*, 362 Fed. App'x 100 (11th Cir. 2010).
[88] Similarly, the basic purpose of a limestone mine is mining limestone, regardless of the permit applicant's preferred mining location. *Sierra Club v. Van Antwerp*, 362 F. App'x at 106. In *Sierra Club v. Van Antwerp*, the court recognized that the Corps had correctly defined the purpose of a project as the extraction of limestone, but then acted arbitrarily and capriciously by concluding that the project was water dependent. The court rejected the idea that, although the extraction of limestone is not always water dependent this particular project was water dependent because of its location, and vacated the section 404 permit.

practicable alternative to the Project that does not involve the proposed location for the Project.

Fourth, alternatives where there are no pipelines in the Straits overlap with "No Action" alternatives that NEPA requires the Corps to consider.[89] "Where a choice of 'no action' by the agency would result in predictable actions by others, this consequence of the 'no action' alternative should be included in the analysis."[90] Uncertainty regarding what would happen in the absence of an agency action supports the discussion of multiple no action alternatives.[91] The scope of the EIS must account for the various scenarios that would occur in the absence of agency action here, including those in which no pipeline operates in the Straits because:

- Enbridge complies with or is forced to comply with the Notice of Revocation and Termination of the 1953 easement and ceases to operate the dual pipelines in the Straits;[92]

- A court enjoins the operation of the dual pipelines in the Straits in the ongoing litigation brought by the Michigan Attorney General;[93]

- Enbridge ceases to operate Line 5 (including the dual pipelines in the Straits) because it is forced to cease operating a portion of the pipeline in Wisconsin as a result of ongoing litigation;[94] or,

- Enbridge ceases to operate the dual pipelines earlier than it would cease to operate the Project, consistent with its depreciation study for the current pipeline system (by 2040) as compared to the length of time for which it has obtained an easement to operate the Project (99 years).[95]

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[89] 43 C.F.R. § 1502.14(d), 1508.25(b).

[90] Council on Environmental Quality, Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 Fed. Reg. 18,026 (March 23, 1981).

[91] *See Indigenous Envtl. Network v. U.S. Dep't of State*, 347 F.Supp.3d 561, 575 (D. Mont. 2018) (recognizing the appropriateness of considering three no action alternatives in the absence of the Keystone pipeline).

[92] State of Michigan, Notice of Revocation and Termination of Easement (Nov. 13, 2020).

[93] *See Nessel v. Enbridge Energy, LP, et al*, No. 1:21-cv-01057 (W.D. Mich.); *see also* Press Release, Governor Gretchen Whitmer, Governor Whitmer Takes Action to Protect the Great Lakes (Nov. 30, 2021), https://www.michigan.gov/whitmer/news/press-releases/2021/11/30/governor-whitmer-takes-action-to-protect-the-great-lakes.

[94] Enbridge was found liable of trespass on the Bad River Band Reservation by a federal court this year. *Bad River Band of the Lake Superior Tribe of Chippewa Indians v. Enbridge Energy Co.*, No. 19-cv-602-wmc, 2022 WL 4094073, *1 (W.D. Wis. Sept. 7, 2022). Litigation is ongoing.

[95] Enbridge Energy, Limited Partnership, Enbridge May 2021 Depreciation Study Update at 2 (May 21, 2021); *see also* Sheri McWhirter, *Line 5 tunnel could be a 'stranded asset' in 20 years, report suggests*, MLIVE (Jan. 20, 2022). Enbridge filed the May 2021 Depreciation Study Update regarding the Lakehead Pipeline System with the Federal Energy Regulatory Commission pursuant to 18 C.F.R. 347.1(e)(1)-(5).

Finally, the Advisory Council on Historic Preservation's Section 106 implementing regulations require the Corps[96] to consider "a broad range of alternatives."[97] In order to resolve any adverse effects to historic properties that may occur because of the undertaking, the Corps must "develop and evaluate alternatives and modifications to the undertaking that could avoid, minimize, or mitigate adverse effects on historic properties."[98] Naturally, to avoid, minimize, or mitigate adverse effects, alternatives that do not involve a pipeline in the Straits must be considered given that the Straits are a Traditional Cultural Property and home to many historic properties.[99]

C. The Tunnel Agreements Between The State Of Michigan And Enbridge Do Not Determine Or Limit The Scope Of The EIS, Location, Or Project Alternatives.

The NOI acknowledges a Tunnel Agreement executed by Enbridge and the State of Michigan and Public Act 359;[100] however, neither the Tunnel Agreements nor Act 359 circumvent the EIS process or any other permitting process. Instead, both the Tunnel Agreement and Act 359 demand that the permitting processes be carried out, anticipating and supporting a full EIS. Subject to the consent and approvals of federal and state agencies,[101] Act 359 "creates the Corridor Authority and . . . authorizes the Corridor Authority to operate the utility tunnel."[102] The Tunnel Agreement dated December 19, 2018 followed Act 359 and recognized that there were "required" governmental permits or approvals that would precede any construction or use in furtherance of a tunnel.[103] In conditioning the construction of a utility tunnel on agency approvals, Act 359 and Tunnel Agreements not only contemplate the possibility that the tunnel would not be approved, but they do not limit the reviews that permitting agencies like the Corps must conduct. The Corps should not artificially limit the alternatives to the project based on Act 359 or the Tunnel Agreements.

VI. THE SCOPE OF THE EIS MUST INCLUDE RELATED ACTIONS ON THE LINE 5 PIPELINE.

The scope of the EIS must account for the relationship between this Project and other connected, cumulative, and similar actions, including: (1) other actions along Line 5 that require federal approval, including the Line 5 Segment Relocation Project that is being considered by

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[96] "[F]ederal agencies must comply with these regulations," and the Corps is a federal agency. *Te-Moak Tribe of W. Shoshone of Nev. v. U.S. Dep't of Interior*, 608 F.3d 592, 607 (9th Cir. 2010) (citations omitted)).

[97] 36 C.F.R. § 800.1(c); *see Safeguarding the Historic Hanscom Area's Irreplaceable Res. v. Fed. Aviation Admin.*, 651 F.2d 202, 214 (1st Cir. 2011) ("This directive makes it pellucid that agencies are not expected to delay NHPA review until all details of the proposal are set in cement.").

[98] 36 C.F.R. § 800.6(a).

[99] *See* Sections II.D, III.C, *supra*.

[100] Notice of Intent To Prepare a Draft Environmental Impact Statement for the Line 5 Tunnel Project, Mackinac and Emmet Counties, Michigan, 87 Fed. Reg. 50,075 (Aug. 15, 2022).

[101] MCL § 254.324a(4).

[102] *Enbridge Energy, LP v. State*, 2020 WL 3106841, ***4 (Mich. App. June 11, 2020).

[103] Tunnel Agreement between the Mackinac Straits Corridor Authority and Enbridge Energy, Limited Partnership at 1, 3, 8-9 (Dec. 19, 2018), https://www.michigan.gov/-/media/Project/Websites/MDOT/About-Us/Commissions/MSCA/Documents/MSCA_Tunnel_Agreement_Enbridge_Energy.PDF?rev=fc26f727ef02446081e65a510aee72b8

the Corps' St. Paul District (File No. MVP-2020-00260-WMS)[104] and the applications for Line 5 special use permits currently and/or imminently pending before the U.S. National Forest[105]; (2) the decommissioning of the dual pipelines; and (3) planned and future projects to repair, reroute, and maintain Line 5 to keep oil flowing to and from this Project. To look only at the Straits would effectively ignore the impacts of this Project.

NEPA's implementing regulations direct federal agencies to consider three types of actions in order to determine the scope of an EIS: connected actions, cumulative actions, and similar actions.[106] The tunnel, reroute, and U.S. National Forest projects of Line 5, as well as the decommissioning of the dual pipelines and repairs to Line 5, are all connected, cumulative, and similar actions, and thus the Corps should address the environmental effects of all of these actions in the EIS for the Project.[107] There is sufficient federal "control" over other parts of the project (through permit approvals) that the cumulative federal involvement calls for this inclusive scope.[108]

Connected actions are "closely related and therefore should be discussed in the same impact statement."[109] Actions are connected if they: "[a]utomatically trigger other actions which may require environmental impact statements"; "[c]annot or will not proceed unless other actions are taken previously or simultaneously"; or "[a]re interdependent parts of a larger action and depend on the larger action for their justification."[110] Projects are "connected" where they lack independent utility. Further, where projects are concurrently pending before

[104] U.S. Army Corps of Engineers, Public Notice Re MVP-2020-00260 (Jan. 6, 2022),
[105] U.S. Forest Service, Enbridge Energy Limited Partnership SUP (last visited Sept. 29, 2022), https://www.fs.usda.gov/project/?project=44889&exp=detail. Line 5 travels through multiple National Forests, including the Chequamegon-Nicolet National Forest (special use permit expired and application for renewal pending), the Ottawa National Forest (special use permit expiring in 2024), and the Hiawatha National Forest (special use permit expiring in 2026). Line 5's history of oil spills includes environmental damage in the National Forests. For example, in 1980, oil leaked from Line 5 in the Hiawatha National Forest, and "contaminated soil and groundwater persisted at the site for more than three decades." *See* Keith Matheny, 30 years later, contamination remained at site of pipeline spill, Detroit Free Press (May 7, 2016), https://www.freep.com/story/news/local/michigan/2016/05/07/enbridge-line5-oil-spill-hiawatha-national-forest/83507228/.
[106] 40 C.F.R. § 1508.25 (1978).
[107] *See Kleppe v. Sierra Club,* 427 U.S. 390, 409-10 (1976); *Native Ecosystems Council v. Dombeck,* 304 F.3d 886, 893-94 (9th Cir. 2002).
[108] 33 C.F.R. § Pt. 325, App. B(8)(d). The November 21, 2021 Memorandum of Understanding Regarding Interagency Coordination and Collaboration for the Protection of Tribal Treaty Rights and Reserved Rights, to which the Department of Defense (Corps) and Department of Agriculture (Forest Service) are both signatories, counsels in favor of the Corps, Forest Service, and Tribal Nations working together to ensure that treaty rights and resources "are considered early in . . . decision-making processes." https://www.doi.gov/sites/doi.gov/files/interagency-mou-protecting-tribal-treaty-and-reserved-rights-11-15-2021.pdf.
[109] 40 C.F.R. § 1508.25(a)(1) (1978).
[110] 40 C.F.R. § 1508.25(a)(1).

an agency, proposed by the same company, and logically interdependent, they may be connected.[111]

Cumulative actions are actions "which when viewed with other proposed actions have cumulatively significant impacts and should therefore be discussed in the same impact statement."[112] Where multiple proposed actions are pending before an agency at once, the agency should consider the cumulative and collective impacts of those actions.[113] A meaningful cumulative impact analysis must identify: "(1) the area in which the effects of the proposed project will be felt; (2) the impacts that are expected in that area from the proposed project; (3) other actions—past, present, and proposed, and reasonably foreseeable—that have had or are expected to have impacts in the same area; (4) the impacts or expected impacts from these other actions; and (5) the overall impact that can be expected if the individual impacts are allowed to accumulate."[114]

Similar actions are actions "which when viewed with other reasonably foreseeable or proposed agency actions, have similarities that provide a basis for evaluating their environmental consequences together, such as common timing or geography."[115]

A. The EIS Must Consider The Environmental Impacts Of Other Segments Of Line 5 Requiring Permits.

The Project is dependent on the approval of the proposed Relocation Project and the reauthorization of multiple Forest Service special use permits. The Relocation Project and National Forest segments are necessary to supply the fuels to be transported by the Proposed Project.[116] Oil from Alberta, Canada will not be able to reach its destination in Sarnia, Ontario via the Project without the oil flowing through the segments of Line 5 traversing around the Bad River Reservation and through the pipeline as it crosses the Chequamegon-Nicolet National Forest, the Ottawa National Forest, and the Hiawatha National Forest. If any one of these projects is not permitted, the product will not reach the Straits and there will be no purpose for the tunnel project. Each segment of the pipeline cannot proceed without the other. The

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[111] *Delaware Riverkeeper Network v. FERC*, 753 F.3d 1304, 1307, 1315 (D.C. Cir. 2014); *see also Hammond v. Norton*, 370 F. Supp. 2d 226, 253 (D.D.C. 2006) (holding that an agency improperly segmented its analysis of a pipeline project by concluding that part of the pipeline project had independent utility).
[112] 40 C.F.R. 1508.25(a)(2).
[113] *Blue Mountains Biodiversity Project v. Blackwood*, 161 F.3d 1208, 1214-15 (9th Cir. 1998) (concluding that five potential logging projects in the same watershed "were reasonably foreseeable" and an EIS was required to address their cumulative effects).
[114] *Delaware Riverkeeper*, 753 F.3d at 1319 (quoting *Grand Canyon Trust v. FAA*, 290 F.3d 339, 345 (D.C. Cir. 2002).
[115] 40 C.F.R. § 1508.25(a)(3).
[116] *See Hammond v. Norton*, 370 F. Supp. 2d 226, 253 (D.D.C. 2006) (stating that, for the agency to treat the pipeline projects as independent, it had to substantiate "with record evidence beyond mere assertions of [the applicant's representatives or agency personnel] the existence of reasonably certain alternative petroleum supply sources . . . or other circumstances indicating with reasonable clarity that the Williams pipeline will not rely on the proposed Equilon pipeline").

Relocation Project, special use permits, and this Project are interdependent parts of the entire Line 5 and depend on each other and the continued operation of Line 5 for their justification.

Moreover, these projects are proposed by the same company, at approximately the same time, along the same pipeline, and all within the ecological area of the Great Lakes Basin.[117] When viewed together, the Project, the Relocation Project, and the reauthorization of the Forest Service special use permits are actions have reasonably foreseeable and cumulatively significant impacts, and thus the impacts of each action must be included in this EIS. Therefore, each of these actions should be discussed in this EIS.

B. The EIS Must Consider the Environmental Impacts Of Decommissioning The Line 5 Dual Pipelines, Including Alternative Methods Of Decommissioning.

Enbridge has characterized decommissioning as "the only activity that is certain to occur once the Project has been constructed."[118] Decommissioning of the existing Line 5 dual pipelines is an integral part of the Project, and the environmental impacts of each of the decommissioning alternatives must be considered in the EIS.[119] However, Enbridge has also changed its plans for decommissioning—and Enbridge's changing plans cannot be a basis for improperly segmenting decommissioning from the Project.[120] The scope of the EIS must address all impacts of each possible decommissioning alternative.

At the inception of the Line 5 Tunnel Project plan, Enbridge, the Corps, and the State of Michigan acknowledged in writing on multiple occasions the need for compliance with federal and state regulations and well as the need to study two options for decommissioning: removal of or abandonment of the pipelines in place.

Enbridge's April 8, 2020 Joint Permit Application includes decommissioning of the existing pipelines, stating that "[o]nce the new segment of the pipeline across the Straits is put into service, the existing dual pipelines will be decommissioned in accordance with federal, state, and local regulations . . ."[121] On April 14, 2020, recognizing the inadequacy of this description, the Corps sought substantial additional information about the Project including

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[117] *See Delaware Riverkeeper Network v. FERC*, 753 F.3d 1304, 1307, 1315 (D.C. Cir. 2014) (dismissing the idea that a single, linear pipeline could have logical termini other than the two major points it connected); *Hammond v. Norton*, 370 F. Supp. 2d 226, 253 (D.D.C. 2006) (noting that pipeline projects initially proposed by the same company were not independent).

[118] Letter from Paul Turner, Environmental Specialist, Enbridge Energy, to Kerrie Kuhne, U.S. Army Corps of Engineers at 1 (March 25, 2021) (responding to an Army Corps of Engineers Information Request that was dated January 25, 2021). In this response, Enbridge also announced its intent to decommission the pipelines by "deactivating them in place." *Id.* As noted in the response, the proposal to decommission in place has not been approved by the State of Michigan. *Id.*

[119] *See* 42 U.S.C. § 4332(C); 40 C.F.R. § 1508.25(a)(1); 33 U.S.C. § 1344; 33 C.F.R. § 320.4(e).

[120] While the NOI mentions Enbridge's plans to decommission the dual pipelines in place, it does not indicate that it will be studying the decommissioning alternatives in the draft EIS. Notice of Intent To Prepare a Draft Environmental Impact Statement for the Line 5 Tunnel Project, Mackinac and Emmet Counties, Michigan, 87 Fed. Reg. 50,076 (Aug. 15, 2022).

[121] *See* Joint Permit Application at 103.

details of the decommissioning, and indicated that Enbridge's permit application would not be deemed complete unless the information was submitted. [122]

On May 4, 2020, in response to the Corps' information request, Enbridge provided two options for decommissioning the pipelines.[123] The first option was "Abandonment in Place of Dual Pipelines:" Enbridge would leave all 21,000 feet of each pipeline in place and would purge and clean the pipelines and plug/grout the ends.[124] The second option was "Removal of Unburied/Exposed Sections of the Dual Pipelines:" Enbridge would remove those portions of the pipelines that are fully or partially exposed and not fully buried along the shoreline. The removal option would entail: (1) purging/cleaning the pipelines; (2) removing all screw anchor supports or cutting them near the mudline; (3) "jet sledding" the partially covered portions of the pipelines and anchor supports to remove sediment to allow for cutting and removal; (4) cutting the pipelines into segments; (5) capping the ends of the remaining, buried portions of the pipelines; (6) winching the pipelines segments of pipe that are closer to the shoreline of the Straits and cutting them into lengths suitable for transportation; (7) cleaning and transporting the pipeline segments off-site; and (8) monitoring the remaining sections of the pipelines.[125] The Corps' May 15, 2020 Public Notice included these two decommissioning options.[126]

Throughout the Michigan permitting process for the Project, EGLE inquired about Enbridge's plans to decommission the dual pipelines; in response to one of EGLE's inquiries, Enbridge acknowledged that decommissioning may involve disturbance to the bottomlands, require an NPDES permit, and cause other environmental impacts.[127]

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[122] Letter from Kerrie Kuhne, Chief, Permit Evaluation Western Branch, U.S. Army Corps of Engineers to Paul Turner, Environmental Specialist, Enbridge Energy (April 14, 2020).
[123] Letter from Paul Turner, Environmental Specialist, Enbridge, to Kerrie Kuhne, U.S. Army Corps of Engineers at 5 (May 4, 2020). This description of decommissioning—a part of the Project and an activity reasonably related to the Project—lacks sufficient detail for the permit application to be deemed complete. *See* Section III, *supra*; 33 C.F.R. § 325.1(d)(1); 33 C.F.R. § 325.1(d)(2).
[124] Letter from Paul Turner, Environmental Specialist, Enbridge, to Kerrie Kuhne, U.S. Army Corps of Engineers at 5 (May 4, 2020).
[125] *Id.*
[126] Army Corps of Engineers, Public Notice Re Enbridge Energy, LP No. LRE-2010-00463-56-A19, at 2-3 ("Public Notice") (May 15, 2020) ("the pipeline would be purged, cleaned, and abandoned in place, *or* . . . the pipeline would be cleaned, and exposed portions of the pipeline between the 65-foot depth contours would be removed.") (emphasis added). The Tunnel Agreements between the State of Michigan and Enbridge also contemplate that the two alternatives for decommissioning will be considered by regulatory agencies and will require regulatory approvals. Second Agreement Between the State of Michigan, Michigan Department of Environmental Quality, and Michigan Department of Natural Resources and Enbridge Energy, Limited Partnership, Enbridge Energy Company, Inc., and Enbridge Energy Partners, L.P., Sec. H (Oct. 2018), available at: https://www.michigan.gov/documents/line5/Enbridge_Second_Agreement_with_Governor_Snyder_October_2018_695450_7.pdf; Third Agreement Between The State Of Michigan, Michigan Department Of Environmental Quality, And Michigan Department Of Natural Resources And Enbridge Energy, Limited Partnership, Enbridge Energy Company, Inc., And Enbridge Energy Partners, L.P., Sec. 7.2. (Dec. 2018), *available at* https://www.michigan.gov/documents/mdot/ThirdAgreementMichiganEnbridge_684307_7.pdf. The two options listed are abandon the lines in place or remove only those portions not fully buried.
[127] Letter from Paul Turner, Environmental Specialist, Enbridge, to Kerrie Kuhne, U.S. Army Corps of Engineers at 5 (May 4, 2020),

However, in March 2021, without explanation or support, Enbridge began asserting that it would decommission in place without consideration of the alternatives or environmental impacts.[128] The NOI repeats Enbridge's plans to decommission in place upon completion of the tunnel construction: "Upon completion, Enbridge proposes to decommission the existing submerged Line 5 dual pipelines crossing the Straits by purging, cleaning, and abandoning them in place."[129] The NOI does not indicate that the EIS will consider the impacts of both decommissioning in place and removal of the pipelines; the Corps should not accept Enbridge's unilateral selection of one decommissioning option without undertaking the proper analysis required under NEPA.

The direct, indirect, and cumulative impacts of decommissioning must be assessed. These effects include impacts to cultural and archeological resources, threatened and endangered species, critical spawning grounds, environmental impacts, and public trust considerations.[130] As the Corps and SHPO have acknowledged, the Straits are a Traditional Cultural Property, which means that the removal of the extant lines might disturb the bottomlands and disrupt the integrity of the Traditional Cultural Property. Even under the narrowest decommissioning option—leaving the pipelines in place—there are potential effects; given the pipelines' elevated position in many sections, the danger of anchor strikes remains, risking disturbing the retired lines and impacting surrounding bottomland resources. Corrosion of the abandon lines could harm surrounding aquatic environments.[131] Maintenance of the remaining pipelines threatens critical elements of the Traditional Cultural Property because the maintenance equipment and activities could disturb cultural resources.

The decommissioning options should not be segmented from the rest of the Project or ignored.

C. The EIS Must Consider The Environmental Effects Of Repairs To Line 5.

The direct, indirect, and cumulative environmental effects of this Project include the effects of likely future projects to repair, reroute, or maintain Line 5 to keep the Project operating as a pipeline through and on either side of the Straits. In other words, this Project is a foot-in-the-door for other projects along Line 5. First, the Project will require repairs to the proposed tunnel or pipeline in the tunnel, including the possibility of flammable or explosive product escaping during a repair. Second, the Project will entail repairs to the facilities and pipeline on the north and south sides of the Straits, especially in light of potential erosion along the lakes. Third, foreseeable effects of the Project include repairs to the pipeline traveling to and from tunnel to other segments where products are added to the pipeline or taken off of the pipeline, including the possibility that repairs will cause the clearing of wetlands or other habitats, trenching through waterways, or other land- or water-based environmental impacts.

[128] Enbridge Response to Army Corps of Engineers Information Request, at 1 (March 25, 2021).

[129] Notice of Intent To Prepare a Draft Environmental Impact Statement for the Line 5 Tunnel Project, Mackinac and Emmet Counties, Michigan, 87 Fed. Reg. 50,076 (Aug. 15, 2022).

[130] *Id.*

[131] *See* Second Agreement Sec. H; Third Agreement Sec. 7 ("Permanent Deactivation of Dual Pipelines").

The impacts of all of these projects add up. To that end, the EIS should include information on how long a pipeline built in 1953 is expected to safely function.

It is reasonably foreseeable that such repairs will occur, and they must be within the scope of the EIS.

VII. THE EIS MUST INCLUDE THE LIKELIHOOD AND ENVIRONMENTAL IMPACTS OF AN OIL SPILL IN THE GREAT LAKES BASIN.

The Proposed Project is one of the key determinants of whether and how long into the future Line 5 will continue to operate. The environmental effects of the Proposed Project thus include the direct, indirect, and cumulative impacts of Line 5—namely, the risk that oil spills into the environment. [132] Accordingly, the impacts of an oil spill from Line 5 into any of the interconnected waters of the Great Lakes Basin must be part of the scope of the EIS. A tunnel, or any other purported solution to the risk of the dual pipelines spilling in the Straits, is not foolproof and does not reduce the likelihood of an oil spill elsewhere along the pipeline.[133] Oil pipelines spill, damaging the environment. In the Great Lakes Basin, where the waters are interconnected, a spill from Line 5 in one waterway will travel through the waters, thus threatening a larger area.

The Corps cannot narrow its focus to the Straits crossing or Mackinac and Emmet Counties – as the NOI appears to – because the Project implicates a much larger area.[134] An EIS cannot set artificial boundaries on hydrologically connected resources or on ecosystems.[135]

A. Pipelines Spill.

It is not a matter of *if* a pipeline will spill oil, but a matter of *when*. Data from the Pipeline and Hazardous Materials Safety Administration ("PHMSA"), reveals that pipeline spills or leaks occur approximately every other day in the U.S. From 2004 to 2017, PHMSA data showed there were an average of 186 incidents involving crude oil pipeline systems in the

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[132] *See Delaware Riverkeeper Network v. FERC*, 753 F.3d 1304 (D.C. Cir. 2014) (requiring meaningful analysis of cumulative impacts); *Grand Canyon Trust v. FAA*, 290 F.3d 339, 345 (D.C. Cir. 2002) (same); *Indigenous Envt'l Network v. United States Dep't of State*, 347 F. Supp. 3d 561, 582, 590 (D. Mont. 2018) (requiring an agency to address oil spills more fully, including with information about new spills and new studies and by conducting additional modeling).

[133] To the contrary, this Project likely would increase the risk of a spill by extending the lifespan of the pipeline.

[134] *See Save Our Sonoran, Inc. v. Flowers*, 408 F.3d 1113, 1122 (9th Cir. 2005) ("[W]hile it is the development's impact on jurisdictional waters that determines the scope of the Corps' permitting authority, it is the impact of the permit on the environment at large that determines the Corps' NEPA responsibility. The Corps' responsibility under NEPA to consider the environmental consequences of a permit extends even to environmental effects with no impact on jurisdictional waters at all.").

[135] *See id.*; *see also* Cumulative Environmental Risk of Crude Oil and Natural Gas Pipelines in the 1836, 1837, 1842, and 1854 Ceded Territories, by Esteban Chiriboga, Environmental Specialist, Great Lakes Indian Fish and Wildlife Commission (April 2022) (hereinafter "Cumulative Environmental Risk Report") (included as Attachment E).

United States each year, averaging 42,517 barrels of crude oil released per year.[136] Twenty-nine percent of that oil was never recovered from the environment.[137]

Enbridge's record for oil spills highlights the need for the EIS to study and analyze spill scenarios. From 1999 to 2010, Enbridge pipelines spilled nearly 7 million gallons of crude oil in over 800 different incidents across the United States and Canada.[138] The combined environmental effect of these incidents to wetlands, surface and ground waters has not been quantified. The most notorious spill involves Enbridge's ruptured 6B pipeline which spilled over a million gallons of heavy crude oil into the Kalamazoo River in the lower peninsula of Michigan in 2010. Cleanup activities at this site are ongoing and the total cost to the environment currently exceeds $1.2 billion, including clean-up costs, remediation, and fines levied against Enbridge.[139] One of the largest inland crude oil spills in the United States occurred at Enbridge Line 3 pipeline near Grand Rapids, Minnesota where approximately 1.7 million gallons of crude oil were spilled, much of it into the Prairie River, only 2 miles from reaching the Mississippi River.[140] Line 5 itself has spilled approximately 1 million gallons of oil in approximately 30 separate incidents; see Figure 2. For example, a spill in the Hiawatha National Forest that occurred around 1980 was never properly cleaned up by Enbridge.[141] Elevated levels of petrochemicals were detected by field surveys in 2011 in the soil and in groundwater, and the

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[136] Attachment E, Cumulative Environmental Risk Report at 2 (citing an analysis of PHMSA information conducted by the U.S. Forest Service); *see also* Troy R. Thompson, US Forest Service Hydrogeological Assessment of the Enbridge Pipeline Section on the Chequamegon-Nicolet National Forest: Technical Report at 4, USDA Forest Service, Region 9 (2019).

[137] Attachment E, Cumulative Environmental Risk Report at 2 (citing an analysis of PHMSA information conducted by the U.S. Forest Service)

[138] National Wildlife Federation, Importing Disaster: The Anatomy of Enbridge's Once and Future Oil Spills 3 (2012), https://www.nwf.org/~/media/PDFs/Global-Warming/Reports/NWF_EnbridgeOilSpill_WEB_Final.ashx.

[139] *See* Garrett Ellison, *New price tag for Kalamazoo River oil spill cleanup: Enbridge says $1.21 billion*, MLIVE (Nov. 5, 2014). https://www.mlive.com/news/grand-rapids/2014/11/2010_oil_spill_cost_enbridge_1.html.

[140] Dan Kraker & Kirsti Marohn, *30 years later, echoes of largest inland oil spill remain in Line 3 fight*, MPR NEWS (March 3, 2021), https://www.mprnews.org/story/2021/03/03/30-years-ago-grand-rapids-oil-spill. Even after this disaster, Enbridge has had multiple releases in its construction of a new Line 3. On July 6, 2021, near Palisade, Minnesota, 80-100 gallons of drilling fluid were released into the Willow River, and the Minnesota Pollution Control Agency later found that there had been more releases of drilling fluid, totaling 28 releases at river crossings from June 8 to August 5, 13 spills into wetlands, and 14 releases in upland areas. *Regulator reports new spills along Line 3 construction route*, AP NEWS (Aug. 10, 2021), https://apnews.com/article/business-environment-and-nature-fcc53cb031a58e4536c1c29bcaec2100.

[141] *See* Keith Matheny, *30 years later, contamination remained at site of pipeline spill*, DETROIT FREE PRESS (May 7, 2016), https://www.freep.com/story/news/local/michigan/2016/05/07/enbridge-line5-oil-spill-hiawatha-national-forest/83507228/.

U.S. Forest Service has no record that Enbridge notified them of this release before 2012.[142] A significant oil spill is a probable negative effect of the proposed project, with many negative direct, indirect, and cumulative impacts to be considered in the EIS.

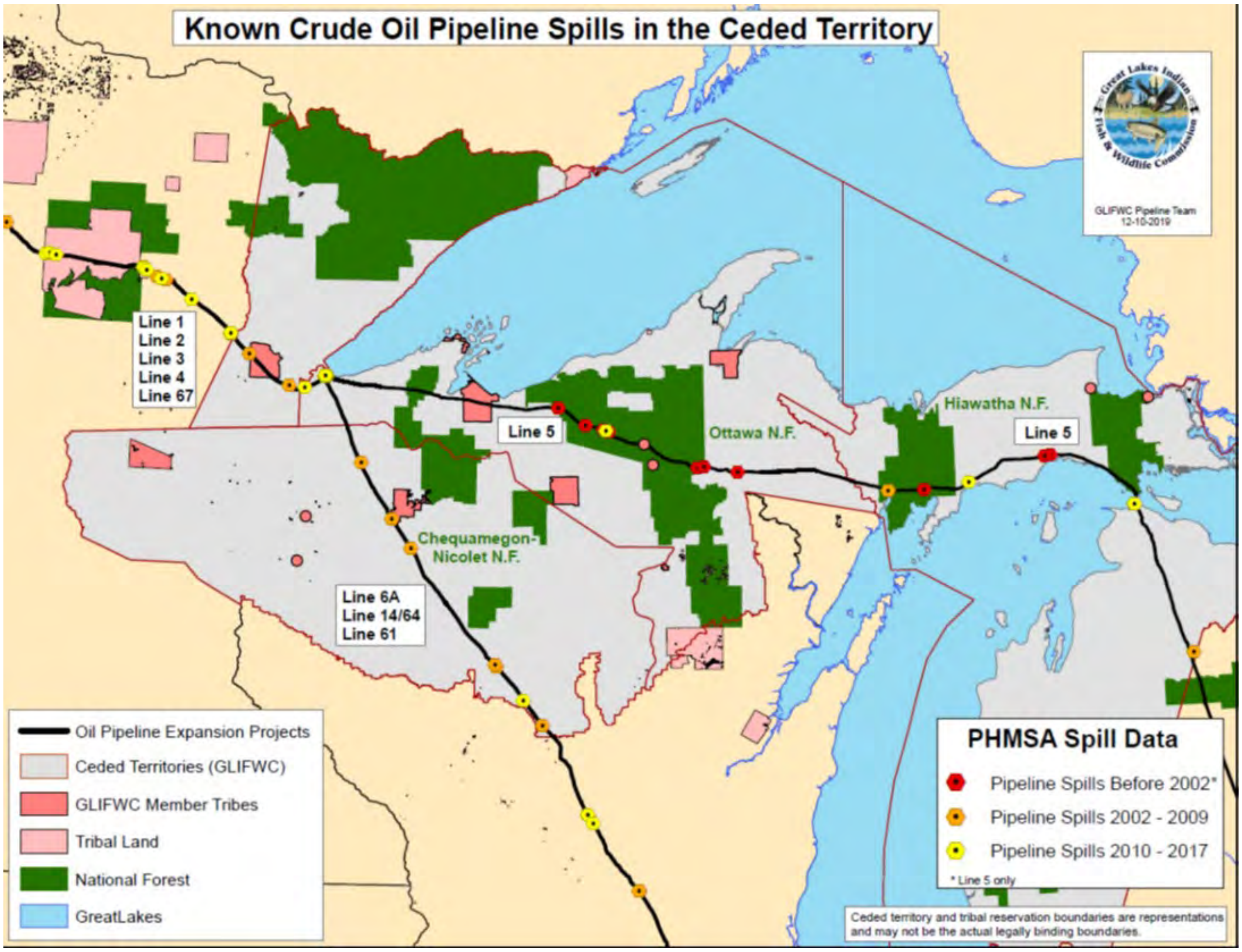

Figure 2 Map of Known Crude Oil Pipeline Spills in the Ceded Territory through 2017, prepared by GLIFWC

B. Oil Spills Harm Fish, Birds, Plants, And Other Organisms.

Oil is toxic to aquatic and terrestrial organisms. Freshwater fish, an important piece of this ecosystem and a major source of income for subsistence fishers, are seriously affected by oil releases. Fish can be affected through a variety of pathways across life stages. Effects of oil spills on fish include fish mortality, a decline in abundance and diversity of fish, and fish consumption advisories affecting the ability of community members to fish for consumption.[143] While dead fish may be observed immediately after the spill, sublethal effects have been observed two months following a spill, while increases in fish deformities have been observed two years after a spill.[144]

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[142] *Id.*
[143] *See* Attachment E, Cumulative Environmental Risk Report at 10.
[144] *See* Attachment E, Cumulative Environmental Risk Report at 10.

Birds that spend time near or in waterbodies, such as Canada geese, mallard ducks, and great blue herons, are also highly susceptible to the impacts of oil spills.[145] For example, the Marshall, Michigan spill led to the death of 52 birds, and necessitated rehabilitation for 144 birds affected by released oil.[146] Oil spills may also require birds to be relocated from the area, in addition to the resources needed to clean and release birds safely into the environment.

Amphibious and terrestrial animals are also affected by oil spills. Oil-coated skin or scales in amphibians and reptiles can lead to absorption of toxins, and potentially suffocation.[147] Spills in warmer times of the year are particularly dangerous to reptiles and amphibians. The Marshall, Michigan spill resulted in over 100 dead reptiles, and thousands of turtles requiring capture and treatment for oil effects.[148] Mammals that are adapted to living near water (semi-aquatic mammals) are also prone to impacts from oil spills. The Marshall, Michigan spill killed 40 mammals, primarily affecting muskrats, raccoons, and beavers.[149]

These effects extend to benthic organisms, microorganisms, and plant life.[150] The effect on microorganisms can lead to permanent impacts on the quality of the soil, requiring soil tilling, burning, fertilizer, or bioremediation techniques to return the soil to its original quality, but these processes require long periods of time.[151] Upon plant exposure to oil, deciduous plants may show effects within hours, and recovery and regrowth are impeded for many years into the future.[152]

C. Spilled Oil Moves Through Connected Waters.

The waters of the Great Lakes Basin are connected. A spill from the Project, including where the pipeline will be routed in and out of the tunnel on the sides of the Straits, would reach beyond the area of the Straits that the NOI suggests the EIS would be limited to. That would cause devastating effects to tribal, commercial, and recreational fishing, as well as long term damage to tourism in the area, ecosystems in the lakes and along the shorelines, and the many species that live in or migrate through that habitat.

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[145] *See* Attachment E, Cumulative Environmental Risk Report at 11.
[146] *See* Attachment E, Cumulative Environmental Risk Report at 11.
[147] *See* Attachment E, Cumulative Environmental Risk Report at 11.
[148] *See* Attachment E, Cumulative Environmental Risk Report at 12.
[149] *See* Attachment E, Cumulative Environmental Risk Report at 12.
[150] *See* Attachment E, Cumulative Environmental Risk Report at 10, 20.
[151] *See* Attachment E, Cumulative Environmental Risk Report at 20 (citing Hemmings, D., T. Noble, S. Gilmour, M. Doucet, J. Leatherdale and N. Re*id.* 2015, A Multiple Lines of Evidence Approach to Remediation of a Sensitive Unique Environment, Proceedings of the 38th AMOP Technical Seminar, Environment Canada, Ottawa, ON).
[152] *See* Attachment E, Cumulative Environmental Risk Report at 20. After oil spills near the Great Slave Lake, regrowth was considerably less robust in oil-exposed plants, while plants in oil-saturated soil did not regrow. After one season, recovery ranged from only 20%-55% (depending on oil exposure and treatment). *Id.* Another study showed that changes in species composition and decreased vegetation may last 10 years. *Id.* (citing Robson, D.B., Knight, J.D., Farrell, R.E. and Germida, J.J., 2004, Natural revegetation of hydrocarbon- contaminated soil in semi-arid grasslands, Canadian Journal of Botany, 82(1), pp.22-30.).

Line 5 is located within the Great Lakes watershed and there are areas where oil spilled from this pipeline could flow into Lake Superior, Lake Michigan, and/or Lake Huron through tributaries that have no flow interruptions such as lakes or dams; see Figures 3 and 4. Thus, any spill from Line 5 is a spill of product that would not be in the pipeline or spilled from it without this Project. Because of the interconnectedness of Great Lakes Basin waters, a spill from one part of Line 5 can reach waterways throughout the Basin.

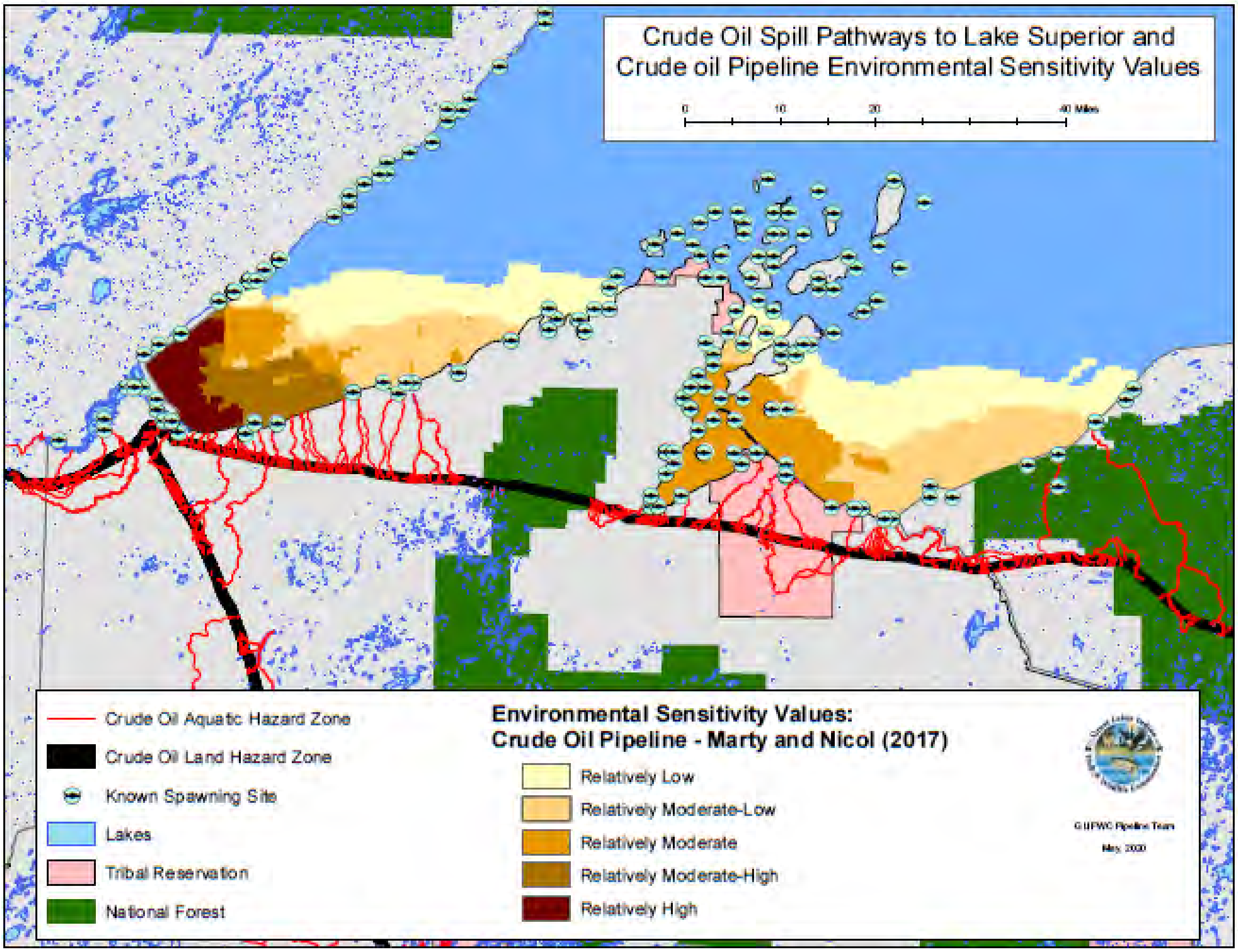

Figure 3: Crude oil spill pathways from Line 5 to Lake Superior, prepared by GLIFWC

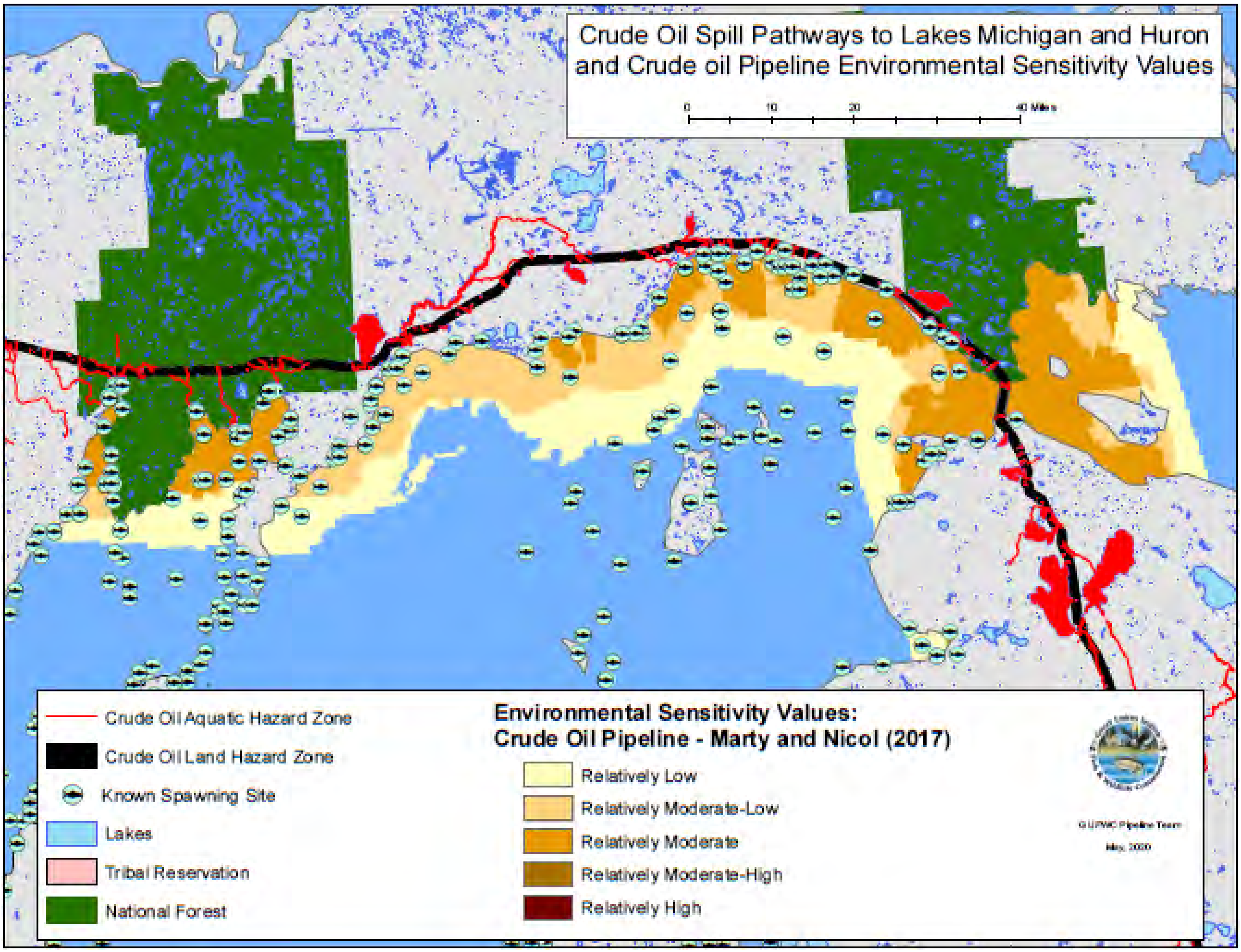

Figure 4: Crude oil spill pathways from Line 5 to Lakes Michigan and Huron, prepared by GLIFWC

D. This Project Threatens The Ceded Territory With An Oil Spill By Causing Line 5 To Continue Operating Into The Future.

Permitting this Project would have enormous costs in the form of allowing the Line 5 pipeline to operate and/or extending the lifetime of the Line 5 pipeline. Without a pipeline segment in the Straits, it is unlikely that oil would flow through any other part of Line 5. There are 454 miles of the Line 5 pipeline in the Ceded Territories under the 1836, 1837, 1842, and 1854 Treaties. Based on GLIFWC's analysis of reasonable hazard zones,[153] within the Ceded Territories, Line 5 places at risk of oiling and explosion impacts:

- 275,002 acres of land,
- 450 or more inland lakes,
- 2,254.2 river miles,
- 101,892 acres of wetlands.[154]

Accordingly, a cumulative impacts analysis must include all potential impacts where the pipeline travels, including the lands and waters downgradient of the pipeline. An appropriately scoped EIS will include a detailed fate and transport model that illustrates the potential spatial extent of downgradient impacts of a failure of Line 5 in the Great Lakes basin. This information is necessary to evaluate the risk of spilled oil reaching the Great Lakes, as well as the impacts of spilled oil on other lands and waters in the Ceded Territory, on public lands (e.g., state forests), drinking water sources, plants, and animals that tribal members harvest, etc. The modeling must include a variety of scenarios, including a range of small incidents to catastrophic failures on the pipeline. The modeling must include different temporal scenarios and it should account for seasonal variation in conditions such as ice cover, which may hinder spill response time, and spring floods, which may move the oil across the ecosystem more quickly. Different climatic scenarios should account for the likelihood of climate change exacerbating oil spill risks by increasing extreme weather events and contributing to erosion around the pipeline, among other things.

Additionally, the EIS should include information on how Enbridge would respond to oil spills in each of those scenarios, including whether Enbridge has the ability to pay for an oil spill clean-up and response.[155] Enbridge's ability to pay for a clean-up remains an open question. Although the Third Tunnel Agreement between the State of Michigan and various Enbridge

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[153] *See* Attachment E, Cumulative Environmental Risk Report at 3 ("In general, the analysis follows methods detailed in an Environmental Protection Agency guidance document titled 'Applying Cumulative Impact Analysis Tools to Tribes and Tribal Lands' (Appendix 3.1-B).").
[154] *See* Attachment E, Cumulative Environmental Risk Report at 29 (percentages of ceded territory at risk from Line 5 events, out of total risk to ceded territory from crude oil and natural gas pipelines).
[155] *See* EPA Scoping Comments – Notice of Intent to Prepare a Draft Environmental Impact Statement for the Enbridge Line 5 Tunnel Project, Mackinac and Emmet Counties, Michigan at 26-27 (Oc. 7, 2022) (hereinafter "EPA Scoping Comments")..

entities called for the maintenance of liability insurance until the dual pipelines are decommissioned, Enbridge entities involved in the proposed project either did not exist at the time or did not exist in their present form.[156] Cleanup and remediation of an oil spill requires a lot of time and money. The EIS should describe, in detail, the types of financial assurance that Enbridge has or can be required to provide to ensure that the public is not burdened with cleanup and remediation costs.

VIII. THE EIS MUST ADDRESS CLIMATE CHANGE.

A. The EIS Must Account For How The Proposed Project Will Cause Greenhouse Gas Emissions.

The EIS must evaluate the greenhouse gas ("GHG") emissions and climate change impacts of the Proposed Project and alternatives. The NOI is correct to include "climate change, including greenhouse gas emissions and the social cost of greenhouse gases" in the list of relevant issues.[157] The Proposed Project is a fossil fuel pipeline that would, for nearly a century, transport fuels that emit GHGs when burned. GHG emissions wreak havoc on the climate, changing temperature and precipitation patterns and devastating natural resources that are culturally, spiritually, and economically important to tribal communities like Bay Mills. Moreover, holdings from federal courts regarding NEPA review and this administration's orders and guidance demand that the Corps take a hard look at the Proposed Project's GHG emissions and do all it can to reduce GHG emissions. An EIS that properly accounts for the GHG emissions of this Proposed Project will conclude that the project would have dramatic environmental impacts and is inconsistent with this Administration's and the Corps' climate plans and guidance.

1. Legal requirements in the statute, case law, and Executive Orders

GHG emissions and their climate impacts are a proper subject of NEPA analysis—and a necessary subject of environmental effects and cumulative impacts analyses when an agency considers permitting a pipeline. NEPA requires agencies to take a "hard look" at the environmental effects of their actions. Agencies must use the best scientific information available in their NEPA analyses, including information about climate change.[158] Climate

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[156] Third Agreement Between the State of Michigan, Michigan Department of Environmental Quality, and Michigan Department of Natural Resources and Enbridge Energy, Limited Partnership, Enbridge Energy Company, Inc., and Enbridge Energy Partners, L.P., Sec. 5.1 (Dec. 2018), https://www.michigan.gov/documents/mdot/ThirdAgreementMichiganEnbridge_684307_7.pdf.

[157] Notice of Intent To Prepare a Draft Environmental Impact Statement for the Line 5 Tunnel Project, Mackinac and Emmet Counties, Michigan, 87 Fed. Reg. 50,076 (Aug. 15, 2022).

[158] *See, e.g.*, *San Juan Citizens All. v. U.S. Bureau of Land Mgmt.*, 326 F. Supp. 3d 1227, 1249-50 (D.N.M. 2018) (summarizing cases).

change, and the GHG emissions that cause it, are a necessary subject of direct, indirect, and cumulative effects analyses when an agency considers permitting a pipeline.[159]

Moreover, federal administrative orders and guidance call on federal agencies to reduce GHG emissions and factor climate pollution and impacts into decision making. Executive Order 13990 recognizes the threat of climate change and provides that it is the policy of the Administration "to reduce greenhouse gas emissions" and "bolster resilience to the impacts of climate change."[160] The Executive Order 13990 further "directs all executive departments and agencies (agencies) . . . to immediately commence work to confront the climate crisis."[161]

Executive Order 14008 recognizes that climate change considerations are central to United States national security and foreign policy, that there must be a "Government-wide approach that reduces climate pollution in every sector of the economy," and that the federal government must take a coordinated approach with state, local, and tribal governments.[162] Per Executive Order 14008, the Corps prepared a Climate Action Plan, which calls for preparing responses to climate change and reducing the nation's vulnerability to climate change.[163]

Additionally, the Memorandum of Understanding Regarding Interagency Coordination and Collaboration for the Protection of Tribal Treaty Rights and Reserved Rights ("MOU") requires the Corps to consider and account for the effects of its actions (such as permitting an oil pipeline) on habitats that support treaty-protected rights and resources (such as the 1836 Treaty Territory), including via climate change.[164]

The inclusion of climate change in the EIS is especially important to Bay Mills because climate change disproportionately impacts Tribal communities. An analysis of climate impacts of this project should include the GHG emissions from project construction, as well as from the fuels to be transported by the project. Climate change impacts plants and animals that are significant in tribal cultures, ceremonies, medicines, diets, and economies. Climate change also creates more extreme weather events including flash floods which impact rural, low-laying

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[159] *Indigenous Envtl. Network v. U.S. Dept. of State*, 347 F. Supp. 3d 561, 578-79 (D. Mont. 2018); *see also Food & Water Watch v. FERC*, No. 20-1132, 2022 WL 727037 (D.C. Cir. Mar. 11, 2022); *Center for Biological Diversity v. Bernhardt*, 982 F.3d 723, 736-40 (9th Cir. 2020) (holding that a federal agency that assumed the permitting of oil infrastructure would not affect climate change is arbitrary and capricious); *Friends of the Earth v. Haaland*, 2022 WL 254526 at *17 (D.D.C. 2022) (same); *Indigenous Envtl. Network v. U.S. Dep't. of State*, 2019 WL 652416, *4-5 (D. Mont. Feb. 15, 2019) (recognizing that omitting an analysis of greenhouse gas emissions from pipelines in an EIS was an "error [that] precluded informed decision-making and public participation based on complete information").

[160] Exec. Order No. 13990, Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis, 86 Fed. Reg. 7037 (Jan. 25, 2021).

[161] Exec. Order 13990, Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis, 86 Fed. Reg. 7037 (Jan. 25, 2021).

[162] Exec. Order 14008, Tackling the Climate Crisis at Home and Abroad, 86 Fed. Reg. 7619 (Jan. 27, 2021).

[163] U.S. Army Corps of Engineers, USACE Climate Action Plan (2021), https://www.sustainability.gov/pdfs/usace-2021-cap.pdf

[164] Memorandum of Understanding Regarding Interagency Coordination and Collaboration for the Protection of Tribal Treaty Rights and Reserved Rights (Nov. 9, 2021), https://www.doi.gov/sites/doi.gov/files/interagency-mou-protecting-tribal-treaty-and-reserved-rights-11-15-2021.pdf.

tribal communities. These same weather patterns cause more frequent power outages, which last longer in rural areas.

2. GHG emissions calculation

The EIS should incorporate Peter A. Erickson's GHG emissions calculation for the Proposed Project. Mr. Erickson quantified the GHG emissions from the Proposed Project in testimony publicly filed with the Michigan Public Service Commission.[165] Mr. Erickson is a Senior Scientist and the Climate Policy Program Director at Stockholm Environment Institute U.S., a 501(c)(3) organization affiliated with Tufts University.[166] He has done numerous GHG emissions calculations,[167] and courts have often relied on and favorably cited his methodology and calculations in the NEPA context.[168] Mr. Erickson's calculation is based on a method consistent with those used in other GHG assessments of oil pipelines, as well as in peer-reviewed, scientific literature, and standards for life-cycle assessments and oil market analysis.[169] Information provided by Enbridge and published information about energy use and the activities involved in the proposed project were used in the GHG accounting.[170]

There are two main ways that the Proposed Project will cause GHG emissions. First, the equipment used to build and operate the tunnel will cause GHG emissions.[171] Emissions sources during construction include the use of a tunnel-boring machine and other electric- and diesel-powered equipment, as well as the production and installation of construction materials such as steel and concrete.[172] There will be annual GHG emissions from the energy required to operate the proposed project's ventilation fans, sump pump, tunnel service vehicle, and lighting. To evaluate the combined effects of emissions from different GHGs, where each gas causes different amounts of warming, climate scientists combine GHG emissions into a single metric of carbon dioxide equivalent ("CO2e").[173] According to Mr. Erickson's calculation,

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[165] Direct Testimony of Peter A. Erickson, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763), (hereinafter "Erickson Testimony"). Rebuttal Testimony of Peter A. Erickson, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763)

[166] Sept. 14, 2022, Curriculum Vitae of Peter A. Erickson at Exhibit ELP-1, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763), https://mi-psc.force.com/sfc/servlet.shepherd/version/download/0688y000001qFWcAAM; Stockholm Environment Institute, Peter Erickson, https://www.sei.org/people/peter-erickson/.

[167] Erickson Testimony at 2.

[168] *Friends of the Earth v. Haaland*, No. CV 21-2317 (RC), 2022 WL 254526, at **14 (D.D.C. Jan. 27, 2022); *Ctr. for Biological Diversity v. Bernhardt*, 982 F.3d 723, 738 (9th Cir. 2020); *Sovereign Inupiat for a Living Arctic v. Bureau of Land Mgmt.*, No. 3:20-CV00290-SLG, 2021 WL 3667986, at **12 n. 129 (D. Alaska Aug. 18, 2021)).

[169] Erickson Testimony at 5, 6.

[170] Erickson Testimony at 12-13.

[171] Erickson Testimony at 11.

[172] Erickson Testimony at 12, 14.

[173] Erickson Testimony at 11-12 (defining CO2e and noting that the Intergovernmental Panel on Climate Change ("IPCC") makes calculations in CO2e).

construction will cause 87,000 metric tons of CO_2e emissions, and operation will cause at least 520 metric tons of CO_2e annually.[174]

Second, the products transported by the Proposed Project will release GHG emissions when produced, processed, and combusted.[175] Based on the amount of crude oil and natural gas liquids that the Proposed Project will transport, the proposed project is associated with an additional 87,000,000 metric tons of CO_2e annually, according to Mr. Erickson.[176]

3. Impacts of GHG emissions

These GHG emissions will have real world impacts.[177] GHG emissions—including those associated with the Project—cause climate change.[178] Climate change has had, and will have, dramatic environmental impacts. These include increasing flooding, wildfires, droughts, heat waves, expanding impacts of pests and pathogens, and other effects that pollute, impair, and destroy natural resources.[179] In Michigan, and across the Midwest, "climate change will lead to increased temperatures and precipitation that will reduce agricultural productivity, erode soils, and lead to pest outbreaks, while also leading to poor air quality, substantial loss of life, and worsening economic conditions for people."[180]

Climate change is uniquely burdensome for the Tribal Nations because of its impact on treaty-protected natural resources that are culturally and economically important to the Tribal Nations. GLIFWC climate change staff have conducted a vulnerability assessment of

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[174] Erickson Testimony at 11, 14; *see also id.* at 14-18 (regarding construction); *id.* at 18-19 (regarding operation and noting that this is a "conservative estimate" of the amount of energy needed to operate the Project).
[175] Erickson Testimony at 11, 20.
[176] Erickson Testimony at 20; *see also id.* at 20-23 (explaining calculation).
[177] One way that agencies address the impacts of greenhouse gas emissions is by using a calculation tool called the "social cost of greenhouse gases" or "social cost of carbon." Interagency Working Group on Social Cost of Greenhouse Gases, United States Government, Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (Feb. 2021), https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf; *see also* Direct Testimony of Dr. Peter Howard, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763), (hereinafter "Howard Testimony"). The Corps should consider using that tool in this EIS.
[178] Direct Testimony of Dr. Jonathan T. Overpeck at 6, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763), (hereinafter "Overpeck Testimony"). "In the new, most recent assessment of the science behind climate change, the Intergovernmental Panel on Climate Change described the observed rate of climate change as both "unprecedented" and "unequivocally" caused by human activities." Erickson Testimony at 8 (citing Intergovernmental Panel on Climate Change, In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press (2021)).
[179] Overpeck Testimony at 8-9; Erickson Testimony at 7; *see also id.* 7 n. 11 (citing Holdren, J. P. (2018, September). The Science & Policy of Climate Change: An Update on the Challenge and the Opportunity. Presented at the Low-emissions Solutions Conference, San Francisco, CA, https://lowemissions.solutions/static/uploads/180911_GCAS_Holdren.pdf).
[180] Erickson Testimony at 8; *see also* Jim Angel, et al., *Midwest* in IMPACTS, RISKS, AND ADAPTATION IN THE UNITED STATES: FOURTH NATIONAL CLIMATE ASSESSMENT, VOLUME II at 872–940 (David Reidmiller, et al., eds. 2018), https://nca2018.globalchange.gov/chapter/21/.

beings/species of particular interest to member tribes including Bay Mills, and the vulnerability assessment integrates Traditional Ecological Knowledge and Scientific Ecological Knowledge.[181] Bay Mills has also worked with scientists to assess climate threats to species. For example:

- Lake Whitefish – or adikameg – is a species held in sacred regard and is part of Tribal Nations' oral histories. This fish is one of the primary commercial and subsistence fish for tribal fishers.[182] But Lake Whitefish is a cold water species, and "[i]t is widely recognized that climate change leads to the warming of their habitat."[183] With climate change, fish habitats are impacted by warming waters, and a weakened natural ecosystem creates opportunities for invasive species.[184]

- Walleye – or ogaa – a cool water fish, are also harmed by climate change. Walleye support tribal commercial and subsistence fisheries.[185] As the climate warms, walleye populations will become less sustainable.[186] As the warming climate has increased the water temperatures of inland lakes, walleye populations are already declining,[187] and additional population losses are expected under projected climate scenarios.[188] Climate change will likely also indirectly impair walleye populations in the Great Lakes by improving habitat conditions for predator species and diminishing habitat conditions for prey species.[189]

- Wild rice—or manoomin—is an irreplaceable cultural, spiritual, nutritional, and commercial resource and sacred relative to Bay Mills and other Tribal Nations in the Upper Midwest and Great Lakes region.[190] Bay Mills, along with other tribal

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[181] Hannah Panci, et al., Great Lakes Indian Fish and Wildlife Commission, Climate Change Vulnerability Assessment: Integrating Scientific and Traditional Ecological Knowledge (April 2018),https://glifwc.org/ClimateChange/GLIFWC_Climate_Change_Vulnerability_Assessment_Version1_April2018.pdf.
[182] Gravelle Testimony at 15.
[183] Gravelle Testimony at 16.
[184] Overpeck Testimony at 26.
[185] Direct Testimony of Dr. Karen M. Alofs at 3, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763), (hereinafter "Alofs Testimony"); Direct Testimony of Kevin Donner at 3, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763), (hereinafter "Donner Testimony") . In addition to being important to tribal fisheries, walleye are an important part of Michigan's 2.3 billion dollar recreational fishing economy. Alofs Testimony at 3.
[186] Alofs Testimony at 7.
[187] Alofs Testimony at 8.
[188] Alofs Testimony at 11.
[189] Alofs Testimony at 12.
[190] Hannah Panci, et al., Great Lakes Indian Fish and Wildlife Commission, Climate Change Vulnerability Assessment: Integrating Scientific and Traditional Ecological Knowledge at 28 (April 2018),https://glifwc.org/ClimateChange/GLIFWC_Climate_Change_Vulnerability_Assessment_Version1_April2018.pdf.

nations, has worked to revitalize wild rice beds.[191] Wild rice is an aquatic natural grass that is a critical component of aquatic ecosystems, where it contributes to nutrient cycling, habitat structure, and is a food source for a range of wildlife.[192] Future climate change-induced changes in temperature and precipitation will have direct, negative impacts on wild rice.[193] Warmer temperatures are likely to harm wild rice and contribute to population reductions.[194] Climate change induced alterations in precipitation regimes will likely lead to flooding and high water levels in the spring when wild rice is vulnerable to flooding, and drought conditions later in the season that can impede harvesting.[195] Climate change will also indirectly impair wild rice by improving habitat conditions for species that damage wild rice waters and worsening pathogen and pest infestations.[196] In the coming decades, the projected changes will be catastrophic for wild rice and the tribal practices that depend upon a healthy wild rice species, if the severe effects of future climate change that have been predicted are not prevented.[197]

- Loons—or maang—are culturally significant as one of the seven primary clans of the Anishinaabe. Loons also are ecologically important as top trophic-level predators in lake habitats.[198] Already, climate change has caused or contributed to loon population loss,[199] and it is projected to have further negative effects on loons by reducing breeding habitats in Michigan and increasing the frequency and intensity of botulism outbreaks.[200] As a result, climate change will drastically reduce the loon population in Michigan. Three degrees of global warming, by 2080, for example, likely will extirpate loons from the state of Michigan.[201]

- Sugar maple—or ininaatig—has profound cultural and traditional importance to Tribal Nations. Harvesting maple syrup – or zhiiwaagamizigan – is a traditional

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[191] Peter F. David, Great Lakes Indian Fish & Wildlife Commission, Manoomin (Wild Rice) Enhancement and Research in the Ceded Territories in 1998 (July 2010), https://s3.us-east-2.amazonaws.com/glifwc.archive.bio/Administrative%20Report%2010-09.pdf; *see also* Gravelle Direct at 16 (wild rice continues to be harvested near tribal nations reservations in Michigan).
[192] Direct Testimony of Dr. Daniel Larkin at 4, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763), (hereinafter "Larkin Testimony"); Direct Testimony of John Rodwan at 6, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763), (hereinafter "Rodwan Testimony").
[193] Larkin Testimony at 10. And climate stressors are already affecting wild rice. Rodwan Testimony at 7-8; *see also id.* at 15 (describing how climate change impacts, including storms and the humid weather that influences Brown Spot Disease, have already affected wild rice).
[194] Larkin Testimony at 11.
[195] Larkin Testimony at 12-13.
[196] Larkin Testimony at 13-14.
[197] Larkin Testimony at 16.
[198] Direct Testimony of Dr. Alec R. Lindsay at 3, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763), (hereinafter "Lindsay Testimony").
[199] Lindsay Testimony at 7.
[200] Lindsay Testimony at 10-12.
[201] Lindsay Testimony at 11. Loons will not fare much better elsewhere as, with three degrees of warming, they will lose 97% of their breeding habitat in the continental U.S. *Id.*

> practice, and maple syrup is considered a medicine, a traditional food, and a gift that brings about a new season of life.[202] Sugar maple is also an important part of the health of Michigan forests, providing ecosystem benefits such as healthy soil that can support other species, water filtration and purification, and landslide protection.[203] Climate change is the current "major threat" to sugar maple.[204] Warming will cause large-scale shifts in forest tree species and other vegetation, including greater tree mortality.[205] Climate change will cause changes in temperature and precipitation that will threaten the tree species.[206] Increasing aridity due to climate change will hurt the sugar maple, and it will compound other forest stresses such as invasive species, insect pests and plant disease, and the likelihood of severe wildfire.[207]

Sugar maple, along with the fishery, wild rice, and loons, are merely some examples of the myriad ways that GHG emissions pollute, impair, and destroy not only natural resources, but cultural practices and lifeways. Through GHG emissions the Proposed Project would compound those climate impacts.

The Proposed Project would ensure the continued operation of Line 5's shipment of fossil fuels and their subsequent combustion. It is well established in the scientific community that we must stop burning climate warming fuels altogether and in order to ensure the sustainability of our planet. A consideration of the Project's fossil fuel and climate impacts is a necessary part of the EIS.

B. The EIS Must Account For The Synergistic Effects Of Climate Change.

The scope of the EIS must include addressing how climate change will affect the Proposed Project and alternatives. The Corps must evaluate how the effects of climate change such as changes in precipitation, flooding, and erosion increase risks of oil spills and environmental harms from construction and operation of the Proposed Project.[208] For this evaluation, the Corps cannot rely solely on historical climate data, but must use current data

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[202] Gravelle Testimony at 17.

[203] Direct Testimony of Dr. Ines Ibanez at 3, Appl. for Auth. To Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763), (hereinafter "Ibanez Testimony").

[204] Ibanez Testimony at 7; *see also id.* at 10. "[T]he maple [syrup] industry is being impacted by climate change including shifts in tapping season characteristics along with sap quality and quantity." Rapp et al 2019. The Shifting Sweet Spot of Maple Syrup Production: Climate Change Impacts on Sugar Maple Sap, https://mapleresearch.org/wp-content/uploads/1019climate.pdf .

[205] Overpeck Testimony at 25.

[206] Ibanez Testimony at 8, 9.

[207] Overpeck Testimony at 26.

[208] *See, e.g.*, *Wild Fish Conservancy v. Irving*, 221 F. Supp. 3d 1224, 1233 (E.D. Wash. 2016) (holding that the failure to discuss the potential effects of climate change on the agency's analysis of a hatchery's operations and water use was arbitrary).

and climate change projections.[209] Doing so is consistent with CEQ guidance for NEPA reviews, which notes that "the reasonably foreseeable affected environment" includes "[t]he current and projected future state of the environment" and explicitly recognizing the need for a proper NEPA analysis to consider "the effects of climate change on a proposed action and its environmental impacts."[210] It is also consistent with the Corps' Climate Action Plan, prepared per Executive Order 14008, which includes a goal that the Corps' investments be climate resilient for future climatic conditions.[211]

For this Proposed Project, then, the EIS must address how climate change impacts such as increased and flashy spring floods, much more variable Great Lakes water levels, and corresponding erosion will affect pipeline safety, the future of this proposed project, and the environmental effects of this Proposed Project. For example, pipelines along inland waterways are at particular risk of increased flood events and "unplanned discharges of oil into waterways."[212] Erosion along the Great Lakes may make the portions of the pipeline that go into and come out of the proposed tunnel on either side of the Straits more vulnerable.

The scope of the EIS must address both how the proposed project will contribute to climate change and how a worsening climate scenario will impact the project and increase associated environmental risks.

IX. THE EIS MUST ADDRESS THE ENVIRONMENTAL IMPACTS OF TUNNEL CONSTRUCTION AND OPERATION.

A. The Evaluation Of A First-Of-Its-Kind Underground Tunnel Transporting Hazardous Liquids In The Great Lakes Necessitates An Extra Level Of Scrutiny Of Potential Environmental Impacts.

The scope of the EIS must include an analysis of the Project's design risks, and the direct, indirect, and cumulative environmental impacts that would flow from those risks. This is critical to this EIS because: (1) no similar project – a pipeline with hazardous liquids in an underground

[209] *See, e.g.*, *AquAlliance v. U.S. Bureau of Reclamation*, 287 F. Supp. 3d 969, 1028-29 (E.D. Cal. 2018) (relying on historical data to assess the impacts of a water transfer program failed to address a key precipitation factor); *National Wildlife Fed. v. National Marine Fisheries Serv*., 184 F. Supp. 3d 861, 918-19 (D. Or. 2016) (holding that using recent ocean conditions as a baseline in an analysis of a hydropower project and assuming that they would not worsen with climate change was arbitrary); *Nat. Res. Def. Council v. Kempthorne*, 506 F. Supp. 2d 322, 370 (E.D. Cal. 2007) (noting that it was a problem that an agency's Biological Opinion "does not gauge the potential effect of various climate change scenarios on Delta hydrology").

[210] Christina Goldfuss, Council on Environmental Quality, Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews at 20, 4 (Aug. 1, 2016), https://ceq.doe.gov/docs/ceq-regulations-and-guidance/nepa_final_ghg_guidance.pdf; *see generally id.* at 20-25.

[211] USACE Climate Action Plan (Oct. 7, 2021), https://www.sustainability.gov/pdfs/usace-2021-cap.pdf.

[212] R. M. Webb *et al*., Evaluating Climate Risk in NEPA Reviews: Current Practices and Recommendations for Reform, Sabin Center for Climate Change Law, Columbia Law School & Environmental Defense Fund at 8 (Feb. 2022), https://scholarship.law.columbia.edu/cgi/viewcontent.cgi?article=1185&context=sabin_climate_change; *see also* Mashkiiziibii Natural Resources Department, Enbridge Line 5 Issues Within the Bad River Reservation (Feb. 2020), http://www.badriver-nsn.gov/wp-content/uploads/2020/02/202002_NRD_EnbridgeLine5_Brochure.pdf.

tunnel – exists; (2) the geology of the Straits, which includes a valley within the bedrock and methane pockets, makes the tunnel boring construction process particularly risky; and (3) the Project is designed in a way that creates a unique explosion risk. Because the Straits are an area of enormous cultural importance, they are not the place for an experimental pipeline.

1. Untested pipeline design

A project like this one—running a hazardous liquids pipeline through an underground tunnel—has never been constructed. No other Army Corps District has permitted a design that includes a hazardous liquids pipeline running through an underground tunnel. The EIS must scrutinize all aspects of design and operation to ensure that tunnel construction will not cause catastrophic damage to the Straits.

Enbridge's application materials suggest that "[t]unneling as a means of carrying pipelines through or below difficult obstacles is a proven technology, and is in use for this application in many places around the world."[213] However, this statement is followed up with examples that are not only different types of pipelines (i.e., not hazardous liquids pipelines), but each of the examples has since experienced serious environmental consequences.[214] When taking the necessary "hard look" that NEPA demands, these examples strongly counsel against building an untested pipeline tunnel in the Great Lakes.

Once Enbridge begins tunnel boring beneath the Straits, impacts will be irreversible. The enormity of a decision to irreversibly alter the largest freshwater supply in the United States must be recognized. The Corps' EIS must acknowledge that the construction and operation of a hazardous liquids pipeline through an underground tunnel has never been undertaken before and, due to the novelty of the Project, explicitly detail the way in which the Corps is evaluating the risk to the environment and Tribal Nations.

2. Concerns based on the geological setting for the Project

The scope of the EIS must include an in-depth analysis of the geology along the tunnel configuration in the Straits so the Corps can assess the feasibility of constructing a tunnel there, including the possible consequences of encountering methane and other toxic gas, using a

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[213] Dynamic Risk Assessment Systems, Inc. *Alternatives Analysis for the Straits Pipelines*, at Appendix E.1 Tunneling Overview (Oct. 26, 2017).

[214] For example, the U.S. Department of Defense shuttered the underground Red Hills fuel storage facility near Pearl Harbor, Hawaii after nearby residents reported a petroleum-like smell and oily sheen in their tap water; and a worker died during construction of the Corrib Gas pipeline tunnel with a tunnel boring machine in Ireland. Karoun Demirgian & Alex Horton, *Pentagon to Shutter Fuel Storage Facility That Contaminated Drinking Water at Pearl Harbor*, THE WASHINGTON POST (March 7, 2022), https://www.washingtonpost.com/national-security/2022/03/07/red-hill-fuel-storage-pear-harbor/; *Company Fined 300,000 Over Death of Worker at Corrib Gas Tunnel*, THEJOURNAL.IE (June 14, 2017), https://www.thejournal.ie/corrib-gas-worker-death-fine-3443030-Jun2017/; Mark Jansen, *The Sleepy Irish Village That Challenged Shell Over Controversial Pipeline*, THE ECOLOGIST (March 21, 2011), https://theecologist.org/2011/mar/21/sleepy-irish-village-challenged-shell-over-controversial-pipeline.

tunnel boring machine in challenging mixed-face conditions, and the possibility of, and the consequences of, a bentonite slurry release.

First, the scope of the EIS must assess whether the geology of the Straits is consistent with Enbridge's claim that the Project will be constructed "entirely within the bedrock."[215] Enbridge has not provided the Corps—or the public—with data sufficient to support this claim. What is known is that there is significant overburden—a valley of mud, silt, and clay—in the deepest part of the Straits;[216] however, the nature and depth of the bedrock valley in the Straits remains unknown. Enbridge conducted 14 deep water borings in the "general vicinity" of where the proposed tunnel will be located.[217] In at least one location (BH19-24), bedrock was not even encountered.[218] Moreover, Enbridge has indicated the tunnel depth will be between 30 and 370 feet below the lakebed of the Straits but has not conducted any borings at that lowest depth. Enbridge's ability to complete the tunnel entirely in bedrock thus remains unsubstantiated due to insufficient boring data from the Straits.[219] This unknown poses a risk to the Straits as,

> it is critical during the design of open water tunnels that engineers consider the nature of the ground, or geology, along the alignment, the limitations of the site investigation program in characterizing the ground, and the anticipated range of ground behavior under the proposed excavation technique. One short section of tunnel where a geologic condition was not identified, or not prepared for, can result in a costly and potentially disastrous situation.[220]

The Corps should require that sufficient boring data be collected by Enbridge, and provide that data to the public for comment, before continuing forward with the EIS process. Specifically, to better understand and analyze the risks associated with Enbridge's open water

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[215] Notice of Intent To Prepare a Draft Environmental Impact Statement for the Line 5 Tunnel Project, Mackinac and Emmet Counties, Michigan, 87 Fed. Reg. 50,076 (Aug. 15, 2022) ("Except for the entrance points on either side of the Straits, the tunnel would be constructed entirely within the bedrock at depths between 30 feet and 370 feet beneath the lakebed of the Straits.")

[216] *See* Line 5 Replacement and Tunnel Project Geotechnical Data Report, March 9, 2020 at Section 5.2.3 (Deepwater Borings);

[217] *See Id.*; *see also id.* at Appendix B-2 (Boring Logs), http://www.deq.state.mi.us/documents/wrd-line5-geotechnical-data-report.pdf.

[218] *Id.* at Table 5.4 (Deepwater Drilling Program) (noting that BH19-24 indicated N/A for rock depth); *see also id.* at Appendix B-2 (Boring Logs) at 260 (indicating that boring number BH19-24 was terminated at 156.5 feet and did not encounter rock), http://www.deq.state.mi.us/documents/wrd-line5-geotechnical-data-report.pdf.

[219] *See* McMillen Jacobs Associates, Technical Memorandum Re: DRAFT Geotechnical Exploration Level of Effort for the Line 5 Replacement Tunnel at 3 (Jan. 13, 2021), https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Multi-Division/Line-5/MDOT_Question_on_Geotechnical_Investigation_Jan_2021.pdf?rev=2fe08f3e6cf64563869bf19780b1ccac ("A minimum cover of approximately 25 feet of bedrock occurs near the middle of the alignment. However, due to a significant number of borings terminating before the tunnel invert near the middle portion of the alignment, there are portions of the alignment where the rock quality and conditions within the tunnel have not been directly investigated. This lack of data spans the majority of the length of the middle half of the tunnel alignment.").

[220] Tunneling Beneath Open Water, A Practical Guide for Risk Management and Site Investigations, Thomas W. Pennington P.E. (April 2011) at 33 (included as Attachment F).

tunnel design, the Corps should require that sufficient geological data on the Straits is collected, and that Enbridge produce a comprehensive Geotechnical Baseline Report ("GBR") so that it—and members of the public—can analyze the geology of the Straits and risk of environmental impacts during tunneling during the EIS process. Although Enbridge prepared a Geotechnical Data Report, the data within the 3,000-page report, which was lacking in many respects, does not include conclusions, recommendations, or interpretations of the findings. As a result, it is largely inaccessible for public review. On the flip side, Enbridge's Summary and Pamphlet of its GDR is a 2-page summary of the 3,000-page document and, although readable, is missing huge swaths of information and, critically, misinterprets key facts. In the U.S., GBR has become the "preferred method" for understanding underground risks in construction. [221] A GBR "provides an interpretation of the geotechnical data, subsurface and site conditions and ground behavior likely to be encountered during the performance of the work,"[222] which Enbridge's 2-page summary fails to do. The scope of the EIS must address this deficiency in the applicant's materials. Further, once the critical geological data is provided by Enbridge, the Corps should issue a supplemental, revised, or corrected public notice based on the change in the application data that would affect the public's review of the proposal.[223]

Even if Enbridge gathers data that proves its tunnel can be completed entirely in bedrock, the overburden that is present in the deepest part of the Straits necessitates the tunnel be constructed in a U-shape or V-shape. This shape is not consistent with Enbridge's initial design plans and has not been adequately studied. A U- or V-shaped tunnel contributes to the risk of an explosion during operation, as explained in more detail in Section IX.A.3. Further, the U- or V-shaped tunnel contributes to the risk of flooding occurring both during construction and operation. The scope of the Corps' EIS must balance these geology considerations with associated operational risks.

Second, the scope of the EIS must include an analysis of the risk of an explosion if and when methane is encountered during tunneling. Only 24 groundwater samples were collected in the location where Enbridge proposes to construct the tunnel and dissolved methane was detected in four of the samples.[224] Significantly, none of the 24 samples were collected from the deepest tunnel alignment) Because of the lack of geotechnical data, as explained above, it is possible that elevated concentrations of methane will be encountered during construction along the proposed path of the tunnel. Encountering methane during tunneling could lead to an

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[221] *Id.* at 85
[222] *Id.* at 85
[223] *See* Section III *supra*.
[224] *See* Line 5 Replacement and Tunnel Project Geotechnical Data Report, March 9, 2020 at Appendix F-3 Groundwater Testing Summary Table, http://www.deq.state.mi.us/documents/wrd-line5-geotechnical-data-report.pdf. This data is in direct conflict with the assumptions raised in the Technical Memorandum dated January 12, 2021 on the subject of Potential Gas Encounters in the Enbridge Line 5 Tunnel Project at page 4 (stating that "no gas was actually encountered during the any [sic] of the geotechnical exploration program"). The scope of the Corps' EIS must recognize that the data suggests the presence of methane in the groundwater samples.

explosion during the construction phase of the project, risking both environmental consequences and human life.[225]

Third, the Corps should require that Enbridge identify the specific type of TBM that is proposes be used for this Project and all risks of failure that may harm the environment. In addition, the scope of the EIS must consider the risks of the TBM and analyze the environmental impacts of the tunnel boring machine failing beneath the Straits. Based on the limited geotechnical data available, it remains possible- despite Enbridge's assertions—that the Project would be constructed in both rock and sediments, including through karstic features or poor rock conditions. This is referred to as "mixed face" condition and it is the most difficult of all tunnel driving conditions.[226] Mixed face tunneling, combined with the very high ground and groundwater pressures, increases the likelihood of a TBM failure or the TBM becoming stuck and either abandoned in place or requiring a timely and costly rescue operation of the machine.

Fourth, the scope of the EIS must analyze the environmental risks posed by bentonite slurry, a material that is used to stabilize the excavation and reduce groundwater inflow into the tunneling process. The bentonite slurry system is a "closed loop" system:

> Slurry is mixed in a treatment plan, cycled through the excavation face, and returned to the treatment plant where the spoils are separated out for disposal. The separated slurry is then recirculated in the tunnel or diverted to the water treatment plant, if it does not meet design criteria. Slurry diverted to the water treatment plant is treated for discharge into allowable discharge points subject to meeting regulatory criteria. Solids from the water treatment plant are disposed of off site.[227]

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[225] Methane may also seep into the tunnel by way of groundwater infiltration and pose a risk of explosion during operation of the pipeline. This, too, must be considered in the scope of the EIS. *See* Section IX.A.3., *infra*. The scope of the Corps' EIS must take consideration of the risk of methane explosion seriously to avoid the tragedies that have occurred in previous Great Lakes tunneling projects. *See* James Graham, Lou Mleczko & James Tittsworth, *In Michigan History: Deadly Lake Huron Tunnel Explosion,* THE DETROIT NEWS (Sept. 17, 2016), https://www.detroitnews.com/story/news/local/michigan-history/2016/09/17/deadly-lake-huron-water-tunnel-explosion/90522336/ (detailing a methane explosion in Lake Huron); *see also* Elizabeth Lightfoot, *Three Workers Killed, One Missing in Tunnel Explosion,* AP NEWS (Nov. 10, 1988), https://apnews.com/article/a190525cd388425f128e5fc951bdc437 (detailing a methane explosion in Milwaukee).

[226] Attachment F at 68 (Mixed Face Excavations); *see also* McMillen Jacobs Associates, Technical Memorandum Re: DRAFT Geotechnical Exploration Level of Effort for the Line 5 Replacement Tunnel at Section 3.3 Design Challenges due to Ground Conditions (Jan. 13, 2021), https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Multi-Division/Line-5/MDOT_Question_on_Geotechnical_Investigation_Jan_2021.pdf?rev=2fe08f3e6cf64563869bf19780b1ccac ("However, due to the highly fractured and poorly cemented brecciated nature of the rock based upon core recovery and RQD data, it is possible that the ground behavior will be very poor, especially in the zone of lowest rock cover. However, as discussed above, there is a lack of boring information at tunnel depth within the roughly middle half of the project.").

[227] Enbridge Energy, Technical Memorandum on the subject of Slurry Systems with Excavation by TBM (January 12, 2021).

The Corps' EIS process must analyze every aspect of the bentonite slurry system to ensure that a "release does not occur that impacts the underwater environment and that the risks associated with the on-land facilities are avoided or minimized. In order to fully understand any potential environmental impact, the Corps must require that Enbridge provide for public review the specific chemical additives and bentonite source material properties of the slurry mixture it intends to use as well as the details of how the slurry will be conveyed, monitored, contained, and all other measures and practices that will be employed to prevent and respond to releases into the environment.

As Enbridge described, the slurry will be injected at high pressure into the front chamber of the TBM to balance earth and water pressures, and the slurry circulation system carries the excavated material back to the surface.[228] Because of the very high earth and water pressures that will be encountered under the Straits, the slurry will have to be injected at roughly the same pressure to prevent an uncontrolled inflow of rock, soil and water into the TBM and the tunnel. An uncontrolled over-excavation of solids (rock and sediments) can lead to the development of large voids and possibly large sinkholes above the tunnel which could seriously damage the existing Line 5 pipeline, especially the west leg which is closest to the proposed tunnel alignment.

Over-pressurization of the bentonite slurry can lead to conditions where the slurry is displaced well beyond the immediate vicinity of the TBM and can breach through the bedrock and overlying sediments. In a worst-case scenario, the bentonite slurry would erupt through the lake bottom surface (mudline), possibly damaging an existing Line 5 pipeline, and be released into the water column and cover the bottom of the Straits which would be devastating to the environment and ecosystem.

Bentonite slurry risks are also associated with the design, construction, and operation of on-land facilities to treat the bentonite mixture once it enters the treatment facility and/or maintained in storage tanks. The EIS must include a review of the design, construction, and operation of the on-land facilities to ensure adequate containment and secondary containment capabilities. In the event the bentonite mixture leaked into the environment it could cause a catastrophic disaster on land, in the wetlands, and at the surface of the water.[229]

While the impacts of a bentonite slurry risk during construction would be devasting to the environment, the Corps must view the issues related to the risk of a release through an environmental justice lens; in particular, how the devastation would affect the Tribal Nations who depend on the Straits for economic, cultural, and spiritual needs. See Section II.B. Finally, near-shore vibration impacts from tunnel construction must studied and included in the scope

[228] Enbridge Energy*, Tunnel Stability Pamphlet* at 2 (April 7, 2020).
[229] *See* EPA Scoping Comments at 18.

of the EIS.[230] The vibrations from tunnel boring may exceed the level that will result in damage to fragile historic buildings, ruins, and ancient monuments.[231]

There are significant geological risks involved in tunneling a Project of this size—especially in an area with critical freshwater and other natural resources and enormous cultural significance—and the scope of the EIS must analyze and assess those risks.

3. Explosion risk based on the design of the tunnel

The scope of the EIS must include an analysis of the risks associated with the design of the tunnel intended to house a hazardous liquids pipeline in the Straits. The design of the Project carries the risk of an explosion either from a hydrocarbon leak within the enclosed tunnel or an infiltration of methane from the groundwater. An explosion by any means may release Line 5 product into the Straits—causing an oil spill and other harms.[232] Explosion risks are related to and foreseeable based on the design of the tunnel as proposed by Enbridge and the direct, indirect, and cumulative effects of an explosion must be considered within the EIS.[233]

First, the V- or U-shaped tunnel design has the potential to contain an explosive atmosphere at its lowest part heightening the risk of product reaching the Straits by way of a catastrophic explosion. As described above, the underground tunnel is designed to run deep underground in a V- or U-shaped profile. Enbridge has proposed that that the purpose of the tunnel is to house Line 5, which carries liquid propane and crude oil, two highly volatile and flammable substances. Design plans also indicate both utilities and maintenance equipment. Enbridge's design thus includes an enclosed tunnel where the three necessary elements for an explosion have the potential to be present at the same time: (1) a failure of the pipeline resulting in a hydrocarbon release, (2) that forms a heavier than air vapor cloud, and (3) that is ignited by a source of electricity.[234] The explosion risk from a hydrocarbon leak is a direct consequence of Enbridge's design plans and the Corps cannot ignore this connection in the scope of its EIS.

The Project design has attributes that should be cause for concern. A hydrocarbon release from a crack or rupture of the X70 pipeline running through the tunnel will mix with the

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[230] *See* Attachment B.

[231] McMillen Jacobs Associates, Technical Memorandum Re: Vibration Impacts of the Enbridge Line 5 Tunnel Project at 10 (Jan. 12, 2021) (listing the "Vibration Damage Potential Threshold Criteria" at a maximum peak particle velocity of 0.08 in/sec for "Extremely fragile historic buildings, ruins, ancient monuments," and noting that vibratory impacts can be 0.1 in/sec at a depth of 75 feet and even greater at shallower depths and concluding that "more site-specific analyses may be warranted for very sensitive structures at shallow depths"), https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Multi-Division/Line-5/MDOT_Question_on_Vibrations_Jan_2021.pdf?rev=728327bb60384a6eaac583617e322acb.

[232] *See generally* Section VII, *supra*.

[233] Additionally, consideration of whether the Project will actually "minimize environmental risks" as stated in the NOI must be balanced with consideration of who will bear the catastrophic consequences of the risks. While a risk of release of Line 5 product into the Straits may generally be considered low under different scenarios, the Corps cannot ignore that the consequences of a catastrophic explosion are extremely high.

[234] Kuprewicz Rebuttal, at 7-8.

air to form a heavier than air vapor cloud.[235] The heavier than air vapor cloud will sink to the low spots of the tunnel elevation directly falling near equipment.[236] This differs from a natural gas pipeline, which is known to operate through underground tunnels, and which would result in a lighter than air vapor cloud following a pipeline rupture. A vapor cloud that is lighter than air in an enclosed tunnel will rise and be more likely to settle in closer proximity to gas detection systems and away from electrical equipment. A leak from a liquids pipeline in an enclosed tunnel also stands in marked contrast to a leak from a pipeline operated in an open field. The resulting vapor cloud that forms following a pipeline failure there, whether heavier or lighter than air will more likely be dispersed by air flow in the open environment. Simply put, Enbridge's "never been done before" design creates a unique and particular risk that the vapor cloud that results from a leak will sink to the low spots of the tunnel and stay there, unmoving and undetected, until ignited by an electrical spark.[237]

Once ignited, an explosion within the tunnel will cause a high-pressure event, usually followed by multiple fires and explosions, such as the 36-hour long fire that was the result of the ignition of a vapor cloud released from Line 5 in Crystal Falls, Michigan in 1999.[238] Blast forces of this magnitude have the potential of shattering concrete, especially segment concrete linings. This risk, in turn, runs the risk of releasing material from Line 5 into the Straits. This high-risk occurrence is contrary to the Enbridge's purported purpose of constructing a tunnel to serve as a secondary containment vessel in the event of a spill.[239] In short, the scope of the Corps' EIS must include the risk of an explosion that would cause a high-pressure event and the ways in which the explosion would put the concrete structures at risk.

It is well-documented that the pipeline's most likely point of failure is at the girth welds or heat affected zones. The specific grade of pipe Enbridge specified in its Joint Permit Application for use for the project—5L X70—has a known and demonstrated risk of failure at those areas.[240]

Once there is a leak of the X70 pipeline, an explosion within the tunnel is feasible. Enbridge's design system lacks independency, meaning that each aspect of the design is linked to a common failure—a hydrocarbon release that produces a heavier than air vapor cloud. Multiple design features within the tunnel project are all vulnerable to this same failure and therefore the design fails to provide independent, multi-level protection. The EIS must

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[235] *Id.*
[236] *Id.*
[237] *Id.*
[238] One major Line 5 spill occurred near Crystal Falls in 1999 when more than 220,000 gallons of oil and natural gas liquids were spilled. When responders ignited the vapor cloud that formed it resulted in a 36-hour fire. *See* Kuprewicz Rebuttal at 10 (citing https://www.mlive.com/news/2017/04/enbridge_line_5_spill_history.html).
[239] *See* NOI ("The tunnel would provide secondary containment, which is intended to minimize the potential for leakage of fluids from Line 5 into the lakebed or the Straits.").
[240] S*ee generally, Joint Industry Report, Final Summary Report, Enhanced Girth Weld Performance for Newly Constructed Grade X70 Pipelines* at iv (May 29, 2020), https://www.ingaa.org/File.aspx?id=38629&v=4654ede7. *See also* Sur-Sur-Rebuttal Testimony of Richard Kuprewicz Appl. for Auth. to Replace and Relocate Segment of Line 5 Crossing the Straits of Mackinac (MPSC No. U-20763).

scrutinize the operational plans of the Project to ensure that the Project minimizes environmental risks, especially relative to alternatives in which there is no pipeline in the Straits.[241] The operational risks are a direct consequence of Enbridge's design plan to build "entirely through bedrock," and therefore the direct, indirect, and cumulative effects of an explosion must be considered within the EIS.

Second, the presence of methane in the Straits poses an additional explosion risk to the Project. Dissolved methane was found in nearly 20 percent of ground water samples that were tested.[242] It is the nature of the underground tunnel that groundwater will continually be seeping into the tunnel and will be pumped out during operations. When water with dissolved methane comes into contact with air, the methane will escape, and elevated levels of methane create an explosion hazard. This scenario must be considered by the Corps; failure to do so would ignore lessons from both Michigan and Wisconsin's history.[243] The explosion risk from methane leaking into the tunnel is a direct consequence of Enbridge's design plans and the Corps cannot ignore this connection in the scope of its EIS.

Third, Enbridge has not provided a spill response plan that addresses an explosion event. The scope of the EIS must include an analysis of such a plan and the extent of the environmental impacts of an explosion and/or spill from the Project. The Corps should require that Enbridge produce a comprehensive spill plan based on the explosion risks outlined above so that it—and members of the public—can analyze the appropriate response to such an event. Further, once the spill plan is provided by Enbridge, the Corps should issue a supplemental, revised, or corrected public notice based on the change in information that may affect the public's review of the proposal.[244]

Finally, the Corps must be transparent in the EIS process about the methodology and data it uses to determine the risks posed by the Project. [245]A risk assessment cannot be generic—not all pipelines pose the same level of risk, and not all environments will experience the same vulnerabilities to pollutants in the same way. As the Straits are a Traditional Cultural Property and a place of deep importance to the Tribal Nations, any characterization of the risk of an explosion in the EIS must be coupled with the gravity of the consequences. An explosion, as well as all other risks identified throughout these comments, would have catastrophic consequences for Bay Mills and other Tribal Nations. The manner in which the risk of an

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[241] *See* Section V.B., *supra*.
[242] *See* Geotechnical Data Report at Appendix F-3 Groundwater Testing Summary Table.
[243] *See* James Graham, Lou Mleczko & James Tittsworth, *In Michigan History: Deadly Lake Huron Tunnel Explosion,* THE DETROIT NEWS (Sept. 17, 2016), https://www.detroitnews.com/story/news/local/michigan-history/2016/09/17/deadly-lake-huron-water-tunnel-explosion/90522336/ (detailing a methane explosion in Lake Huron); *see also* Elizabeth Lightfoot, *Three Workers Killed, One Missing in Tunnel Explosion,* AP NEWS (Nov. 10, 1988), https://apnews.com/article/a190525cd388425f128e5fc951bdc437 (detailing a methane explosion in Milwaukee).
[244] *See* Section III, *supra*.
[245] *See City of Dallas, Tex. v. Hall*, 562 F.3d 712, 720 (5th Cir. 2009) ("Properly analyzing the risks of an action requires an agency to use updated information or data; reliance on out-of-date or incomplete information may render the analysis of effects speculative and uncertain […]").

explosion of Line 5 within the Project is assessed with the Corps' EIS is an environmental justice issue that the Corps is mandated to address.[246]

B. Species

Impacts to species must be part of the EIS analysis as direct, indirect, and cumulative effects. Impacts to be addressed in the EIS are those from construction and operation of the Project and alternatives, including impacts to species that have occurred or will occur during pre-construction work such as the archaeological surveys that Enbridge is carrying out.

As the Corps states in the NOI, the Corps has obligations under the federal Endangered Species Act ("ESA"). The scope of the EIS must include a robust analysis of endangered and threatened species, both under the ESA and those species covered by the Michigan Endangered and Threatened Species Act.

The scope of the EIS cannot be limited, however, to endangered and threatened species. Impacts to species that members of Tribal Nations fish, harvest, hunt, or have other cultural, spiritual, or economic relationships with are also direct, indirect, and cumulative impacts of this Project and will be an important consideration for the EIS. These species include, but are by no means limited to, lake whitefish, walleye, sturgeon, loons, sugar maple, northern white cedar, wild rice, wild cranberry, migratory birds, deer, moose, and wolves.

Also, development and land clearing, such as would occur during Project construction, create opportunities for invasive species to move in and compromise the ability of other native species to grow and these environmental effects should be addressed within the EIS.

In enacting the ESA, Congress declared its policy that all federal departments and agencies shall seek to conserve threatened and endangered species, and to utilize their authorities in furtherance of the purposes of the Act.[247] The legislative history of the ESA "reveals an explicit congressional decision to require agencies to afford first priority to the declared national policy of saving endangered species."[248] Congress intended "to give endangered species priority over the 'primary missions' of federal agencies," and to "halt and reverse the trends toward species extinction--whatever the cost."[249] Under the ESA, all federal agencies must afford ESA-protected species "the highest of priorities."[250] The ESA requires coordination with expert wildlife agencies so activities which undermine ESA goals can be avoided; here, the ESA calls for coordination with the U.S. Fish and Wildlife Service (FWS).

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[246] *See* Exec. Order No. 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (Feb. 11, 1994); *see also Standing Rock Sioux Tribe v. U.S. Army Corps of Engineers*, 255 F. Supp. 3d 101, 140 (D.D.C. 2017).
[247] 16 U.S.C. § 1531(c)(1).
[248] *Tennessee Valley Authority v. Hill*, 437 U.S. 153, 185 (1978).
[249] *Tennessee Valley Authority*, 437 U.S. at 184, 185.
[250] *Tennessee Valley Authority*, 437 U.S. at 174.

Under the Section 7 of the ESA, the EIS must include or incorporate by reference Biological Assessments for federally- and state-listed species and their critical habitats, including descriptions of the outcomes of consultations with the federal services and tribes. The EIS must also quantify and disclose the amount of incidental and direct take regarding ESA-listed and resident species due to the impacts of this proposed project. The EIS must include similar evaluations for state listed fish stocks of concern.

To meet its obligations under the ESA to protect and recover threatened and endangered species, the Corps must conduct a comprehensive review of effects on threatened and endangered species. The most recently prepared Biological Assessment ("BA") for this Project is inadequate to satisfy the ESA or NEPA; it must be revised and completed before the Corps can initiate formal consultation with FWS.[251]

The most recent version of the draft BA is outdated and must be revised as part of the NEPA and ESA process. This most recent version is dated July 9, 2021. There are at least six reasons why this BA is inaccurate and outdated.

First, the BA takes an inappropriately narrow view of the project activities and makes a false assumption that all activities will go as planned.[252] Effects to be analyzed and addressed include "the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action."[253] These include effects that "are later in time."[254] The BA defines the activities too narrowly by exclusively addressing tunnel construction and the decommissioning of the dual pipelines. The BA errs in omitting activities that may cause direct, indirect, or cumulative effects on threatened and endangered species. For example, the BA excludes as part of the project activity the Line 5 pipeline's operations in and around the tunnel.

The BA makes a false assumption that all activities will go as planned by omitting any discussion of the risks of an oil spill, pipeline or tunnel explosion, overtopping or other failure of stormwater ponds, or any other project risks. The risk of such disasters exists and may affect threatened and endangered species.[255]

Second, the BA is artificially narrow and should not be used to determine the geographic scope for species reviewed as part of the EIS. The BA is based on an "Action Area" of tunnel construction and 100-foot buffer. But a properly defined action area is "not merely the

[251] 50 C.F.R. § 402.14(c).
[252] *See* Stantec Consulting Services Inc., Biological Assessment – Great Lakes Tunnel Project at 3-7 (July 9, 2021) (hereinafter "July 2021 BA"), attached to Letter from Paul Turner, Environmental Specialist, Enbridge Energy, to Kerrie Kuhne, U.S. Army Corps of Engineer (July 9, 2021).
[253] 50 CFR § 402.02; U.S. Fish & Wildlife Service and National Marine Fisheries Service, Endangered Species Consultation Handbook at xiii-xiv (March 1998), https://www.fws.gov/sites/default/files/documents/endangered-species-consultation-handbook.pdf.
[254] 50 CFR § 402.02; U.S. Fish & Wildlife Service and National Marine Fisheries Service, Endangered Species Consultation Handbook at xv (March 1998), https://www.fws.gov/sites/default/files/documents/endangered-species-consultation-handbook.pdf.
[255] *See* Section VII.B, *supra* (discussing oil impacts to species).

immediate area involved in the action."[256] The action area should include "waterbodies that may be impacted by the Project," including the Straits and Great Lakes basin.[257]

Moreover, by leading to the continued operation of the Line 5 pipeline, this Project could dramatically affect many more species than are considered in the present BA, including but not limited to many endangered and threatened freshwater mussels in the small streams that Line 5 crosses such as the snuffbox (*Epioblasma triquetra*), northern riffleshell (*Epioblasma rangiana*), and rayed bean (*Villosa fabalis*).

Third, the discussion of piping plovers is inadequate. After noting that there is suitable plover habitat within and near to Enbridge's preferred Action Area, the BA notes that "eBird data indicate no records within or immediately adjacent to the Action Area."[258] Relying only on eBird data to determine whether plovers will be impacted and only looking at records "within or immediately adjacent to the Action Area" is insufficient. There will be information gaps and spatial limitations to using a single data source, particularly one such as eBird that withholds data on protected species or provides it only on a coarse scale.[259] Piping plover is considered a "Regionally Sensitive Species" by eBird and is given all of the data sharing protections offered. eBird also encourages its users to "use discretion" when reporting rare and endangered species as to best protect species recovery. Given this information, eBird should not be the sole source of information for drawing conclusions on impacts to piping plovers. A proper species analysis must be based on "the best scientific and commercial data available"[260] and consider the environmental baseline[261].

Fourth, the discussion of the endangered northern long-eared bat is inadequate. Enbridge conducted a bat survey in 2021;[262] however, FWS revised bat survey guidelines in March 2022 which now include species-specific guidelines for the northern long-eared bat.[263] The previous survey does not meet the new, species-specific guidelines. For example, new acoustic survey guidelines for the northern long-eared bat for non-linear projects such as this one call for a minimum of 14 detector nights of data, whereas Enbridge's survey only had 8 detector nights of data for the north and south shore sites combined. The scope of the EIS and a revised BA should include site-specific information about the northern long-eared bat that meets or exceeds current FWS guidelines.

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[256] 50 C.F.R. § 402.02.

[257] *Appalachian Voices v. United States Dep't of Interior*, 25 F.4th 259, 271 (4th Cir. 2022) (recognizing that the action area for a pipeline includes the construction area *and* waterbodies the project may impact).

[258] July 2021 BA at 10 (citing Sullivan, B. L., C. L. Wood, M. J. Iliff, R. E. Bonney, D. Fink, and S. Kelling. 2009. eBird: a citizen-based bird observation network in the biological sciences. Biological Conservation 142: 2282-2292.).

[259] *See* eBird, Sensitive Species in eBird (Aug. 22, 2022), https://support.ebird.org/en/support/solutions/articles/48000803210-sensitive-species-in-ebird.

[260] *See* 16 U.S.C. § 1536(a)(2); *see also Appalachian Voices*, 25 F.4th at 269 (noting that the ESA requires an agency to "seek out and consider" all relevant scientific data).

[261] 50 C.F.R. § 402.02 (defining "environmental baseline").

[262] Stantec Consulting Services Inc., Northern Long-eared Bat Presence or Probable Absence Survey (July 29, 2021).

[263] U.S. Fish & Wildlife Service, Northern Long-Eared Bay Survey Guidelines (March 2022), https://www.fws.gov/media/range-wide-indiana-bat-and-northern-long-eared-bat-survey-guidelines.

Fifth, there is new information about Houghton's goldenrod and Dwarf Lake Iris—threatened species—in the Action Area, and the BA must account for it. Specifically, surveys were performed in the summer of 2021 – after the most recent BA – to establish baseline conditions of stem counts for Houghton's goldenrod and dwarf lake iris near the project's North Straits Facility.[264]

Dwarf lake iris are petite flowers that only bloom in the porous, sandy soils and moist air of the Great Lakes Region. Their deep violet petals radiate from a stout stem stretching 2 inches above the ground, dotting the landscape like ready-cut corsages. Houghton's goldenrod is also native only around the Great Lakes. Neighbor to the dwarf lake iris, Houghton's goldenrod grows closer to the water where wet beach abuts land. Houghton's goldenrod is a wetland obligate species. Houghton's goldenrod towers over the dwarf lake iris at 2 feet, displaying around 600 completely yellow, tiny flowers in clusters.

The Corps should pay particular attention to Houghton's goldenrod and dwarf lake iris, as they are endemic to the northern Great Lakes shoreline.[265] Houghton's goldenrod, for example, is found mostly within the Straits region and usually occurs near shore; in other words, the habitat for Houghton's goldenrod within the Action Area is some of the only and best habitat for this rare plant.[266]

The BA noted that 8.3 acres of suitable habitat for the Houghton's goldenrod and Dwarf Lake Iris will be cleared, and 3,777 individual Houghton's goldenrod plants and 7,757 individual dwarf lake iris plants will be cleared or relocated.[267] The BA then confidently stated that proposed mitigation activities "will offset the effects and no long-term adverse effects to [either of these] species are anticipated."[268] Those numbers were based on woefully inaccurate data; in 2019 surveys, according to the BA, approximately 6,682 Houghton's goldenrod stems and 19,544 dwarf lake iris stems were located within the North Side LOD and the Action Area immediately adjacent to it.[269]

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[264] Stantec Consulting Services Inc., Plant Mitigation – Baseline Conditions Report (Feb. 17, 2022).
[265] *Solidago Houghtonii* (Houghton's Goldenrod), Michigan Natural Features Inventory, https://mnfi.anr.msu.edu/species/description/13632/Solidago-houghtonii (last visited Oct. 14, 2022); *Iris lacustris* (Dwarf lake iris), Michigan Natural Features Inventory, https://mnfi.anr.msu.edu/species/description/15374/Iris-lacustris (last visited Oct. 14, 2022).
[266] *Solidago Houghtonii* (Houghton's Goldenrod), Michigan Natural Features Inventory, https://mnfi.anr.msu.edu/species/description/13632/Solidago-houghtonii (last visited Oct. 14, 2022).
[267] *See* July 2021 BA at 22,23.
[268] *See* July 2021 BA at 22, 24. The mitigation plans are questionable as well. In order to prepare an area for the plants to be relocated to, other plants, including mature trees, will need to be cleared. That may damage habitat for other species of tribal significance (such as habitat for deer browsing), and it may create further opportunity for invasive species (such as spotted knapweed with its allelopathic compounds that compromise the ability of other plants to grow nearby) to move in and make it difficult for the threatened native plants to survive. Further, to the extent that the trees and other plants originally in that area grow back, they will harm the relocated Houghton's goldenrod and dwarf lake iris.
[269] *See* July 2021 BA at 20, 23.

More recent information and a better scientific understanding of Houghton's goldenrod tells a different story. The 2021 Baseline Report concluded that there are approximately *149,282* Houghton's goldenrod stems and *1,223,307* dwarf lake iris stems within the North Side LOD.[270] That is 22 times the number of Houghton's goldenrod stems and 62 times the number of dwarf lake iris stems in the area that the BA considered. The more recent study demonstrates, (1) the importance of interrogating data provided by Enbridge and the Corps' duty to independently verify all information submitted as part of the Project application, and (2) that the habitat in and around the Action Area is one of the few remaining strongholds for these rare endemic plants.

Additionally, more Houghton's goldenrod and dwarf lake iris plants will be impacted by the Project than just what is in the LOD. The LOD does not include proposed enhancement areas that Bay Mills visited and observed with Enbridge, the Corps, and other Cooperating Agencies on a September 9, 2022 site visit. The existing vegetation at the enhancement areas and animals that use the area will be disturbed and impacted by any work Enbridge does in those areas. While on site, Bay Mills observed dwarf lake iris in the enhancement area, pileated woodpeckers calling and using the northwestern enhancement area, and signs of deer browsing on cedars.

Sixth, there are additional reasons to revisit the BA. For example, the gray wolf (ma'iingan) was briefly delisted during the BA drafting process, but it is now relisted as an endangered species throughout the entire region where Line 5 operates and where the tunnel would be constructed. Special attention to the gray wolf is warranted in light of its spiritual and cultural importance to Bay Mills and Ojibwe people.

Finally, the Michigan Endangered and Threatened Species Act protects additional species, and the EIS should address how the Project will impact them.[271] Notably, although Michigan state agencies have been involved in reviewing or permitting other aspects of this Project, no agency has reviewed impacts to endangered and threatened species. In fact, Michigan's EGLE noted that the Corps would be required to comply with the ESA, deferring full review of impacts to rare species to the Corps and making it all the more critical that a complete review of at-risk species is included in the EIS.[272]

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[270] Stantec Consulting Services Inc., Plant Mitigation – Baseline Conditions Report at 8, 11 (Feb. 17, 2022).

[271] MCL 324.36501 *et seq.* There are at least an additional 24 species that are listed by Michigan's Department of Natural Resources as endangered (E), threatened (T) or of special concern (SC) that the Project may impact: peregrine falcon (E), common loon (T), common tern (T), calypso bulbosa (T), Lake Huron tansy (T), hills pondweed (T), pine-drops (T), Lake Huron locust (T), delicate vertigo (T), American bittern (SC), black tern (SC), bald eagle (SC), osprey (SC), black-crowned night heron (SC), marsh wren (SC), little brown bat (SC), lady's slipper (SC), butterwort(SC), Sprague's pygarcita (SC), grizzled skipper (SC), widespread column (SC), vertigo cristata (SC), vertigo pygmaea (SC), Great Lakes physa (SC). *See* https://mnfi.anr.msu.edu/species/animals. The EIS should identify whether the Project will impact other species protected by Michigan law, including by construction, an oil spill, climate change, or other cumulative impacts of the Project.

[272] *See* Michigan Department of Environment, Great Lakes, and Energy, Responsiveness Summary (Jan. 28, 2021) Resources Responsiveness Summary at 4. Moreover, EGLE's issuance of the resources permits predates the most recent plant studies, which show many more endangered plants in the wetlands area.

C. Wetlands

The EIS for this Project must include direct, indirect, and cumulative impacts to wetlands.

The NOI states:

> The proposed project would involve placement of fill into a total of approximately 0.13 acre of wetlands, including 0.10 acre of permanent impact and 0.03 acre of temporary impact. The purposes of the fill include: construction of two outfall structures (0.02 acre wetland impact), widening Boulevard Drive to the south and east of the work area for construction equipment access (0.08 acre), and providing access to an upland materials staging area (0.03 acre). After completion of construction, the fill in this 0.03-acre area would be removed, and the area would be seeded with emergent wetland seed mix.[273]

In addition to addressing those wetlands impacts, the scope of the EIS must include impacts to neighboring wetlands and a discussion of the quality of the wetlands that will be impacted, impacts to wetlands from other foreseeable Project activities, and an independent analysis of Enbridge's wetland mitigation plan. It is reasonably foreseeable that the Project will further impact wetlands in the event of an overflow from the stormwater pond that Enbridge will use during construction or an oil spill that occurs during project operation.

First, the area of impacted wetlands may be larger than what the NOI states. As part of the EIS, the Corps should revisit the wetlands determination. In fact, many lines of evidence suggest that wetland acreage was underestimated at the site. For example, an area of coastal fen has been delineated within the north side LOD by Enbridge contractors, but this area has not been included as delineated wetland. This area of coastal fen was also evident at the September 9, 2022 site visit.

Ground penetrating radar data suggests that there are more wetlands within the North Side LOD than have been quantified as wetlands in the NOI or by the Corps.[274] A report prepared by Commonwealth Heritage Group notes many instances of "standing water," "rain and trapped water," and "shallow trapped water," as well as a "depression containing water"—all of which are indicative of wetlands.[275] The report also includes photographs that show standing water on site.[276] Additionally, while multiple wetland surveys have been conducted in the area, none of the surveys have taken a holistic approach to analyzing the site all at once; this segmenting of surveys may lead to information gaps.

[273] Notice of Intent To Prepare a Draft Environmental Impact Statement for the Line 5 Tunnel Project, Mackinac and Emmet Counties, Michigan, 87 Fed. Reg. 50,076 (Aug. 15, 2022).
[274] Commonwealth Heritage Group, Ground Penetrating Radar Archaeological Survey for the Great Lakes Tunnel Project (July 2022) (provided by the Corps to participating Section 106 tribes on July 22, 2022).
[275] *See, e.g.*, *id.* at B-11, B-15, B-16, B-18, B-48 B-53.
[276] *Id.*

There is also no indication that the existence of shallow limestone soils has been considered at the north side LOD as being a potentially problematic hydric soil. Higher pH within limestone soils can alter processes that allow redoximorphic characteristics (hydric indicators) to develop. Not considering shallow limestone soil as a problematic hydric soil could lead to an underestimation of the amount of wetland at the project site.

Second, there are several foreseeable Project activities with wetlands impacts that the EIS must address:

- the expansion of Boulevard Drive for Project construction may result in increased stormwater runoff and pollution to wetlands, especially when coupled with climate change impacts of increasing precipitation events and/or erosion in the area;

- the stormwater ponds that Enbridge plans to use during tunnel construction may overflow and pollute area wetlands;

- the dewatering process used to create the tunnel shaft may result in a drawdown of groundwater that could impact wetlands; and

- Project operation may result in an oil spill to wetlands.

Third, the scope of the EIS must include a close analysis of Enbridge's mitigation plans. The EIS should address the enduring nature of wetlands impacts; there is no temporary wetland impact.

D. Rare Natural Community Types

There are many acres of rare natural community types found within the project area that provide preferred habitat for many state- or federally protected species, including Great Lakes endemic species found nowhere else in the world. The scope of the EIS must include direct, indirect, and cumulative impacts to the rare natural community types. Natural community types that will be affected include but are not limited to, limestone bedrock glade (alvar glade), coastal fen, limestone cobble shore, wooded dune and swale complex, and rich conifer swamp.[277]

The draft BA noted that dwarf lake iris and Houghton's goldenrod were found within coastal fen, limestone bedrock glade, and limestone cobble shore and that 8.3 acres of these

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[277] For example, coastal fen is a unique wetland community and ranked – both globally and by the State – as imperiled. Coastal Fen, Michigan Natural Features Inventory, https://mnfi.anr.msu.edu/communities/description/19006/coastal-fen (last visited Oct. 14, 2022). Limestone bedrock glad is also ranked as imperiled by the State and is a habitat home to many rare plants and animals. Limestone Bedrock Glade, Michigan Natural Features Inventory, https://mnfi.anr.msu.edu/communities/description/15983/limestone-bedrock-glade (last visited Oct. 14, 2022).

natural community types would be cleared. [278] The impacts of this clearing must be addressed in the EIS.

E. Water quality

Great Lakes waters serve important ecological functions, support the tribal fishery, and supply drinking water. The scope of the EIS must evaluate the impacts of the Project on water quality, including the water quality impacts for each alternative.

Under Michigan's Water Quality Standards, Lake Michigan, Lake Huron, and the Straits of Mackinac are designated for use as both a coldwater fishery and a warmwater fishery.[279] The waters within the Straits of Mackinac are not to receive a heat load that would warm the receiving water at the edge of the mixing zone more than 3 degrees Fahrenheit above the existing natural water temperature.[280] As the U.S. Environmental Protection Agency ("EPA") noted in its comments, the EIS should identify any waters of interest that might be impacted by the Project, including Outstanding Resource Waters, Exceptional Resource Waters, Wild and Scenic Rivers, Trout Streams, Blue Ribbon Trout Streams, and Water Trails.[281]

There are many outstanding questions related to the Project's potential impact on water quality: (1) actual specifications for the proposed wastewater treatment system; (3) the amount of water that will be reused vs. discharged; (4) which water treatment additives will be utilized, and how the additives will be stored and used; (5) exact locations of the proposed discharges; (6) the impact on groundwater from infiltration of collected stormwater; and (7) the impact of stormwater discharges caused by storm events or overflows.[282] Further, information about water treatment additives, including flocculants or coagulants, that Enbridge will utilize in its treatment facility, is needed to understand the discharge's potential impact on aquatic life. As far as we know, Enbridge has not yet provided a detailed physical and chemical analysis of the composition of the effluent to any permitting agency.

The Project will result in "an increased loading of pollutants to Lake Michigan, which will lower the water quality with respect to certain parameters."[283] The EIS should consider how the impacted water quality will in turn impact fish and other aquatic species.

F. Air quality and Greenhouse Gas Emissions

Air quality impacts from Project construction and operation must be part of the EIS analysis as direct, indirect, and cumulative effects. Air quality effects from the Project include:

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[278] July 2021 BA at 22-23.
[279] Mich. Admin. Code R. 323.1100(1), (5).
[280] Mich. Admin. Code R. 323.1070(1).
[281] EPA Scoping Comments at 17.
[282] Bay Mills previously has raised detailed concerns about these issues. *See* Bay Mills Indian Community and Little River Band Comments on EGLE's Permits for Line 5 at 18, 27, 31, 49-50 (October 2020).
[283] Department of Environment, Great Lakes, and Energy, Public Notice of Draft Permit No. MI0060278 (Aug. 28, 2020).

(1) GHGs from construction, including GHGs from electricity used by the tunnel boring machine and GHGs from materials such as cement and steel used to construct the tunnel (described more fully above in Section VIII.A, *supra*); (2) GHGs from the burning of products the Project transports (described more fully above in Section VIII.A, *supra*); (3) the risks and impacts associated with encountering gas while tunneling, especially given that gas is known to occur in the bedrock of the Michigan Basin[284]; (4) the release of gases or other pollutants in the event of an explosion during operation (described more fully above in Section IX.A.3, *supra*); (5) construction-related dust and its impacts on adjacent biota; and (6) air emissions associated with internal combustion engines used during construction and operation.

G. Impacts to Indigenous Women

The scope of the EIS should include impacts of violence against Indigenous women and girls. Indigenous women and girls face disproportionate violence.[285] Pipeline development projects, including those managed by Enbridge, are associated with a documented increase in levels of these negative impacts.[286] In light of this documented connection between pipeline projects and violence, as well as the Project's location[287], the Corps should look at the impact that the Project will have on violence against Indigenous women and girls, as well as whether and how law enforcement and/or Enbridge will coordinate with each other, provide victim services, and engage in outreach and communications responses.

H. Cultural Resources

Impacts to cultural resources from Project construction and operation must be part of the NEPA and Section 106 processes. As described more fully in Sections I.D and II.C, *supra*, the Straits of Mackinac are a Traditional Cultural Property with numerous documented archaeological sites and many more that have yet to be documented.

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[284] *See* Line 5 Replacement and Tunnel Project Geotechnical Data Report, Enbridge Energy, Limited Partnership, at Appendix F-3 Groundwater Sampling Table (March 9, 2020), http://www.deq.state.mi.us/documents/wrd-line5-geotechnical-data-report.pdf.

[285] *See* May 5, 2022: Missing and Murdered Indigenous Persons Awareness Day, Governor Gretchen Whitmer (May 5, 2022) https://www.michigan.gov/whitmer/news/proclamations/2022/05/05/may-5-2022-missing-and-murdered-indigenous-persons-awareness-day (declaring a "Missing and Murdered Indigenous Persons Awareness Day" in Michigan and recognizing that Bay Mills, the State, and the Sault Ste. Marie Tribe of Chippewa Indians are working together to raise awareness of missing and murdered indigenous persons).

[286] *See* Violence from Extractive Industry 'Man Camps' Endangers Indigenous Women and Children, Univ. of Colo. Boulder (Jan. 29, 2020), https://www.colorado.edu/program/fpw/2020/01/29/violence-extractive-industry-man-camps-endangers-indigenous-women-and-children; Julia Stern, Pipeline of Violence: The Oil Industry and Missing and Murdered Indigenous Women, IMMIGR. AND HUMAN RIGHTS L. REV. (May 28, 2021), https://lawblogs.uc.edu/ihrlr/2021/05/28/pipeline-of-violence-the-oil-industry-and-missing-and-murdered-indigenous-women/ .

[287] Many tribal citizens live in the Upper Peninsula and the Straits area. *See* Lindsay M. McCoy, Capital News Service, *Two UP Tribes Involved In New Project Look At Missing, Murdered Native Americans*, THE DETROIT NEWS (March 26, 2022), https://www.detroitnews.com/story/news/local/michigan/2022/03/27/missing-murdered-native-americans-alaskan-natives-fbi-database-cold-cases/7173871001/ (noting that Mackinac County has the "highest rate of Native American residents" in Michigan).

Any disturbance to one part of a TCP is a disturbance to the integrity of the whole. For example, direct and indirect effects from Project construction, including ground disturbance, work activity, and excavation necessary to create the tunnel boring machine ("TBM") retrieval shaft on Point La Barbe, would negatively impact the cultural and historic values associated with not only this site, but would negatively impact a tribal burial mound, [288] and the Straits as a sacred and cohesive cultural landscape. Construction on McGulpin point, including excavation for the TBM entrance portal and operation of the TBM, will disturb and degrade nearby cultural sites, including those directly adjacent to the Project area.[289]

Cultural resources are not exclusively archaeological sites. The fish in the lake are cultural resources. Plants—including those at burial sites, those that are used for medicines, and those that are part of the ecosystem as a whole—are cultural resources. To Bay Mills, natural resources are cultural resources.

X. THE EIS CANNOT IGNORE ENBRIDGE'S CAVALIER APPROACH TO PIPELINE SAFETY.

In order to evaluate the environmental effects of the Project it is important to review Enbridge's pipeline safety record, as well as its dismissive treatment about governments that are concerned with safety.

A. The EIS Must Take Into Account Enbridge's Safety Record.

The scope of the EIS must recognize Enbridge's failures in order to effectively evaluate the environmental effects of permitting Enbridge to route a hazardous liquids pipeline through an underground tunnel and continuing to operate the pipeline. Not only has Enbridge been responsible for at least 1.3 million gallons of product spilling along Line 5,[290] but Enbridge is also responsible for the some of the largest inland oil spills in U.S. history and has a history of overstating its ability to stop or prevent a spill.

The largest inland oil spill in U.S. history occurred on Enbridge's Line 3 pipeline—part of the same Lakehead System as Line 5—on March 3, 1991, in Grand Rapids, Minnesota, when the

[288] Commonwealth Heritage Group, Phase I Cultural Resources Survey for the Enbridge Mackinac Straits Project, 20-22 (August 2019).
[289] *Id*.
[290] This does not include additional spills across Enbridge's pipeline system. Using Pipeline Hazardous Materials Safety Administration ("PHMSA") data, Beth Wallace, a National Wildlife Federation pipeline safety specialist, compiled an interactive ArcGIS map of the spill locations along Enbridge's Line 5: https://www.arcgis.com/apps/View/index.html?appid=f817f5abad9a4cb09e942c1941fd0060 (last accessed Oct. 14, 2022). Enbridge has been responsible for 1,068 spills across the entire Enbridge pipeline system, which have collectively dumped 7.4 million gallons of oil into the environment between 1999 and 2013—an average of 71 spills and 500,000 gallons per year. *See* Enbridge Safety Record, Oil and Water Don't Mix, https://www.oilandwaterdontmix.org/enbridge_safety_record (last accessed Oct. 14, 2022).

pipeline spilled 1.7 million gallons of crude oil into the frozen Prairie River—a mere 2 miles from reaching the Mississippi River. [291] The reported clean-up cost was $7.5 million.[292]

The failure on Line 3 occurred in fatigue cracks along the pipeline.[293] As crude oil spilled out of the pipeline, personnel in Enbridge's Edmonton Control Center[294] incorrectly interpreted all alarms and indications coming from the line to be a condition of column separation and instrument error.[295] During the Line 3 spill, Enbridge personnel continued to pump oil into the ruptured 34-inch diameter line for more than an hour before finally recognizing the leak.[296] Enbridge thereafter revised its operation maintenance procedures to require a pipeline shutdown after 10 minutes of uncertain operational status; however, as the National Transportation Safety Board ("NTSB") notes, among many other problems that unfolded after the Line 3 disaster, "Enbridge control center staff . . . developed a culture that accepted not adhering to the procedures."[297]

A pipeline failure and ineffective response by Enbridge led to the largest oil spill in Michigan, as well.[298] Enbridge's Line 6B pipeline ruptured on July 25, 2010, in Marshall, Michigan and spilled into in a wetland releasing just short of a million gallons of toxic tar sands crude into Talmadge Creek and the Kalamazoo River.[299] The Line 6B rupture caused a disaster that is still being felt today, including, notably, by the Nottawaseppi Huron Band of the Potawatomi.[300]

The Line 6B spill occurred just days after Enbridge's Vice President of U.S. Operations for liquid pipelines boasted in testimony before the United States Congress that Enbridge's

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[291] Pipeline Accident Report, Enbridge Incorporated Hazardous Liquid Pipeline Rupture and Release, Marshall Michigan, July 25, 2010, National Transportation Safety Board, NTSB/PAR-12/01 PB2012-916501 at 52 (Sept. 14, 2012), https://www.ntsb.gov/investigations/AccidentReports/Reports/PAR1201.pdf; *see also* Dan Kraker & Kirsti Marohn, *30 Years Later, Echoes of Largest Inland Oil Spill Remain in Line 3 Fight*, MPR NEWS (March 3, 2021), https://www.mprnews.org/story/2021/03/03/30-years-ago-grand-rapids-oil-spill.

[292] Pipeline Accident Report, Enbridge Incorporated Hazardous Liquid Pipeline Rupture and Release, Marshall Michigan, July 25, 2010, National Transportation Safety Board, NTSB/PAR-12/01 PB2012-916501 at 52 (Sept. 14, 2012), https://www.ntsb.gov/investigations/AccidentReports/Reports/PAR1201.pdf.

[293] *Id.* at 52.

[294] The Edmonton Control Center, located in Edmonton, Alberta, in Canada and over 1,000 miles from the Straits, is used for the entire Lakehead System. *See id.* at 44. While Enbridge opened the Enbridge Straits Maritime Operations Center (ESMOC) in addition to the Edmonton Control Center, neither Control Center removes the very real and demonstrated threat that human error has on pipeline spill disasters, as seen time and again through Enbridge's spill history.

[295] *Id.* at 52.

[296] *Id.* at 52.

[297] *Id.* at 119.

[298] Kenny Bruno, et al., Enbridge Over Troubled Water, The Enbridge GXL System's Threat to the Great Lakes (at 11 (Jan. 2016), https://www.nwf.org/-/media/PDFs/Global-Warming/Tar-Sands/Enbridge-Over-Troubled-Water-Report-Final.ashx (last visited Oct. 14, 2022).

[299] *Id.* at 11.

[300] *See* The Great Stain: 10 Years After the Kalamazoo River Oil Spill, Nottawaseppi Huron Band of the Potawatomi, https://nhbp-nsn.gov/media/the-great-stain-10-years-after-the-kalamazoo-river-oil-spill/ (last visited Oct. 14, 2022).

response time "can be almost instantaneous."[301] Despite the self-imposed 10-minute rule following the Line 3 spill, Enbridge's public assurance that it would instantaneously stop a leak, and multiple warnings and alarms sounding, Enbridge staff continued to pump oil through the ruptured pipe.[302] Enbridge employees did not even report the leak; it was not until after a citizen in the area called 911 to report odors did any Enbridge employees, finally, begin sealing off the site over 17 hours after the rupture occurred.[303]

Following its investigation, the NTSB determined that the Line 6B disaster was not the result of isolated failures, but rather due to

> an approach to safety that did not adequately address the combined risks. By focusing on only the immediate cause of each incident, the company failed to look for and to determine patterns or underlying factors. Some of the underlying factors in this accident began many years earlier and converged with more recent changes only at the time of rupture.[304]

Additionally, the NTSB determined that Enbridge became "increasingly tolerant of the procedural violations designed to minimize the adverse consequences of a rupture" and that "Enbridge's emergency response to this accident was ineffective."[305] The scope of the Corps' EIS must take these determinations into consideration when deciding whether to permit Enbridge to operate in the Straits. As explained in Section IX.A., a rupture in Line 5 in the Tunnel Project could cause devastation, including an explosion.

Enbridge's record for pipeline failures extends beyond oil pipelines. Notably, on August 1, 2019, an Enbridge 30-inch natural gas transmission pipeline ruptured in Danville, Kentucky, releasing about 101.5 million cubic feet of natural gas that ignited and exploded into a fireball

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[301]Enbridge Pipeline Oil Spill in Marshall, Michigan, Hearing before the Committee on Transportation and Infrastructure, House of Representatives, September 15, 2010 at 2, https://www.govinfo.gov/content/pkg/CHRG-111hhrg58236/pdf/CHRG-111hhrg58236.pdf. Enbridge has a history of concealing or misrepresenting information about the safety of its pipelines. In Wisconsin, it took Enbridge over a year to report a spill from Line 13 that threatened drinking water wells. *Enbridge Line 13 Spill Timeline,* MADISON.COM (May 27, 2021) https://madison.com/enbridge-line-13-spilltimeline/html_65e6b665-75c4-5bfd-8d3e-cd1ae0f982dd.html. In Michigan, Enbridge provided testimony to a State Pipeline Advisory Board in 2017 that there were no gaps or breakdowns in the coating on the Line 5 dual pipelines to protect them from corrosion, despite Enbridge having been aware of deficiencies in its coating since 2014. Keith Matheny, *Enbridge didn't tell state about Mackinac Straits pipeline problems for 3 years*, DETROIT FREE PRESS (October 27, 2017), https://www.freep.com/story/news/local/michigan/2017/10/27/enbridge-straits-pipelinecoating-michigan/807452001/.

[302] Pipeline Accident Report, Enbridge Incorporated Hazardous Liquid Pipeline Rupture and Release, Marshall Michigan, July 25, 2010, National Transportation Safety Board, NTSB/PAR-12/01 PB2012-916501 at 1-7 (Sept. 14, 2012), https://www.ntsb.gov/investigations/AccidentReports/Reports/PAR1201.pdf.

[303] *Id.* at 1-7.

[304] *Id.* at 115.

[305] *Id.* at 115

causing significant destruction, many injuries, and one death.[306] Although Enbridge's gas control center received alarms indicating a change in pressure within the pipeline, crucial time passed before the station operator closed the necessary valve.[307] The delay increased the volume of gas released and the duration and intensity of the fire.[308]

For this pipeline failure too, the NTSB investigation reveals Enbridge's dismissive approach to pipeline safety. NTSB found that just three months prior to the explosion, an emergency shutdown occurred along the same line and the same station operator at fault in the August 2019 explosion "demonstrated a fundamental lack of knowledge" when he "closed a valve irrelevant to the event" during the May 2019 incident.[309] Between the May incident and August explosion, Enbridge neither terminated the station operator's employment nor adequately re-trained him on safety protocol.[310]

Enbridge's pipeline failures and poor responses in Grand Rapids, Minnesota, Kalamazoo, Michigan, and Danville, Kentucky are just examples of the disastrous effects of its cavalier approach to pipeline safety. The Corps' EIS must take Enbridge's failures regarding pipeline safety into consideration to avoid permitting similar disasters to occur in the Straits.

B. Enbridge's Cavalier Approach To Safety Extends To Its Disregard For Tribal, State, And Federal Government Requests And Orders.

Enbridge's conduct demonstrates a disregard for government orders, especially when such orders are motivated by concerns about the safety of Enbridge pipelines. The Corps should be skeptical of Enbridge's ability to construct and operate the Project safely and, specifically, to respond to governmental concerns about safety.

For example, Enbridge was forced—by court order—to shut down the dual pipelines in the Straits following damage to an anchor support. In June 2020, Enbridge re-opened a portion of the pipeline without consulting the State of Michigan over the State's request.[311] In addition,

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[306] Pipeline Investigation Report, Enbridge Inc. Natural Gas Transmission Pipeline Rupture and Fire, Danville Kentucky, August 1, 2019, National Transportation Safety Board, NTSB/PIR-22/02 at 1-8 (Aug. 15, 2022), https://www.ntsb.gov/investigations/AccidentReports/Reports/PIR22002.pdf.

[307] *Id.* at 1-3; *see also Id.* at Table 1 (indicating that "Enbridge employee received notification from a friend" about the rupture a full minute before the first alarm was received in Enbridge's gas control center). This is reminiscent of Marshall, Michigan where, as described above, the first report of the rupture came from a citizen—not from Enbridge.

[308] *Id.* at 44.

[309] *Id.*

[310] *Id.*

[311] Brief in Support of Plaintiff's Ex Parte Motion for Temporary Restraining Order at 1 & Exhibit A at 3, *Nessel v. Enbridge Energy,* No. 19-474-CE (Circuit Court for 30th Judicial Circuit of Ingham County. June 22, 2020), available at https://www.michigan.gov/ag/-/media/Project/Websites/AG/releases/2020/June/Brief_in_Support_of_Motion_for_TRO_with_Exhibit.pdf?rev=0e7a52c853d34c8e8591a7fc8eea6b10&hash=CB61B483F05FA7EC7E7359E87145287C ("Enbridge's actions of informing the Governor via a letter from its CEO that the pipelines were shut down pending investigation, only to almost immediately resume operation of one leg of the pipelines, demonstrate that its statements to government regulators are, at best, inconsistent with its actions. At worst, they are misleading.").

Enbridge has shown a lack of regard for its commitments established in the 2017 Consent Decree with the federal government, which required maintenance work along the entire Lakehead Pipeline system.[312] Enbridge's lack of compliance with the 2017 Consent Decree has resulted in $11.6 million in stipulated penalties.[313]

Moreover, Enbridge is presently operating the Line 5 pipeline across two areas where it lacks an easement in defiance of the government authority that had granted – and later revoked or refused to renew – that easement: the Straits of Mackinac[314] and the Bad River Band Reservation[315]. Trespassing on the Bad River Band Reservation is by no means the only instance of Enbridge defying tribal governments or disrespecting tribal citizens. Bay Mills was not initially consulted when Line 5 was constructed through its Ceded Territory, and Bay Mills has objected to Enbridge's archaeological and cultural survey methods and contractors, as well as its public relations campaign of using traditional cultural practices against tribal nations.[316]

Enbridge's conduct should give the Corps pause and requires a deeper evaluation of the potential impacts of this Project through an EIS.

XI. CONCLUSION

Bay Mills is very concerned about the serious and irreversible consequences of the Project. Enbridge proposes to construct the Project in a place that is a sacred wellspring of Anishinaabe life and culture, a Traditional Cultural Property where Bay Mills retains treaty rights. Project construction threatens cultural and historic resources, the geological integrity of the Straits, wetlands and other ecosystems, water and air quality, threatened and endangered species, as well as other species of importance to Tribal Nations, and it may increase violence against indigenous women and girls (as so many pipeline projects do).

The Project itself is just one piece of a set of related actions that Enbridge is pursuing to reroute, reconstruct, and perpetuate the use of the Line 5 pipeline over the objections of the Tribal Nations that will be impacted. As a result of this Project, much of the tribal ceded territory is threatened by an oil spill and tribal lifeways are threatened by the greenhouse gas emissions and climate impacts—without any demonstrated a need for the perpetuation of the Line 5 pipeline or the fuels it transports.

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[312] ECF Docket No. 14 Consent Decree, United States v. Enbridge Energy, Limited Partnership, 1:16-cv-00914-GJQ-ESC (W.D. Mich. May 23, 2017).

[313] *See* EPA Scoping Comments at 23.

[314] State of Michigan, Notice of Revocation and Termination of Easement (Nov. 13, 2020). *See also id.* at 9 (basing the revocation of the easement in part on the risk and harm that would befall tribal nations and treaty rights and resources in the event of a spill).

[315] *Bad River Band v. Enbridge Energy Co*., 19-cv-602-wmc, 2022 WL 4094073 at *11 (W.D. Wis. Sept. 7, 2022) (finding that the Bad River Band had presented "overwhelming evidence" of Enbridge's trespass on the Reservation and granting the Band summary judgment).

[316] *See* Resolution No. 21-05-10A, Banishment of Enbridge Energy, Inc. Line 5 Dual Pipelines from the 1836 Treaty of Washington Ceded Territory, waters of the Great Lakes, and the Straits of Mackinac (May 10, 2021)..

The Corps must address all issues identified in these scoping comments as part of the EIS process. This includes identifying and assessing direct, indirect, and cumulative impacts, evaluating the design of the tunnel, and developing alternatives, including options that do not involve a pipeline that crosses the Great Lakes.

Bay Mills appreciates this opportunity to comment and will continue to work with the Corps throughout the EIS process.

Attachment A

Brian J. O'Mara

Founder

https://agateharbor.com

Mr. O'Mara founded Agate Harbor Advisors LLC in 2020. He serves as an independent client advisor and technical expert providing strategic and tactical environmental consulting and litigation support to leading private and public sector clients. He is also the Director of Power and Industrial Solutions for Lone Wolf Resources, LLC a Texas based Heavy Civil and Environmental Remediation General Contractor.

He has more than 30 years of experience in environmental consulting specializing in geotechnical and hydrogeologic investigations, heavy civil and underground construction and environmental remediation projects and is expert in assessing the risks and liabilities associated with projects. His experience spans the entire lifecycle of major capital projects including alternatives analyses, conceptual design, predesign studies, feasibility analyses, permitting, bench and field scale studies, construction, operations and maintenance, decommissioning, demolition and redevelopment.

Mr. O'Mara more than 12,000 hours of field experience with more than two dozen tunnels and shafts totaling more than 80 miles in length at sites in Arizona, Florida, Illinois, Maryland, Massachusetts, Michigan, Minnesota, Montana, New York, Ohio, Pennsylvania and Wisconsin. Much of this field experience has been underground during construction of tunnels and shafts in a variety of hard rock and soft ground situations. He has worked with all manner of tunnel and shaft construction methods including various tunnel boring machine (TBM) types, drill and blast, cut and cover, ground freezing, sheet piling, rib and lagging and excavation with heavy equipment.

He has directed a variety of pressure grouting programs to limit groundwater infiltration into deep tunnels and shafts via "pre-grouting" in advance of a TBM or "post-grouting" after tunnel and shaft excavation. He has also operated groundwater recharge wells systems directly over tunnels that to minimize differential settlement of multi-story structures with wooden pile foundations.

Mr. O'Mara has experience working in gassy tunnels with unsafe levels of methane, hydrogen sulfide, carbon dioxide and oxygen and has taken actions to monitor, detect, mitigate dangerous atmospheres and prevent explosions, injuries or deaths. He is an expert in conducting geologic, hydrogeologic and geotechnical investigations and has logged miles of soil borings and rock corings for tunnel and shaft pre-design studies, geotechnical instrumentation and grouting.

Mr. O'Mara has served as an expert witness and prepared expert reports for hydrogeologic investigation and remediation litigation. He has served as Arbitrator, deciding an $12 million-dollar dispute and has participated in multi-million-dollar tunnel construction claim disputes related to pressure consolidation grouting and karst condition/extremely poor rock quality delays.

Education

B.S. Geological Engineering, Michigan Technological University

Graduate Studies: Environmental Engineering and Hydrogeology, University of Wisconsin-Milwaukee and Wayne State University

Continuing Education: Grouting for Tunnels and Shafts; Underground Construction; MSHA Ventilation for Tunnels and Shafts; Geotechnical Instrumentation; OSHA Construction; OSHA Underground Construction (Tunneling); Draeger Mine Team Rescue and Self Rescue Training.

Employment History

Lone Wolf Resources, LLC Grosse Pointe MI, 2020 to present

Agate Harbor Advisors LLC – Grosse Pointe, MI 2020 to present

Energy Renewal Partners LLC – Detroit MI 2017 to 2020

Principal-in-Charge, Ramboll, Ann Arbor Michigan 2016-2017

Principal Engineer, SLR Consulting, Detroit, MI 2015-2016

Vice President, Principal-in-Charge ARCADIS, Detroit MI 2002-2015

Operations Manager, Weston Solutions, Detroit MI 2001-2002

Principal-in-Charge, TRC Solutions, Lowell, MA 1996-2001

Project Engineer, ChemCycle Corp, Boston, MA 1993-1996

Engineer/Hydrogeologist, Earth Tech, Milwaukee, WI 1991-1993

Hydrogeologist, Layne GeoSciences, Pewaukee, WI 1990-1991

Staff Engineer, Barrientos and Associates, Madison, WI 1987-1990

Licensure

Professional Geologist – State of New Hampshire, License No. 365 (active 2001 - 2012)

Mr. O'Mara has also spent more than 120 hours years reviewing the Enbridge Line 5 Tunnel submittals, supporting documents and relevant geologic reports prepared for the vicinity of the proposed Line 5 Tunnel in 2020 and 2021.

Select experience related to tunnels and expert work is summarized below.

Tunnel Planning and Pre-Construction Experience

Pre-Design Studies

Milwaukee Metropolitan Sewerage District – Multiple Tunnels and Shafts, Milwaukee County, WI

Staff Geologist for the Program Management Office, Geotechnical Group for the Water Pollution Abatement Program of the MMSD. Responsible for directing, overseeing and logging thousands of feet of soil borings and rock corings to depths of 200 to 400 feet for proposed Cross-Town CT 3&4 CT 5 &6 drop shafts, CT Phase IIA tunnel, and Kinnikinic and Lake Michigan (KK-LM) shafts and tunnels. Completed hundreds of bedrock borehole packer tests. Installed piezometers, observation wells and multi-point borehole extensometers (MPBXs) to evaluate hydraulic heads, water levels and estimate deformation of rock mass and adjacent soils. Conducted bedrock aquifer tests and slug test using submersible downhole pressure transducers and data loggers to evaluate hydraulic conductivity. Completed elevation surveys to monitor differential settlement near tunnels and shafts.

Detroit River Third Tunnel Crossing Evaluation

Confidential Investment Group, New Detroit River Tunnel. Detroit, MI and Windsor, ON

Technical Advisor to Investment Group considering acquiring the 1909 Michigan Central Railway Tunnels, the first immersed tube tunnels to carry traffic. The twin tube rail tunnels were to be renovated and converted for commercial truck traffic and a new tunnel or two would be constructed to accommodate double stacked intermodal shipping containers on railcars. Inspected the existing rail tunnels and reviewed property condition assessment documentation and geologic reports and studies of other tunnels and attempted tunnels and bridges in the site vicinity. Helped evaluate various tunnelling and trenching techniques.

Pre-Construction Studies

Massachusetts Bay Transportation Authority – Silver Line BRT Tunnel (Fort Point Channel Crossing), Boston, MA

Project Engineer for Section A of the Silver Line, a $600M, 1.1-mile bus tunnel between South Station and the Waterfront which includes a more then 600-ft long immersed tube tunnel section beneath the Fort Point Channel.   Developed a Work Plan to "pre-characterize" and "waste profile" potentially contaminated sediments prior to tunneling to comply with environmental requirements of the Massachusetts Contingency Plan and ensure proper disposal and management of tunnel spoils.

During immersed tube tunnel construction a massive boulder was discovered under the Fort Point Channel (it was not identified in the Geotechnical Baseline Report) and delayed the project by a year. The project was finally completed three years behind schedule and almost $200M over budget, mostly related to geologic conditions not identified in the GBR.

Environmental Due Diligence

DWSD Upper Rouge Tunnel, Wayne County, MI

Environmental Engineer, consultant for DWSD. Developed, directed and completed Phase I and Phase II Environmental Site Assessments (ESA's) of select parcels along the proposed $1.2B, 7-mile CSO tunnel alignment for parcels that the DWSD was planning to acquire for the propose of constructing access and drop shafts for the new tunnel and shaft construction.

Permit Reviews

Enbridge Line 5 Tunnel Permit Submittals to EGLE, MPSC and MSCA, Lansing, MI

Tunneling Consultant and Environmental Engineer reviewed numerous technical submittals from Enbridge and their consultants for the proposed Line 5 Pipeline Replacement Tunnel to EGLE, MPSC and MSCA. Also reviewed historic geologic and geotechnical reports prepared for the Mackinac Bridge project and other reports prepared from the USGS and Michigan Geological Survey. Identified numerous deficiencies, flaws, errors and omissions with the submittals.

Tunnel and Shaft Construction Experience

Soft Ground Tunnel and Shaft Construction

Milwaukee Metropolitan Sewerage District – Multiple Tunnels and Shafts, Milwaukee County, WI

Resident Inspector. Responsible for observing, inspecting and confirming miles of soft ground tunnel and shaft construction was completed in accordance with contract plans and specifications. Provided fulltime oversight of CT-8 Collector Tunnel, Drop Shaft and ancillary structures. Provided part-time oversight of CT-5&6, CT-7 and KK-LM shaft construction through overburden. Construction means and methods included sheet piling, rib and lagging, and ground freezing support of overburden while sinking shafts using hydraulic excavators, clamshell and orange peel buckets from crawler lattice cranes. Shaft diameters sometimes exceeded 100-feet diameter and soft ground tunnel diameters were up to 20 feet. For the smallest tunnels, hand excavation methods using power tools to remove overburden as it was not economical to use TBMs or Horizontal Directional Drilling (HDD) for relatively short runs of small diameter sewer pipe. The TBMs in soft ground were earth pressure balanced machines operated in open and closed modes and sometimes with workers operating under compressed air.

Brian J. O’Mara
Founder

https://agateharbor.com

agate harbor advisors
strategic environmental consulting and litigation support

Hard Rock Tunnel and Shaft Construction

Milwaukee Metropolitan Sewerage District – Multiple Tunnels and Shafts, Milwaukee County, WI

Resident Inspector. Responsible for observing, inspecting and confirming miles of hard rock tunnel and shaft construction was completed in accordance with contract plans and specifications. Provided fulltime oversight of Cross-Town Phase I (32-feet diameter) and Cross-Town Phase IIA (17-Feet diameter) and North Shore (32-Feet diameter) tunnels. Most of these tunnels were excavated using open TBMs but drill and shoot methods were used in some locations to facilitate construction launch areas, drop shaft connections from shallow soft ground collector tunnels. Both the Cross Town and North Shore tunnels exceeded 5 miles in length and required extensive mucking, dewatering and ventilation, lighting and communications systems to facilitate safe construction.

TBM Blow-In/Sink Hole Mitigation/TBM Rescue

Cross Town CT-8 Collector Tunnel. Milwaukee, WI

Resident Inspector for CT-8 Collector Tunnel (12-Feet diameter) soft ground, with pre-cast concrete segmented liner system. An uncontrolled inflow of saturated soft round sediment through cutting wheel doors of the TBM face that occurred sometime over a holiday weekend when no workers were present. Approximately 200 cubic yards of sediments migrated into the tunnel which created a void which became a surface sinkhole immediately adjacent to and just above the tunnel. This sinkhole caused significant structural damage to a nearby commercial building and caused a two-story, concrete block addition to separate from the main structure. The separation exceeded 14-inches at the roof line and emergency shoring and bracing was erected to stabilize the structure and prevent further damage or collapse. The void also caused the TBM to become sink and become “stuck” in place. Flowable Fill as placed in the subsurface void to stabilize the subsurface situation. But the TBM could not be moved because of an impingement of the tunneling shield. A closed loop, liquid nitrogen-based ground freezing system was then installed to further stabilize the ground surrounding the TBM. A 40-feet deep rescue shaft was completed to expose the TBM, free the shield and re-direct the TBM on the proper angle. The damaged building was also remedied, and the addition was saved but at significant expense. Overall the project was delayed for months because the doors of the TBM were not properly secured prior to leaving for the holiday weekend.

Another soft ground TBM for another shallow collector tunnel located just a few blocks away become stuck just steps from Milwaukee’s City Hall and had to be rescued. That project was delayed 9 months and cost the $1M in additional fees.

Tunnel Methane Mitigation/Tunnel Methane Explosion

Cross Town CT-8 and CT-7 Collector Tunnels. Milwaukee, WI

Resident Inspector for CT-8 Tunnel and part-time inspector for select CT—7 Drop Shaft activities. Elevated methane and hydrogen sulfide gas levels were detected during construction of the CT-8 tunnel which was excavated through highly organic rich sediments of paleo estuarine deposits. Gas detection monitoring at the TBM and by workers and inspectors resulted in operations being ceased when unacceptable levels of toxic gasses were encountered. However, at the nearby CT-7 Tunnel, three workers were killed in a methane explosion inside the tunnel. As a result, the work on the CT-8 Tunnel was suspended and additional measure were taken to mitigate the risk of methane during construction. A network of groundwater methane depressurization wells was installed along the remaining unconstructed tunnel alignment to reduce the levels of dissolved methane present in the saturated sediments. Additional remote monitoring and detection equipment were acquired and installed as were upgrade ventilation systems to provide additional fresh air during construction. All tunnel construction personnel received mandatory comprehensive methane detection and mitigation training prior to resuming working underground. As a result, the CT-8 Tunnel was completed without further incident despite having several shut-downs when elevated gas was detected during tunneling.

Pre-Grouting Tunnels and Shafts
Cross Town, North Shore, Kinnikinic and Lake Michigan Tunnels and Shafts Milwaukee County, WI
Directed pressure grouting operations using cementitious grouts to fill fractures, faults, solution cavities/karst features, bedding planes and joints in bedrock where tunnels and shafts were to be excavated and constructed. Conducted dozens of packer tests, determined and modified grout mixes based on hydrogeologic properties of the rock. Pre-grouting is often more cost-efficient and time savings as it allows excavations to be completed with minimal groundwater infiltration and improves the quality and strength of the bedrock before removal begins. Completed pre-grouting in advance of the TBM when possible, but most often the pre-grouting was completed using angled/directional drilling boreholes initiated from the ground surface and grout was placed within the envelope of the tunnels. While pre-grouting of the shafts was completed as per industry standards, pre-grouting of the North Shore tunnel from the ground surface was very expensive as the borehole depths often exceeded more than 400 feet to grout a 60-feet tunnel envelope. Pre-grouting through the TBM faces was not possible because this capability was not anticipated when the machines were built, and this was part of multiple construction claims.

Post-Grouting Tunnels and Shafts
Cross Town and North Shore Tunnels. Milwaukee County, WI
Directed pressure consolidation grouting operations using cementitious grouts to fill fractures, faults, solution cavities/karst features, bedding planes and joints in bedrock after the TBM had bored the rock tunnels. Completed multiple passes of grouting wherever excessive groundwater infiltration was observed. While most areas that required grouting were obvious as groundwater was raining down from the tunnel crown, dye studies were required in areas where groundwater infiltration was limited to the invert of the tunnel which is covered with rail, sediment and water. Directed pressure grouting drilling, mixing, pumping and placement operations which included

calculating directional drilling to intercept water bearing features at a proper distance behind the tunnel to prevent blow-ins and excessive bleeding of grout into the tunnel.

Conducted thousands of packer tests to determine the proper grout mix viscosity, density and placement pressures. Post-grouting after TBM is often inefficient and costly because the grout fluids often infiltrate or return back into the tunnel and are wasted. This results in having to use thicker grout mixes which plug the larger features, but subsequent passes are then required to block finer features. Both the North Shore and Cross-Town Tunnel post grouting programs were subject to construction claim disputes based on Differing Site Conditions which were not identified in the geotechnical pre-design studies (GBR) for these projects. Because of the nature of many of the water bearing features (i.e., high angle faults and joints) it would not have been practical to identify most of these problems prior to construction. Horizontal water bearing features such as extensive vuggy horizons, fracture zones and permeable bedding planes were evident in pre-design rock cores.

Post-Grouting Tunnel
MWRA MetroWest Water Supply Tunnel. Worcester and Middlesex Counties , MA
Technical Advisor to Designer (Sverdrup-Jacobs) regarding consolidation grouting of the 17.6 Mile long, $728M, water tunnel that runs 200 to 500 feet below ground. The tunnel was mined with TBMs to diameter of 16-feet and then lined with cast in place concrete to a final diameter of 14-feet. The tunnel was bored through granite, gneiss, schist and quartzite and various zones of high groundwater infiltration were encountered. Contact and consolidation grouting was completed behind the liner and supplemental consolidation grouting was required to minimize groundwater infiltration into the lined pressure tunnel.

Tunnel Grouting Claims and Dispute Resolution
Dillingham Healy Grow & Dew JV v MMSD; Traylor Brothers, Inc. v MMSD; Layne Western, Inc. v MMSD
Provided testimony, fieldnotes, and other documentation and opinions as Resident Inspector and Staff Engineer/Geologist directing tunnel grouting in the Crosstown Interceptor and NorthShore Tunnel over disputes between the grouting contractors and the MMSD. Completed 360-degree geologic mapping of North Shore Tunnel geologic features. The contractors claimed the extreme karst conditions and other poor rock quality conditions present in the tunnels and shafts represented Differing Site Conditions (DSC) and were entitled to claims for millions of dollars in additional compensation for damages related to out of scope quantities, material and labor.

<u>Tunnel and Shaft Operations and Decommissioning</u>

Tunnel Groundwater Recharge Infiltration Gallery
Cross Town Interceptor Deep Tunnel. Milwaukee County, WI
Operated and maintained a series of shallow (overburden) groundwater recharge injection wells to prevent unacceptable drawdown of water table in the vicinity of the

Cross-Town Interceptor Tunnel. Without maintaining the water levels with the groundwater recharge infiltration gallery, many of the late 19th and early 20th century commercial and industrial buildings that were supported on wooden piles founded in saturated sediments would be subject to damage and unacceptable differential settlement. Duties included checking groundwater flow rates, pressures, water levels and surveying foundations of critical buildings and infrastructure.

Ten Mile Drain Tunnel Operations
Macomb County Public Works Department, 10-Mile Drain Storm Sewer Tunnel, PCB Matter, St. Clair Shores, MI
Technical Advisor to Macomb County. Reviewed USEPA investigations to study then nature and extent of PCBs that had entered the tunnel and been discharged to nearby residential canals that open to Lake St. Clair. Reviewed tunnel inspection videos, laboratory analytical reports and advised the County of meaning of the results and made recommendations for actions to mitigate/prevent continued influx of PCB into the tunnel and minimize or eliminate migration of PCB to the residential canals.

Tunnel Decommissioning
Power Plant Coal and Limestone Tunnel Decommissioning, Abandonment or Removal Jacksonville, FL
Technical Advisor and Construction Quality Control Manager responsible to developing means and methods to decommission to safely backfill more than 6-miles of tunnels and shafts and recirculation water tunnels up to 10-feet wide and 8-feet tall using, controlled low strength material (CLSM -aka flowable fill), recycled demolition debris and or soil. Used conveyors and upper slingers to place aggregate and soils in ling inclined tunnels/shafts. Developed in-situ testing methods to confirmand demonstrate backfilling conformed with contract plans and specifications.

Tunnel Decommissioning
Power Plant Recirculation Water and Coal Reclaim Tunnel Decommissioning. Luna Pier, MI
Technical Advisor and Owners Engineer responsible for working with Demolition contractor to develop means and methods to decommission and safely backfill and/or bulkhead and abandon more than 2-miles of tunnels and shafts and recirculation water tunnels and intake/discharge structures to/from Lake Erie. These structures were up to 40-feet deep and some required the use of divers to seal intake structures. Used controlled low strength material (CLSM -aka flowable fill), recycled demolition debris and or soil. Confirmed structures were abandoned per contract plans.

Tunnel Decommissioning
Power Plant Recirculation Water and Coal Reclaim Tunnel Decommissioning. Muskegon, MI
Technical Advisor and Owners Engineer responsible for working with Demolition contractor to develop means and methods to decommission to safely backfill and/or bulkhead and abandon more than 2-miles of tunnels and shafts and recirculation water tunnels and intake/discharge structures to/from Muskegon Lake. These structures were up to 50-feet deep. Used CLSM, recycled demolition debris and soil. Confirmed structures were decommissioned per contract plans and specifications.

Various Power Plant Tunnel Systems Closure or Re-Use Evaluations
Various Environmental Risk Transfer Clients. Coal Power Plants in AZ, IL, MD, MI, MN, MT, NV, OH, PA, TX and WV
Technical Advisor to Prospective Purchasers responsible for developing closure and/or re-use strategies and cost estimates to decommission more the 70 miles of cooling water recirculation tunnels, fresh water intake tunnels, water discharge tunnels, coal and limestone tunnels as part of Environmental Liability Risk Transfer and Redevelopment proposals from more than two dozen fossil fueled power plants across the United States. Developed detailed costs estimates and plans to place CLSM, bulkheads, remove or re-use these tunnels.

Underground Mine Shaft Closure
Former Salt Mine Shaft Closure. Livingstone County, New York
Technical Advisor responsible for working with AkzoNobel to develop a plan to properly and permanently close access to a former underground salt mine in the Genesee Valley. Developed Conceptual Design that involved construction of an engineered (reinforced concrete), vented, surface plug and cap that was in compliance with NYSDEC regulations and BMPs for abandoned mine lands.

<u>Select Expert Work Experience</u>

Expert Report & Testimony – Major Permit Modification Contestation
Cell "M" Groundwater Evaluation Expert Report Envirosafe Services of Ohio, Inc. (ESOI), Oregon, Ohio.
Provided Expert Testimony when deposed and cross-examined by attorneys for the City of Oregon Ohio (Plaintiff), ESOI (Defendant), OEPA and Attorney General for the State of Ohio in relation to various longstanding disputes between the parties over environmental contamination found at the hazardous waste treatment and disposal facility. ESOI wanted to significantly expand vertically their existing Cell M RCRA C Landfill Prepared expert report on the occurrence of groundwater with the various geologic units at the Site which includes both historic and operating hazardous waste landfills. ESOI and OPEA suggested the upper and lower tills contained isolated connate glacial water and are incapable of supplying useable water volumes to wells due to low horizontal and vertical permeabilities and the upper till is not hydraulically connected to overlying lacustrine deposits and the tills are not fractured or capable of transmitting significant quantities of groundwater.

Demonstrated that the existing groundwater level data, analytical chemistry results and numerous published sources do not support the opinions of OEPA and ESOI. Demonstrated water levels at the Site exceed the bottom elevation of the Cell M Landfill Primary liner and pose a significant risk to the performance of the landfill liner. Demonstrated the proposed expansion did not satisfy the requirements of the GeoRG Manual and additional geotechnical stability analyses were required. Showed that the upper till and lower till were not homogeneous, massive impermeable clays incapable of transmitting groundwater but were actually, heterogenous, fractured, and capable of transmitting groundwater at rates many orders of magnitude greater than reported in the Permit Modification. Demonstrated that portions of the clay liner are in direct contact with site groundwater and over time the clay portion of the liner will become saturated and highly ineffective at preventing diffusion of contaminant directly from the landfill into groundwater. The City eventually settled numerous disputes with EOSI and OEPA and prevailed in getting the concessions and revisions they requested for the Permit Modifications.

Remediation Escrow Dispute Arbitration and Expert Report
Warren E. Gast and RDV Aria LLC v IDEX Corporation, State of Michigan, Circuit Court of Kent, County Michigan Case No. 04-08730-CK Hon. Paul J. Sullivan. Two Western Michigan Industrial Facilities
Selected as the Technical Arbitrator after attorneys for the parties in dispute interviewed two other remediation experts from Arcadis (both with PhDs and co-authored Remediation Hydraulics textbook) based on Mr. O'Mara's practical experience with remediation and transactions. Teamed with Environmental Attorney as part of two-person panel to settle a remediation escrow dispute over chlorinated solvent impacts to soil and groundwater. Defendants and Plaintiffs' attorneys argued their respective cases and engaged more than a dozen of technical experts (environmental engineers and hydrogeologists, risk assessors) which provided four days of testimony and cross-examination by the attorneys and arbiters. Reviewed more than 99 exhibits to assess the completeness and effectiveness of the hydrogeologic investigation and groundwater remediation work completed and the terms of the M&A contract. Completed a technical assessment of both costs that had been incurred over ten years plus develop independent estimate of likely future costs required to achieve regulatory closure. Coauthored 12-page Decision and Award document which described the nearly $4MM award to the Defendant and release of the remaining escrow funds to the Plaintiffs.

Expert Report on Environmental Liabilities
Detroit Steel Company Tax Appeal Matter (Trenton Land Holdings, LLC and Detroit Steel Company, LLC v City of Trenton, Michigan Tax Tribunal Docket No. 0394858
Provided expert opinion on previously prepared work products and prepared independent estimates of environmental liability for a 195-acre former McLouth Steel Mill site in Trenton, MI. Work involved a comprehensive review of relevant technical documents, and inspection of the facility, interviews with individuals with knowledge of the site and an analysis of findings and preparation of the opinion of costs related to environmental liability issues that must be addressed in order to achieve compliance with environmental laws and regulations. Site is situated on the Detroit River and had extensive soil and groundwater contamination related to the more than 60 years of steel making operations, beginning in 1948. Remediation liabilities ranged from over $23 million to more than $33 million.

Attachment B

GRETCHEN WHITMER
GOVERNOR

MARK A. BURTON
PRESIDENT

November 10, 2020

Joseph Haas
Gaylord District Supervisor
Water Resources Division
Michigan Department of Environment, Great Lakes and Energy

RE: Enbridge Energy Line 5 Straits of Mackinac

Mr. Hass,

The Michigan Department of Environment, Great Lakes, and Energy (EGLE) asked the State Historic Preservation Office (SHPO) to provide comments regarding potential cultural resources impacts of the proposed Enbridge Line 5 tunnel project. We appreciate this opportunity to assist your permit review. We've identified concerns as well as gaps in existing data that support the need for additional cultural resources surveys. Forthcoming surveys should address the project's direct and indirect impacts to all types of cultural resources; this memo primarily addresses archaeological survey needs.

The Straits of Mackinac (Straits) area is one of the most strategically located areas in the Great Lakes region and has been the center for cultural contact and interaction for thousands of years. This area is sensitive for the presence of terrestrial and bottomland archaeological sites (including historic aircraft and shipwrecks), submerged paleo landscapes, cemeteries and isolated human burials, significant architecture and objects, and historic districts. Numerous previously reported cultural resources eligible for or listed in the National Register of Historic Places (NRHP) and four National Historic Landmarks are immediately present in the Straits. Survey for significant cultural resources in the Straits is incomplete and we expect numerous additional resources to be present that have yet to be reported, documented, and evaluated. Additionally, the Straits is an important cultural area for regional Tribes and other communities, and it is possible that the Straits is NRHP-eligible as a Traditional Cultural Property and/or Traditional Cultural Landscape encompassing tangible and intangible values such as cultural resources, culturally significant natural resources, and traditional place-based beliefs and practices.

Potential project impacts to all historic property types must be assessed by the applicant and considered by state and federal permit application reviewers. The following comments are particular to the identification and evaluation of archaeological properties with a special focus on approaching the potential for submerged resources.

Archaeological Resources

Two archaeological studies were submitted to the SHPO in 2019 by the U.S. Army Corps of Engineers (USACE) related to the review of geotechnical borings work under Section 106 of the National Historic Preservation Act:

Phase I Archaeological Survey for the Enbridge Line 5 Straits of Mackinac Geotechnical Boring Project, Mackinac and Emmett Counties, Michigan (Commonwealth Heritage Group 2019)

Maritime Archaeology Desktop Assessment in Support of the Enbridge Line 5 Geotechnical Surveys Project, Emmet and Mackinac Counties, Michigan (SEARCH 2019)

These reports focused on the USACE's permit area that included the areas on the bottomland of the Straits in which geotechnical borings would take place as well as associated upland areas in which borings, test pits, and access road work would occur. The SEARCH report relied on existing maps and databases and examined processed side-scan sonar mosaic imagery; it also pointed out that the bottomland corridor has not been subjected to archaeological investigation. Upon review of these reports, the SHPO concurred with the determination of the USACE that no historic properties would be affected by the geotechnical borings work. We also noted that while these reports were sufficient to support the geotechnical borings work, subsequent activities associated with the Enbridge Line 5 project may require additional evaluation of effect on historic properties.

All additionally proposed upland work, including temporary and permanent use areas, should be assessed for archaeological impacts. Archaeological survey of the bottomland should also be conducted to assess impacts to submerged resources present. Surveys should consider direct and indirect impacts of all project activities, including those related to the interim operation and proposed removal of the extant lines, proposed tunnel construction, and projected project maintenance activities in perpetuity.

We recommend the following for bottomland archaeological survey:

1. The applicant will work with an underwater archaeology consultant that meets federal qualifications for prehistory and history. The consultant should have access to appropriate geological and geomorphological expertise to assist in understanding survey area sedimentation, site preservation potential, and evaluating whether anomalies identified during survey are culturally or naturally formed. Consultants should have experience in this portion of the Great Lakes region.

2. Archaeological resources on state-owned bottomland are the property of the State of Michigan. The consultant will complete an Application for Archaeological Exploration on State-Owned Land. The application may take 45 days to process and a 30-day review window involving Department of Natural Resources and Tribal specialists is built into that timeframe. Additional EGLE permits may be required for the disturbance of bottomland sediments (e.g. dredging permit) to appropriately investigate, document, and evaluate potential cultural resources.

3. The consultant will prepare a work plan for bottomland survey for SHPO approval. The workplan should synthesize extant data and lay out additional methods proposed to complete survey of the entire area of potential direct and indirect effects. All categories of archaeological resources must be considered including, but not limited to, prehistoric sites and shipwrecks. Assessing the potential for submerged prehistoric sites may be challenging. We suggest using bathymetric data to model the potential for submerged lands that would have been open to habitation prehistorically and using a combination of rigorous remote and dive-based methods to adequately test the model and provide adequate survey coverage.

4. Documented anomalies should be verified as culturally or naturally formed.

5. Archaeological resources must be evaluated for NRHP eligibility, with direct or indirect impacts to eligible resources avoided, minimized, or mitigated.

6. Survey will address the concerns submitted by Dr. John O'Shea regarding consideration of submerged prehistory and those reported by an independent research group who claim to have newly identified three possible cultural sites within the corridor.

7. Survey will adhere to a safety plan to avoid inadvertent impacts to the existing pipelines and other infrastructure and resources.

8. Survey will be scheduled to avoid weather conditions that could skew or limit survey results.

9. In the unlikely event that human remains associated with shipwrecks, aircraft losses, or inundated prehistoric or historic burials are discovered, response will follow Michigan Attorney General Opinion No. 6585 *Cemeteries and Dead Bodies*, additional guidance from the SHPO, and the Native American Graves Protection and Repatriation Act, as applicable.

10. All survey reports must meet the Secretary of the Interior's Standards and Guidelines for Archaeological Documentation and any additional guidance provided by the SHPO. Reports will be submitted to the SHPO for review and comment with final hard and digital copies submitted for inclusion in the State Archaeological Site File.

Risk Assessment

We've reviewed the *Independent Risk Analysis for the Straits Pipelines Final Report September 15, 2018*, a multi-organizational effort led by Michigan Technological University produced for the State of Michigan. This report assessed the potential costs of a worst-case spill from Line 5 in the Straits. The projected extents of environmental impacts and containment, cleanup, and restoration efforts suggest substantial impacts to nonrenewable cultural resources and place-based heritage. We agree with this report that it is important to have baseline data for at-risk cultural resources to inform damage assessments and mitigation planning. For this reason, the survey area must be sufficiently broad and not limited to the footprint of proposed work.

We recommend not moving forward with permit approvals until further research is completed to provide baseline cultural resources data. Should any permits be issued in the future, they would require the execution of a MOU addressing cultural resources protections.

State Cultural Resources Review Team

The state's cultural resources review team should include SHPO staff as well as relevant subject matter experts (e.g. terrestrial and underwater archaeology, geology, and geomorphology) from additional state agencies, as necessary. It may also be appropriate to include select outside experts.

Tribal Consultation

We participated in the October 21, 2020 Michigan Anishinaabek Cultural Preservation & Repatriation Alliance meeting and the October 29, 2020 joint consultation meeting hosted by the Bay Mills Indian Community (Gnoozhekaaning). Tribes have expressed concern for impacts to their heritage sites in the Straits, as well as across the length of the pipeline. Tribes have also expressed concern regarding process transparency across the state and federal nexus. We support a clear path for Tribal consultation regarding cultural resources concerns. In addition to the mandatory Tribal consultation built into the larger permit review, note that the twelve federally recognized Tribes in Michigan, as well as additional Tribes as appropriate, will have the opportunity to participate in the archaeological exploration permit process, both reviewing the application and consulting on the results of exploration.

We've reviewed available Tribal comments submitted to the EGLE and the Petroleum Pipeline Task Force. We are copying federally recognized Tribes in Michigan on the comments presented here, as well as the Red Cliff Band of Lake Superior Chippewa Indians (Miskwabekaang) who submitted a comment letter to the EGLE dated October 18, 2020. We'll need to coordinate on any additional Tribal consultation requests received.

Freedom of Information Act

Sensitive archaeological site locations are restricted under state and federal Freedom of Information Act (FOIA) exemptions. When photocopying or otherwise reproducing archaeological information or reports for public release, all sensitive location information must be redacted, including address blocks, verbal boundary descriptions, coordinates, maps, and other descriptive text. We stress that all parties privy to project-related archaeological information must not publicly disclose sensitive archaeological site locations in conflict with state and federal FOIA protections.

Final archaeological survey reports should be submitted to the SHPO in both intact and redacted forms to assist any FOIA requests.

In closing, we've identified concerns as well as gaps in existing data that support the need for additional cultural resources surveys. SHPO staff will be available to participate in planning meetings to clarify expectations for archaeological as well as other (e.g. historic architectural or landscape) cultural resources survey initiatives. Thank you for the opportunity to comment on this permit application and for your commitment to the cultural resources of our state.

Please contact me with questions or concerns,

Stacy Tchorzynski
SHPO Senior Archaeologist
tchorzynskis@michigan.gov

copy: Sandra Clark, Director, Michigan History Center-DNR
Martha MacFarlane-Faes, Deputy State Historic Preservation Officer
Chris Antieau, Great Lakes Bottomland Specialist, Water Resources Division-EGLE
Kara Cook, Policy Advisor on Energy and Environment, Executive Office of Governor Gretchen Whitmer
Katie Otanez, Regulatory Project Manager, USACE Detroit District
William Johnson, Chairman, Michigan Anishinaabek Cultural Preservation & Repatriation Alliance
Bryan Newland, President, Bay Mills Indian Community
Paula Carrick, Tribal Historic Preservation Officer, Bay Mills Indian Community
Cindy Winslow, Museum Director, Grand Traverse Band of Ottawa and Chippewa Indians
Earl Meshigaud, Cultural Director, Hannahville Indian Community
Alden Connor, Tribal Historic Preservation Officer, Keweenaw Bay Indian Community of the Lake Superior Band of Chippewa Indians
Daisy McGeshick, Tribal Historic Preservation Officer, Lac Vieux Desert Band of Lake Superior Chippewa Indians
Jonnie J. Sam, Historic Preservation Department Director, Little River Band of Ottawa Indians
Melissa Wiatrolik, Tribal Historic Preservation Officer, Little Traverse Bay Bands of Odawa Indians
Lakota Pochedley, Tribal Historic Preservation Officer, Match-E-Be-Nash-She-Wish (Gun Lake) Band of Pottawatomi Indians
Douglas Taylor, Tribal Historic Preservation Officer, Nottawaseppi Huron Band of the Potawatomi
Matthew J.N. Bussler, Tribal Historic Preservation Officer, Pokagon Band of Potawatomi Indians
Marcella Hadden, Tribal Historic Preservation Officer, Saginaw Chippewa Indian Tribe of Michigan
Colleen Medicine, Director or Language and Culture, Sault Ste. Marie Tribe of Chippewa Indians
Nathan Gordon, Tribal Vice Chairman, Red Cliff Band of Lake Superior Chippewa

Attachment C

Bay Mills Indian Community
"*Gnoozhekaaning*" Place of the Pike

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October 12, 2022

VIA ELECTRONIC MAIL

Martha MacFarlane-Faes
Deputy State Historic Preservation Officer
300 N. Washington Sq.
Lansing, MI 48913

RE: REQUEST TO SUPPORT THE LISTING OF THE STRAITS OF MACKINAC TO THE NATIONAL REGISTER FOR HISTORIC PLACE

On behalf of Gnoozhekaaning, "Place of the Pike," or Bay Mills Indian Community ("Bay Mills"), I write to seek Michigan State Historic Preservation Office's support in listing the Straits of Mackinac on the National Register of Historic Places (NRHP). Bay Mills, as a sovereign Tribal Nation, has a long-standing and critical interest in the waters of the Great Lakes, the Straits of Mackinac ("Straits"), and the surrounding region. As one of the signatories to the 1836 Treaty of Washington, which ceded nearly 14 million acres to the United States for the creation of the State of Michigan, Bay Mills reserved the right to fish, hunt, and gather throughout the territory — including in the Great Lakes and the Straits. Not only do these waters give meaning to and support the Treaty rights of our people but they are central to Bay Mills' cultural, traditional, and spiritual identity all of which are placed in harm's way by Enbridge's proposed Line 5 Tunnel Project.

In a letter dated November 10, 2020, your office, submitted comments to Michigan's Environment, Great Lakes, and Energy, in their permit review of the Tunnel Project, highlighting that the "Straits is an important cultural area for regional Tribes and other communities, and it is possible that the Straits is NRHP-eligible as a Traditional Cultural Property and/or Traditional Cultural Landscape encompassing tangible values such as cultural resources, culturally significant natural resources, and traditional placed-based beliefs and practices." SHPO's letter and recommendations are illuminating and consequential in how to protect the cultural resources located in and around the Straits of Mackinaw and Bay Mills strongly agrees with SHPO's assessment and recommendations

A determination that a property is eligible for the National Register assures that the values that make it significant are considered in the planning of projects which the Federal Government is involved. A traditional cultural property is generally one that is eligible for inclusion in the National Register because of its association with cultural practices or beliefs of a living community that are rooted in that community's history and are important in maintaining the continuing cultural identity of the community.[1] The Bay Mills Indian Community will demonstrate that the Straits of

[1] National Register Bulletin 38: Guidelines for Evaluating and Documenting Traditional Cultural Properties.

Mackinac meets all applicable criteria and should be listed in the National Register as a traditional cultural landscape that has yielded and has the potential to yield additional important information about Anishinaabe peoples and our cultural lifeways tied to the Straits.

Generally, there are two key inquiries in making determinations for a traditional cultural property's integrity under the Nation Historic Preservation Act[2] ("NHPA"): first, whether the property, in this case, the Straits, has an integral relationship to the traditional cultural practices or beliefs, and second, whether the condition of the property is such that the relevant relationships survive. The answer to both inquiries is an unequivocal yes. The Straits is integrally related to the traditional cultural practices and beliefs of the Anishinaabe. This association is not with any body of water, it is with this one, the Straits. The stories involving the relationship between the Straits and Anishinaabe's defining landscape known as Turtle Island, are well documented and will be borne out over the coming months in accordance with the NHPA.

As to the second factor, the Straits itself maintains a high degree of overall integrity as an integral part of a landscape whose boundaries will need to be more precisely defined. Although there are some modern navigational devices such as buoys and historical shipwrecks, the Straits remains much as it has for thousands of years. Neither the size of the Straits nor the fact that it is a large water body disqualify it from being found eligible for listing in the National Register. Scientific investigations have verified the oral history and traditions of the Anishinaabe people and tied historical and current use and cultural lifeways to the Straits since time immemorial. Testimony and artifacts recovered from known archaeological sites demonstrate that the Straits was and remains a central feature of Anishinaabe culture and that people were present in the environs of the Straits throughout time. The water, submerged lands and shorelines have yielded and has the potential to yield further critical information regarding the Anishinaabe cultural lifeways to the Straits during the historic and precontact periods.

The Anishinaabe maintain a continuous association with and use of the Straits for economic and ceremonial purposes such as fishing, hunting, gathering, and as a central focus of traditional cultural practices and beliefs such as those relating to the Creation of what Anishinaabe refer to as Turtle Island. The Anishinaabe creation story describes how the Great Turtle emerged from the Straits to save humanity and all the animals from a great flood. The Turtle transformed into the North American continent after the humble muskrat placed on the Turtle's back a fistful of dirt that he retrieved from the Straits' bottomlands. The Anishinaabe maintain special ceremonies and traditions specifically associated with the Straits and a deep commitment to preserving this landscape for the next seven generations. In addition, the Straits of Mackinac area is one of the most strategically located areas in the Great Lakes region and has been the center for cultural contact, interaction and commerce for thousands of years. This area is sensitive for the presence of terrestrial and bottomland archaeological sites (including historic aircraft and shipwrecks), submerged paleo landscapes, and cemeteries or isolated human burials, many of which are Native American occupation sites which collectively contain a record of thousands of years of tribal history. Numerous previously reported cultural resources eligible for or listed in the National Register of Historic Places and four National Historic Landmarks are immediately present in the Straits. The Straits area contains 141 recorded sites, and more are likely to be present. These sites and resources are non-renewable so that once they are damaged or destroyed, there are no

[2] Id. at 10.

alternative means of learning about the lives of the native people who first settled and developed unique adaptions to the natural environment in what is today northern Michigan. An oil spill from Line 5 in the Straits or the proposed tunnel project could destroy a sacred cultural landscape central to Anishinaabe life.

Bay Mills along with several Tribal Nations view the Straits as one cohesive traditional cultural landscape or Traditional Cultural Property, an area that contains a remarkable concentration of sites and resources that are culturally and historically significant. As the U.S. Army Corps' NEPA process continues and when the National Historic Preservation Act's Section 106 process commences in earnest, Bay Mills looks forward to collaborating with you and your team at Michigan's State Historic Preservation Office in order to demonstrate that the Straits of Mackinac satisfy the National Register Criteria and therefore, is eligible for listing as a Traditional Cultural Property on the NRHP. Should you have any questions about this communication, please do not hesitate to contact Rebecca Liebing (rliebing@baymills.org) with Bay Mills legal department.

Miigwetch,

Whitney B. Gravelle
President, Executive Council

cc: Sarah Surface-Evans
Michael Hambacher
Amy Krull
Scott Slagor

Attachment D

BAY MILLS INDIAN COMMUNITY
"*GNOOZHEKAANING*" PLACE OF THE PIKE

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August 10, 2021

DELIVERY – VIA Electronic Mail

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RE: BAY MILLS INDIAN COMMUNITY REQUEST FOR THE U.S. ARMY CORPS OF ENGINEERS TO REINITIATE THE NATIONAL HISTORIC PRESERVATION ACT SECTION 106 PROCESS

Gnoozhkekaaning, "Place of the Pike," or Bay Mills Indian Community ("Bay Mills") requests that the U.S. Army Corps of Engineers ("USACE") reinitiate the National Historic Preservation Act ("NHPA") Section 106 process. At the July 6, 2021, recurring tribal consultation meeting, Katie L. Otanez informed the Tribal Nations that the USACE was pausing the Section 106 process until after scoping so that the USACE could better coordinate the National Environmental Policy Act ("NEPA") and Section 106 process and so that the USACE could receive information from the public about historic properties that would inform the Section 106 process.[1] Ms. Otanez provided no estimate about when the USACE would publish its notice of intent ("NOI") to prepare and environmental impact statement, when scoping would begin, how long it would last, and when the Section 106 process would be restarted.[2]

As you are aware, Section 106 "is a 'stop, look, and listen' provision that requires each federal agency to consider the effects of its programs" on historic properties.[3] To that end, the Advisory Council on Historic Preservation's Section 106 implementing regulations require that the Section 106 process be "initiated early enough in the undertaking's planning, so that a broad range of alternatives may be considered during the planning process for the undertaking."[4] Indeed, the final step of the Section 106 process requires agencies "to develop and evaluate alternatives and modifications to the undertaking that could avoid, minimize, or mitigate adverse effects on

[1] U.S. Army Corps of Eng'rs, *Meetin Record: Recurring Tribal Consultation Meeting* 1, 2 (July 6, 2021) (attached).
[2] *Id*. at 1, 3.
[3] *Muckleshoot Indian Tribe v. U.S. Forest Serv.*, 177 F.3d 800, 805 (9th Cir. 1999) (quoting *Apache Survival Coal. v. United States*, 21 F.3d 895, 906 (9th Cir. 1994)).
[4] 36 C.F.R. § 800.1(c).

historic properties."[5] The regulations encourage agencies to coordinate this process with their NEPA review of project alternatives.[6]

Bay Mills is concerned that by pausing the Section 106 process, the UASCE is undermining its purpose and efficacy. The Section 106 process is not a mitigation tool employed after an agency decides on an action; instead, it must inform that decision.[7] Waiting until after scoping to reinitiate the Section 106 process will only ensure that it will never inform the USACE's decision making, especially the project alternatives the USACE evaluates in the NEPA process. These concerns are exacerbated by the USACE's failure to provide a sufficient justification for the pause.

Pausing Section 106 now will not help coordinate the USACE's NEPA and NHPA reviews.[8] Instead, it will cause significant delays in the NEPA process, if the USACE actually intends for the Section 106 process to inform its NEPA analysis. The USACE is presented with a unique opportunity to make significant headway in its Section 106 review, by engaging in early, meaningful, and good faith consultation with Bay Mills and other Tribal Nations and consulting parties about the existence, location, and National Register of Historic Places-eligibility of historic properties that may be affected by this undertaking. This information is critical to the USACE's Section 106 process, the development of project alternatives, and in its ability to take a hard look at certain resources in its substantive NEPA review. There is no incentive for the USACE to delay this work, unless the USACE's goal is to undermine the Section 106 process.

Finally, while Bay Mills appreciates the USACE's commitment to involving the public in the Section 106 process, Section 106 is not a public facing process—the USACE's first, and most important source of information regarding historic properties are the Tribal Nations and other consulting parties.[9] To be sure, both 36 C.F.R. Part 800 and 33 C.F.R. Part 325, Appendix C[10]

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[5] *Id.* § 800.6.

[6] *See id*. § 800.8(a)(2).

[7] *See Safeguarding the Historic Hanscom Area's Irreplaceable Res. v. Fed. Aviation Admin.*, 651 F.2d 202, 214 (1st Cir. 2011) ("This directive makes it pellucid that agencies are not expected to delay NHPA review until all details of the proposal are set in cement.").

[8] *See* 36 C.F.R. § 800.8(a) ("Agencies should consider their section 106 responsibilities as early as possible in the NEPA process, and plan their public participation, analysis, and review in such a way that they can meet the purposes and requirements of both statutes in a timely and efficient manner.").

[9] *See id*. § 800.2(c).

[10] In citing the USACE's obligation under Appendix C, Bay Mills in no way endorses its use by the USACE to fulfill its Section 106 requirements. Appendix C is not a lawfully promulgated and adopted alternate procedure and the USACE's use of it is unlawful. *See generally Comm. to Save Cleveland's Huletts v. U.S. Army Corps of Eng'rs*, 163 F. Supp. 2d 776, 792 (N.D. Ohio 2001); Advisory Council on Historic Pres., *Improving Tribal Consultation in Infrastructure Projects* 13-14 (May 24, 2017), *available at* https://www.achp.gov/sites/default/files/2019-08/ImprovingTribalConsultationinInfrastructureProjects5-24-17-2.pdf; Gov't Accountability Office, *Tribal Consultation: Additional Federal Actions Needed for Infrastructure Projects* 51-55 (Mar. 2019), *available at* https://www.gao.gov/assets/gao-19-22.pdf; U.S. Dep't of Interior et al., *Improving Tribal Consultation and Tribal Involvement in Federal Infrastructure Decisions* 24 (Jan. 2017), *available at* https://www.achp.gov/sites/default/files/reports/2018-06/ImprovingTribalConsultationandTribalInvolvementinFederalInfrastructureDecisionsJanuary2017.pdf; 69 Fed. Reg. 57,662, 57,663 (Sept. 27, 2004). Indeed, the Advisory Council on Historic Preservation ("ACHP") recently sent a letter to the Acting Assistant Secretary of the Army for Civil Works urging the USACE to reengage in efforts with the ACHP to address Appendix C's "systemic issues[.]" Letter from Reid J. Nelson, Acting Exec. Dir., Advisory Council on Historic Pres., to Jaime A. Pinkham, Acting Assistant Sec'y of Army (Civil Works), U.S. Dep't of Army 2 (July 30, 2021) (attached).

impose public notice and comment requirements,[11] but these requirements do not supersede the USACE's paramount obligation to engage in early consultation with consulting parties, and in particular Tribal Nations.[12] Indeed, the USACE must give Tribal Nations "*special consideration* in the" Section 106 process.[13] The public may well provide information relevant to the Section 106 process in scoping. When, and if, the public provides such information, the Section 106 process is flexible enough to allow the USACE to synthesize that information with that received through consultation with consulting parties. While the public may provide information regarding historic properties, the USACE must nevertheless defer to Tribal Nations' "special expertise" about properties of traditional religious and cultural significance.[14] No information received from the public can outweigh Tribal Nations' knowledge about such historic properties.

Bay Mills appreciates the USACE's commitment to coordinating the NEPA and NHPA processes and involving the public. The pause in the Section 106 process, especially for an indeterminate amount of time, however, misses the mark. The USACE is perfectly capable of selecting a NEPA contractor, publishing a NOI, and starting scoping as required by NEPA while continuing its Section 106 obligation to engage in early, reasonable, and good faith consultation with consulting parties. Bay Mills looks forward to the USACE reinitiating the Section 106 process and continuing to engage in consultation. Should you have any questions regarding these comments, please do not hesitate to contact the Bay Mills Legal Department at: candyt@bmic.net.

Miigwetch,

Whitney Gravelle
President, Executive Council
Bay Mills Indian Community

c.c.

Mark A. Rodman, State Historic Preservation Officer
Michigan State Historic Preservation Office

Jaime Loichinger, Assistant Director
Office of Federal Agency Programs, Advisory Council on Historic Preservation

[11] *Accord id*. §§ 800.2(d), 800.3(e), 800.4(d)(1), 800.5(a), 800.6(a)(4); 33 C.F.R. pt. 325, app. C, §§ 2(f), 3(b), 4, 5(a), 7(a), (c).
[12] 54 U.S.C. § 302706(b); 36 C.F.R. § 800.2(c)(2)(ii)(A) ("Consultation should commence early in the planning process[.]").
[13] *Quechan Tribe of Fort Yuma Indian Reservation v. U.S. Dep't of Interior*, 755 F. Supp. 2d 1004, 1109 (S.D. Cal. 2010) (emphasis in original); *c.f. Wyoming v. U.S. Dep't of Interior*, 136 F. Supp. 3d 1317, 1345-46 (D. Wyo. 2015), *vacated as moot sub nom. Wyoming v. Sierra Club*, No. 15-8126, 2016 WL 3853806 (10th Cir. July 13, 2016) ("The BLM's efforts, however, reflect little more than that offered to the public in general. The DOI policies and procedures require extra, *meaningful* efforts to involve tribes in the decision-making process." (emphasis in original)).
[14] 36 C.F.R. § 800.4(c)(1).

Attachment E

Cumulative Environmental Risk of Crude Oil and Natural Gas Pipelines in the 1837, 1837, 1842, and 1854 Ceded Territories

by
Esteban Chiriboga
Environmental Specialist

Administrative Report 22-04

April 2022

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Assessment of Cumulative Environmental Risk for Crude Oil and Natural Gas Transmission Pipelines in the Ceded Territories

The network of pipelines that crosses the Ceded Territories has not been assessed for combined environmental impacts. The purpose of this document is to provide information that will inform GLIFWC's work to protect habitats that are necessary for treaty protected natural resource harvests. Cumulative risk characterization is also important because of efforts to renew existing pipeline permits such as the special use authorization in the Chequamegon-Nicolet National Forest, and to permit new pipelines such as the Line 5 re-route in Wisconsin and the proposed Line 5 tunnel at the Straits of Mackinaw.

Since the gas and oil pipeline network in the Ceded Territories is extensive and intersects with many natural and cultural resources, cumulative risks should be considered. The construction and excavation of the right-of-way has filled wetlands, altered vegetation, modified streambanks and soils, and contributed to changes in land use. In addition to these impacts, the continued operation of crude oil and natural gas pipelines means that there continues to be a likelihood of spills and explosions anywhere along a pipeline.

Risk of a Pipeline Incident

The specific risk of a spill or explosion for any single pipeline is difficult to determine because that calculation depends on a large number of variables (e.g., subsurface stress, maintenance, chemical degradation). However, a general estimate of release risk may be made by considering the recent history of releases from crude oil pipelines within the United States. An analysis of spill risk was developed by the U.S. Forest Service (Appendix 3.1-A) and is summarized below:

> Information on crude oil pipelines operating within the Unites States from 2004 to 2017 was obtained from the Pipeline and Hazardous Materials Safety Administration (PHMSA) website (https://www.phmsa.dot.gov/). An annual average of 42,517 barrels of crude oil was released from all incidents (186 per year average) with an average unrecovered volume of 11,820 barrels or 29%. This equates to an average volume of 228 barrels released and 64 barrels unrecovered per incident. To better understand the risk in terms of the range of potential spills volumes and volumes not recovered, additional available data on individual crude oil spill incidences was downloaded from the PHMSA website for the years 2010 to 2018. This information was narrowed down to attempt to identify those that represented actual onshore crude oil pipeline spills by restricting them to incidences involving onshore pipelines. It was further narrowed down by screening out causes identified as equipment failure (non-pipeline) or operator error incorrect operation as these indicate spills that likely are not due to structural failure of the pipeline. The data does include valve sites as it did not allow differentiation between spills involving valves and the pipeline.
>
> The average annual number of reported crude oil pipeline system incidents and the number of crude oil pipeline miles from 2007 to 2017 were used to estimate an upper end

of potential release risk by assuming all incidents resulted in releases. It should also be noted that incidents include both pipelines and pipeline-associated facilities. This constitutes an annual average of one release incident per 318 miles of pipeline, or, alternatively, as much as 0.0031 incidents per mile of pipeline per year. Based on past crude oil pipeline incidents, the 1,277 miles of crude oil pipeline in the ceded territories can expect approximately 4 crude oil pipeline incidents every year. As explained in Appendix 3.1-A, this is considered an upper end estimate.

Because pipeline spills and explosion incidents have occurred, it is reasonable to assume that they will occur again as long as the pipelines remain operational. The following analysis identifies natural resources that lie within the hazard zone of crude oil and natural gas transmission pipelines and provides an assessment of the cumulative risk of spills and explosions to those resources and to tribal use of those resources. In general, the analysis follows methods detailed in an Environmental Protection Agency guidance document titled "Applying Cumulative Impact Analysis Tools to Tribes and Tribal Lands" (Appendix 3.1-B). The analysis is based on spatial relationships of geographic features, meaning that any natural feature (e.g., lake, river, species) that intersects a pre-defined pipeline hazard zone is considered at risk of being impacted by a spill and/or explosion event.

Scale of Cumulative Environmental Risk Analysis

Spatial scope may be the most important factor in an analysis of cumulative environmental risk. An analysis with a spatial scope that is too small will potentially miss impacts that may be important to quantify when developing results or conclusions. Conversely, a spatial scope that is too large will potentially provide information that is unrelated to the project under analysis. As detailed in Appendix 3.1-B, the following considerations were used to define the spatial scope of the cumulative environmental risk analysis:

1. The ceded territories where Ojibwe Tribes have reserved usufructuary rights.
2. Resources that may be impacted. The areas are defined by the hazard zone, but it should be noted that different resources will have hazard zones of different sizes. For example, the hazard zone for rivers will be larger than the hazard zone for terrestrial vegetation because oil can travel greater distances in water than over land.
3. Cultural and natural resource considerations rather than the management or regulatory interests of any agency. For example, even though the Forest Service may be considering a permitting decision on approximately 11 miles of Line 5 that runs through the Chequamegon Nicolet National Forest, the oil and gas transmission network covers a greater area. For cumulative analysis the entire network presents a risk to the ceded territories that cannot be separated from the permit area in question.

An analysis of natural resources potentially affected by releases along oil and gas transmission lines is presented at three scales.

1. The 1836, 1837, 1842, and 1854 ceded territories. Until now a comprehensive accounting of oil and natural gas pipeline related risks to treaty reserved resources in

the Ceded Territories of GLIFWC's member tribes does not exist. This analysis scale is needed in order to understand the implications of permitting decisions to tribes.

2. National Forest Lands. This focus provides an example of analysis directly related to decision making by an agency. This scale is also important because National Forests are important areas of tribal hunting and gathering activities.
3. The Line 5 crude oil pipeline. This pipeline is different from other pipelines when it comes to its environmental risk. Characterizing those differences is important given that permitting decisions are made on a pipeline-by-pipeline basis.

Crude Oil Pipeline Hazard Zone

The hazard zone for spilled oil is a combination of land and aquatic hazard zones. The land hazard zone for spills at crude oil pipelines is defined as 2,500 feet from the pipeline for a total corridor width of 5,000 feet. This distance is based on spill and explosion hazards. For oil spills, the hazard zone is calculated by adding the distance that spilled oil would typically travel over flat ground (1,214 feet from the pipeline) with an additional distance of 1,050 feet for estimated migration in groundwater. The combined distance of 2,264 feet on either side of the center line is rounded to 2,500 feet. This method was chosen after a review of existing information, particularly the Final Environmental Impact Statement for the Line 3 Replacement Project in Minnesota (MDOC, 2018). The crude oil pipeline hazard zone in the ceded territories is 423,080 acres.

The aquatic hazard zone is added to the land hazard zone because crude oil can be highly mobile in water (Hollebone, 2017). For rivers that intersect the pipeline and the land hazard zone it is assumed that the entire downstream stretch of river could be impacted by oil to and including any lakes that the river flows into. The presence of two dams in a potentially impacted river are considered sufficient to stop downstream oil flow. The entire area of lakes that intersects the land hazard zone and potentially impacted rivers are considered potentially impacted. Finally, all sections of wetlands that intersect the land hazard zone and border potentially impacted rivers or lakes, are considered as potentially impacted by spilled oil.

The explosion hazard zone is derived from the evacuation distance for oil spill (300 meters or 984 feet) and fire (800 meters or 2,625 feet) listed in the Enbridge Energy Field Emergency Response Plan for the Lake Superior Region (Enbridge, 2017). A distance of 2,500 feet on either side of the center line was selected to match the land and aquatic hazard zones described above. It is important to note that the explosion hazard zone does not include areas potentially affected by air quality impacts from (e.g. smoke). The spatial extent of air quality impacts is dependent on many site-specific factors and cannot be characterized in this analysis.

Natural Gas Pipeline Hazard Zone

The primary hazards associated with natural gas transmission pipelines are explosion and fire. The blast radius or evacuation zone is the distance from the pipeline that fire damage can be expected to occur. It is also the distance beyond which people would need to move in order to avoid burns or respiratory injuries in the event of a pipeline explosion. This distance is calculated based on the diameter of the pipe and the pressure at which natural gas is transported (Figure

3.1.1). In the ceded territories, PHMSA data indicates that diameters of natural gas pipelines range from 4 to 42 inches. Information on transportation pressure is not available. Given that operating pressures of pipelines can be increased by an operator and pipelines can be upgraded to increase capacity, a blast radius of 3,500 feet was used to represent the evacuation zone. This distance is close to the maximum distance in Figure 3.1.1 would be an appropriate evacuation zone for the majority of natural gas pipeline incidents in the Ceded Territories because it maximizes protection of human life consistent with a worst case analysis.

Recommended Minimum Evacuation Distances
For
Natural Gas Pipeline Leaks and Ruptures
(Not applicable for Butane, Propane, or other Hazardous Liquids)

Pressure (psig)	Pipeline Size (inches)											
	4	6	8	10	12	16	20	22	24	30	36	42
100	91	137	182	228	274	365	456	502	547	684	821	958
200	129	193	258	322	387	516	645	709	774	967	1161	1354
300	158	237	316	395	474	632	790	869	948	1185	1422	1659
400	182	274	365	456	547	730	912	1003	1094	1368	1642	1915
500	204	306	408	510	612	816	1020	1122	1224	1529	1835	2141
600	223	335	447	558	670	894	1117	1229	1340	1675	2011	2346
700	241	362	483	603	724	965	1206	1327	1448	1810	2172	2534
800	258	387	516	645	774	1032	1290	1419	1548	1935	2322	2709
900	274	410	547	684	821	1094	1368	1505	1642	2052	2462	2873
1000	288	433	577	721	865	1154	1442	1586	1730	2163	2596	3028
1100	302	454	605	756	907	1210	1512	1664	1815	2269	2722	3176
1200	316	474	632	790	948	1264	1580	1738	1896	2369	2843	3317
1300	329	493	658	822	986	1315	1644	1809	1973	2466	2959	3453
1400	341	512	682	853	1024	1365	1706	1877	2047	2559	3071	3583
1500	353	530	706	883	1060	1413	1766	1943	2119	2649	3179	3709
1600	365	547	730	912	1094	1459	1824	2006	2189	2736	3283	3830
1700	376	564	752	940	1128	1504	1880	2068	2256	2820	3384	3948
1800	387	580	774	967	1161	1548	1935	2128	2322	2902	3482	4063
1900	398	596	795	994	1193	1590	1988	2186	2385	2981	3578	4174
2000	408	612	816	1020	1224	1631	2039	2243	2447	3059	3671	4283
2100	418	627	836	1045	1254	1672	2090	2299	2508	3134	3761	4388
2200	428	642	856	1069	1283	1711	2139	2353	2567	3208	3850	4492

Figure 3.1.1 - Minimum evacuation distances for natural gas pipelines (NTSB, 2015)

Within the evacuation zone, the analysis also includes a high consequence zone. This is an area where damage from a natural gas pipeline explosion is expected to be catastrophic and there is a high risk of death to people and wildlife. Based on available model data (Figure 3.1.2), the high consequence area for this analysis is a radius of 1,100 feet on either side of a natural gas pipeline (Stevens, 2000).

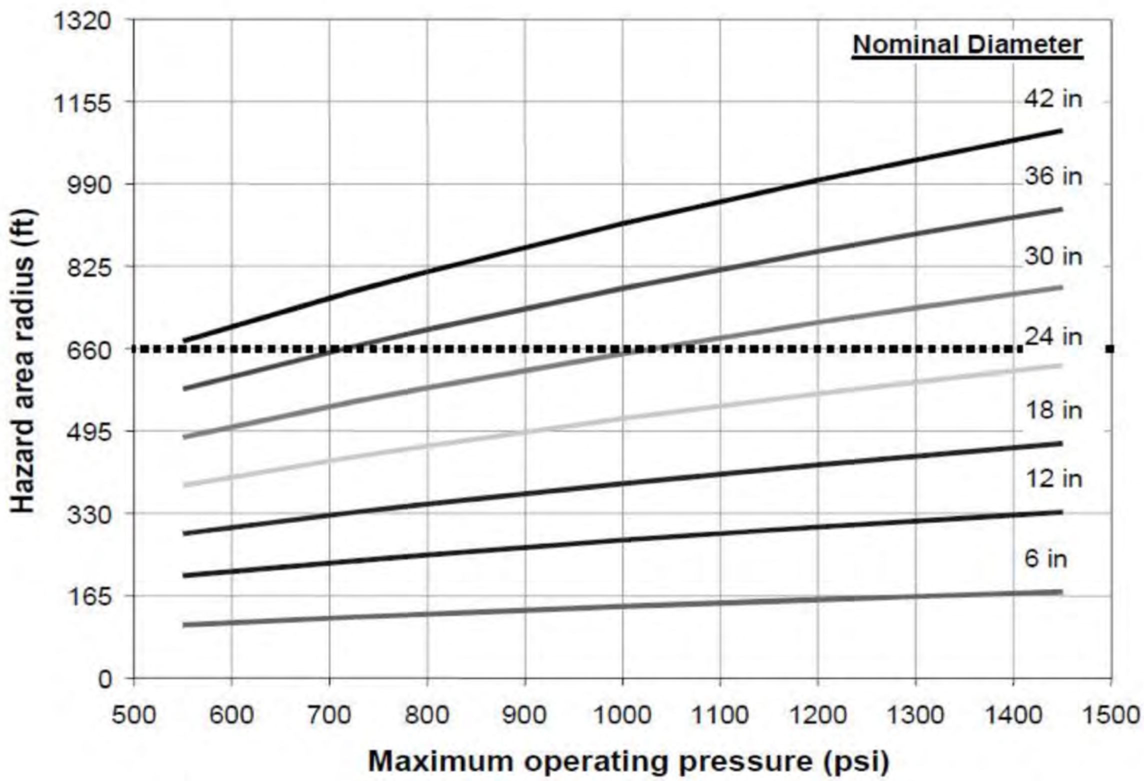

Figure 3.1.2 - Model curves for sizing high consequence areas (Stevens, 2000).

Risk to Human Health

Oil spills and explosions can affect human health through direct skin contact, inhalation, or ingestion of crude oil and gaseous byproducts. The Enbridge Line 6B spill in the area of Marshall, Michigan, involved public health responses to air quality, surface water and fish, and possible groundwater impacts (Michigan Department of Community Health, 2015). Public health was of concern because 40,000 people lived within a mile of the affected release area. Though no residents were located in the area with the highest impacts on air, nearby residences did relocate as a result of odors. An evacuation of the Notawaseppi Huron Band of the Potawatomi was ordered because of concerns about possible explosions. The resulting damage is still affecting the environment and the tribe almost 10 years later. Loss of life related to pipeline incidents can involve pipeline company employees and the general public (MDOC, 2018). Repair of an Enbridge pipeline near Clearbrook, Minnesota, resulted in the deaths of two pipeline workers in 2010 when leaking oil ignited (Duluth News Tribune, 2010). People are known to use the Line 5 pipeline right-of-way and tribal members engage in treaty harvest activities in the vicinity. The presence of the pipeline presents some level of risk in the spill and explosion impact areas.

Figure 3.1.3 - Explosion at an Enbridge natural gas pipeline that impacted the Lheidli T'enneh First Nation in British Columbia, Canada (https://globalnews.ca/news/4531677/prince-george-fire-evacuation/)

Risk at Ceded Territory and National Forest Scales

The Ceded Territories have 1,277 miles of crude oil pipelines and 6,460 miles of natural gas transmission pipelines. Oil pipelines are located in three right-of-way corridors that converge at the Enbridge Terminal in Superior Wisconsin. Natural gas transmission pipelines are widely distributed throughout the Ceded Territories (Figure 3.1.4).

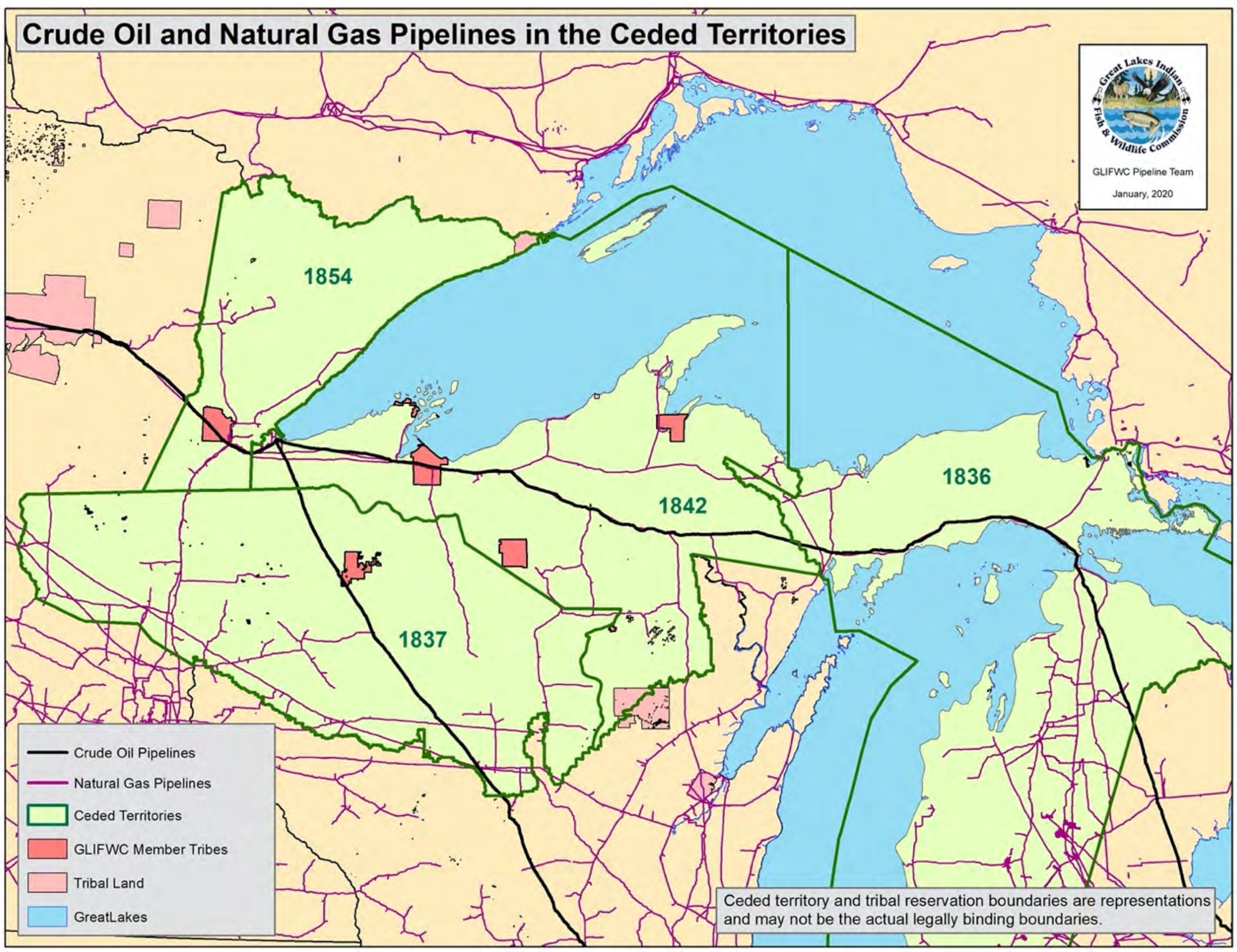

Figure 3.1.4. Crude oil and natural gas pipelines in the 1836, 1837, 1842, and 1854 ceded territories.

Crude Oil Spill Risk – Aquatic Environments

Oil released into aquatic environments is difficult to recover in large quantities because water surface and weather conditions must be sufficiently calm to permit recovery equipment to function well and for response personnel to safely operate the equipment (International Tanker Owners Pollution Federation Limited, 2016). Oil spilled into surface waterbodies generally floats initially and is transported by winds and currents depending on the waterbody type and conditions during the spill. Spills tend to spread shorter distances in standing water such as lakes and ponds with minimal currents. However, wind can increase oil dispersal in those surface waters. Currents in streams and rivers transport oil downstream, and thus impacts are likely to occur over greater areas than in lakes or ponds. The Saskatchewan River spill of 2016 had oiling impacts up to 217 miles downstream of where oil entered the river. The distance that spilled oil travels in flowing water can be considerable (Hollebone, 2017) and the specific morphology and flow of a stream will determine downgradient oil impacts. In larger, fast-moving rivers and creeks, oil would be quickly dispersed downstream with the flow of the river, while in smaller flowing streams and backwater eddies an oil spill could have a more localized effect on the water column and surrounding habitat due to the lower volume and rate of water flow.

Figure 3.1.5 **-** Impacts to the river and riparian wetlands from the Kalamazoo oil spill (Photo courtesy of the USEPA Region 5).

Wetlands, including marshes, swamps, peat bogs, and fens, are particularly sensitive to oil spills. In wetlands, small areas of shallow water, finer sediments with high organic content, greater vegetation cover, and high biochemical oxygen demand (leading to anaerobic conditions) would affect the dispersion and weathering of spilled crude oil. Oil spilled into wetlands could be widely dispersed by wind or water movement and would typically become stranded on fine sediments or vegetation. In this case, oil would not likely travel as far as it would in open water. Transport out of a wetland may occur via small stream discharge points. If the spilled oil becomes entrained within anaerobic sediments, the rate of biodegradation may be significantly reduced (Boufadel et al. 2015).

The fate and transport of crude oil in groundwater is a complex process. The USGS has been conducting research into this topic at the site of an Enbridge pipeline crude oil spill in Bemidji, Minnesota. The spill occurred from a ruptured pipeline that released approximately 10,700 barrels of oil. After recovery efforts, including a pump and treat system, it is estimated that approximately 2,000 barrels remain underground. Continued research at the USGS Bemidji research lab has shown that when spilled oil enters the groundwater system, biological activity is minimal, and the oil can be expected to remain in the aquifer for decades. Furthermore, contaminants such as benzene, toluene, ethylbenzene, xylene (BTEX), and polycyclic aromatic hydrocarbons (PAHs) are commonly present in groundwater plumes from crude oil. (https://www.usgs.gov/mission-areas/environmental-health/science/us-geological-survey-identifies-crude-oil-metabolites?qt-science_center_objects=0#qt-science_center_objects). The groundwater oil plume at the Bemidji, MN site has been relatively stable over time and biodegradation of oil is extremely slow. Revesz et al. (1995) calculated that the minimum life expectancy of the release was 110 years. However, they stated that this was an order of magnitude estimate due to expectations that calculated degradation rates used for the estimate would actually be slower in the future. It is unclear if the oil in groundwater will attenuate in the foreseeable future.

Freshwater fish are important components of aquatic ecosystems and food webs, as well as major economic resources in recreation and commercial fishing industries. Fish can be affected by oil releases through multiple exposure pathways and at multiple life stages, and the toxicity effects can be either acute, chronic, or indirectly related to contamination of habitat features (Enbridge 2016d). The Marshall, Michigan, spill resulted in 42 dead fish immediately after the spill, which was considered negligible (USFWS 2015). Though scientists and local officials debated the exact cause, roughly 100 dead fish were found following the crude oil release to Wabamun Lake (Birtwell 2008). The Pine River, Missouri spill resulted in 1,637 observed dead fish immediately following the spill. These fish tended to be larger, bottom-feeding fish, with a small proportion (<15 percent) being surface feeders. Fish mortality was noted up to 30 miles downstream of the release. Longer term effects of spills include habitat degradation and sublethal effects, including deformities. Longer term effects of the Marshall spill included declines in abundance and diversity of fish in Talmadge Creek in the year following the release. Recovery occurred shortly thereafter, but changes in fish community composition also occurred in response to spill induced habitat changes in the following three years (USFWS et al. 2015). Sublethal effects on fish were present for 27 miles downstream of the release site, as revealed by a fish health study two months following the spill (Papoulias et al. 2014). Fish consumption advisories were issued for two years as a result of crude oil exposure. In Wabamun Lake, important juvenile and spawning habitat for various species was significantly affected by oil contamination, and in the two years following the spill, increases in fish deformities were attributed to the spill.

The Pine River spill also impacted benthic organisms. Immediately following the spill event, benthic populations within the affected area were 0.1 percent of typical populations, with a complete loss of mayfly and stonefly species. By 9 months following the release, the mayfly and stonefly populations had recovered to levels observed in unaffected areas upstream of the spill (Crunkilton and Duchrow 1990). By 18 months, the mayfly and stonefly populations had recovered to levels observed in healthy Missouri streams. In a similar 18-month timeframe at a separate Missouri pipeline spill (Gasconade River, 1988, intermediate weight sweet crude), macroinvertebrate communities had not fully recovered in their diversity and abundance due to residual hydrocarbon contamination, which was particularly concentrated in sloughs (Poulton et al. 1997). Greater recovery had occurred in riffle habitats where more frequent bed scour helped to flush oil contamination from sediments.

Numerous bird species spend their time near or within waterbodies and can be highly susceptible to oil spill impacts. The Marshall, Michigan, spill affected roughly 400 birds, 52 of which died shortly after the spill (USFWS et al. 2015). An additional 144 birds affected by released oil were captured and rehabilitated, and roughly 140 birds were observed with oil effects but were not captured. Affected birds were generally waterfowl, including Canada geese, mallard ducks, and great blue herons. For comparison, of the birds affected by the Rainbow Pipeline release, approximately one-third were waterfowl and two-thirds were shorebirds and songbirds. The explosion of the Husky refinery in Superior Wisconsin also impacted birds. EPA reports indicate that 3 grackles, 3 robins, 1 starling, 1 American bittern, 2 geese, 1 redwing blackbird, and 4 unidentified birds were killed as a result of oiling. In addition, 9 geese (5 adults and 4 goslings), 3 mallards, 3 killdeer (1 adult and 2 chicks), and 1 robin were cleaned and released back into the environment. Finally, 30 adult geese and 63 goslings had to be relocated from the impacted area. It should be noted that the wildlife survey occurred several days after the explosion so these numbers of impacted birds are likely a fraction of the total impact.

Figure 3.1.6 - Great Blue Heron oiled during the Enbridge pipeline spill in Marshall Michigan (Photo courtesy of the Michigan Department of Environment, Great Lakes, and Energy EGLE).

Reptiles and amphibians are particularly vulnerable to oil spills. In the event of an oil spill, an external oil coating of skin or scales in amphibians and reptiles can lead to reduced thermoregulatory capacity and suffocation in amphibians. Amphibians may absorb toxins from oil through their skin. Exposure to toxins that occurs during egg formation in reptiles and amphibians can lead to reduced productivity and teratogenic effects. Reptiles, such as turtles, may be more susceptible to carcinogenic effects of PAHs compared to shorter-lived animals (Burns et al. 2014). The timing of a spill is important for impacts to reptiles and amphibians. Spills in winter over ice may cause fewer impacts to reptiles and amphibians. However, spills that occur in warm periods of the year are disastrous to these animals. The Marshall, Michigan spill occurred at a time of receding flood flows in the Kalamazoo River. As a result, oil was distributed into and trapped within floodplain depressions, resulting in a substantial effect on amphibians and reptiles. Over 100 reptiles died, and nearly 4,000 turtles and 73 amphibians were captured and treated for oil effects (USFWS et al. 2015).

Figure 3.1.7 - Painted turtle oiled during the Kalamazoo oil spill (photo courtesy of EGLE).

Semi-aquatic mammals are those specially adapted to live near water and inhabit aquatic environments. While most mammals are terrestrial, the semi-aquatic variety are generally most prone to impacts from oil spills (Enbridge 2016d). The Marshall, Michigan spill reportedly killed 40 mammals, and an additional 23 were captured and rehabilitated, though it was expected that additional mammals were affected but not observed during monitoring efforts (USFWS et al. 2015). Of the affected mammals, the primary species included muskrat (45 percent), raccoon (13 percent), and beaver (13 percent). Oil spilled as a result of the 2018 refinery explosion in Superior, Wisconsin is known to have impacted water voles in the vicinity of the explosion.

<u>Rivers and Streams</u>

There are 4,335 river miles at risk of oiling impacts from a crude oil pipeline spill in the ceded territories. Table 3.1.1 contains an additional breakdown of miles of river at risk within National Forests and tribal reservations. Rivers and streams at risk of impacts from crude oil pipeline spills are illustrated in figure 3.1.8 and in greater detail in the spill mapbook.

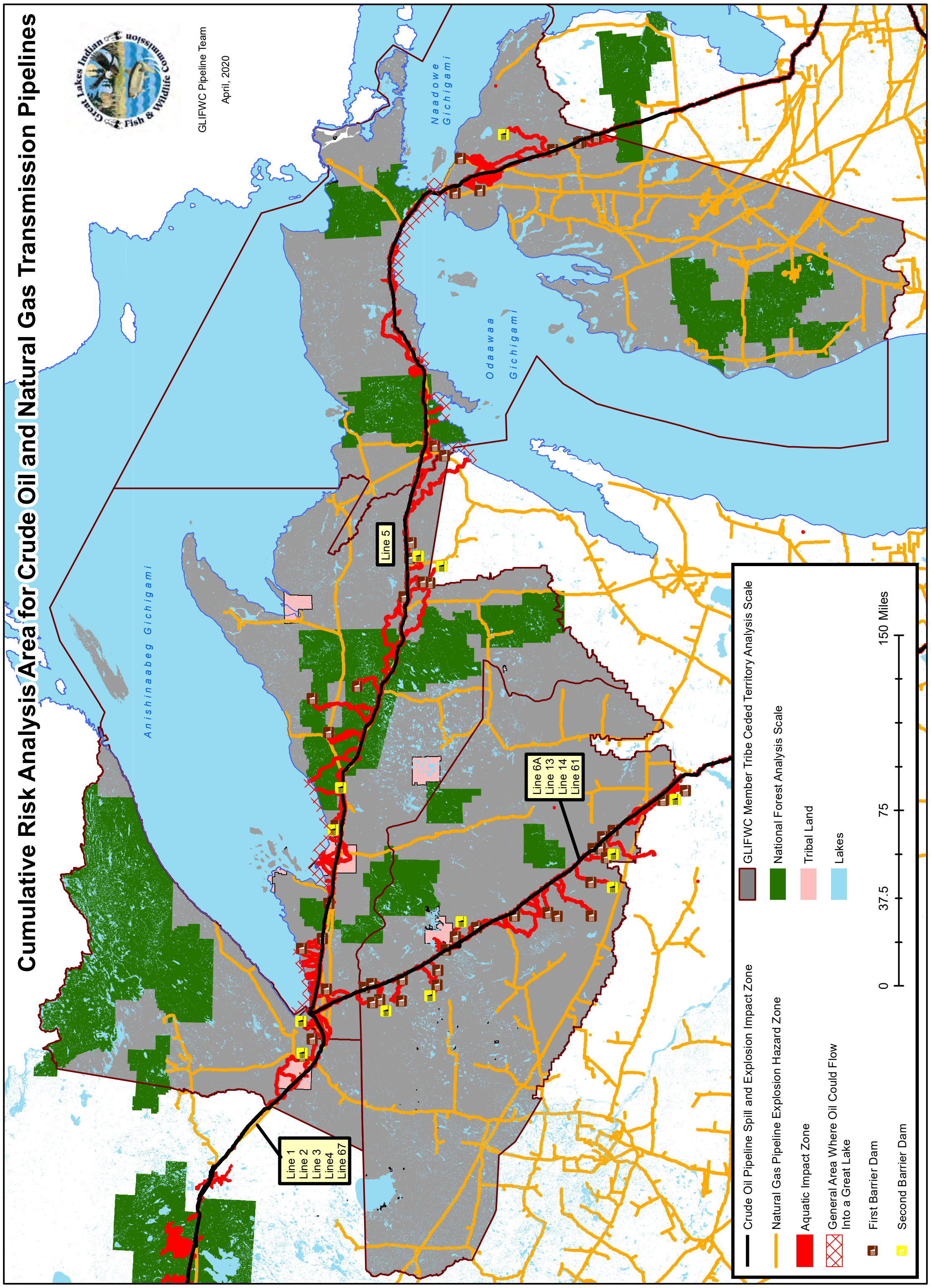

Figure 3.1.8 - Rivers and streams in the ceded territories at risk from crude oil pipeline spills.

Table 3.1.1 - Miles of rivers and streams at risk from crude oil pipeline spills

Rivers and Streams at Risk from Crude Oil Pipeline Spills		
		Miles
Ceded Territory		4,335
Fond Du Lac Reservation		74
Bad River Reservation		155
Lac Courte Oreilles Reservation		30
Chequamegon - Nicolet National Forest		37
Ottawa National Forest		444
Hiawatha National Forest		159

Seven river segments that are available for tribal spearing harvest are at risk from crude oil pipeline spills. These rivers are listed in table 3.1.2 and illustrated in the spill mapbook.

Table 3.1.2 River segments available for tribal spearing harvest at risk from crude oil pipeline spills.

RIVER	DESCRIPTION
Namekagon River, Sawyer and Washburn Counties	
Namekagon River, Washburn and Burnett Counties	From Lake Hayward in Sawyer County to Highway E (also U.S. Highway 63) in Washburn County above the Trego Flowage.
St. Croix River, Douglas, Washburn and St. Croix Counties	Croix River in Burnett County.
Yellow River, Taylor County	County, including the Yellow River below the Danbury Dam, Loon Creek from the Minerva Dam to its confluence with the Yellow River, the Clam River below the Clam River Dam, and t
Thornapple River, Rusk County	County Line.
Couderay River, Sawyer County	River at the Village of Bruce.
Flambeau River, Rusk County	extends from County Road E (outlet of Little Lac Courte Oreilles) to the Grimh Flowage.
Chippewa River, Sawyer and Rusk Counties	From Highway 27 to the tip of the island just south of Port Arthur Road.
	its confluence with the Flambeau River. Note: According to the Tribal Fish Refuge and Closed Areas document, the area between the dam to 500 ft is closed from April 1 to May31.

Eight rivers with known manoomin (wild rice) presence are at risk from crude oil pipeline spills. These rivers are listed in table 3.1.3 and illustrated in the spill mapbook.

Table 3.1.3 - Rivers with known manoomin presence at risk from crude oil pipeline spills.

County	River Name
Burnett, Douglas, Polk	St Croix River
Rusk	Rice Creek
Douglas	St. Louis River
Douglas, Washburn	Totogatic River
Ashland	Kakagon River
Ashland	Beartrap Creek
Douglas	Pokegama River/Bay
Gogebic	Ontonagon River

Lakes

There are 1,013 ceded territory lakes with 101,202 acres of open water that are at risk of oiling impacts due to a crude oil pipeline spill. Table 3.1.4 contains additional breakdown of acres of lakes at risk from crude oil pipeline spills within National Forests and Tribal Reservations. Lakes at risk of impacts from crude oil pipeline spills are illustrated in the spill mapbook.

Table 3.1.4 - Acres of open water lakes at risk of crude oil pipeline spills that are located within Tribal Reservations and the proclaimed boundaries of National Forests.

Lakes at Risk from Crude Oil Pipeline Spills			
		Lakes	Acres
Ceded Territory		553	97,262
Fond Du Lac Reservation		13	693
Bad River Reservation		8	287
Lac Courte Oreilles Reservation		1	5140
Chequamegon - Nicolet National Forest		6	108
Ottawa National Forest		120	16,424
Hiawatha National Forest		86	13,399

Crude oil spills originating from several oil pipelines, including Line 3 and Line 5, have the potential to impact the St. Louis River Estuary as well as the Lake Superior National Estuarine Research Reserve (NERR). This protected area is one of only two freshwater estuaries in the Great Lakes. The NERR includes the world's largest freshwater bay mouth sandbar and rare estuarine wetlands. It is also an area of great cultural significance to the Ojibwe tribes. The estuary itself encompasses 11,197 acres of open water and the NERR protects almost 17,000 acres of land. The risk of crude oil spills to the estuary and the NERR are depicted on page 3 of the spill mapbook.

Seventeen lakes that GLIFWC member tribes have declared for walleye fishing are at risk from crude oil pipeline spills. These lakes are listed in table 3.1.5 and illustrated in the spill mapbook.

Table 3.1.5 - Lakes declared for walleye spearing at risk from crude oil pipeline spills.

County	Lake
Chippewa	Holcombe Flowage
Rusk	Thornapple Flowage
Sawyer	Lac Courte Oreilles
Sawyer	Whitefish Lake
Sawyer	Sand Lake
Washburn	Minong Flowage
Gogebic	Lake Gogebic *
Washburn	Trego Lake
Douglas	Upper St. Croix Lake
Bayfield	Bladder Lake **
Iron	Peavy Pond
Iron	Sunset Lake
Iron	Emily Lake
Iron	Paint Pond
Iron	Tamarack Lake *
Ontonagon	Bond Falls Flowage *
Ontonagon	Victoria Pond *

Eleven lakes and sloughs with known wild rice presence are at risk from crude oil pipeline spills. These waters are listed in table 3.1.6 and illustrated in the spill mapbook.

Table 3.1.6 - Known manoomin waters at risk from crude oil pipeline spills.

County	Lake/Slough
Chippewa, Rusk	Holcombe Flowage
Ashland	Unnamed (Northeast) Slough
Ashland	Wood Creek Slough
Ashland	Bad River Sloughs
Ashland	Honest John Lake
Washburn	Trego Flowage
Douglas	St.Croix (Gordon) Flowage
Douglas, Washburn	Minong Flowage
Douglas	Upper Saint Croix Lake
Douglas	Allouez Bay
Gogebic	Slate River Slough

Wetlands

There are two categories of wetlands that are at risk of impacts from pipeline spills of crude oil in the ceded territories. First, there are 12,340 wetlands totaling 145,560 acres located inside the 5000-foot hazard zone surrounding the crude oil pipelines. Second, there are 5,743 riparian wetlands that are hydrologically connected to rivers and lakes within the aquatic hazard zone. These potentially impacted riverine and lacustrine wetlands total 270,526 acres in the ceded territories. Table 3.1.7 contains additional breakdowns of wetlands at risk from pipeline crude oil spills in the ceded territories.

Wisconsin's wetland inventory includes information on small wetlands that do not have acreage or delineation information. These are often small wetlands that despite their size, may have significant biological significance. There are 7,258 of these wetlands located within the 5,000-foot hazard zone. The size and ecosystems supported by these wetlands is largely unknown. Wetlands at risk of impacts from crude oil pipeline spills are illustrated in the spill mapbook.

Table 3.1.7 - Wetlands at risk from crude oil pipeline spills.

Wetlands at Risk from Crude Oil Pipeline Spills			
		Wetlands	Acres
Ceded Territory		12,340	145,560
Fond Du Lac Reservation		437	4,636
Bad River Reservation		394	2,431
Lac Courte Oreilles Reservation		54	252
Chequamegon - Nicolet National Forest		25	38
Ottawa National Forest		625	11,943
Hiawatha National Forest		282	19,324
		Riparian	Acres
Ceded Territory		5,743	270,526
Fond Du Lac Reservation		139	3,424
Bad River Reservation		318	3,535
Lac Courte Oreilles Reservation		70	388
Lac Vieux Desert		1	16
Chequamegon - Nicolet National Forest		1	2
Ottawa National Forest		349	23,254
Hiawatha National Forest		135	28,192
Total Wetlands at Risk		18,083	416,086

Groundwater

To help illustrate the potential impacts to groundwater we use a groundwater model developed by the United States Forest Service (USFS) for the Chequamegon-Nicolet National Forest (CNNF). Modeling results indicate that the water table largely mirrors surface topography with a groundwater mound located below the Bayfield highlands. Groundwater flow is dominated by gravity because there are no pumping sites within the National Forest boundary. Figure 3.1.9 illustrates the location of the groundwater mound and particle tracking points show the general direction of groundwater flow away from the mound.

As an example of how oil might travel with groundwater, oil spilled along the section of Line 5 that is located within the CNNF would quickly infiltrate the sandy soils. Some oil would become bound with the sand but it is highly likely that oil would reach the water table. The groundwater model indicates that an oil plume would move away from the spill location along two general flow paths and flow along the pathways is expected to continue for hundreds of years. The model indicates that spilled oil could daylight at surface water bodies and existing water supply wells (Figure 3.1.9). It is important to note that even if the spilled oil never intersects a surface water body, the groundwater aquifer would remain contaminated for the foreseeable future. The full USFS modeling report is available in Appendix 3.1-A.

The USGS research site in Bemidji, Minnesota is the only location in the Great Lakes region that has information on ongoing effects of oil spills to groundwater. In addition, a groundwater model for the ceded territories is not available to identify areas at risk of impacts from spilled oil traveling through groundwater. Additional research would be needed to determine if past oil spills in the ceded territories have ongoing, unidentified groundwater impacts.

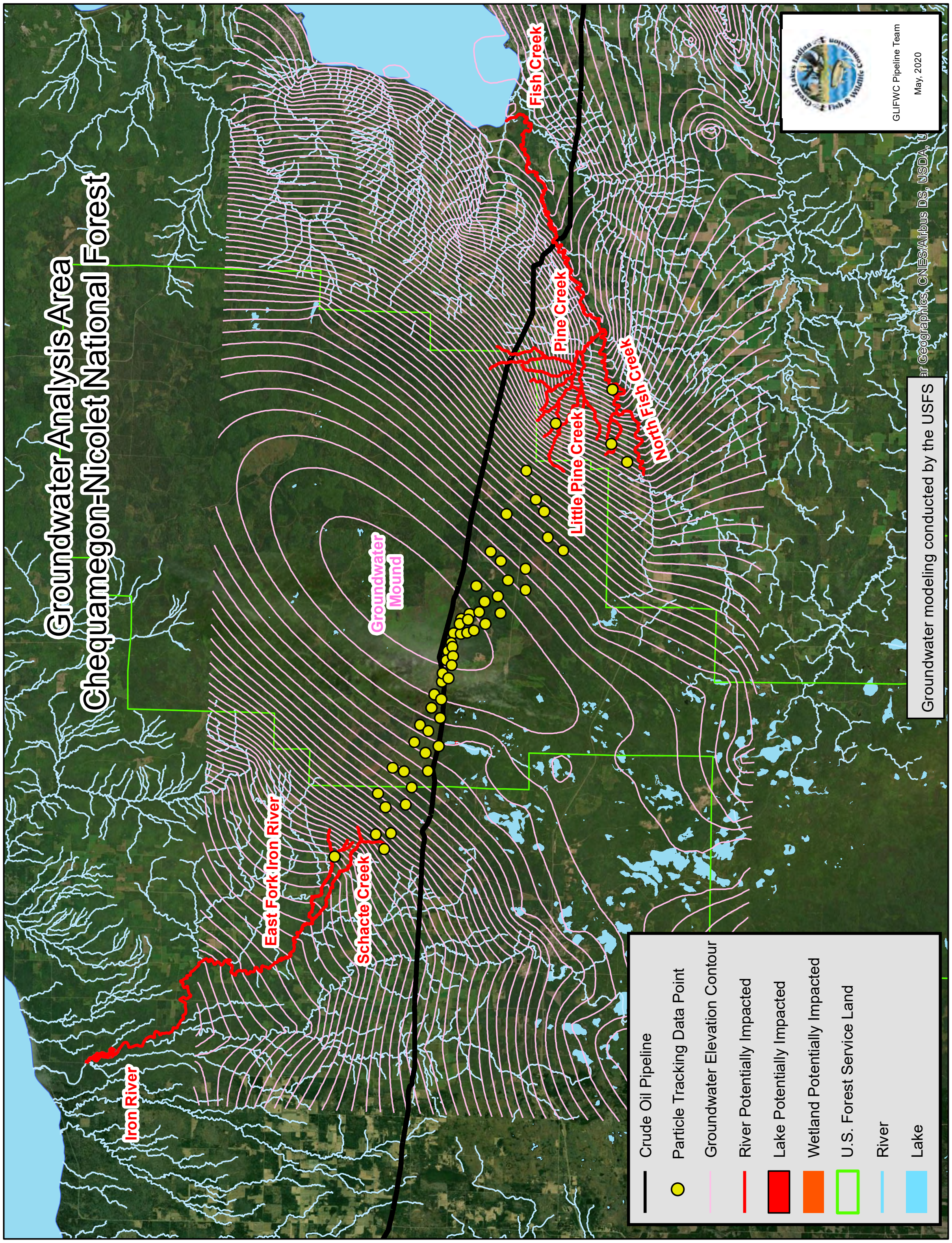

Figure 3.1.9 - Modeled crude oil spill from the section of Line 5 that crosses the proclaimed boundary of the Chequamegon-Nicolet National Forest.

Crude Oil Spill Risk – Terrestrial Environments

Crude oil releases to the ground surface can have harmful effects on soil and important resident microorganisms (Enbridge 2016). Remediation of spilled oil usually involves the removal of affected material from the area resulting in permanent impacts to soil structure. After a series of oil spills near Great Slave Lake in Alberta, Canada, soil tilling, burning, and fertilizer applications were used to remediate the soils. Twenty-five years later, oil concentrations within the first foot in soil depth were still high. More recently, bioremediation techniques have been developed where microbial communities are used to promote biodegradation. These techniques have had success over long periods of time (Hemmings et al, 2015).

Figure 3.1.10 - 2018 Keystone XL pipeline oil spill in South Dakota (https://www.argusleader.com/story/news/crime/2018/04/07/keystone-pipeline-spill-south-dakota-twice-big-first-thought/496613002/).

At impacted areas around Great Slave Lake, oil-contaminated deciduous plants showed effects within hours of oil exposure and evergreen vegetation took weeks to show stress. Regrowth in oil-exposed plants was less robust than would typically occur. Plants in oil-saturated soil showed no regrowth. After a single growing season, recovery varied between 20 and 55 percent, depending on the oil treatment rate. A similar study in the Northwest Territories involving light-crude application revealed changes in species composition and diminished vegetation cover in the test area after 10 years (Robson et al. 2004). A test release of heavy crude in Caribou-Poker Creek Watershed of Alaska, in 1976 showed that mosses and lichens died shortly after the release, but some specific grass species persisted.

Oil spills affect terrestrial animal species through mortality or displacement. Impacts to specific species will be highly site and species specific and cannot be characterized in detail in this analysis with the available data.

The area of uplands potentially impacted by crude oil pipeline spills in the ceded territories was obtained by subtracting acres of wetland from the land terrestrial hazard zone acreage. Table 3.1.8 contains additional breakdowns of uplands at risk from pipeline crude oil spills in the ceded territories.

Table 3.1.8 - Acres of uplands in the crude oil pipeline land hazard zone.

Upland Areas at Risk from Crude Oil Pipeline Spills		
		Acres
Ceded Territory		277,520
Fond Du Lac Reservation		4,137
Bad River Reservation		5,025
Lac Courte Oreilles Reservation		2,450
Chequamegon - Nicolet National Forest		7,307
Ottawa National Forest		29,756
Hiawatha National Forest		11,027

There are crude oil pipeline hazard zones that are located on public or protected lands. Table 3.1.9 lists some of those areas as well as the acres located within the hazard zone. Protected areas at risk of impacts from pipeline explosions are illustrated in the explosion mapbook. Additional information would be needed to characterize the environmental risk of crude oil spills to these areas and to determine if crude oil pipelines are compatible with local management goals.

Table 3.1.9 Acres of lands in the USGS Protected Areas Database (PADUS) that are potentially impacted by a crude oil pipeline spill.

Area Database (PADUS)	Acres
Atlanta State Forest Area	20
Bean Brook Fishery Area	90
Bennet Communication Tower	10
Benson Creek Fishery Area	4
Brule River State Forest	827
Bullock Ranch Flooding State Wildlife Management Area	860
Cisco Branch Ontonagon National Wild and Scenic River	744
Critical Dune Barrier dunes	1342
Critical Dune Exemplary dune associated plant comm	1397
Crystal Falls State Forest Area	7911
Cut River Bridge	36
Dingman Marsh Flooding State Wildlife Management Area	503
Douglas County Wildlife Area	309
Escanaba State Forest Area	1598
Flambeau River State Forest	145
French Farm Flooding State Wildlife Management Area	406
Gaylord State Forest Area	8087
Genes Pond Flooding State Wildlife Management Area	252
Grayling State Forest Area	3571
Gwinn State Forest Area	406
Jump River Fishery Area	8
Kirtlands Warbler Wildlife Management Area	621
Little Brevort Lake Scenic Site	437
Middle Branch Ontonagon River	786
North Country National Scenic Trail	8
Pershing Wildlife Area	7
Pigeon River Country State Forest Area	4171
Presque Isle River National Wild and Scenic River	288
REM-Namekagon River	84
REM-Weirgor River	122
Sand Lake Rearing Station	83
Sand Lake Tower Site	1
Sault Ste. Marie State Forest Area	10715
Shingleton State Forest Area	3153
South Branch Paint River National Wild and Scenic River	319
South Shore Lake Superior Fish and Wildlife Area	304
St. Croix National Scenic Riverway	504
St. Louis River Stream Bank Area	105
Statewide Habitat Area	11
Statewide Habitat Area	59
Statewide Non-point Easement Program	21
Statewide Public Access	22
Sturgeon River National Wild and Scenic River	386
Tuscobia State Trail	12
unnamed - private lands managed by DNR	33
Wagner Falls Scenic Site Park	260
Whitefish River National Wild and Scenic River	63
Wild Rivers State Trail	96
Wyman Nursery	95

Crude Oil and Natural Gas Pipeline Explosion Risk

Tribal, Public and Protected Lands

The land area at risk from an oil pipeline explosion totals 423,080 acres in the Ceded Territories. The land area at risk from a natural gas transmission pipeline explosion totals 3,331,762 acres. The combined explosion risk area for both pipeline types is 3,536,902 acres. Explosion hazard areas include portions of the Fond Du Lac, Lac Courte Oreilles, Keweenaw Bay Indian Community, and Bad River Reservations as well as portions of the Chequamegon-Nicolet, Ottawa, Hiawatha, Superior, and Huron-Manistee National Forests (Table 3.1.10). While the analysis here focuses on tribal and National Forest lands as examples, there are additional large areas of public lands in state and county forests. Figure 3.1.11 depicts land ownership in relation to the explosion hazard area with greater detail in the explosion mapbook. The combined area of the USGS protected lands database at risk of being impacted by an explosion from crude oil and natural gas pipelines is 373,593 acres.

Table 3.1.10 - Acres at risk of impacts from a crude oil or natural gas pipeline explosion.

Combined Crude Oil and Natural Gas Pipeline Explosion Hazard Areas		
		Acres
Ceded Territory		3,563,902
Fond Du Lac Reservation		21,413
Bad River Reservation		20,795
Lac Courte Oreilles Reservation		2,702
Keweenaw Bay Indian Community		6,128
St. Croix Reservation		408
Chequamegon - Nicolet National Forest		55,368
Ottawa National Forest		122,184
Hiawatha National Forest		100,201
Huron - Manistee National Forest		89,265
Superior National Forest		6,297

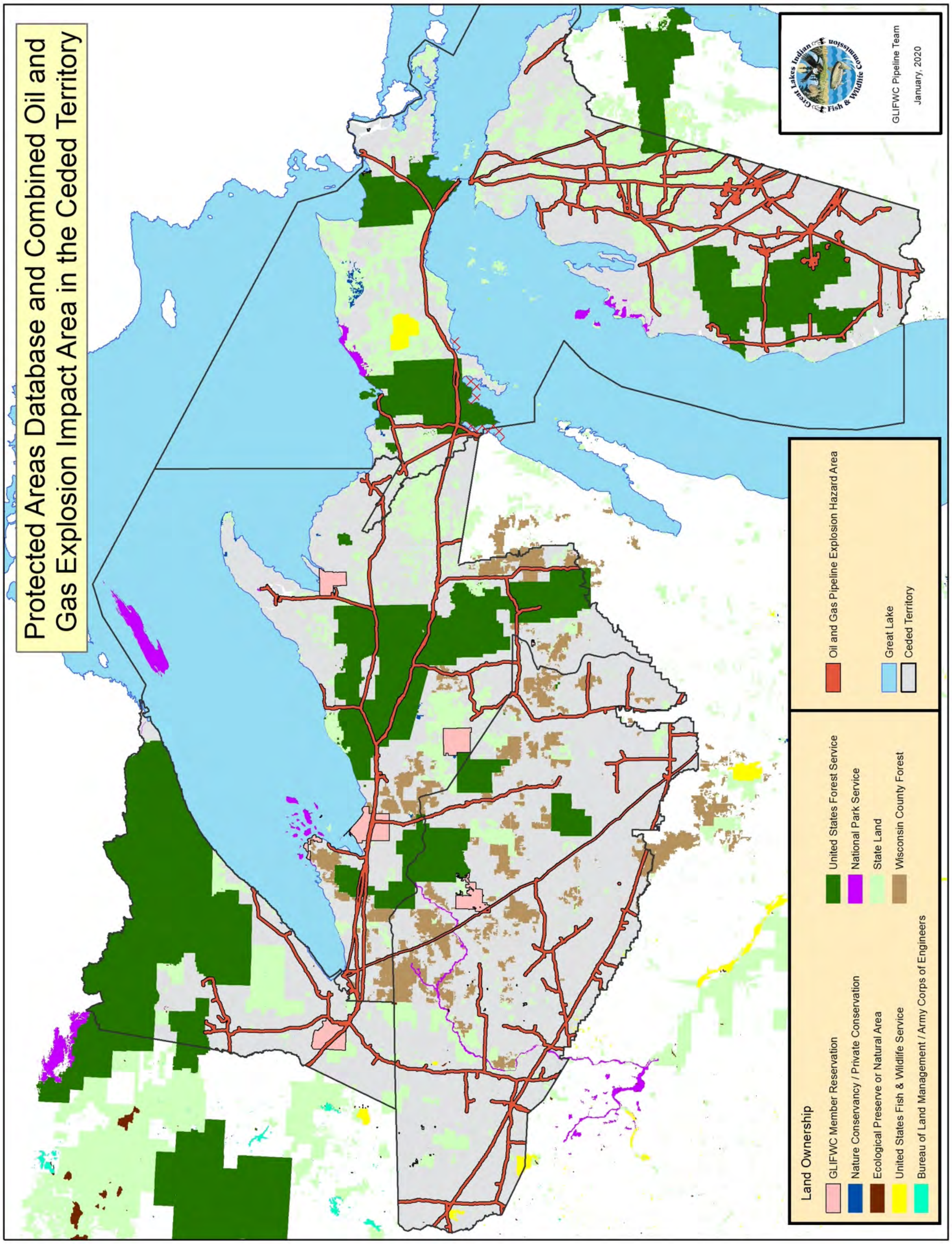

Figure 3.1.11 **-** Explosion hazard area for crude oil and natural gas pipelines in the 1836, 1837, 1842, and 1854 ceded territories.

Rivers and Streams

The Ceded Territories have 2,003 miles of rivers and streams that are at risk of impacts from a crude oil pipeline explosion. There are 7,492 miles of rivers and streams within the evacuation zone of natural gas pipelines and 2,273 of those miles are in the high consequence zone. The combined crude oil and natural gas explosion impact area (evacuation and high consequence) for the Ceded Territories contains 8,762 miles of rivers and streams. Table 3.1.11 contains additional breakdown of miles of rivers and streams at risk from pipeline explosions within National Forests and Tribal Reservations. Rivers and streams at risk of impacts from pipeline explosions are illustrated in the explosion mapbook.

Table 3.1.11 - Miles of rivers and streams that are located within the explosion hazard areas of crude oil and natural gas pipelines.

Miles of Rivers and Streams At Risk from Pipeline Explosions				
	Crude Oil	**Natural Gas**		**Combined Risk Zones**
		Evacuation Zone	**High Consequence Zone**	
Ceded Territory	2,003	7,492	2,273	8,762
Fond Du Lac Reservation	9	17	6	22
Bad River Reservation	47	82	30	97
Lac Courte Oreilles Reservation	13	0	0	13
Keweenaw Bay Indian Community	0	28	9	28
Chequamegon - Nicolet National Forest	3	46	11	47
Ottawa National Forest	164	401	119	426
Hiawatha National Forest	76	232	72	279
Huron - Manistee National Forest	0	210	54	210
Superior National Forest	0	8	3	8

Lakes

There are 491 lakes with 47,785 acres of open water at risk of impacts from an oil pipeline explosion in the Ceded Territories. There are 6,016 lakes with 223,564 acres of open water that are located within the evacuation zone for natural gas pipelines and of those, 2,127 lakes with 77,345 acres of open water are located in the high consequence area. Combined crude oil and natural gas explosion impact area for the Ceded Territories contains 6,202 lakes with 237,075 acres of open water. Table 3.1.12 contains additional breakdown of acres of lakes at risk from pipeline explosions within National Forests and Tribal Reservations. Lakes at risk of impacts from pipeline explosions are illustrated in the explosion mapbook.

Table 3.1.12 - Number of lakes and acres of open water that are located within the explosion hazard areas of crude oil and natural gas pipelines.

Lakes At Risk from Pipeline Explosions								
	Crude Oil		**Natural Gas**				**Combined Risk Zones**	
			Evacuation Zone		**High Consequence Zone**			
	Lakes	**Acres**	**Lakes**	**Acres**	**Lakes**	**Acres**	**Lakes**	**Acres**
Ceded Territory	491	47,785	6,016	223,564	2,127	77,345	6,202	237,075
Fond Du Lac Reservation	11	553	30	143	16	48	32	660
Bad River Reservation	6	17	7	18	6	16	7	18
St. Croix Reservation	0	0	2	2,772	2	2,772	2	2,772
Keweenaw Bay Indian Community	0	0	21	27	6	4	21	27
Chequamegon - Nicolet National Forest	5	23	69	2,601	30	1,874	69	2,601
Ottawa National Forest	93	811	232	14,850	85	628	241	14,959
Hiawatha National Forest	85	9,070	157	16,179	61	1,060	201	16,278
Huron - Manistee National Forest	0	0	136	1,304	41	462	136	1,304
Superior National Forest	0	0	22	1,988	10	1,452	22	1988

Of the lakes listed above, 39 are known to support manoomin (wild rice) (Table 3.1.13) and 57 are lakes that Tribes have declared for walleye spearing (Table 3.1.14). An explosion at one of the pipelines could impact tribal members as they harvest these important resources as well as damage the resources themselves. These lakes are depicted in the explosion mapbook.

Table 3.1.13 - Wild Rice waters at risk of crude oil and natural gas pipeline explosion.

County	**Lake**		**County**	**Lake**
Burnett, Douglas, Polk	St Croix River		Douglas	Fasteland Road Ponds
Douglas	St. Louis River		Lincoln	Wisconsin River
Vilas	Mud Creek		Burnett, Washburn	Yellow River
Barron	Rice Creek		Forest	Rat River (GLIFWC long term study)
Douglas	Pokegama River/Bay		Chisago	Mud Lake
Lincoln, Oneida	Wisconsin River (above Lake Alice)		Isanti	Grass
Vilas	Wisconsin River		Isanti	North Stanchfield
Forest	Little Rice Lake		Morrison	Pelkey
Burnett	Clam Lake, Lower		Isanti	Rice
Burnett	Big Sand Lake		Sherburne	Long Pond
Burnett	Memory Lake		Pine	Stanton
Burnett	Mud Hen Lake		Crow Wing	Unnamed
Oneida	Spur Lake		Chisago	North Sunrise Pool
Polk	Little Butternut Lake		Pine	Fox
Oneida	Cuenin Lake		Morrison	Popple
Forest	Scattered Rice Lake		Morrison	Coon
Polk	Balsam Lake		Kanabec	Twin
Polk	Unnamed Pond			Mississippi River
Lincoln	Alice Lake			Mississippi River
Burnett	Clam Lake, Upper		Pine	Snake River

Table 3.1.14 - Walleye waters at risk of crude oil and natural gas pipeline explosion.

County	Lake		County	Lake
BENTON	MAYHEW L		POLK	BALSAM L
CHISAGO	SOUTH LINDSTROM L		BURNETT	DUNHAM L
CHISAGO	NORTH CENTER L		BURNETT	UPPER CLAM L
CHISAGO	LITTLE L		BURNETT	BIG SAND L
CHISAGO	NORTH LINDSTROM L		GOGEBIC	SUNDAY L
CHISAGO	GREEN L		GOGEBIC	ALLEN L
CHISAGO	LITTLE COMFORT L		GOGEBIC	L GOGEBIC
TAYLOR	RIB L		BAYFIELD	BLADDER L
ONEIDA	MINOCQUA L		BAYFIELD	LONG L
ONEIDA	TOMAHAWK L CHAIN		ISANTI	SKOGMAN L
LINCOLN	L ALICE		ISANTI	FLORENCE L
ONEIDA	GEORGE L		ISANTI	FANNIE L
ONEIDA	HASBROOK L		ISANTI	NORTH STANCHFIELD L
ONEIDA	GILMORE L		HOUGHTON	TORCH L
ONEIDA	SWEENEY L		HOUGHTON	PORTAGE L
ONEIDA	PICKEREL L		IRON	SUNSET L
ONEIDA	RAINBOW FL		IRON	EMILY L
VILAS	LITTLE ST GERMAIN L		IRON	IRON L
ONEIDA	PLANTING GROUND L		FOREST	TRUMP L
ONEIDA	TOWNLINE L		MORRISON	PIERZ FISH L
DUNN	TAINTER L		MORRISON	PELKEY L
BARRON	BIG MOON L		MARQUETTE	GREENWOOD RES
BARRON	LOWER TURTLE L		FOREST	SILVER L
BARRON	UPPER TURTLE L		PINE	STANTON L
BARRON	BEAVER DAM L		PINE	CROSS L
BARRON	BEAVER DAM L		BARAGA	BEAUFORT L
BARRON	LOWER VERMILLION L		BARAGA	KING L
PRICE	DUROY L		ONEIDA	CLEAR L
ST CROIX	CEDAR L		ONEIDA	L JULIA (RHINELANDER)

Wetlands

Wetlands at risk from an oil pipeline explosion total 145,457 acres in the Ceded Territories. Wetlands at risk from a natural gas transmission line explosion total 630,265 acres in the Ceded Territories and of those, 187,029 acres are within the high consequence hazard zone. Combined crude oil and natural gas impact area for the Ceded Territories contains 92,297 individual wetlands covering 675,047 acres. In the Wisconsin portion of the ceded territories, there are 7,258 small wetlands within the crude oil explosion hazard zone and 27,584 small wetlands within the natural gas explosion hazard zone. Wetlands at risk of impacts due to explosion are summarized in Table 3.1.15 and in the explosion mapbook. These small wetlands do not have acreage information in the Wisconsin Wetland Inventory. Table 3.1.15 also contains additional breakdown of acres of wetlands at risk from pipeline explosions within National Forests and Tribal Reservations.

Table 3.1.15 - Number of wetlands that are located within the explosion hazard areas of crude oil and natural gas pipelines.

Wetlands At Risk from Pipeline Explosions								
	Crude Oil		**Natural Gas**				**Combined Risk Zones**	
			Evacuation Zone		**High Consequence Zone**			
	Wetlands	**Acres**	**Wetlands**	**Acres**	**Wetlands**	**Acres**	**Wetlands**	**Acres**
Ceded Territory	12,340	145,457	85,076	630,265	33,474	187,029	92,297	675,047
Fond Du Lac Reservation	442	4,725	923	8,366	379	2,409	973	9,004
Bad River Reservation	395	2,434	817	4,695	385	1,804	862	4,822
St. Croix Reservation	0	0	17	91	3	24	17	91
Keweenaw Bay Indian Community	0	0	27	312	14	124	27	312
Lac Courte Oreilles Reservation	61	279	0	0	0	0	61	279
Chequamegon - Nicolet National Forest	25	38	1,168	8,403	423	2,287	1,191	8,438
Ottawa National Forest	629	12,012	1,472	23,875	550	6,821	1,558	24,505
Hiawatha National Forest	287	129,648	723	37,937	357	10,056	827	39,679
Huron - Manistee National Forest	0	0	1,758	9,412	701	2,586	1,758	9,412
Superior National Forest	0	0	156	1,016	60	207	156	1,024

Risk Associated with the Enbridge Line 5 Crude Oil Pipeline

This section describes the environmental risks of Line 5. This analysis scale is appropriate given the unique geographic setting of this pipeline compared to the other pipelines in the ceded territories. This focus is also necessary because of the need to evaluate risk of this line as part of the permitting of existing and new line segments.

The 454 miles of Line 5 account for 36% of all crude oil pipeline miles in the ceded territories. It is also the only pipeline that does not share the right-of-way with other crude oil pipelines. Line 5's isolation means that it is solely responsible for a large percentage of the risk to natural resources from future oil spills. These include:

- 65% of all Ceded Territory acres that are at risk of oiling and explosion impacts.
- 82% of all Ceded Territory inland lakes that are at risk of oiling and explosion impacts.
- 52% of all Ceded Territory river miles that are at risk of oiling and explosion impacts.
- 70% of all Ceded Territory wetland acres that are at risk of oiling and explosion impacts.

Another way of describing this risk is to say that if Line 5 was to be decommissioned, the environmental risk to the ceded territories from crude oil pipeline spills and explosions would be reduced by the percentages listed above. Natural resources at risk are detailed in table.

Line 5 also has risks that are almost completely absent for the other pipelines in the Ceded Territories. Line 5 is the only crude oil pipeline in the ceded territories that crosses National Forest lands. If Line 5 was to be decommissioned, there would no longer be any risk of oiling or explosion to the lands and waters located within the Chequamegon-Nicolet, Ottawa, and Hiawatha National Forests. Line 5 is also the pipeline that presents the greatest risk to the Great Lakes. Line 5 is located entirely within the Great Lakes watershed and there are areas where oil spilled from this pipeline could flow into Lake Superior, Lake Michigan and/or Lake Huron through tributaries that have no flow interruptions such as lakes or dams (figures 3.1.12 and 3.1.13). A report from the Great Lakes Commission characterizes the risk of crude oil spills from Line 5 to shorelines of Lake Superior (Marty and Nicol, 2017). The project developed an environmental sensitivity index which combines data on physical, biological and human environments. This index is then spatially overlayed with oil transportation infrastructure in a GIS. The results are maps of environmental sensitivity to oil spilled from the different conveyance methods, including the Line 5 pipeline. Data from this study are also mapped in figures 3.1.12 and 3.1.13.

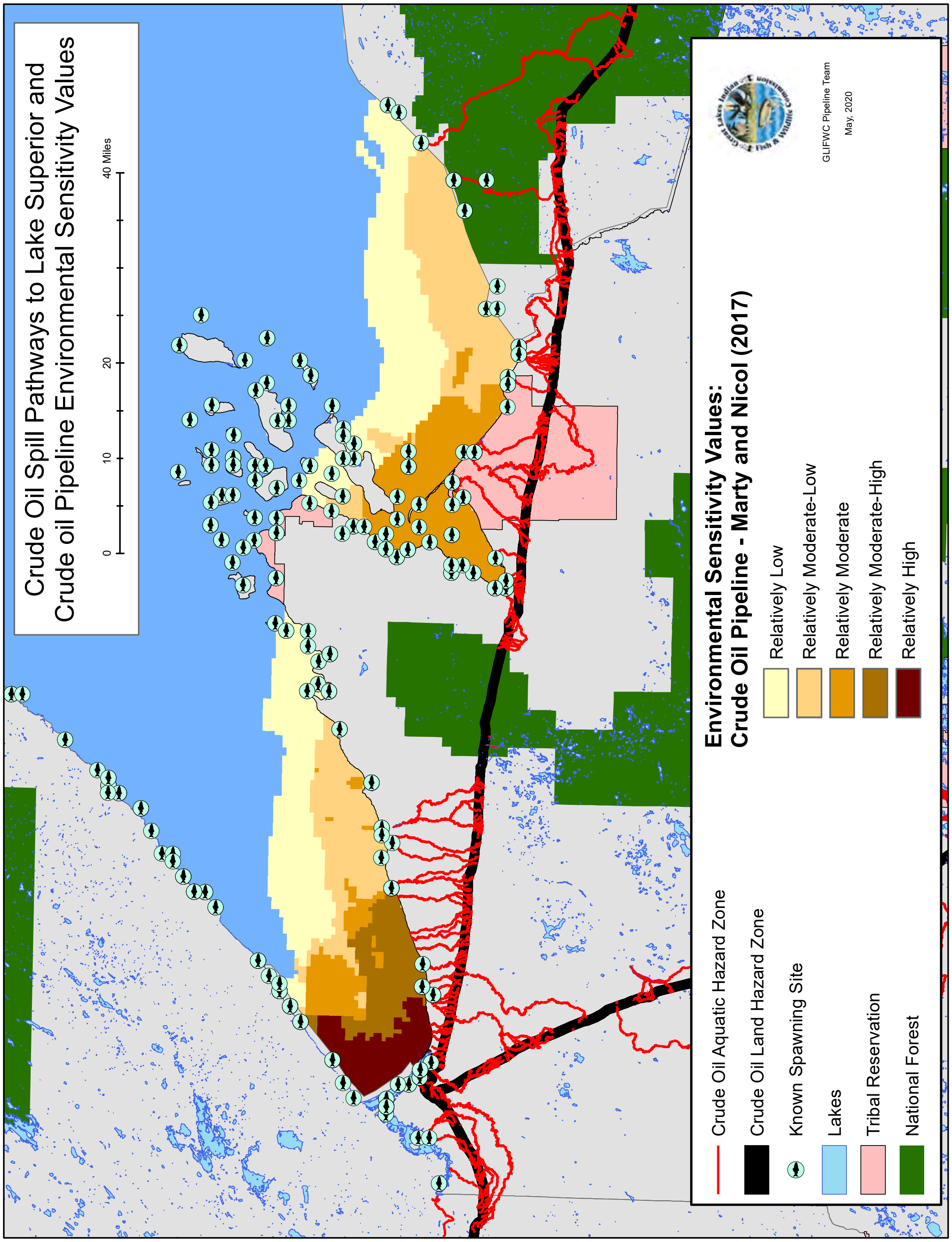

Figure 3.1.12 - Crude oil spill pathways from Line 5 to Lake Superior.

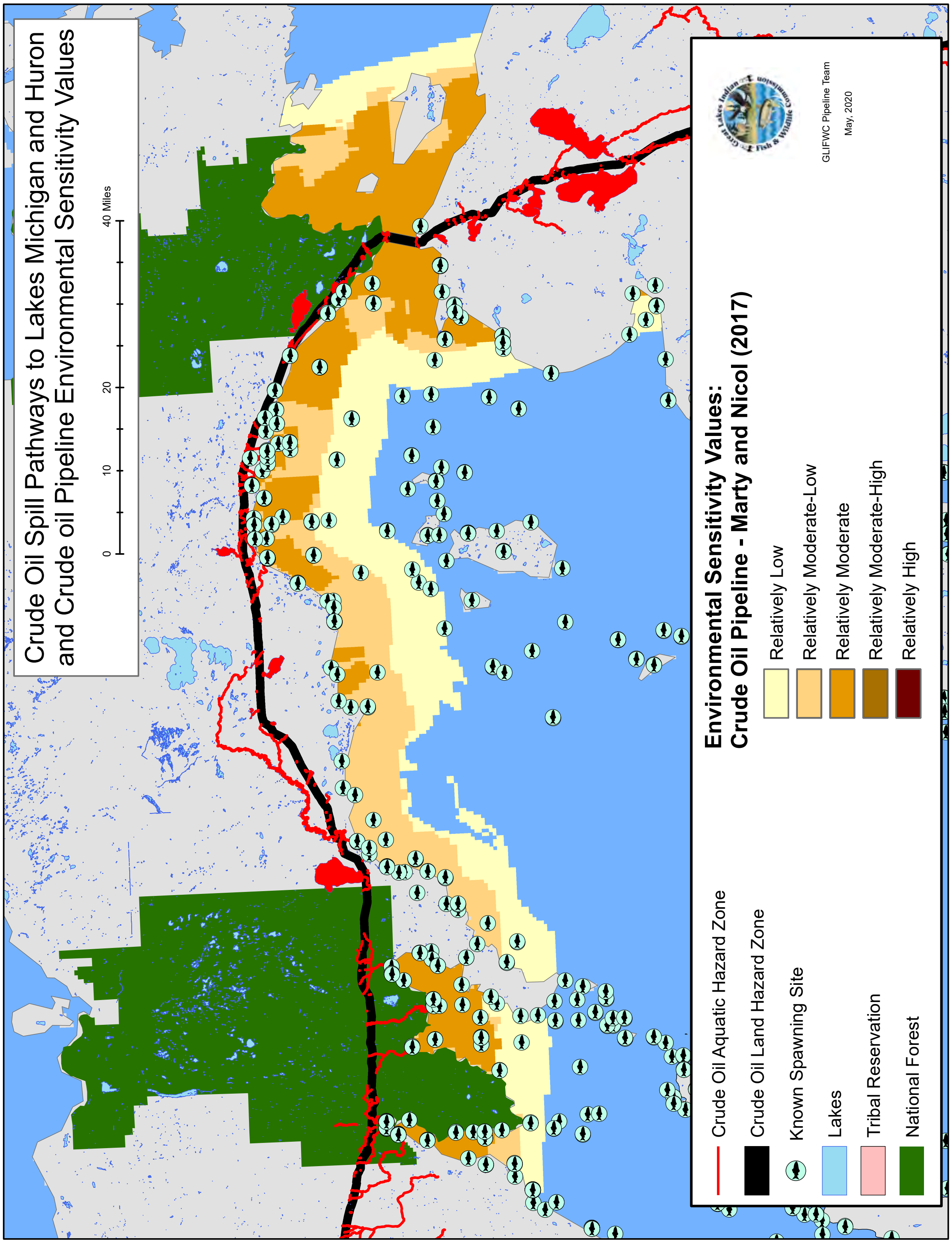

Figure 3.1.13 - Crude oil spill pathways from Line 5 to Lakes Michigan and Huron.

The analysis conducted by Marty and Nicol (2017) indicates that some of the most environmentally sensitive areas of the south shore of Lake Superior are also some of the most vulnerable to pipeline oil spills. This includes Chequamegon Bay which could be impacted by a spill occurring within the administrative boundaries of the Chequamegon Nicolet National Forest. The entire report is available in Appendix 3.1-C.

Of all the areas at risk of oiling from a Line 5 spill, the potential impacts of an oil spill at the Straits of Mackinac is the only area that has been well studied. Modeling done at the University of Michigan Water Science center indicates that over 700 miles of Great Lakes shoreline could be impacted by a Line 5 spill with devastating effects to tribal, commercial and recreational fishing, as well as long term damage to tourism in the area (Figure 3.1.14)(Schwab, 2016). Modeling of oil spill impacts is not available for other areas at risk in Lakes Superior and Michigan.

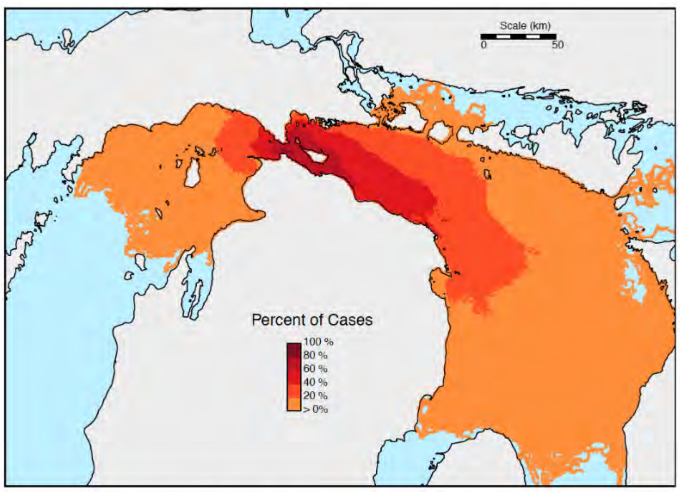

Figure 12. Percent of cases in which oil is present at *any* time after initial release.

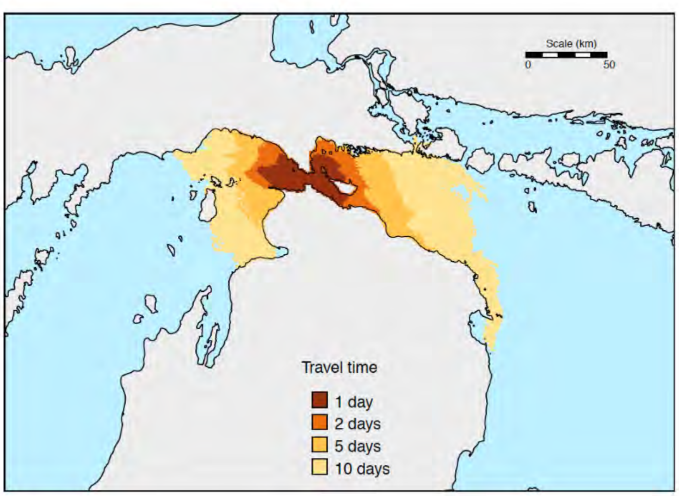

Figure 13. Minimum travel time (up to 10 days) to a location from *any* case.

Figure 3.1.14 - Modeled extent of oiling from a spill at the Straights of Mackinac section of Line 5 (Schwab, 2016).

In addition to ecological impacts to Lake Superior, an oil spill in the sensitive areas identified above could be catastrophic to the tribal commercial fishery. This treaty guaranteed fishing activity is not only central to the cultural identity of tribes but also a critical economic activity and source of income for the Great Lakes area in general. Figures 3.1.15 - 3.1.19 show the tribal harvest data for areas of the Great Lakes in the ceded territories that could be impacted by a Line 5 oil spill. The data clearly indicate a substantial risk to tribal fishing. Additional work would be needed to fully account for the economic consequences of a spill to tribes as well as losses to the regional economy.

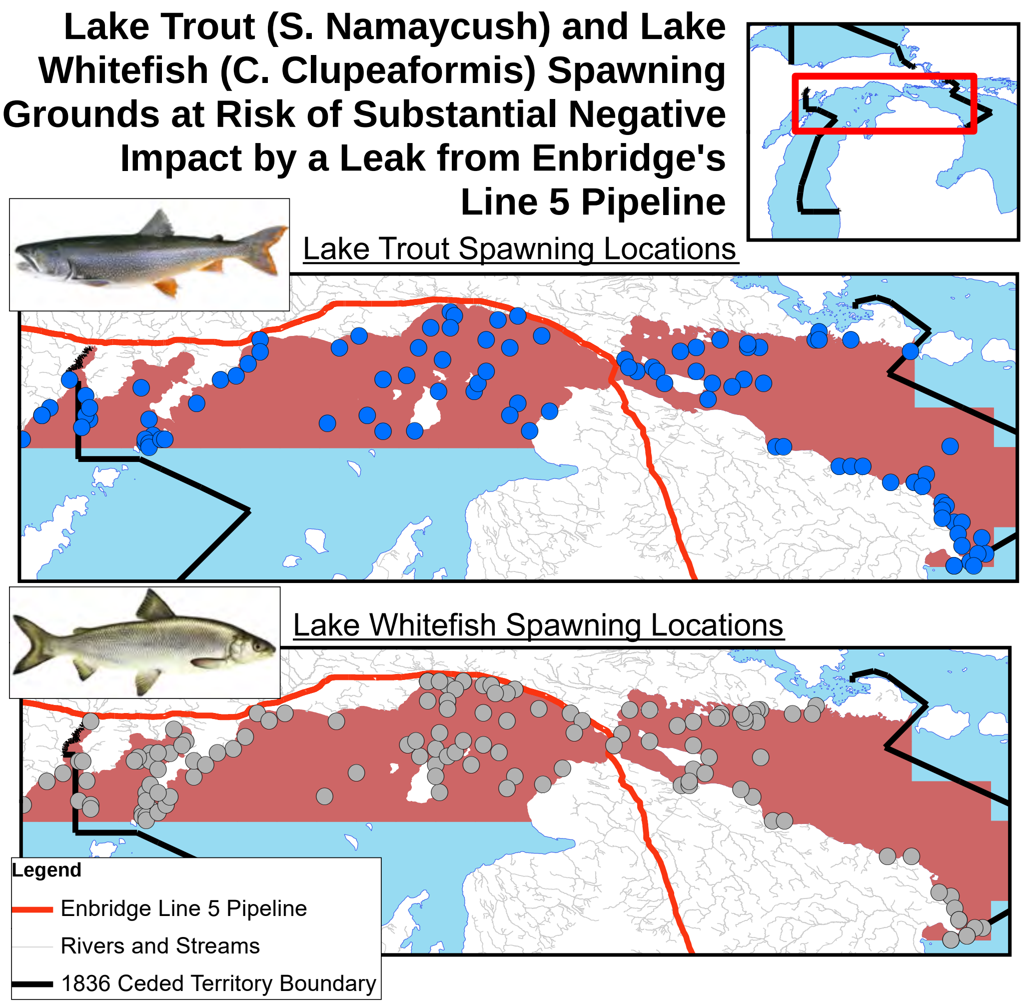

Figure 3.1.15 - Known spawning locations for lake trout and whitefish potentially impacted by a Line 5 crude oil spill at the Straights of Mackinac (Kevin Donner, Little Traverse Band of Odawa Indians, Personal Communication).

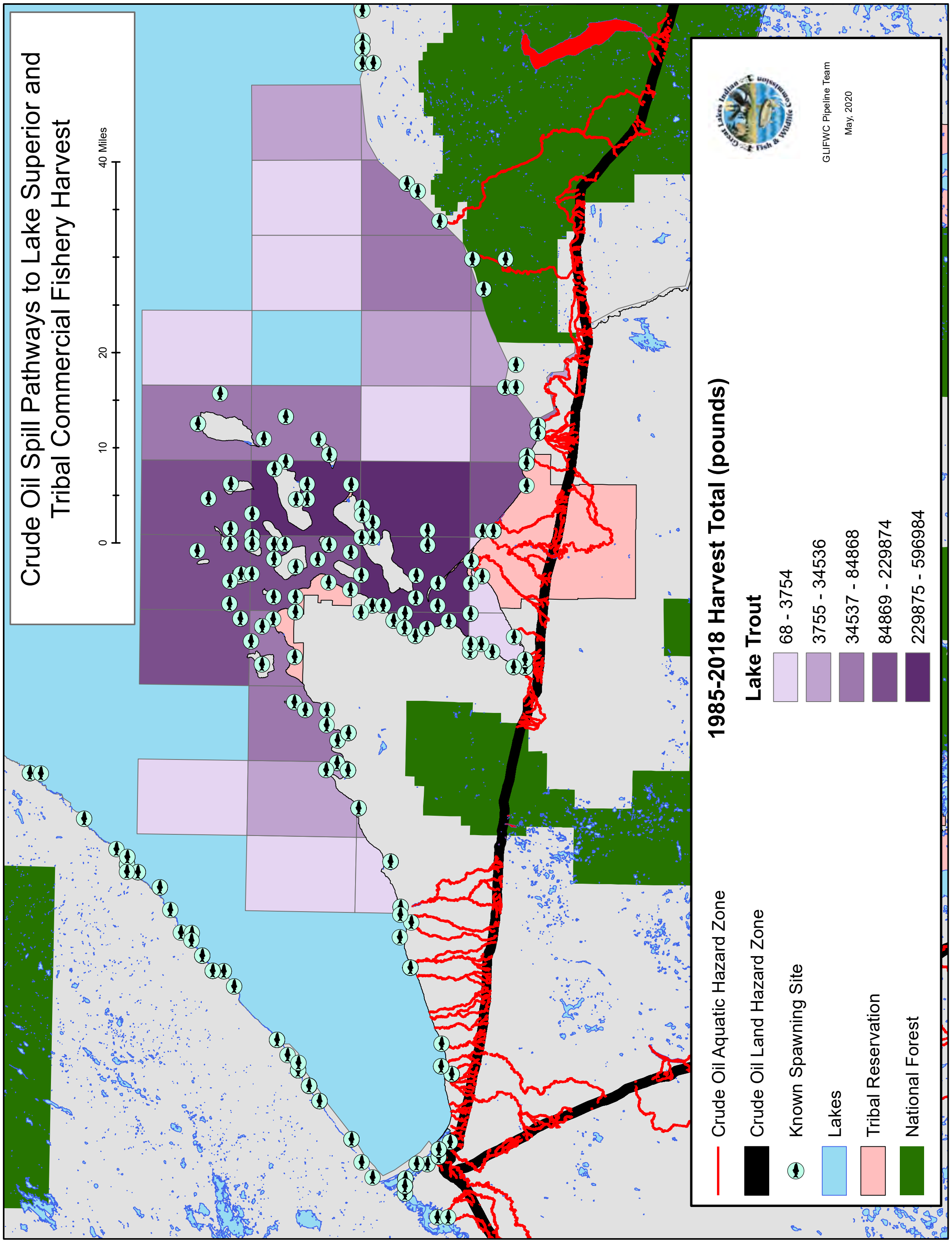

Figure 3.1.16 - Crude oil spill pathways from Line 5 to Lake Superior and potential impacts to known spawning sites and tribal commercial fishing for lake trout.

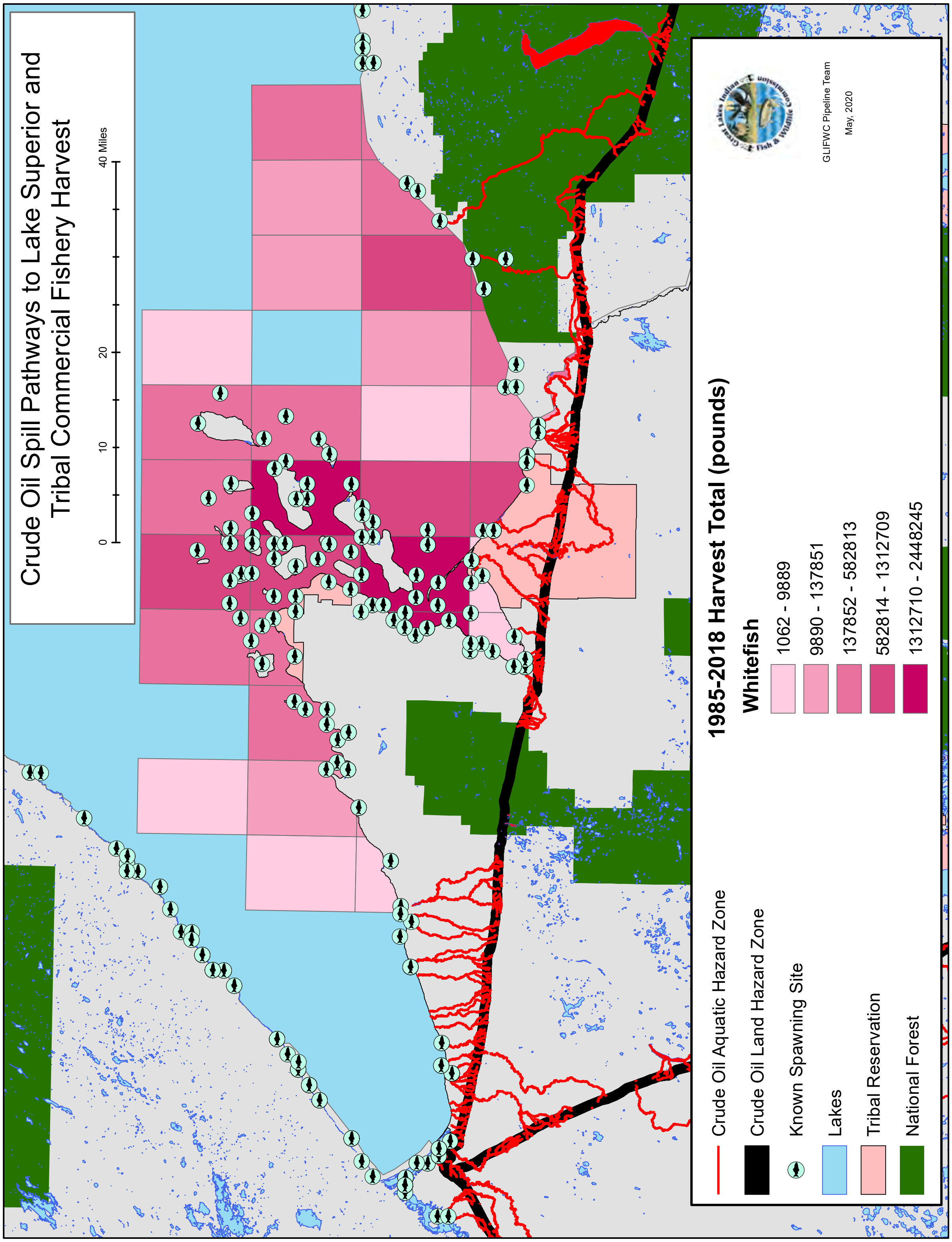

Figure 3.1.17 - Crude oil spill pathways from Line 5 to Lake Superior and potential impacts to known spawning sites and tribal commercial fishing for whitefish.

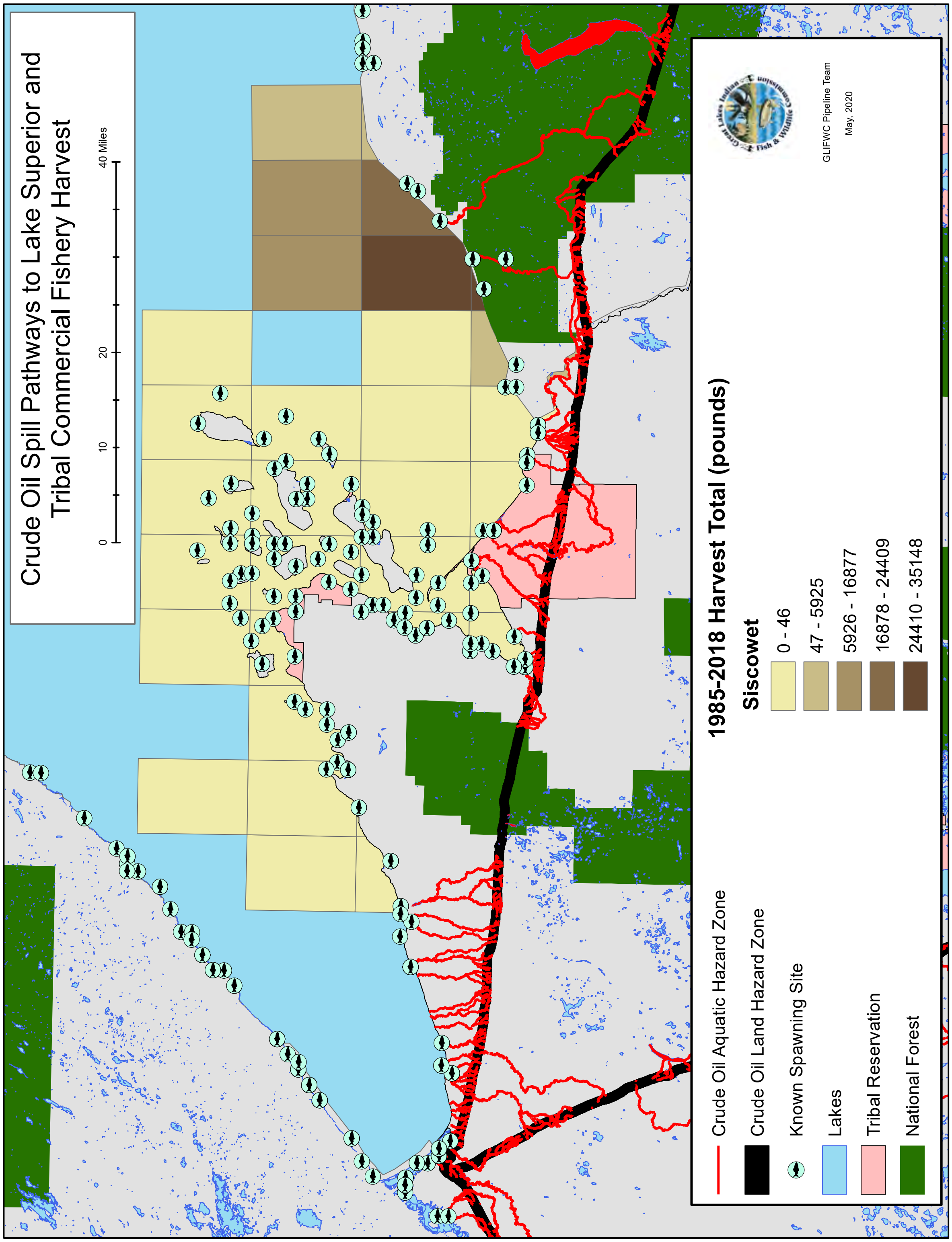

Figure 3.1.18 - Crude oil spill pathways from Line 5 to Lake Superior and potential impacts to known spawning sites and tribal commercial fishing for siscowet.

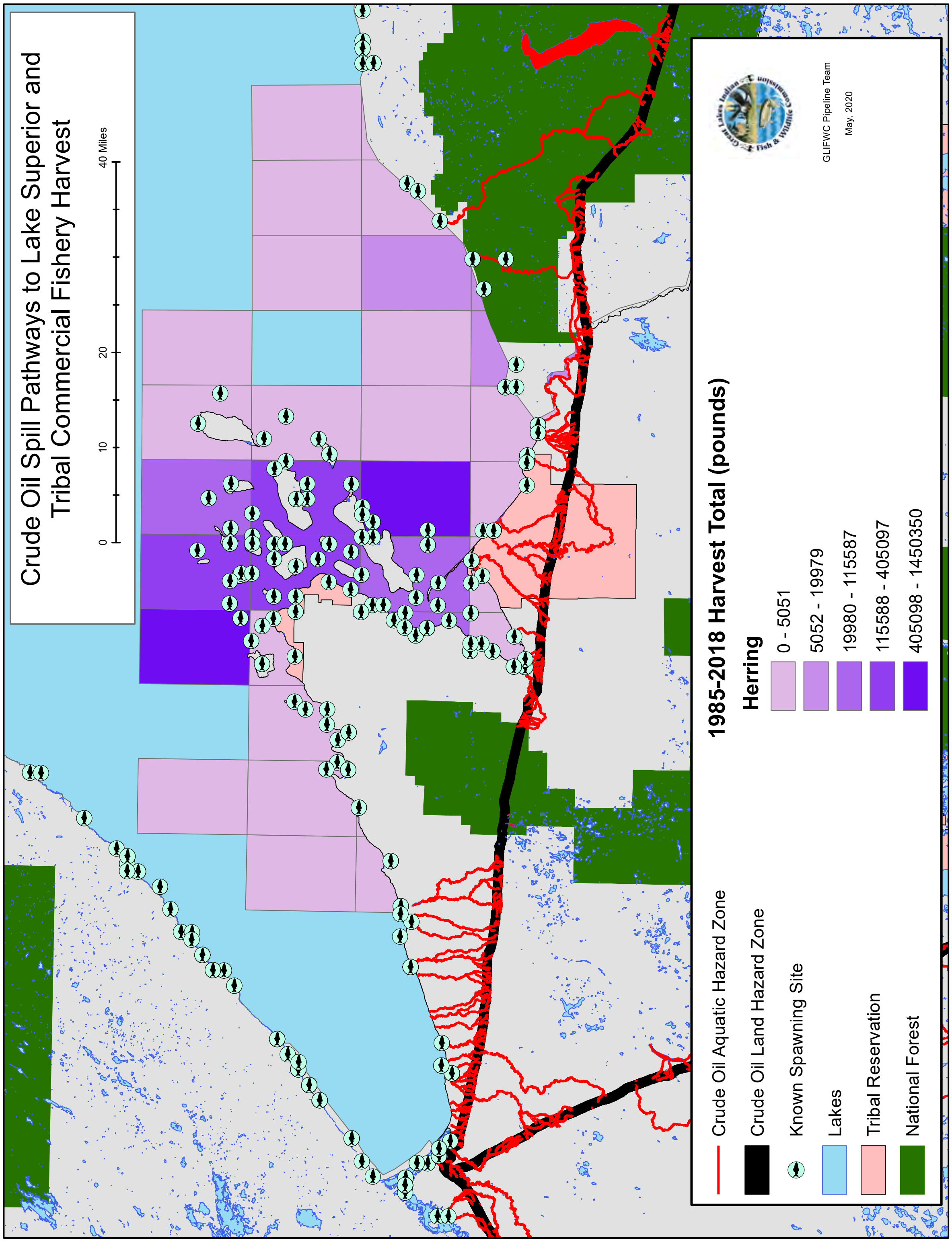

Figure 3.1.19 - Crude oil spill pathways from Line 5 to Lake Superior and potential impacts to known spawning sites and tribal commercial fishing for herring.

Conclusion

This report presents a step towards understanding the risk of crude oil and natural gas pipelines to the ecological integrity of the Ceded Territories. The analysis is based on accepted published methods and defines hazard zones, those areas in the ceded territories that could be impacted by crude oil spills and explosions. Further characterization is made by identifying areas of known tribal natural resource harvest activity and areas of known environmental importance. Mapbooks provide a visualization of potential areas of impact shown overlain with identified areas of resource harvest and/or of particular ecological significance.

The identification of these important resources provides context to the risk of a pipeline failure and is critical to GLIFWC's role in protecting habitats that are necessary for treaty protected natural resource harvests. This information is also important for state and federal agency permitting decisions related to existing and new pipelines in the region. Line 5 does not exist in a vacuum; it is part of a larger pipeline network that has consequences for the whole region, including three Great Lakes, hundreds of inland lakes, hundreds of miles of rivers and streams, and thousands of acres of wetlands.

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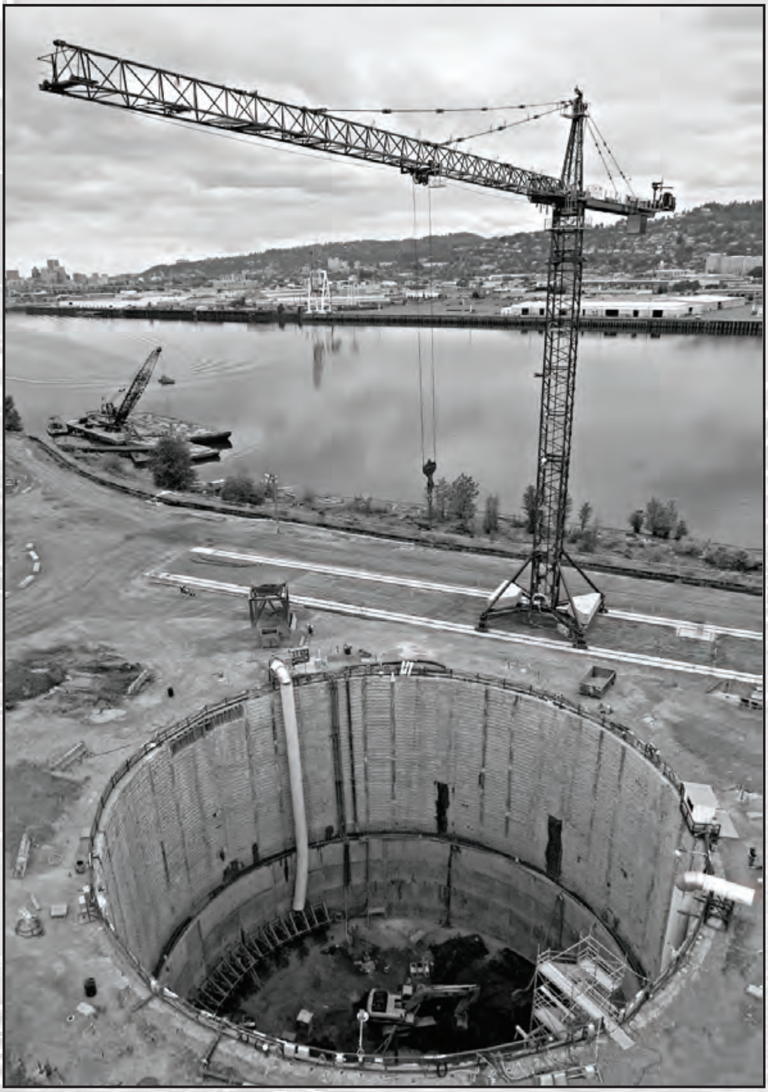
Attachment F

Tunneling Beneath Open Water

A Practical Guide for Risk Management and Site Investigations



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FOREWORD

In 2008, the distribution of the world's population was, for the first time in history, evenly split between urban and rural areas. The rapid urbanization of our population worldwide shows no sign of letting up and places high demands on the infrastructure needed to support this population shift. At the same time, the influx of citizenry to our urban centers is placing significant demands on the civil engineer and often results in projects looking underground for development, as surface real estate becomes increasingly dense.

The tunneling industry worldwide has largely risen to the occasion of population growth through the use of modern tunnel boring machines (TBMs) that are capable of building tunnels at ever greater widths and depths, and in increasingly challenging geologic conditions. For example, the Alaska Way Tunnel in downtown Seattle is anticipated to exceed 50 feet in diameter and will effectively provide a four-lane highway underground in a single pass excavation below Seattle's downtown core. Technological advancements such as large diameter TBMs are allowing engineers to expand our infrastructure into areas that may not have been as attractive, or even feasible. This is particularly true for large tunnels that extend below open water. Examples include the Nanjing tunnels beneath the Yangtze River in China, the Eiksund Tunnel in Norway, and the Port of Miami Tunnel in the US. These tunnels have all capitalized on recent advances in tunneling technology to deliver cost effective solutions to growing infrastructure needs.

Unfortunately for the tunnel engineer, the rapid rise in technology places a great demand on characterization of the ground and assessing the impacts that geotechnical risks can have on a project, particularly when the project extends below open water. There have been relatively few tunnels constructed below large bodies of water and these projects generally carry additional risks that can have severe consequences. The initial drive for the Storebaelt Tunnel in Denmark, for example, was abandoned due to difficult ground conditions, problems with TBM operation, and lack of access above the tunnel. The resulting delay to the project was nine months.

This monograph is dedicated exclusively to tunneling beneath open water and is intended to serve as a guide for tunnel engineers and project managers who are tasked with designing these difficult projects. It provides an overview of some of the risks and challenges facing these projects and discusses historical case studies that provide key lessons learned from previous experience. It also presents guidelines for planning, design, and construction of open water tunnels as they relate to current practice, including detailed discussions on site investigations and management of geotechnical risks.

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1.0 INTRODUCTION

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"Of all engineering work that which is least certain is driving tunnels under rivers or other bodies of water. Usually the tunnel must be driven in clay or river silt or sand and gravel with more or less loose rock and boulders. The trouble is to keep a tight roof and if the material is very soft to keep the tunnel itself in shape."

- Colonel H.G. Prout, American Civil Engineer, 1898

In densely-developed or other highly-valued areas, tunnels can often provide the best solution to infrastructure problems, carrying vehicles and materials along a direct path with minimal impacts to the natural and social environment above. Unfortunately, while technological advances over the past century and a half have made tunneling under open water cheaper, faster, and vastly safer, the risks and unknowns inherent in tunneling can drive up potential costs, limiting the ability of tunnels to provide cost-effective solutions to today's infrastructure needs.

As tunnel designers, we exert significant effort to characterize the nature of the ground so that the assumptions and judgments behind our engineering and constructability analyses represent the most probable, or sometimes most conservative, approximation of what will actually be encountered during construction. This is no simple task, even for the smallest of tunnel projects. Complicating matters is the seemingly litigious nature of the construction industry, where "unknowns" and unanticipated or differing site conditions can rapidly escalate costs when contractors are not prepared for them, and when mechanisms are not provided in the contract to fairly compensate the parties that are impacted.

As Colonel H. G. Prout wisely observes above, tunnels beneath rivers or other bodies of water are no strangers to uncertainty. In fact, these tunnels often carry much greater risk given both the nature of the ground encountered beneath open water and the extreme, hard-to-reach working environment.

1.1 NEED FOR RESEARCH AND INDUSTRY GUIDELINES

In open water tunnels, great demands are made of the tunnel engineer to predict the ground conditions accurately and to design the tunnel to allow for adjustments to respond to changing conditions, such as encountering boulders nested in a stratum of soft soil or worse yet, a buried man-made obstruction at the bottom of a river channel that can halt the progress of excavation. The uncertainties and risks inherent in tunneling beneath open water have changed little over the last 100 years. However, there is considerable opportunity for advancing the existing knowledge base used to guide planning, design and construction of this relatively high-risk infrastructure. Currently, the impacts of uncertainty and risks on tunnels extending beneath an open body of water are not well documented and often this knowledge is possessed only by those few with direct experience with these types of tunnels. It is not surprising that no manual or formal set of guidelines exists; one that summarizes and addresses the challenges and risks specific to tunnels beneath open water.

This monograph was developed to serve as a state-of-the-art survey of open water tunnels. It summarizes our historical experience with an overview of select high-risk open water tunnel projects, and discusses the specific geotechnical risks that these tunnel projects can encounter. Key technical considerations for design and construction are outlined, with specific emphasis on site investigations and risk management techniques. Without a working knowledge of the ground through which a tunnel will be excavated, and a structured plan for how risks will be managed, much of our engineering work might be a wasted effort, or could even result in dangerous conditions.

1.2 HISTORICAL BACKGROUND

Tunnels have been constructed beneath open water for over 150 years; the earliest and most well known being the Thames River Tunnel constructed in 1843 in London, UK. At the time, no tunnel design guide or construction manual existed for the designer or construction engineer. Common sense, experience, innovation, and sometimes just plain luck were the only tools available to guide the project to completion, as engineers developed new ways to meet the fundamental challenge of maintaining a safe and viable working space below the ground. The keys to a successful tunneling operation below open water, then, as now, remain:

- Limiting the face opening to a size that can be excavated
- Supporting the ground as quickly as possible without compromising the safety of the workers
- Minimizing the impact of ground support installation on the efficiency or productivity of the excavation

In today's age of automation and mechanical excavation, the risk of failures similar to those experienced on the Thames River Tunnel (and other historic open water tunnels) have been substantially reduced. However, these advances in tunneling technology have not reduced the need for engineers to properly characterize ground conditions during design in order to select a construction method that can respond to the full range of anticipated ground conditions. The need to properly investigate, characterize and define the subsurface conditions has increased significantly, particularly with advancing technology and in today's competitive tunneling market.

1.3 MONOGRAPH ORGANIZATION

This document is organized to provide the reader with an understanding of the historical challenges for open water tunnels, and from these experiences to expand into relevant planning, design, and construction considerations for modern open water tunnels. Chapter 2 provides background on tunneling techniques and terms, while Chapter 3 provides a brief summary of historical experience with open water tunnels, highlighting several high-profile examples, some over 150 years old. From this review, key risks and challenges are identified, which are then expanded upon in following chapters.

Chapters 4, 5 and 6 provide an in-depth evaluation of risks and challenges common to the planning, design, and excavation/construction phases of open water tunnels as they relate to current design and construction practices.

In addition to identifying risks, this monograph details mitigation measures. Chapter 7 discusses the most essential component of an open water tunnel project, the site investigation. This chapter provides an overview of commonly used site investigation techniques, as well as more infrequently used and “exotic” methods of exploration, presenting the reader with a wide variety of tools to consider when exploring the subsurface. Since no amount of exploration can reveal the actual ground conditions along a tunnel alignment (save, perhaps, a pilot tunnel), Chapter 8 focuses on managing the unknown through commonly used risk assessment and risk management techniques that are uniquely appropriate for open water tunnels.

2.0 TUNNELS UNDER OPEN WATER DEFINED

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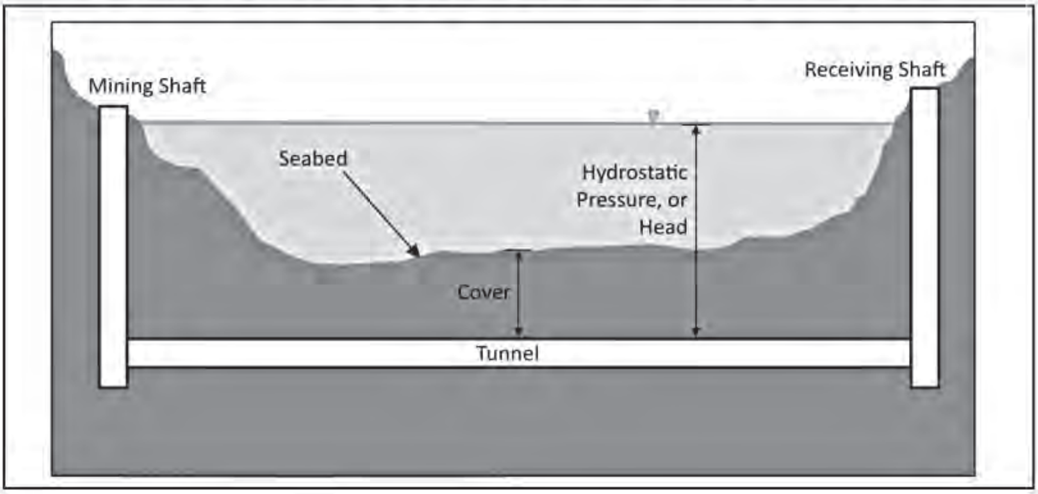
In this monograph, the phrase "open water tunnel" is used to describe any tunnel that extends below a body of water, and also below the seabed, or riverbed, etc. (Figure 1). Open water tunnels are constructed from within the ground as opposed to being sunk into place from the top of the waterbody, such as for immersed tube tunnels. Immersed tube tunnels, and other methods of in-water tunnel construction, were not considered as part of the research for this study. Primary risks for these types of tunnels are uniquely different than for open water tunnels, since many of the constraints and risks are independent of the ground conditions. By the nature of their construction, open water tunnels are exposed to much greater risk since the ground is the most critical and difficult component of the project to plan for.

Figure 1. Profile of a Typical Tunnel Beneath Open Water

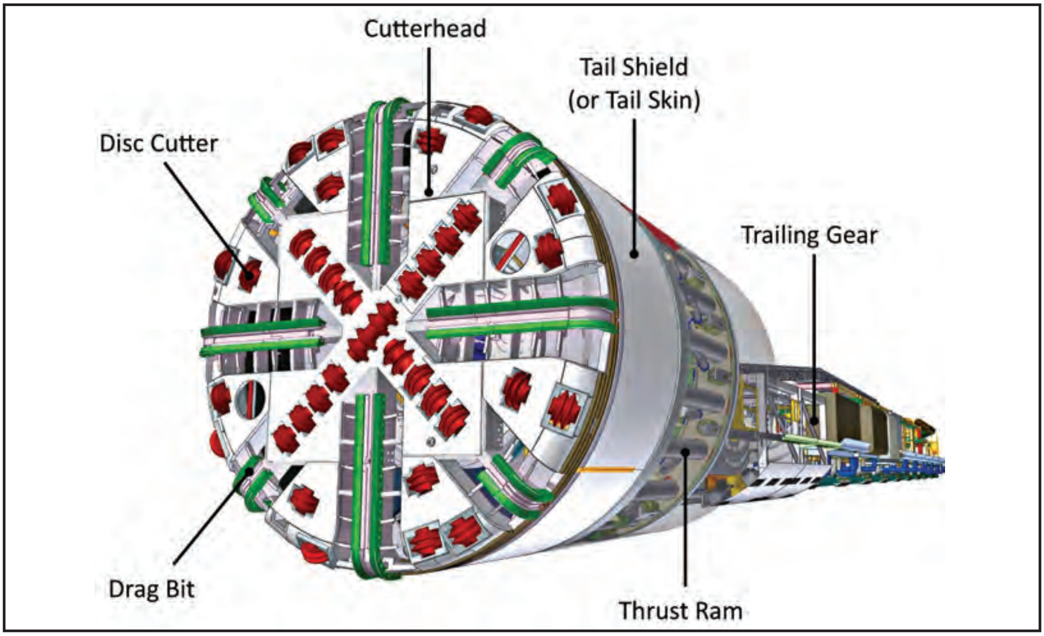


2.1 CONSTRUCTION TECHNIQUES

Primary construction techniques for open water tunnels are by tunnel boring machine (TBM) or by "conventional" drill-and-blast. Both of these techniques have advantages and disadvantages specific to open water tunneling, but most importantly their selection must carefully consider the anticipated geologic conditions to be encountered below the water body. This is not a simple engineering task and often can present a significant challenge to even the most experienced tunneling professional.

TBMs are often considered for open water tunnels due to their industrialized and often efficient excavation and mucking (spoil removal) capabilities. TBMs are circular machines that excavate the ground by mechanical means, typically with picks, teeth, and/or cutting discs (Figure 2). The ground is excavated by rotation of a cutterhead and the pressure applied to the cutting tools. The types of TBMs range from gripper-type TBMs (for hard rock excavation) to confinement-type TBMs (earth pressure balance and mix-shield TBMs for soft ground excavation). Additional details regarding the various types of TBMs are discussed in Chapter 6.

Figure 2. Schematic of a Tunnel Boring Machine (TBM)



TBMs perform the following functional activities: boring (or cutting), thrusting, mucking, and installation of ground support (the tunnel lining), all within the enclosure of the machine. Steering and alignment control is contained within the machine and adjustments to the tunnel alignment can be made with gripper “shoes” or jacks mounted on the main support beam of the TBM or by adjusting the force applied at the thrust rams against the installed tunnel lining.

TBMs can be either open-air or pressurized, the later using slurry or excavated soil to ensure that water and loose ground does not enter the TBM in an uncontrolled manner. Although great efficiency and control can be realized with a TBM excavation, one significant drawback is the limited access to the ground, which in the case of unstable ground can be a significant drawback.

Alternatively, tunnels can also be constructed by drill-and-blast or roadheader excavation. Drill-and-blast excavation uses a drilling jumbo, or platform, to install a predetermined pattern of holes into the excavation face. The drill holes are filled with explosives and subsequently detonated to break apart the rock. The broken rock is then excavated with a wheel loader or other mechanical mucker. Roadheaders are mechanical boom-type excavators that have a rotating cutting head with mucking provided at the base of the machine (Figure 3).

Figure 3. Photo of a Roadheader

Since the capital cost of a TBM is typically high, they are usually selected for larger projects where the tunnel is long, and the benefits of increased productivity can be realized. Therefore, drill-and-blast and roadheader excavation is often employed for short tunnels in rock where the expense of a TBM cannot be justified. Drill-and-blast is also commonly selected for excavation where difficult geologic conditions are anticipated, such as fault zones or other areas of rock weaknesses that may hinder the advancement of a TBM.

3.0 HISTORY OF OPEN WATER TUNNELING

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"The water above our heads looses the silts and sands and runs out, leaving cavities that causes the clay above to break and run down in lumps. This is very awful! This opens the way for the river."

- Marc Isambard Brunel, May 10, 1827
(Chief Engineer of the Thames River Tunnel, London)

Judging from Brunel's early experience with tunneling beneath the Thames River, it is no coincidence that early open water tunnels led to the development of the first shield-driven TBMs. The unstable behavior of submerged soils under free-air excavation required engineers to develop techniques to control the ground they were excavating.

This chapter looks briefly at select case histories from several tunnels constructed beneath open water. The case histories have been selected from two time periods; the first representing the early open water tunnels built in the 1800s up to before the invention of the modern shielded tunnel boring machine (TBM), and the second representing modern experience and encompassing one of the longest tunnels constructed beneath open water – the Channel Tunnel linking England and France. It is important that we gain an appreciation of the challenges encountered in these open water tunnel construction projects, as they are certain to be encountered again.

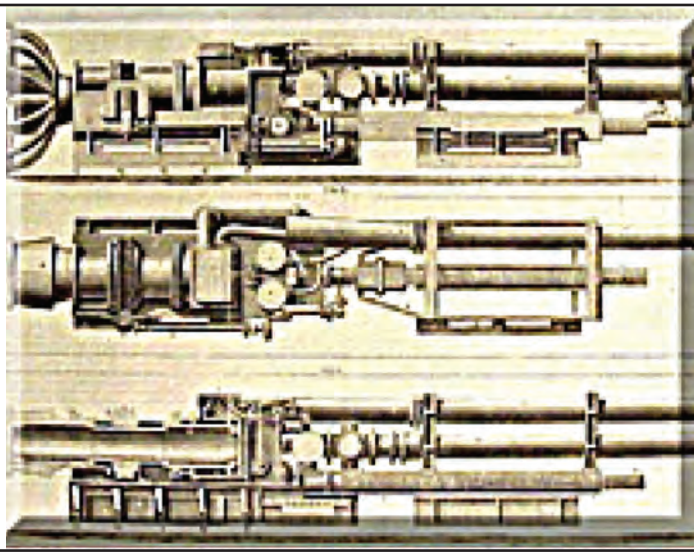
3.1 DEVELOPMENT OF EARLY SHIELD-DRIVEN TUNNELS AND THE USE OF COMPRESSED AIR

Prior to the development of the modern shielded TBM, tunnels beneath open water were constructed (or were attempted) in free air, without any attempt at pressurizing the air to prevent a tunnel breach. The success of these efforts depended on the geologic conditions and the ability of the workers to control groundwater entering the excavation. It was common for early tunnels to be abandoned after the first or second attempt due to the inability of the workers to control the ground and/or groundwater entering the excavation. With limited tools available to adapt to changing ground conditions, a project's success was highly dependent upon the nature of the ground.

The first significant tunnel crossing built under open water is the Thames River Tunnel in London, which was constructed between 1825 and 1843. Previous attempts at this underground river crossing were made between 1799 and 1809 using hand mining techniques, which at the time consisted of manual excavation using hand tools (picks, shovels, etc.). Unfortunately, engineers did not account for the unstable nature of water bearing soils. Or, as it is believed by some, the English miners were accustomed to mining in hard rock and simply weren't able to adapt their excavation techniques to account for the unstable soils beneath the river. Regardless, the early attempts at the crossing were doomed to fail since there was no technology available to control the unstable running sands and gravels which entered the excavation uncontrollably due to groundwater inflow, easily causing the excavation to collapse. After several attempts and subsequent failures, Marc Brunel devised a shield for providing stability at the tunnel heading. Although ultimately successful, Brunel's shield also encountered its share of failures. Unfortunately, the project's delays and the shield's multiple failures, including four or five breeches by the river, prevented this new technology from gaining acceptance on other contemporary tunnel projects.

Advances in Brunel's pioneering tunneling technology continued after the Thames River Tunnel. In 1856 and 1876, Herbert N. Penrice registered his first patents for a rock tunneling machine. Before Penrice, machinery had never been employed for horizontal tunneling and all excavation work was performed by manual labor. Penrice's "TBM" (Figure 4) had multiple pneumatic steel chisels mounted on a platform (called a "cutter holder"). The chisels were attached to the piston of a steam engine and were actuated by means of a valve that opened and shut rapidly. The cutter holder could be driven forward by means of a screw that was also powered by the steam engine, allowing several small diameter holes to be advanced into the rock simultaneously. After the holes were cut they were loaded with explosives and the rock face was removed by blasting.

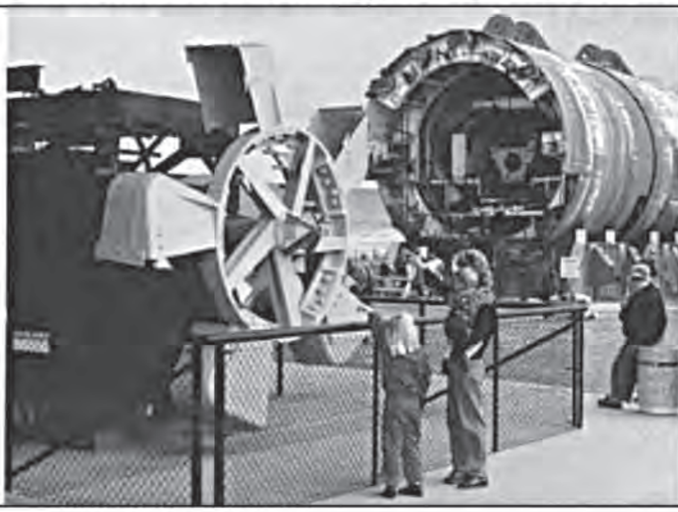
Figure 4. Herbert N. Penrice's Rock Tunneling Machine



Further advances were made towards the end of the 19th century for tunneling shields designed to work in softer ground. The Hay/Cochrane hooded shield machine was arguably one of the most innovative of its time. This machine used pocket holes for excavation and permitted mining in granular soils that would have been difficult if not entirely impossible with the modern shields of the day. The pocket hole method involved advancing the hood of the shield into a circular groove (pocket hole) that was cut out by hand and filled with clay. The clay would then provide a seal between the shield and flowing sands and gravels which would be unstable if not supported (due to the presence of groundwater). This technique was very similar to the one employed for the Hudson and Manhattan Railroad Tunnel, discussed later in this section.

In the 20th century, use of electric motors and compressed air initiated several generations of machines that attempted to use a peripherally-driven cutting wheel, or cutterhead. The Whitaker machine employed electric power to turn its cutting wheel and was actually used to construct a 490-foot long trial tunnel for the proposed Channel Tunnel after World War I. This machine was unique in that it utilized blades mounted at the cutting wheel with large mucking buckets at the periphery, speeding up removal of excavated material from the face of the excavation. The consistency of the chalk marl that the tunnel penetrated, and absence of harder materials or inclusions, made for efficient mining. An average advance rate of 9.2 inches per day was achieved. The Channel Tunnel project was later abandoned due to political reasons, but the experience gained during the trial tunnel was important and laid the foundation for construction of the modern Channel Tunnel many decades later. The Whitaker machine was abandoned in place and recently it was "rescued" and refurbished for display at the 1992 Eurotunnel Exhibition in Cheriton, UK (Figure 5).

Figure 5. Whitaker Machine (left) and Modern TBM (right)



In the 1960s, James Robbins, founder of the Robbins Company, and F.K. Mittry developed one of the first successful full face rock TBMs for the Oahe Dam in South Dakota. The machine, named "Mittry's Mole" utilized a cutterhead very similar to modern-day cutterheads, including cutting wheels and picks. At its peak performance, the machine was able to bore up to 160 feet in 24 hours, which was 10 times faster than contemporary drills. One could argue that the birth of the modern day hard rock TBM began with this machine.

Development of soft ground tunneling technology also advanced in the 1960s with the London Underground extension. The TBMs used for sections of this project utilized new TBM technology and featured shielded machines with the capability to install the tunnel lining immediately behind the shield. The machines also utilized, for the first time, cutterheads that allowed spoils to be discharged through the center of the cutterhead and away from the machine. The technology at the time was so new that the owner of the project actually purchased and supplied the machines for the wary contractors.

Compressed air was employed for initial attempts at constructing the Hudson River Tunnel between New York and New Jersey in the US in 1879, after being used previously for sinking shafts and caissons. At the time, engineers believed that to maintain equilibrium within the excavation, air pressure in the excavation needed to be about equal to the hydraulic pressure outside the excavation. It would later be learned, largely through experience, that equilibrium could be maintained with less pressure. Also, compressed air sickness experienced by workers (from rapid decompression as they left the tunnel) was not well understood, and early compressed air work on the Hudson River Tunnel resulted in a death rate of 25 percent per year.

The first tunnel that was constructed using both these ideas – compressed air and a shield – would not be built until the City & South London Railway Tunnel in 1886. It was later employed to finish the Hudson River Tunnel which had been abandoned in 1885. The Hudson River Tunnel's completion was delayed until 1903 due to financial reasons, but a new invention used in the second attempt at the Hudson River Tunnel was the airlock, where workers could be decompressed slowly, thereby minimizing the risk of "the bends" (compressed air sickness). As a result of implementing the new technology, the tunnel was completed and only two men died out of a total of 120.

Specific open water tunnel projects are described below to give a better sense of the obstacles that inspired the development of these advances in tunneling technology.

Thames River Tunnel (London, 1827)

During the early 19th century, London was in need of a connection between the north and south sides of the Thames River (Figure 6). Bridges already existed and construction of additional bridges would have restricted ship passage. Several attempts were made at constructing an underground passage but failures forced engineers to believe that a route beneath the river was impossible.

Figure 6. Plan of the Thames River Tunnel

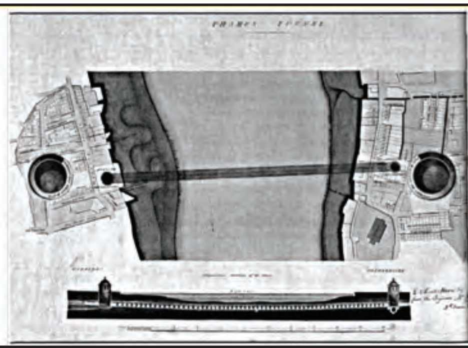


Figure 7. Model of Brunel's Shield

(Source: Vogel, 1963)

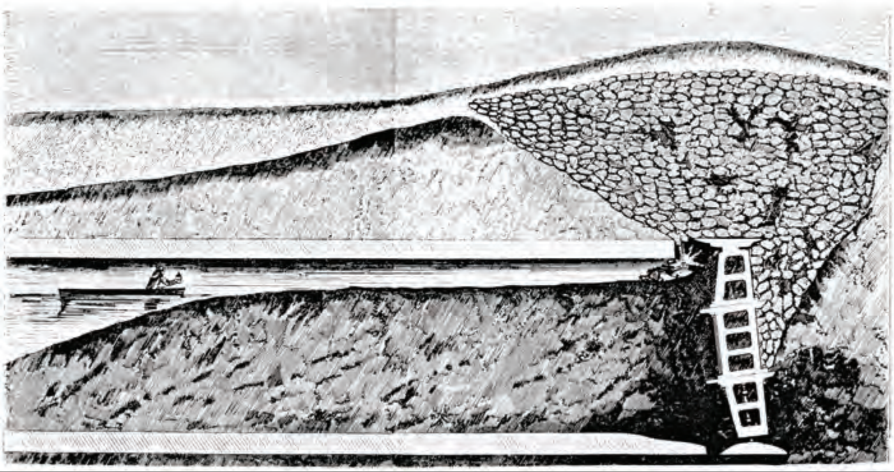
Marc Brunel developed a plan to construct the tunnel beneath the Thames with his newly patented shield method (Figure 7). The shield consisted of 12 frames and a total of 36 cells in which workmen could excavate. The innovative feature of the shield design was the presence of face "plates", which permitted ground support and allowed workers to execute more control of the excavation. The shield also permitted masons to work immediately behind the face of the excavation to install the brick tunnel lining, which would be key to keeping the ground stable and minimizing the risk of dangerous groundwater inflows.

After financing was secured for building the machine, soil conditions along the Thames were surveyed, indicating London clay was located within the bed of the river. Brunel decided he would align the tunnel to excavate in this favorable material since it was likely to be more stable. However, the alignment left as little as 14 feet of cover between the top of the tunnel and the bottom of the river at its closest approach.

Excavation began in 1825 with the sinking of the shaft at Rotherhithe and once the shield began excavating the tunnel, sand and gravel, rather than clay, was encountered. River water and groundwater, both highly polluted at the time, seeped into the excavation and workers regularly succumbed to illness. Progress was slow (8 to 12 feet per week) as the shield approached the river, but the excavation remained stable.

In May of 1827, the tunnel was breached during high tide. All workers managed to escape but it would take six months to clear the tunnel of debris and plug the newly formed connection with the river (Figure 8). Shortly after the repair, another breach occurred, this time killing several workers. Following the second breach, project financiers pulled the plug and the project was dormant for eight years. Work resumed after new financing was secured, but a new shield and the experience gained from previous failures still could not stop further flooding. Tunneling continued slowly and was continually hampered by leaks and poisonous gases. Finally, in 1842, the tunnel reached its destination, after a shaft was sunk in Wapping to receive the shield. The tunnel was opened to the public in 1843.

Figure 8. Plugging the Thames River Tunnel Breach



(Sketch indicates Brunel's shield, at right, after a breach and flooding. The shield has been "buried" with a soil plug above in an attempt to seal the leak so that the tunnel can be pumped dry and excavation can resume.)

Table 1. Thames River Tunnel Construction Details

Location	London, UK
Method	Shield
Construction Complete	1842
Duration	16 years[a]
Length	1,200 feet
Depth	75 feet[b]
Tunnel Size - Excavated	22 feet by 38 feet
Minimum Cover between Riverbed and Tunnel	14 feet
Geology	London Clay, alluvial sands and gravels
Cost	$987 million (USD)[c]

a. Includes delays due to flooding and project abandonment.
b. Depth below river level at high tide.
c. Adjusted for inflation (2010).

Hudson and Manhattan Railroad Tunnel (New York, 1873)

Rail commerce was booming in America in the 19th century and one of the largest ports in the western hemisphere at the time was located in New York City. Seven railroad companies carried passengers and freight in and out of the ports near New York City and the Hudson River was a significant obstacle for rail traffic into and out of the island of Manhattan.

A tunnel crossing beneath the Hudson River had been under consideration for some years. In 1873, the Hudson River Tunnel Company was incorporated with a capital investment of $10,000,000 ($250 million in 2010 dollars) and was charged with the task of constructing this important transportation link (Figure 9). The company selected D.C. Haskin to design the tunnel using his newly patented compressed air technique.

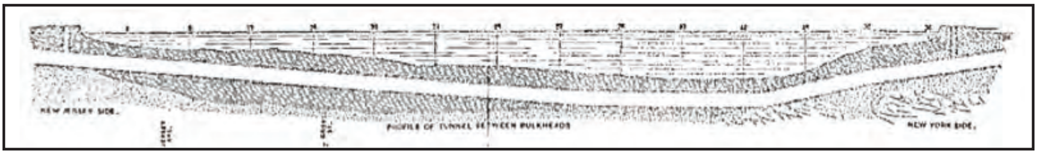
Figure 9. Location of the Hudson River Tunnel

(Source: Burr, 1885)

Studies for the proposed river crossing were undertaken in 1873 and included soundings and borings along the crossing. The data revealed the river bed consisted primarily of silt (Figure 10) which was estimated to be continuous across the mile-wide channel at a depth of about 60 feet. Shallow rock was estimated to come within 28 feet from the bottom of the river near the New York (eastern) side.

After construction began in 1874, an injunction was obtained by the Lackawanna & Western Railroad Company to halt work as the tunnel was believed to unfairly compete with the existing ferries which carried passengers from rail terminals on the west side of the Hudson to New York to continue their journeys (see ferry routes in Figure 9). Work on the tunnel resumed in 1879 as the excavation proceeded from the previously abandoned tunnel workings, this time under compressed air.

Figure 10. Profile of the Hudson River Tunnel (Central Segment)



(Source: Burr, 1885)

One of the unique innovations of this tunneling operation was Haskin's use of compressed air applied at a pressure about equal to the hydrostatic head. The compressed air controlled groundwater inflows and reduced the risk of flowing soils entering the excavation, which often resulted in an unstable condition, such as collapse of the ground and subsequent flooding of the tunnel. The compressed air also balanced ground loads on the temporary iron plate tunnel lining, thus removing the need for interior struts to support the plates and increasing the workable area inside the excavation. It was also assumed that compressed air at 20 pounds per square inch (psi) would be sufficient to support the temporary lining plates at every point, negating the need to design the plates sufficiently thick to carry the ground and hydrostatic loads before the final masonry tunnel lining was installed.

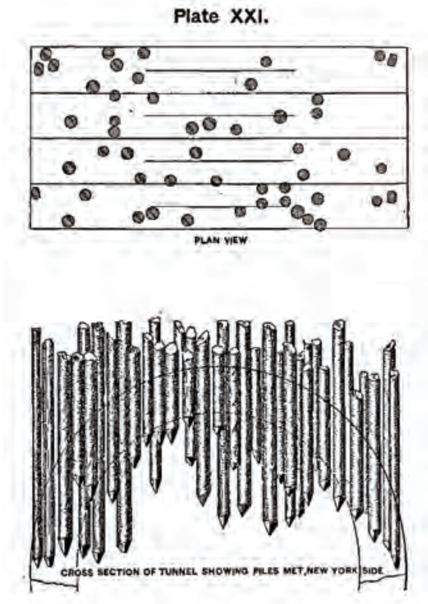
Although the requirement for compressed air to maintain stability of the excavation was carefully considered, little was understood about the actual performance of this relatively new technology as construction began. During initial excavation of the tunnel, a pressure lock was used and compressed air at 12 psi was applied. As the excavation expanded and extended further from the shaft, air pressure was increased. However, as construction proceeded, it was observed that the exact pressure needed fluctuated with the varying density and composition of the soil, and was adjusted according to behavior observed during the excavation. The presence of potential "air leaks" at the heading of the excavation was carefully monitored by using a candle to detect drafts resulting from air escaping into the ground. Excessive leakage would lead to "blows", and if left unplugged the resulting drop in air pressure would allow water to enter the tunnel (Figure 11).

Figure 11. Photograph of a "Blow" During Construction, as Seen from the Surface

(Source: Hewett and Johannesson, 1922)

Excavation of the tunnel progressed until a buried bulkhead was encountered (Figure 12), which, combined with a leak in the air lock, resulted in an inflow of water and flooding of the tunnel. Twenty workers were trapped in the tunnel at the time of the flooding and perished as a result of the inundation.

Figure 12. Obstructions Encountered at Manhattan Bulkhead



(Source: Burr, 1885)

Work resumed and the tunnel continued to advance beneath the river until November of 1882 when work was halted due to a lack of funds. The stoppage came at an unfortunate time as the construction progress was picking up, with 127 feet of tunnel constructed in the last four weeks prior to stopping. At this time, the tunnel was 1,550 feet from the shaft at the New Jersey side.

Twenty years later, in 1902, a new strategy was developed for excavating the remaining length of tunnel beneath the river. A shield would be utilized under compressed air, which would allow simultaneous support of the ground and groundwater (the compressed air balancing the hydrostatic pressures, and the shield reducing the risk of soil instabilities). The shield was advanced by hydraulic jacks that pushed off of the installed iron tunnel lining, while soil was excavated from openings at the front of the shield that could be opened and closed as necessary (in order to maintain stability of the ground ahead of the excavation). At its peak production, the shield was able to advance as much as 72 feet per day, and in September of 1905, the tunnel shields that were pushing from the New Jersey and New York shores met.

The formal opening of the tunnel was held on February 25, 1908, with the governors of New Jersey and New York aboard the first train beneath the river, shaking hands as the state line was crossed and declaring a “formal marriage of the two states.” In the first 24 hours of operation, it is estimated over 50,000 people rode the new line.

Table 2. Hudson River Tunnel Construction Details

Location	New York, New Jersey, United States
Method	Compressed Air, Shield
Construction Complete	1908
Duration	34 years[a]
Length	5,650 feet
Depth	97 feet
Tunnel Size - Excavated	20 feet diameter
Minimum Cover between Riverbed and Tunnel	15 feet
Geology	Silt and sand, rock
Cost	$2.0 billion (USD)[b]

a. Includes delays due to flooding as well as project abandonment due to lack of funds as well as heading failure.
b. Adjusted for inflation (2010).

St. Clair River Tunnel (Port Huron, Michigan, 1891)

At the end of the 19th century, shipping commerce on the St. Clair River between Lake Huron and Lake Erie was five times the amount passing through the Suez Canal. At times ships were “bumper to bumper” as they negotiated the channels and waterways connecting the larger bodies of water. Many consider this the “Golden Age” of the Great Lakes.

At Port Huron the river crossing over to Sarnia, Canada required a ferry, which had to carefully negotiate this stream of transport ships carrying iron ore, wheat, and coal from the major economic hubs of the Midwest. The Grand Trunk Railroad operated the rail line crossing over the river, and could no longer afford the expense and delays of a ferry crossing on one of the most important connections to the Canadian mainline.

The first attempt to cross beneath the St. Clair River was made by the Michigan Central Railroad in 1872. After construction of 1,220 feet on the US side, and 450 feet on the Canadian side, the tunnel was abandoned due to high water pressures and the presence of deadly “sulfur gas.”

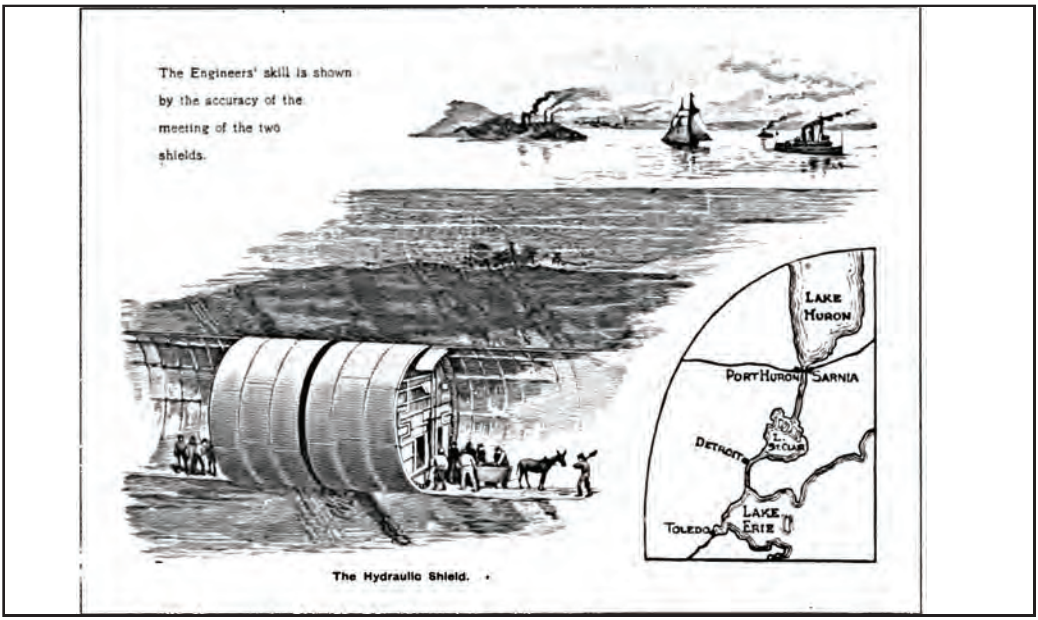
In 1888, a second attempt was made to cross the river by the Grand Trunk Railroad. Prior to construction, engineers decided to perform borings at 20-foot spacing along the length of the proposed alignment. The borings indicated sand, gravel and boulders near the river bottom, but below this were more stable layers of blue clay and shale. There was suspicion that pockets of gas may have existed between the clay and the top of the shale layer, so the decision was made to extend the tunnel within the clay layer.

Construction of the St. Clair Tunnel began in 1889. Two shields, each 21 feet in diameter, were driven on opposite sides of the river (Figure 13). Twenty four hydraulic jacks, capable of supplying as much as 3,000 tons of driving force, were used to advance the shields 18 to 20 inches per stroke (the maximum distance that the shield could be advanced at any one time due to the length of the hydraulic rams). Despite the ability to maintain a stable face, both tunnels were driven under an air pressure of 28 psi. Behind the shields, the tunnel was lined with a one-inch thick segmental cast iron lining.

Tunnel driving progressed easily until the shields extended beneath river, where water inflow and increased presence of sand and gravel lenses (pockets) proved difficult. Engineers had to balance air pressure to avoid a sudden explosion of air into the riverbed, while at the same time reducing groundwater inflow. Several times the tunnel nearly flooded due to loss of air pressure through the gravel lenses, but the engineers responded by placing clay spoils over the exposed gravel lens, effectively sealing off the “leak” before major instability developed. Pilot tunnels were also driven ahead of the shields so that workers could collect samples of the sediment to ascertain the presence of fine- or coarse-grained material.

In August of 1890, nearly one year after the shields began their journey, the two ends of the tunnel met beneath the St. Clair River. At the time of its construction, the tunnel was the first subaqueous tunnel completed in North America, and also the first railroad connection between the United States and Canada.

Figure 13. Shields Used for the St. Clair River Tunnel



(Source: Scientific American, 1890)

Table 3. St. Clair River Tunnel Construction Details

Location	Port Huron, Michigan, United States
Method	Compressed Air, Shield
Construction Complete	1891
Duration	2 years
Length	6,025 feet
Tunnel Size - Excavated	21 feet diameter
Minimum Clearance between Riverbed and Tunnel	65 feet
Geology	Clay, silt, sand, and gravel
Cost	$540 million (USD)[a]

a. Adjusted for inflation (2010).

3.2 MODERN EXPERIENCE

In recent times, the demand for tunnels has steadily increased as urban centers expand, reliable transportation networks are needed, and technological innovation continues to allow safer and more efficient use of underground space. The number of recent large projects involving crossings of open water speaks to the confidence in state-of-the-art tunneling practice and its ability to meet these highly complex and challenging projects.

The following "modern" tunnel case histories were selected to provide an overview of how innovation has improved (or not improved) for tunnels constructed beneath open water. As the experiences described below will illustrate, a handful of simple, yet revolutionary technologies have dramatically reduced or eliminated some of the more significant risks to open water tunneling (i.e., high groundwater pressures, groundwater inflow, flowing ground, and worker safety).

Channel Tunnel (English Channel, 1988)

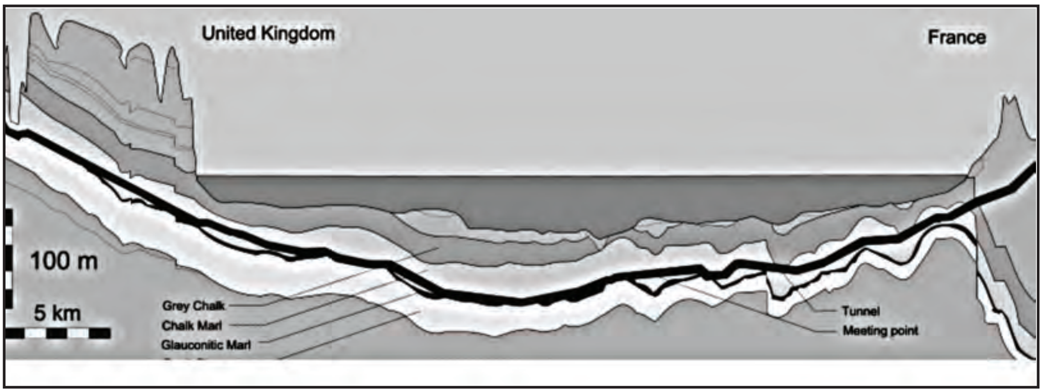
The idea of an underground subsea rail link between England and France had been considered for over 150 years. Not until the 1980s were significant strides made towards construction of the tunnel. In 1994, the 31-mile long Channel Tunnel opened and today serves as a critical freight and passenger rail link between England and France. The Channel Tunnel is the longest undersea tunnel crossing in the world and is identified by the American Society of Civil Engineers (ASCE) as one of the "Seven Wonders of the Modern World."

The Channel Tunnel is actually a series of inter-connecting open water tunnels. It includes two 25-foot diameter rail tunnels, about 100 feet apart, and a 16-foot diameter service tunnel running parallel between the two rail tunnels. Cross passages linking the rail tunnels to the service tunnel are located at 1,230-foot spacing. Two crossover caverns were also constructed beneath the seabed. The crossover caverns permit the railcars to switch tracks so that northbound and southbound trains can move to the adjacent tunnel if, for example, one segment of the tunnel needs to be taken out of service for maintenance.

During the investigation phase, a total of 116 marine borings were advanced and over 2,500 miles of geophysical survey lines were performed along the proposed tunnel corridor between 1958 and 1988. At the time, the investigations had been developed to consider both an immersed tube crossing and a bored tunnel option. Due to the magnitude of the project and length of the open water crossing, significant investigative effort was extended to characterize the subsurface conditions. Key components of the site investigation program included the following:

- Micropalaeontological analysis of samples to establish borehole correlations and to aid in identification of strata and geophysical reflectors.
- Seismic analog profiling concentrated in a 0.5 to 1.3-mile long strip along the alignment. Survey lines ran across the alignment to detect any dips in underlying strata.
- A total of three six-mile long seismic profiles performed for deep mapping of faults and evaluation of potential earthquakes.
- Downhole geophysical logging of marine boreholes was used to assist in identifying seismic reflectors and to enhance the geologic model.
- Results of early geophysical surveys identified a deep zone of weathering near Dover harbor, resulting in a shift in the tunnel alignment.

Figure 14. Channel Tunnel Geologic Profile



(Source: Kirkland, 1995)

Final selection of the tunnel alignment was primarily driven by geology, with the engineer's agreement that the most favorable material for tunneling would be in the chalk marl layer (Figure 14). Instrumented "trial" excavations further confirmed the favorable nature and behavior of this material under large scale excavation. Selection of the tunnel alignment also considered the depth of cover above the tunnel, as higher water inflows were anticipated as the depth of cover decreased due to more frequent and open fracturing in the rock.

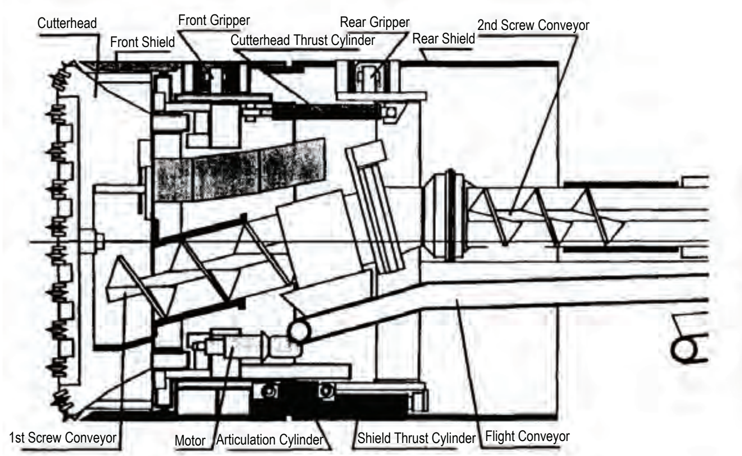
The orientation and character of the chalk marl also dictated the tunnel alignment and excavation methods, as the chalk marl on the UK side was more clay-rich, less hard and brittle, and dipped at about 5° with the French side dipping as much as 20°. The French side also contained considerably more faulted and fractured ground, allowing little room for alignment adjustments. Because of these variations in the chalk marl, two types of TBMs were selected;

an open face TBM for the UK side and a closed face Earth Pressure Balance (EPB) TBM for the France side. Generally, TBMs were favored due to:

- Long driving distance (up to 20 km)
- Dry zones with variable water-bearing zones present
- High hydrostatic pressures (up to 11 bars)

The EPB machines used for the Channel Tunnel were developed to provide positive face support by allowing the excavation chamber to fill with excavated material (or muck) behind a bulkhead and to become pressurized. This pressurized face minimizes the risk of ground loss and groundwater inflow into the tunnel excavation. A unique feature of the French EPB TBM was the double screw system that allowed for a separate confinement chamber between the screws (Figure 15). It was thought this chamber would provide better extraction control in soils where formation of the soil plug in the screw was expected to be difficult. However, one of the primary drawbacks to this system was the coordination and increased effort required to operate the extraction process.

Figure 15. EPB TBM from the Channel Tunnel



Robbins/Kawasaki TBM Section

(Source: Dumont, 1991)

During construction, active geologic mapping was performed to compare actual versus anticipated geology. Sideways probing from the service tunnel was also utilized to obtain additional information in advance of the oncoming, adjacent tunnel drive. Also, the service tunnel always maintained an excavation at least a half-mile ahead of the rail tunnel excavations to allow for adequate characterization of the ground ahead of the larger-diameter TBMs.

Ground conditions were favorable initially but deteriorated as the tunnel approached the channel and the amount of cover above the tunnels decreased. Excavations were slowed by overbreak (blocks or slabs of rock that fall into the excavation causing the excavation to “break” beyond the limit of the excavation) and by excessive groundwater inflow. Overbreak typically resulted from geologic features, such as bedding or jointing of the rock mass, that were oriented unfavorably with respect to the excavation. Open joints, which were more frequent nearer the seabed, also led to high water pressures and further contributed overbreak. These difficult zones were improved by the implementation of pretreatment by grouting, and the tunnels progressed. By the end of the excavation effort, advance rates under good tunneling conditions typically ranged from 100 to 125 feet per day. However, despite these favorable tunneling rates (and also the significant investment in site investigations), the unanticipated groundwater inflows and encounters with unidentified areas of fracturing resulted in delays, construction claims and contract adjustments.

Table 4. Channel Tunnel Construction Details

Location	**Strait of Dover, English Channel between France and England**
Method	Shield (EPB) and open face TBM
Construction Complete	1994
Duration	6 years
Length	31 miles (line length)
Tunnel Size - Excavated	16 to 25 feet diameter
Average Depth between Seabed and Tunnel	150 feet
Geology	Chalk and chalk marl
Cost	$21 billion (USD)[a]

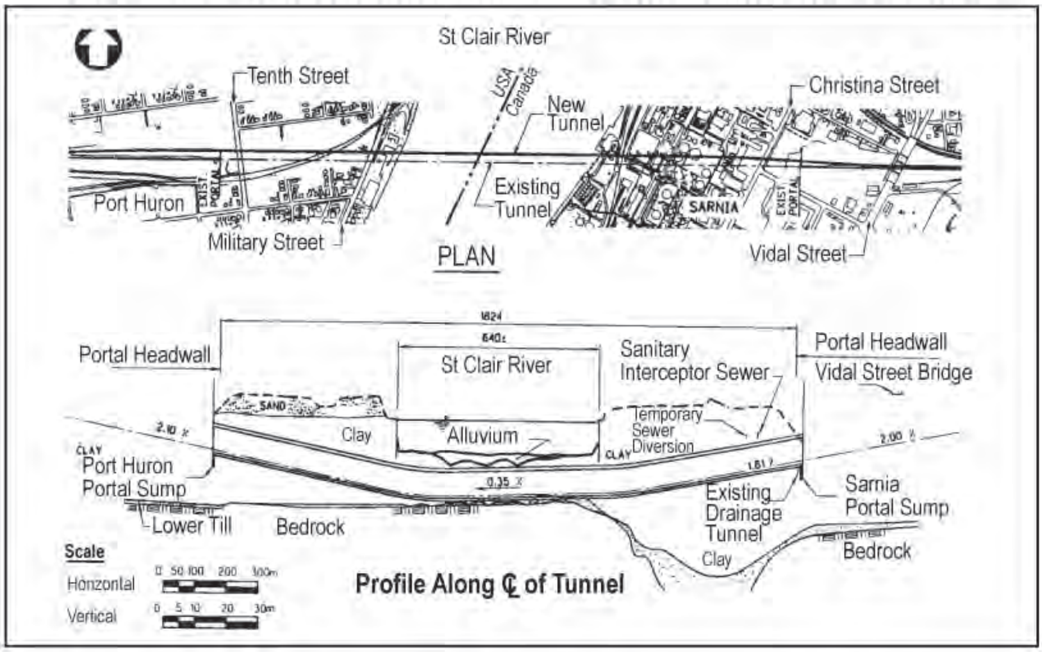
a. Adjusted for inflation (2010).

Second St. Clair River Tunnel (Port Huron, Michigan, 1995)

At the time of its completion in 1995, the Second St. Clair River Tunnel was the world's largest single-track open water rail tunnel. At 27.5 feet inside diameter and slightly over a mile in length, the tunnel under the St. Clair River in Michigan provided a vital link in Canadian National's rail network, allowing double-stacked container trains to pass into the United States and on to the major rail hub in Chicago. The tunnel was driven by one of the largest EPB TBMs at the time of construction (31.2 feet diameter), and extended through soft, squeezing clay and with minimal cover (13 feet) between the tunnel crown and the bottom of the St. Clair River.

Planning and design studies included a significant effort to research and review information retained from construction of the original (and still existing) St. Clair River Tunnel. Additionally, a thorough site investigation was performed consisting of a total of 60 boreholes, including 32 in the river section of the tunnel. Based on results of the investigation, it was determined that a shallow crossing wholly within the St. Clair Till and Lower Till, between the bottom of the river channel and the Kettle Point Shale, would be the most feasible tunneling horizon (Figure 16).

Figure 16. Geologic Profile of the Second St. Clair River Tunnel



(Source: Charalambu and Finch, 1993)

Environmental considerations were considered a significant risk to the project since the tunnel was planned to pass beneath the Sarnia Terminal, which was known to have historically discharged industrial waste into the underlying bedrock by deep well injection. It was believed that this discharged material may have seeped up into the overlying soil layers. Environmental sampling and testing were carried out and results suggested that the groundwater would be contaminated. This would require treatment prior to disposal through a treatment system at the ground surface.

Another significant risk for this cross-border project was permitting, and the impact obtaining the necessary permits would have on the overall project schedule. The project directors realized early on that emphasis on public involvement and interaction would be highly important to overall project success. Public outreach started as early as 1991, two years before construction was scheduled to begin, with public meetings and formal presentations to regulatory groups including agencies from the federal, state/provincial and municipal level.

Construction of the tunnel started in 1993 and proceeded without much difficulty until the TBM's main bearing seal was breached. Repair of the main seal would require full access to the cutterhead and subsequently an emergency access shaft was constructed. Fortunately, the breach in the main seal occurred before the crossing of the river and a shaft site was located ahead of the TBM. After the shaft was constructed, the repair to the TBM required four weeks.

To mitigate the risk of inundation of the tunnel works during excavation beneath the river, a temporary bulkhead was installed in the tunnel. The bulkhead was designed to withstand the full hydrostatic pressure of the overlying river, and could be sealed in about 60 seconds.

Fortunately, the bulkhead was never needed, and the TBM advanced the remaining drive under the river within six weeks and without incident. Total productivity for the tunnel drive was about 30 feet per day.

Table 5. Second St. Clair River Tunnel Construction Details

Location	Port Huron, Michigan, United States
Method	EPB
Construction Complete	1994
Duration	2 years
Length	5,900 feet
Tunnel Size - Excavated	31.2 feet diameter
Minimum Clearance between Riverbed and Tunnel	13 feet
Geology	Silty clay with cobbles and boulders
Cost	$230 million (USD)[a]

[a] Adjusted for inflation (2010).

Bjorøy Subsea Road Tunnel (Norway, 1995)

For many years, the hard rock that comprises the fjords of Norway has made subsea tunneling an ideal medium to connect the country's numerous islands. These tunnels, in addition to connecting Norway's population, help support the country's burgeoning natural resource industries, such as oil and natural gas, by providing transportation links which facilitate movement of equipment and transmission of resources. Over 40 tunnels have been constructed beneath fjords, most without serious incident. However, the Bjorøy Road Tunnel, completed in 1995, was one tunnel where a significant subsurface feature went undetected during the planning phase and resulted in a major impact during construction.

Constructed to provide vehicular passage below the Vatlestraumen Strait near the city of Bergen in southwestern Norway, the Bjorøy Road Tunnel is 6,500 feet in length and was excavated using drill-and-blast techniques under as much as 260 feet of hydrostatic head. Great difficulty was experienced during construction due to an unanticipated fault encountered (Holter et al., 1996). The fault zone had a total thickness of only 12 feet, but comprised extremely poor ground conditions, including breccia, clay, sand, coal fragments and flowing ground. This feature went undetected prior to construction, primarily due to preconstruction investigations that were limited in scope. It should be pointed out that this project was constructed under a fixed price contract, with the responsibility for supplemental investigations falling on the contractor.

Rock cover at the location of the fault was about 100 feet and the hydrostatic head was about 240 feet. The fault was originally detected during probing ahead of the excavation, at a distance of about 25 to 30 feet ahead of the face, when hundreds of cubic feet of sand and water blew into the excavation through the two-inch probe hole. Sustained groundwater inflow through the hole was about 50 gallons per minute.

It was quickly determined that significant pre-treatment would be required to advance the tunnel through this zone. Several methods of treatment were considered with the intent to provide a groundwater cutoff and to stabilize the ground. These included ground freezing, horizontal jet grouting and pre-support spiling (steel bars or pipes advanced horizontally ahead of the excavation to assist with roof support). After much deliberation, an intensive consolidation grouting program was specified to improve stability of the soils and provide the necessary groundwater cut-off.

One of the major challenges of the pre-excavation grouting program was determining the layout and sequencing of grout holes to provide the grouting coverage needed to reduce instabilities and groundwater inflows. Due to the highly variable nature of the fault zone, with its wide variations in rock quality and presence of clay-filled discontinuities, rock mass grouting was essentially completed in two stages. The first stage was directed at sealing open joints and channels where high groundwater inflows occurred. This grouting was typically performed ahead of the advancing excavation to minimize the impact of groundwater inflows on the construction work. The second stage involved grouting the finer joints of the rock, under high pressure, to provide a nearly watertight excavation.

The grouting program to pre-treat the fault zone utilized cement-based compaction and hydrofracturing grouting, chemical hydrofracturing, permeation grouting, and gravity drainage. Pre-support spiling and shotcrete support (including reinforced shotcrete ribs) was also applied, and excavation rounds were shortened. Shortening the rounds (the length of the excavation completed before the final shotcrete lining is installed) minimizes the length of tunnel that is unsupported and thus subject to adverse ground behavior. Under high hydrostatic pressures, quick-setting ultra fine cement was used as permeation grout and provided suitable strengthening in the highly unstable sand and silt material. Also, because of the poor rock mass quality, steel pipes had to be used for packer installation during injection and were left in place to provide additional support of the opening.

Advance of the tunnel through the fault zone was slower than originally anticipated, but ultimately successful. Following pre-treatment, groundwater inflow into the tunnel was minimal, despite additional occurrences of water-bearing joints at full hydrostatic pressure. These areas were also treated with pre-injection grouting to provide groundwater cut-off.

Table 6. Bjorøy Road Tunnel Construction Details

Location	**Bjorøy Island, Hordaland, Norway**
Method	Drill and Blast
Construction Complete	1996
Duration	3 years
Length	6,500 feet
Tunnel Size - Excavated	24 feet diameter
Minimum Clearance between Seabed and Tunnel	98 feet
Geology	Granitic gneiss
Cost	Unknown

3.3 WHAT HAS PREVIOUS EXPERIENCE TAUGHT US?

As demonstrated by the success of the Channel Tunnel and the Second St. Clair River Tunnel, recent advances in TBM technology have enabled tunnel construction within a range of environments that may have been deemed too risky or too difficult in the past. A collapse and inundation of the Channel Tunnel would have been a catastrophic failure given the depth and length of the tunnel. EPB TBM technology provided the engineers a degree of comfort that unfavorable ground and groundwater conditions, when encountered, could be controlled to a certain degree, thus minimizing the risk of a catastrophic failure. This same logic was also followed by the Second St. Clair River Tunnel, where an EPB TBM was selected and contributed greatly to the success of the project. It is also interesting to note that when compared to the first St. Clair River Tunnel, the overall cost of the second tunnel, when adjusted for inflation, was almost half the cost of the first tunnel.

EPB TBM technology, or pressurized face TBMs, is indirectly a product of the original shielded TBMs from the late 19th and early 20th century when engineers first recognized the need to provide immediate and constant support of the ground when working beneath the groundwater table and in soft, unstable ground. This principle is still important to recognize. Without proper pressurization and face support, uncontrolled over-excavation and ground loss can occur. For tunnels beneath open water, this can result in the flowing of ground and groundwater into the excavation and induce a collapse of the ground above the tunnel and possible inundation.

The Bjorøy Road Tunnel is a unique case history in that it demonstrates that utilizing more traditional excavation techniques, specifically drill-and-blast, can allow easier adaptation to varying, or unexpected, ground conditions. Although significant difficulty was encountered when excavating through the fault zone, excavation by an open face, unpressurized hard rock TBM would have been much more difficult since access to the fault zone could only be made from within the tunnel horizon. If a TBM had been selected for this tunnel, excavation costs and delays for penetrating the fault zone would likely have been significantly greater. Therefore, in spite of the difficulties encountered, the excavation method selected can largely be considered a success.

In addition to providing guidance for selection of excavation techniques, previous experience has also taught us that modern site investigation techniques, such as inclined boreholes and intensive geophysical surveys, cannot always fully predict the ground conditions along the tunnel alignment. This was precisely the case with the Channel Tunnel and the Bjorøy Road Tunnel. Increased effort expended during the site investigation phase may not have necessarily prevented the difficulties encountered during construction. The lack of data regarding subsurface conditions and the risk of encountering an unanticipated condition was effectively mitigated by proper selection of excavation technique and by probing ahead of the advancing excavation to detect and prepare for adverse ground conditions.

In short, it is critical during the design of open water tunnels that engineers consider the nature of the ground, or geology, along the alignment, the limitations of the site investigation program in characterizing the ground, and the anticipated range of ground behavior under the proposed excavation technique. One short section of tunnel where a geologic condition was not identified, or not prepared for, can result in a costly and potentially disastrous situation. Thus, while no amount of investigation will reveal all difficulties, the importance of performing a detailed and comprehensive site investigation for open water tunnels must always be emphasized.

4.0 PLANNING FOR OPEN WATER TUNNELS

4.0 PLANNING FOR OPEN WATER TUNNELS

As with almost all tunnel projects, planning for open water tunnels requires collaboration and coordination of multiple disciplines. Each of the disciplines employed during the planning and design process provides crucial input, and decisions made in one area may affect the options available to the other disciplines. It is impractical to coalesce all planning and design considerations for open water tunnels into this monograph, as they are unlikely to address all relevant issues in sufficient detail. Therefore, the following sections will primarily discuss important considerations from the geotechnical and tunneling engineer's perspective.

This chapter on planning presents good practice in the early stages of a project, with subsequent chapters providing additional background and discussing in more detail how these principles should be considered during the project's development from the planning to the design phase.

4.1 KEY ISSUES FOR OPEN WATER

As discussed in the introduction of this monograph, the greatest uncertainty for open water tunnel projects is in the nature and characterization of the ground within which the tunnel will be constructed. Unfortunately, the means by which this information is obtained, i.e., through site investigations, take on a higher degree of complexity (and often expense) when performed above a tunnel planned beneath open water. In addition, there is usually an increased reliance on geophysical techniques, the results of which will likely be relied upon and scrutinized to a level not often experienced in other geotechnical projects. This process is discussed further in Chapter 7.

Historical experience suggests that a significant component of the success of an open water tunnel project can be summarized in the following fundamental principles:

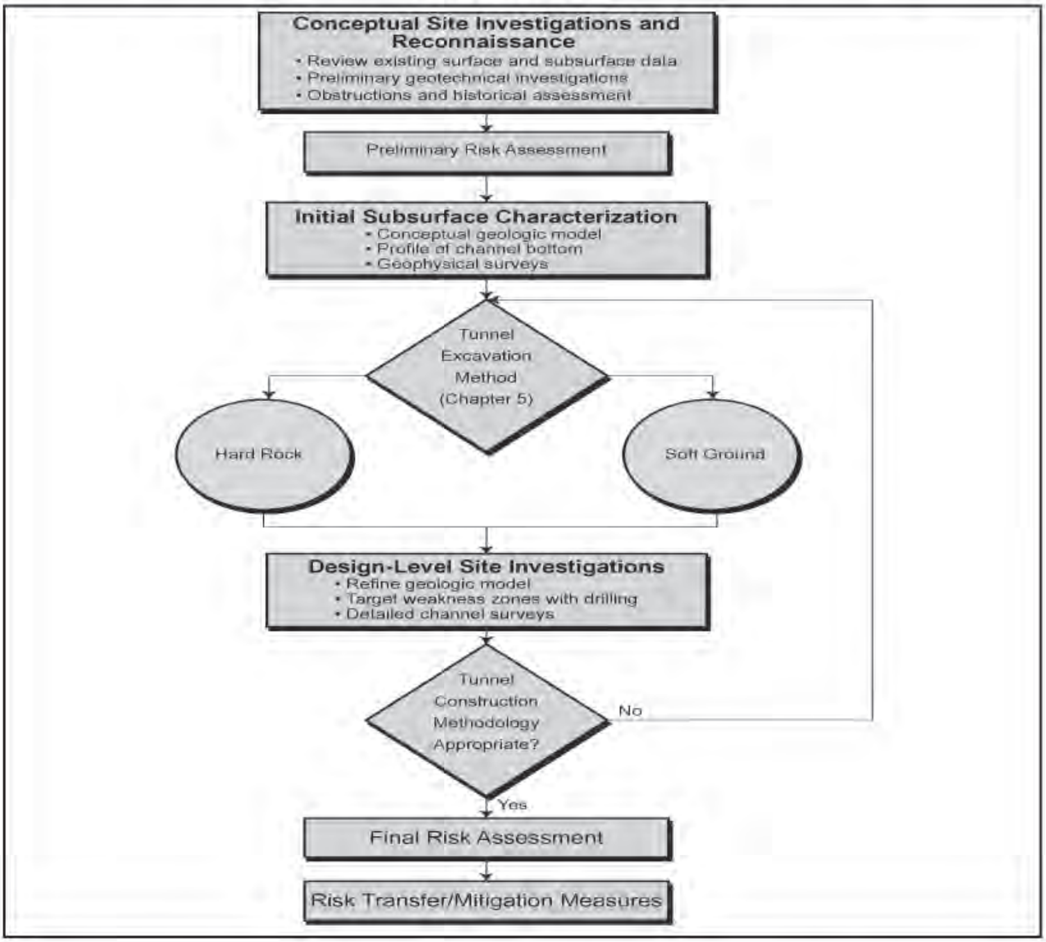
1. Consider the character of the ground and its behavior in the selection of the tunnel alignment and the excavation technique
2. Optimize the alignment to pass through impermeable ground to minimize difficulties from groundwater and potentially flowing ground
3. Determine where transitions in ground conditions, and thus changes in ground behavior, are likely to occur
4. Plan for difficult and infrequent access to the TBM cutterhead (with tunnels under open water, opportunities for access from above the tunnel are difficult and limited)

When properly considered in the planning and design phase of an open water tunnel, adherence to these principles can significantly reduce the overall risk exposure of the project.

4.2 GEOTECHNICAL DESIGN PROCESS

The following flow chart (Figure 17) presents the general geotechnical design process for the planning and design of open water tunnels. This process emphasizes the geotechnical and tunnel components of the project as they relate to ground characterization, selection of appropriate excavation technique, and subsequent risk management. Note that this flow chart may require adaptation to suit project-specific requirements.

Figure 17. Flow Chart for Geotechnical Design Process for Open Water Tunnels



For many open water tunnels, the most critical decision in the geotechnical design process is the selection of the excavation technique. A successful selection begins with the proper characterization of the ground through a thorough site reconnaissance, subsurface investigations, and geophysical surveys (if warranted). Based on this characterization, a proper basis is established to determine the optimal tunnel construction methods or techniques, and subsequent risk assessments can be carried out to further evaluate geotechnical risks and develop compatible contracting methods (e.g., a cost-reimbursable contract for high risk projects, unit price bid items for high risk construction activities, etc.). Ideally, further evaluation of risks during the risk assessment stage will refine the approach to mitigate or eliminate remaining geotechnical risks.

Conceptual Site Investigations and Reconnaissance

Open water tunnels will likely need to consider a range of constraints as project planning and design progresses. Before design can begin, project owners will need to perform preliminary site reconnaissance to establish general site and subsurface conditions along the proposed alignment or alignment alternatives. For tunnels beneath open water, some important considerations during the reconnaissance phase are:

- Location of historic channels, meanderings, and shorelines; historic use of waterway and previous development of shorelines
- Potential for buried man-made obstructions and underground and underwater utilities
- Previous geological studies of the area, including geologic and historic maps
- Previous construction experience from other nearby projects
- Hydrologic data on river, lake, and sea conditions; design will likely need to consider ordinary and mean high water
- Environmental regulations, including restrictions on impact to water environs and water quality, and discharge limitations
- Existing areas of environmental concern, e.g., existing contaminated soils and/or groundwater
- Existing data on built structures along the proposed alignment to determine clearances and to assist in assessing the potential for construction-induced ground movements
- Future development plans along the alignment, including potential for shoreline development and future waterway expansion; consider also the potential use of restrictions or encumbrances on future development to avoid additional loads on the planned tunnel alignment
- Construction site availability and access to basic services during construction, including power and water

The conceptual-level study should be as comprehensive as possible, or as exhaustive as the project schedule allows. The information gathered at this stage will be relied upon as the project advances into design and construction and may also become part of the construction contract (such as historic, or as-built, drawings and construction records). Summary reports (e.g., for historical, archaeological, or other obstructions) should be prepared to document all relevant surface or subsurface issues and constraints. Brief discussions of the potential risks associated with these features should be included and made available to project staff so that they are made aware of potential "unseen" circumstances.

Special attention should be paid to the subsurface conditions, particularly potential adverse conditions gleaned from relevant historic documents. An example of historic subsurface information is presented in Figure 18 where the locations of abandoned timber pile foundations were gathered from the reconnaissance phase for a large tunnel project constructed in close proximity to a navigable river. The river in question was known to have a significant history of shoreline development.

Figure 18. Previous Shoreline Development from Historic Photograph

Preliminary Risk Assessment

Following completion of the conceptual site investigations, subsurface risks should be assessed, whether known or potential (unknown due to limited data available). Ideally, the risk assessment should be a systematic and formalized process that identifies and quantifies all potential impacts to cost, schedule, safety, and the environment, including third party impacts (e.g., permitting for shoreline or any in-water work, need for property acquisition or temporary construction easements, etc.).

Common geotechnical risks for open water tunnels are summarized below in Table 7.

Table 7. Common Geotechnical Risks for Open Water Tunnels

Geotechnical Risk	For Consideration During:	
	Design	Construction
Type, adequacy, and performance of waterproofing system	X	
Major weakness zones (faults) beneath water body	X	X
Permeability of soil and/or rock	X	X
Topographic "lows "along the channel bottom; reduced cover	X	X
Potential for mixed face conditions	X	X
Rock discontinuity structure with hydraulic connection to water body	X	X
Unanticipated obstructions from historic shoreline development	X	X
Muck removal, ventilation, and equipment transport over potentially long distances	X	X
Blow-out potential in soft ground due to excessive face pressures	X	X
Long-term scour potential of channel and related tunnel buoyancy issues	X	

At a minimum, all risks should be tracked through a risk register or similar database that is updated and revised as the project advances into the final stages of design, and ultimately construction. Details regarding risk register preparation and evaluation of risks are provided in Chapter 8.

The interpretation and contractual assignment of risks does not require resolution during the preliminary risk assessment or initial project stages. Initiating the risk assessment at the early stages of a project's development can be viewed as a pro-active approach to a successful risk management philosophy. As the project advances, consideration can then be given to addressing risk through elimination, mitigation, direct control or allocation to other parties.

Initial Subsurface Characterization

Subsurface investigations for open water tunnels provide useful information and data for much of a project's design elements. A sufficiently thorough and properly planned investigation program will target explorations to:

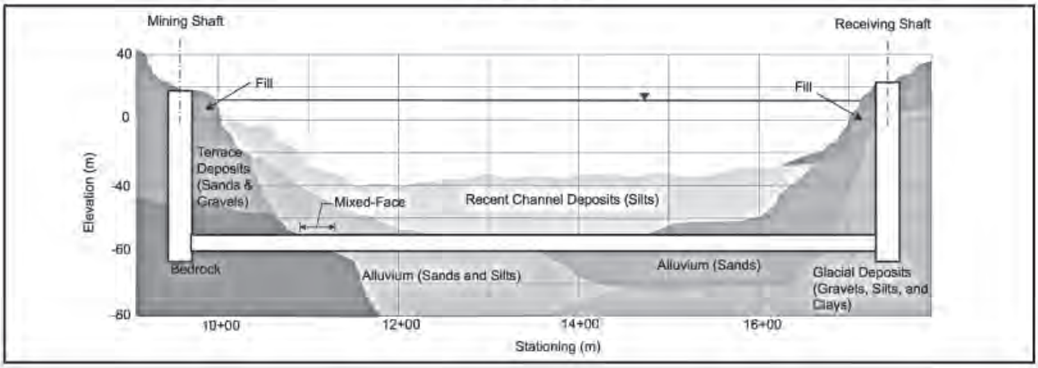
- Enable the selection of an economical, safe and efficient construction method
- Identify "problem" zones along the alignment, including permeable, weak, poor quality and mixed face zones, and also zones of known or potential obstructions
- Fully define soil stratification and/or rock structure and its potential impacts on construction
- Provide an indication of the potential variability, or lack thereof, of subsurface materials below the water body

The earlier investigations can begin, the greater the likelihood that suitable excavation techniques can be selected and relevant geotechnical risks can be addressed. Performing a thorough site investigation also takes time, from several months to a few years depending on project size. Early investigations will therefore allow changes to the project's alignment or configuration, if needed, to be accommodated with fewer complications and delays.

Ideally, a phased approach to site investigations is employed since this allows an ability to modify investigation techniques if necessary and provide a degree of flexibility for changing project requirements. Various investigation techniques should be considered, with preference given to techniques that can be used to support or correlate findings from other site investigations.

As data is collected from the site investigation and other ongoing studies, a conceptual model of the subsurface conditions (geologic, or geomechanic model) along the project alignment should be developed (Figure 19). The model should consider subsurface conditions relevant to the anticipated construction method, including zones of hard rock, mixed face and/or soft ground, and the relationship of these features to the existing water surface. Ideally, the model will include a geologic profile which summarizes the major geologic units that will be traversed and indicate the location of major surface features, such as water depth, existing structures, and configuration of any planned channel improvements or shoreline development. It is important that the geologic model be as simple as possible, but sufficiently detailed to emphasize key geotechnical or geologic risk areas.

Figure 19. Typical Geologic Profile with Well-Defined Geologic Conditions



Tunnel Excavation Method

Initially, the required cross section of the tunnel, that is, the length of tunnel drive without access to the ground surface, may influence the type or method of excavation. However, the behavior of the ground under excavation, particularly where the probability of groundwater inflows is judged to be high or where conditions require the ground to be supported quickly after excavation (commonly referred to as ground with a "short standup time"), will heavily influence the size of excavation and excavation technique. Where rock conditions are of high quality and the likelihood of encountering a significant weakness zone is small, excavation by drill and blast will likely be most favorable. Where soft ground is encountered, high groundwater inflows are anticipated, or where conditions require the ground to be supported as soon as possible after excavation to avoid collapse, a closed face TBM may be more appropriate. Further details regarding appropriate tunnel excavation techniques for select ground conditions are presented in Chapter 6.

Design Level Site Investigations

Design level investigations start after initial, or preliminary engineering, investigations have been performed, and are intended to provide the greatest resolution to the geologic model by providing data needed for the final design of the tunnel and any associated temporary works, such as shafts, staging areas, and muck processing facilities. Design level investigations also provide more reliable information that can be used to identify subsurface risks, including identifying critical areas along the project alignment(s) that may require more detailed investigation and may have significant impact on the selected excavation method. Results from the design level investigation will also be used for completion of subsequent risk assessments and establishing risk allocation within the contract.

During the design level phase, investigation techniques may include the following:

- Drilling and sampling along the project alignment at closely spaced intervals
- In-situ testing including cone penetration tests (CPTs), vane shear tests, packer testing, and groundwater pump tests
- Laboratory testing of high quality undisturbed samples
- Supplemental geophysical surveys

An additional contingency site investigation may or may not be considered at this phase, depending on project requirements and complexity of the subsurface conditions along the project alignment. If ground conditions are anticipated to be especially difficult, a contingency fund may be advantageous in the event the design study does not sufficiently characterize subsurface conditions, or if it is later decided through risk assessment that subsurface risks require further evaluation and additional investigations.

Final Risk Assessment

The final risk assessment stage should incorporate the results of the design level site investigations and should reflect all final design decisions. Results of the risk assessment should be integrated into project drawings, specifications, final risk register, or other technical documents as appropriate. If additional risk assessments are utilized as part of the overall risk management process, these too should be updated with the latest subsurface and design-related information. The final risk assessment should confirm the selected tunnel excavation methodology. Consideration should be given to any additional, or potentially unidentified, "problem" zones along the tunnel alignment, and the potential for high groundwater inflows or adverse ground behavior should be confirmed if possible.

During the final risk assessment, consideration should be given to the requirements for continuing the risk management process through construction. If provisions are provided in the contract for the contractor to continue and update the project risk assessment, the contract documents should be specific in defining what risk management requirements will be included in the contract, and what activities should be carried out during execution of the contract. These contract requirements should be consistent with the previous project risk assessments performed during the conceptual and design level studies.

Risk Transfer and Mitigation Measures

Final documentation of project risks should be presented formally, preferably in the risk register or other risk summary document. As the project transitions from design to construction, and ultimately to operation, the party owning, or sharing, each risk should be identified to clearly communicate responsibility. The final risk transfer, mitigation, and sharing opportunities may take on multiple forms in the contract documents and may include the following:

- Clearly identify subsurface conditions and geotechnical indications in the contract (Geotechnical Baseline Report/Geotechnical Interpretive Report)
- Require pre-qualification of bidders
- Require technical evaluation of significant risks as part of bidder evaluation
- Require continuation of design level risk management practices during construction
- Include risk register in bid documents
- Consider partnering opportunities between owner and contractor
- Use unit pricing for high-risk activities, such as pre-excavation grouting where the quantities of grout or the number of locations that may require grout treatment may be difficult for the contractor to estimate and price.

5.0 DESIGN CONSIDERATIONS

5.0 DESIGN CONSIDERATIONS

Open water tunnels have design considerations that have a unique, and often substantial, impact on project cost and schedule. For example, long-term considerations such as seepage and leakage criteria, as well as waterproofing, can contribute significantly to the construction and operation costs of the tunnel facility. The following design issues are discussed in this chapter:

- Watertightness
- Waterproofing
- Gaskets
- Groundwater Inflow
- Flooding
- Permitting
- Alignment Geometry
- Shoreline Development
- Third Party Considerations (Dredging and Scour, and Anchors)

It is not the intent of this monograph to discuss all relevant design considerations for all types of tunnel structures; rather, important design considerations will be discussed with an emphasis on geotechnical considerations, with only a brief discussion on permitting and other subsurface issues that require consideration during the design phase.

5.1 WATERTIGHTNESS

Tunnels beneath open water must always be designed to withstand the detrimental effects of groundwater. Protection against groundwater can be in the form of waterproofing membranes or gaskets installed on the exterior or interior of the tunnel structure. For this type of protection, the structure must be designed to resist hydrostatic loading and to be watertight over its design life. Where waterproofing is not provided, a system of water collection and drainage is needed. The degree of watertightness required will ultimately depend on the intended function of the tunnel. General guidelines for the degree of watertightness required for tunnel applications are provided in Table 8.

Groundwater control and waterproofing can be achieved through specified design measures, such as an impermeable membrane or sealing gaskets, or during construction using pre-excavation grouting to provide groundwater cut-off in the ground surrounding the tunnel. Groundwater control can also incorporate the use of relatively impermeable construction techniques, such as employing concrete slurry walls as excavation support (a frequently used technique for surface excavations). However, these construction techniques are rarely effective at providing permanent, long term infiltration control, and often some form of positive protection (waterproofing applied to the exterior of the structure) is needed.

Table 8. Watertightness Requirements for Various Tunnel Applications

Intended Function of Tunnel	Degree of Water-Tightness Required	Likely Damage / Problems to be Encountered
Transit stations or areas of prolonged public exposure	Higher ↑	Chronic illness for lengthy exposure
Transit tunnels		Damage to structural materials and operational equipment, corrosion
Utility tunnels		Damage to structural materials, corrosion
Sewage/water tunnels	↓ Lower	Damage to structural materials, corrosion, environmental pollution, additional treatment

(Source: Haack, 1991)

Standards of performance for groundwater infiltration vary by structure type, use, and applicable local or national design standards. Currently in the US, no national standard for infiltration or watertightness exists. A review of European requirements offers some guidance for typical watertightness based on tunnel use (Table 9).

Table 9. Typical European Tunnel Watertightness Requirements

Water-Tightness Class	Wetness	Typical Use of Space	Daily Leakage Rate (gal/ft^2)
1	Completely Dry	Storerooms, Passenger Facilities	0.00002
2	Largely Dry	Subway Tunnel	0.0004
3	Moisture Capillarity	Subway & Tram Tunnel	0.002
4	Slightly Dripping	Railway Tunnel	0.01
5	Dripping	Sewage tunnel	0.02

(Source: Haack, 1991)

Allowable seepage rates are not always satisfied over the operational life of the tunnel. Selected case histories reported by Mueser Rutledge (1988) indicate specified leakage rates for transit tunnels and actual experience, as well as any remedial measures that were required (Table 10). It should be noted that the materials and methods of waterproofing have improved since these case histories were reported. More recent tunnels, open water tunnels included, have adopted more strict infiltration criteria as waterproofing technology and observed performance has improved. Further details on waterproofing techniques applicable for open water tunnels are provided in the subsequent sections.

Table 10. Select Tunnel Leakage Case History Performance for Transit Tunnels

System	Type of Lining	Permissible Leakage	Leakage Experience
WMATA	Cast Concrete, Shotcrete, and Precast Concrete Segments	0.2 gpm/250 lf or 0.1 gpm in any 100 lf	Worst in shallow rock – maximum about 100 gpm/1,000 lf
Baltimore Metro	Precast Concrete Segments and Steel Liner	0.07 gpm/100 lf	Reported no measurable infiltration for precast segments. For CIP concrete, required extensive grouting to meet specifications
NAFTA - Buffalo	Cast Concrete	0.9 gpm/1,000 lf or 0.05 gpm in any 30 lf	Local maximum 250 gpm in 300 lf. Typically 10-60 gpm per 1,000 lf. Reduced infiltration by cement grouting behind lining and acrylimide grouting of cracks in concrete
Singapore Metro: Phase 1&2	Precast Concrete Segments	0.0002 gpm/100 ft^2 and 0.0004 gpm/100 ft^2 for any 32 lf of tunnel	Of 4 different gaskets used, none met specified leakage criteria. Extensive secondary grouting performed and regular maintenance required
London Transport	Precast Concrete Segments and Metal Liner	Not stipulated	Generally 0.1-1.0 gpm/1,000 lf; tunnels in London Clay yielded insignificant leakage

(Source: Mueser Rutledge, 1988, Shirlaw et al., 2006)

gpm = gallons per minute
lf = linear feet

5.2 WATERPROOFING

Several waterproofing systems are available for use in conventionally mined (non-TBM) underground structures, including liquid, sheet, and sprayed systems. Sheet, sprayed, and hybrid systems are typically most practical for these types of tunnel excavation applications, with the waterproofing layer embedded between the initial and final tunnel linings. All of these waterproofing techniques are difficult to install in confined spaces, due to hazardous fumes during installation, strict quality control requirements, and inability of the waterproofing system to withstand elongation, which is often inevitable due to ground displacements and creep.

Under certain groundwater conditions, such as where there is a need to control groundwater in the short-term, shotcrete and concrete have demonstrated that when properly applied they can adequately serve as a temporary groundwater barrier. Additives, such as pozzolan, can also be added to cast-in-place concrete to reduce overall permeability and likely infiltration. However, for better long term performance the primary concern with shotcrete and concrete is the tendency to crack and the requirements for expansion joints, which can be a major weakness in the waterproofing system. Sealing of joints in concrete can be achieved with vinyl, PVC, injection, or swelling-type waterstops. For tunnels with strict leakage criteria, a secondary waterproofing system directly applied to the excavated surface can be considered. Where long-term maintenance of leakage is a concern, crack injection with an expansive resin or other polymer can also provide effective leakage mitigation.

A state-of-the-art guideline document for waterproofing of underground structures, titled *Guidelines for Waterproofing of Underground Structures*, has recently been published by Parsons Brinckerhoff (2008). This guide serves as a comprehensive document on the design of waterproofing systems, waterstops, and leakage mitigation. This guide can be obtained directly from Parsons Brinckerhoff.

5.3 GASKETS

Precast concrete segmental tunnel linings are commonly used as permanent ground support within TBM bored tunnels. The gaskets installed between segment joints can be used to provide effective waterproofing. These lining systems have been used successfully in Europe and Japan since the 1960s. Advances in gasket technology have progressed substantially in recent years, as manufacturers have been able to provide gaskets that are capable of withstanding significant pressures. In some applications these gaskets have provided sufficient sealing for tunnels under hydrostatic head of up to several hundred meters.

There are two primary gasket types used for precast concrete segment application: (1) elastomeric, or EPDM (ethylene, polymer, diene, monomer), and (2) hydrophilic. Elastomeric gaskets consist of a continuous non-swelling “rubber” strip that is continuously applied around each segment within a pre-formed groove ranging in size from about 20 to 40 millimeters in width (Figure 20). An adhesive agent is typically applied into the adjacent segment’s groove to seat the gasket, and water-tightness is achieved by maintaining sufficient compressive stress on the gasket throughout the tunnel design life. Elastomeric gaskets are highly effective waterproofing systems. Tunnels with these systems generally do not require secondary waterproofing measures, even for tunnels with the most strict leakage criteria.

Hydrophilic, or water-expansive, gaskets differ from elastomeric gaskets in that they rely on swelling pressures after coming in contact with water, which allows the gasket to expand and provide a seal between the segment joints (Figure 21). Hydrophilic gaskets are most commonly used as secondary gaskets or in combination with elastomeric gaskets (either co-extruded with the elastomeric gasket, or with each gasket type installed separately.

Figure 20. Precast Concrete Segment with EPDM Gasket and Wood Compression Packing

Figure 21. Precast Concrete Segment with Double Gasket (EPDM and Hydrophilic)

Selection of the type, number, and location of gaskets should consider a number of factors, including design hydrostatic pressure, required factors of safety, tunnel lining design life, tunnel function, groundwater chemistry, tunnel lining thickness, range of potential joint offsets (misaligned segments reduce contact area of the gasket and reduce contact pressure between gaskets), anticipated conditions during TBM driving, risk and consequence of joint leakage, and the cost of leakage risk mitigation. It is the author's experience that use of only an elastomeric gasket is more commonly encountered in North America, with secondary hydrophilic gaskets used where long term durability of the elastomeric gasket was questioned either due to high hydrostatic pressures or adverse groundwater chemistry. In Europe and Asia, co-extruded elastomeric and hydrophilic gaskets are more common. Singapore's Deep Tunnel Sewerage System (DTSS) and Metro transit tunnels have recently specified co-extruded gaskets due to previous leakage problems with bitumastic strips (Shirlaw et al., 2006). Details regarding gasket types, project applications, and relevant material properties can be obtained from gasket manufacturers, such as Phoenix Dichtungstechnik GmbH, Heinke, Dätwyler, and Vertex, Inc.

For tunnels under high water pressures, a key factor in determining the ability of an elastomeric gasket to provide sufficient sealing capabilities is its behavior under compressive forces. Leakage can occur through gaskets when the hydrostatic pressure approaches the applied gasket contact pressure; therefore high contact pressures are required to maintain sealing pressure on the gasket. For critical applications, such as high hydrostatic pressures, watertightness of gaskets can be verified by pressure testing in the lab to verify performance of the gasket under a set of predetermined loading conditions. Gasket manufacturers can often perform these tests using T-shaped steel frames with pressure introduced between gaskets. The frames can also be offset to test for watertightness where gaskets may be installed out of alignment. For high hydrostatic pressures, more rigorous testing may be needed to model the effects of high compressive stresses applied to the gasket (e.g., load deformation) and resulting high line loads applied to the segment. Flaking tests may also be needed to verify shear capacity of the segment at the gasket groove.

Although generally not accepted as a positive means for waterproofing on its own, tail skin grouting in shield-driven TBMs in soft ground is a critical component to the success of gasket performance for tunnels with precast concrete segmental linings. It is critical that tail skin grout be designed with an appropriate setting time and strength to minimize lining distortions due to jacking forces. Tail skin grout should also be compatible with the grout delivery system and forward movement of the TBM. Specifying minimum grout strengths at 1, 3 and 6 hours, or at a prescribed distance from the TBM shield, such as 3 to 6 rings behind the shield or for every 50 feet of tunnel advance, can be considered as a means to achieve adequate grout strength development and can help mitigate potential issues arising from misaligned segments and difficulties in providing the required watertightness. For open water tunnel applications, traditional 7- and 28-day grout strengths are less critical for the performance of the lining system since the grout primarily provides support to the tunnel ring. Short-term grout strength is more important to minimize distortion of the ring since misalignment will impact the ability of gaskets to seal effectively.

5.4 GROUNDWATER INFLOW

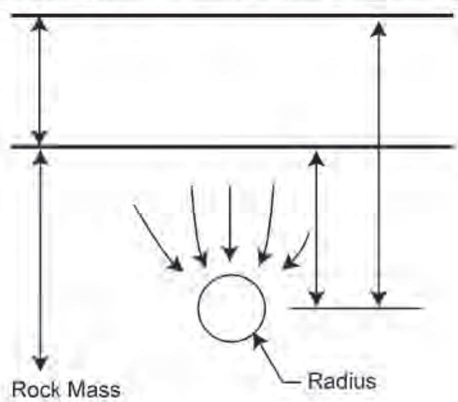
Groundwater flow into a tunnel must be considered during the design process if ground conditions do not dictate the use of a closed (i.e., sealed) excavation with positive control of groundwater infiltration through gaskets or other waterproofing measures. Predicting the quantity and frequency of groundwater inflow is important as it can significantly impact construction progress if not properly planned for. A good example of this problem was illustrated in the discussion on the Bjorøy Subsea Road Tunnel excavation in Section 3.2, which was surprised by 50 gpm of groundwater flowing into the work area from the two-inch probe hole. By itself, 50 gpm of inflow is very manageable, but such flow through a small diameter hole indicated that much higher flows would likely be encountered if the full excavation was exposed to the water-bearing fault zone. Fortunately, extensive grouting was injected into the fault to reduce the risk of a catastrophic inflow of groundwater, but overall the project suffered significant cost overruns due to this unanticipated additional work.

Groundwater inflow into an open water tunnel will be a function of the hydrogeologic conditions through which the tunnel will be built. Estimating this inflow is particularly troublesome for engineers as it is dependent upon the permeability of the ground or the permeability of discrete discontinuities within a relatively impermeable rock mass. These parameters are difficult to estimate even with a very comprehensive site investigation program, and making reliable predictions based on these parameters is even more problematical. Often previous construction experience in the project vicinity can provide the most realistic estimate. As a rule of thumb, estimating groundwater inflow into a tunnel within a few orders of magnitude from what is actually encountered is considered by some to be a reasonably good estimate.

Estimating Groundwater Inflow

One method of estimating steady-state inflow of groundwater into open water tunnels, or into any submerged tunnel, is to assume Darcian flow through a permeable aquifer, where the well is approximated as the tunnel, excavated through porous media (Figure 22). In practice, this model is best applied for tunnels in soft ground, or in ground that exhibits a uniform permeability, such as homogeneous sandstone deposit. For most rock tunnels however, this model becomes increasingly troublesome as groundwater flow occurs along joints or planes of weakness, which cannot be directly accounted for in these models. Additional details and techniques regarding methods for evaluating permeability data and estimating groundwater inflow into tunnels can be found in Heuer (1995). Some of these methods are summarized below.

Figure 22. Steady-State Groundwater Inflow Model

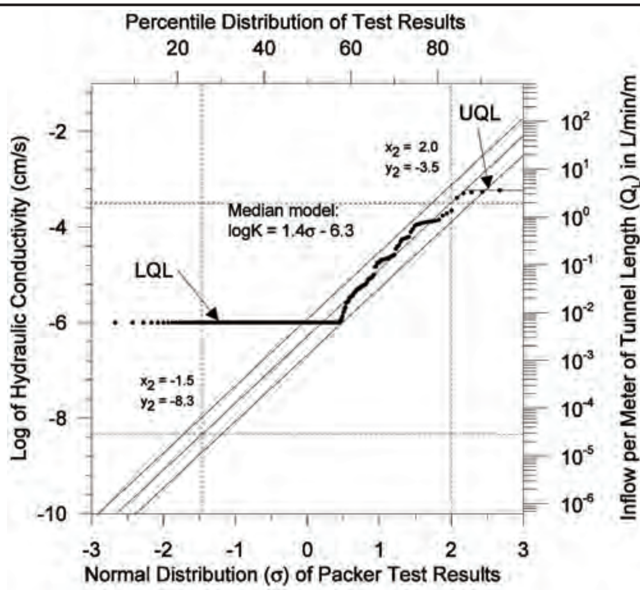


$$q_s = \frac{2\,\pi\,kH}{\ln(2z/r)} = \frac{2\quad\pi}{\ln(2z/r)}\,kH$$

(Source: Heuer, 1995)

For hard rock tunnels where groundwater flow is primarily through discrete fractures in the rock mass, a more rigorous approach to estimating groundwater inflow can be performed using the techniques proposed by Raymer (2001). Raymer's approach models ground permeability based on the results from packer tests performed in boreholes. Packer test data is assumed to be log-normally distributed with an upper and lower quantitative limit that is selected based on limitations of the testing equipment and geologic conditions. Best fit median and upper/lower bound hydraulic models are then developed and tunnel inflow is estimated using Heuer's equation. The result is a tunnel inflow that is based on a more "logical" representation of geologic data, rather than using just an average permeability or a potentially unconservative high permeability (where inflow is calculated by integrating the hydraulic conductivity model(s) over the defined range, typically within ±2 or ±3 standard deviations). Figure 23 presents an example of a hydraulic model based on Raymer's approach.

Figure 23. Cumulative Distribution of Packer Test Data Based on Raymer's Approach



LQL = Lower quantitative limit,
UQL = Upper quantitative limit.

Construction Considerations

Groundwater control, including pumping estimates, discharge volumes, and allowable inflow or seepage, will depend on the functional requirements of the tunnel, construction technique, the final design configuration, lining design and other environmental factors, such as restrictions on groundwater lowering and impacts of salt water ingress on long term performance of the tunnel. Some mechanized excavation techniques, such as pressurized face TBMs with gasketed segmental linings, can eliminate a substantial portion of the risk of groundwater inflows and adverse impacts on the tunnel mining process; whereas open face TBM tunneling will likely need to rely almost exclusively on pre- and post-excavation grouting to control groundwater inflows.

In addition to the need for assessing groundwater control, the mere presence of groundwater, under high pressure, can severely disrupt tunnel excavations if not properly prepared for. Reduced mining advance rates, reduced stand-up time of the ground, ground collapse, difficulty installing ground support, and high grout takes are all common in geologic weakness zones under high hydrostatic pressure. Instabilities associated with rock tunnels beneath open water in Norway serve as excellent examples of the types of instability that can be encountered, all of which are usually exacerbated by the presence of groundwater under high pressure (Dahlø and Nilsen, 1994). Additional discussions on possible means of mitigating potential instabilities associated with high groundwater pressure are discussed further in Chapter 6.

5.5 FLOODING

There are numerous examples of tunnels flooding due to excessive rainfall or breeching of nearby flood prevention measures, such as dykes, levees, and floodwalls. Although this risk is not exclusive to open water tunnels, it is an important design consideration, particularly since mining shafts for open water tunnels are often in close proximity to bodies of water. High-water elevations, storm surges, and flood elevations will all need to be evaluated during the design phase to mitigate the risk of flooding of the tunnel works, both during construction and operation of the tunnel. Typical design requirements for mitigating the risk of tunnel flooding include:

- Flood walls at access/construction shaft to prevent overtopping in the event of a tunnel breach
- Temporary floodgates or bulkheads within the tunnel to allow the tunnel to be immediately sealed following a breach
- Compressed air chamber within TBM to allow sealing of excavation chamber
- Installation of connecting bolts within the tunnel lining to provide additional rigidity and to ensure gasket tightness
- Temporary hatch for construction openings extending beyond the limits of the primary tunnel lining
- Minimizing overlap of scheduled construction activities that may initiate a tunnel breach

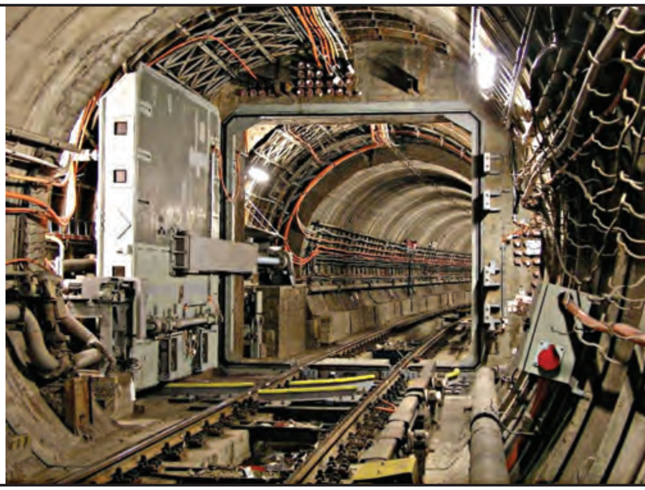
The greatest risk of tunnel flooding will likely occur during construction, where the potential for losing face stability during tunnel excavation, or while making tunnel connections, is highest. Loss of face stability could occur under a number of circumstances, such as encountering an unanticipated obstruction during TBM excavation, or by encountering a direct conduit to the overlying water body. Other potential sources of breaching may include failure of the tunnel lining and waterproofing system due to an explosion, fire, or seismic event.

For open water tunnels, an effective and positive risk mitigation strategy for potential tunnel flooding is a requirement to install permanent floodgates that are capable of immediately sealing portions of the tunnel following a breach (Figure 24). These gates can be permanent or temporary and should be designed to resist full hydrostatic pressure under a conservatively selected water level, as well as hydrodynamic forces from the rapid and large flows.

A primary consideration for floodgates is their operation during a flood event. A carefully designed floodgate should be reliable and fully operable during a flood event and account for the potential for power loss to the tunnel. Seals surrounding the gate and other continuous tunnel elements, such as rails and other conduits, which must pass the bulkhead, should be designed to minimize leakage.

Floodgates can be hinge-type, mechanical, or gate-type. Configuration of the floodgate and selection of a hydraulically or mechanically operated gate are important considerations. Mechanical hoists can be considered if installed with a hydraulic hoist and where a suitable backup system is available in the event of power loss.

Figure 24. Hydraulically Operated Hinged Floodgate



5.6 PERMITTING

Where tunnels pass beneath navigable bodies of water, permits are likely necessary. In the US, authorization is often needed from the Army Corps of Engineers, and occasionally from other agencies. Permits may also be required for siting construction-related facilities on shore, such as for tunnel portals and launching shafts, and for the treatment and disposal of excavated material and groundwater.

The permit approval process can take several months and often includes a public notification process. Regardless of the size of the tunnel, or the potential impact to the resources involved, it is usually advantageous to arrange pre-application consultation meetings with the permitting agencies to streamline the application process and minimize the potential for delays.

Adherence to local agency or third party requirements will also need to be considered. These requirements will vary depending on the location of the project, local laws, and environmental considerations. Agencies with specialized requirements for near-water work may include greenways, parks, transportation, and environmental agencies/groups.

When in-water work is anticipated, a local notice to mariners (LNM) may be required by the US Coast Guard. LNMs are typically issued by the district Coast Guard office where the work will take place. These are generally required for any work in a navigable waterway, including for site investigations performed during the design phase.

Two other permits that may be relevant to in-water or below channel work in the US are from the Army Corps of Engineers (USACE):

- USACE Section 10 (Rivers and Harbors Act of 1899): Authorization for the construction of any structure in or over navigable water.
- USACE Section 404 (Clean Water Act): Authorization for the discharge of dredged or fill material into any water body, including wetlands.

5.7 ALIGNMENT GEOMETRY

It is often desirable to optimize a tunnel alignment by minimizing the thickness of overburden above the tunnel (i.e., building it at a shallower depth) to reduce the length of tunnel approaches and to reduce ground loads on the tunnel. However, other issues are important when selecting a tunnel alignment.

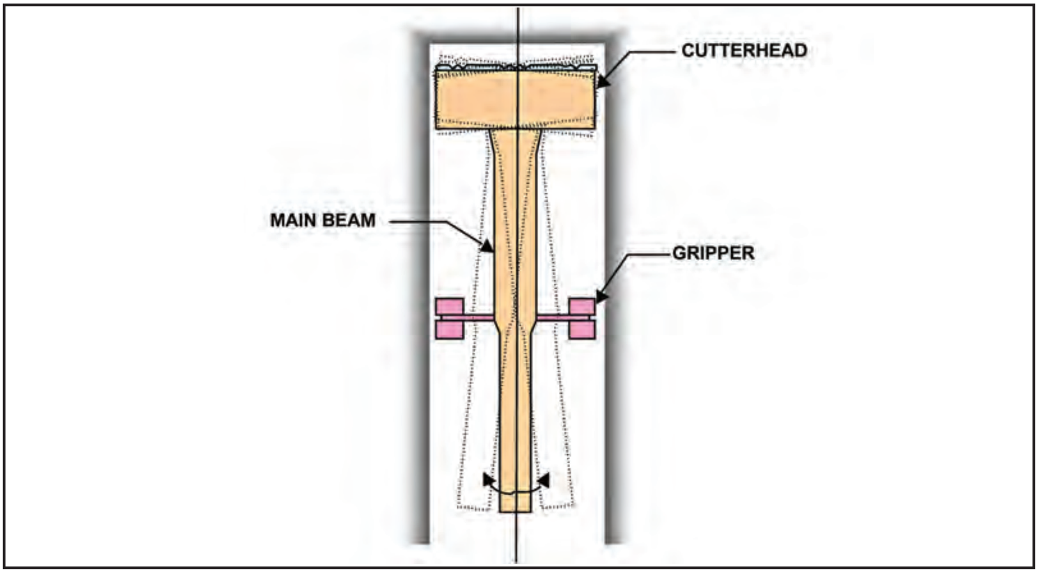
Vertical and horizontal alignment of open water tunnels is typically driven by the minimum clearance required between the channel bottom and the top of the tunnel. Clearance from existing shoreline structures may also be a consideration, with the tunnel alignment influenced by the proximity and arrangement of these structures, type of foundations, and the potential for adverse impacts from tunnel excavation. In addition, geologic conditions beneath the channel are critical, and project managers need to carefully consider the risk and consequence of encountering an adverse or unanticipated condition, such as an undetected fault zone, water-bearing feature, or geologic weakness zone.

For soft ground tunnels, a minimum clearance between the channel bottom and the top of the tunnel of 1.0 to 1.5 times the diameter of the tunnel is commonly used. However, the selected clearance will depend on other technical and non-technical factors, mainly subsurface conditions, maximum grade requirements for the TBM, buoyancy, channel scour, and the configuration of future channel improvements. Minimum cover above hard rock tunnels is typically controlled by functional requirements, such as grade or ventilation requirements. Buoyant forces acting on submerged tunnels in hard rock are generally insufficient to overcome overburden pressures, or cause failure of the overlying rock mass. However, for very shallow tunnels in rock, or tunnels with artesian considerations, stability of the tunnel under hydrostatic forces should be confirmed.

Maximum vertical and horizontal curvature of TBM-driven tunnels is controlled by the type and configuration of the boring machine. For planning and design purposes, a good rule of thumb to follow is the maximum curve radius should be less than about 20 times the tunnel diameter. Typical curvature constraints for TBM driven tunnels are illustrated in Figure 25. Note during design of segmental lining systems installed immediately behind a TBM, consideration should be given to eccentric loads on the lining based on the proposed maximum curvature of the tunnel alignment.

Alignment geometry for tunnels excavated by drill-and-blast is obviously less restrictive and is subject to the intended use of the tunnel structure, construction restrictions, and functional requirements of the tunnel (e.g., curvature and line-of-sight restrictions related to rail or road design speeds).

Figure 25. Constraints on Tunnel Curvature for Main Beam Type TBM (plan view)



For smaller diameter tunnels constructed by pipejacking (microtunnels built by hydraulically pushing one pipe segment into another to drive it along the tunnel alignment), horizontal and vertical alignment has historically been restricted to straight and constant grade alignments due to the nature of the construction method. As is often the case for open water tunneling, available shaft sites can be limited and the requirement for a straight alignment can increase project cost, due to deeper shafts or increased cost of property acquisition. Recent experiences in Europe have demonstrated that curved alignments are possible with microtunnel TBMs that have steering capabilities, thus alleviating the need for a straight microtunnel bore. Currently, this construction technique is only applicable to soft ground crossings, and its viability has yet to be fully demonstrated in the US.

5.8 SHORELINE DEVELOPMENT

Some of the most expensive real estate in the world is located on the waterfront, and subsurface development in the form of open water tunnels can impact property value by limiting future development at a site. Commonly, tunnel easements along shoreline property can be expensive and can present significant costs to open water tunnel projects. Recent increases in international trade have also provided sufficient demand for ports to expand their existing facilities. In many places, this has resulted in expansion or alteration of the shoreline.

When planning for open water tunnels in areas of potential port development, discussions with the local port authority should be held to allow the tunnel project to account for future expansion and/or improvements that may impact tunnel design and construction. Reconfigured shorelines, bulkheads, and associated foundations may impact external loading on the tunnel lining and associated shaft excavation support (e.g., slurry walls, secant piles, etc.).

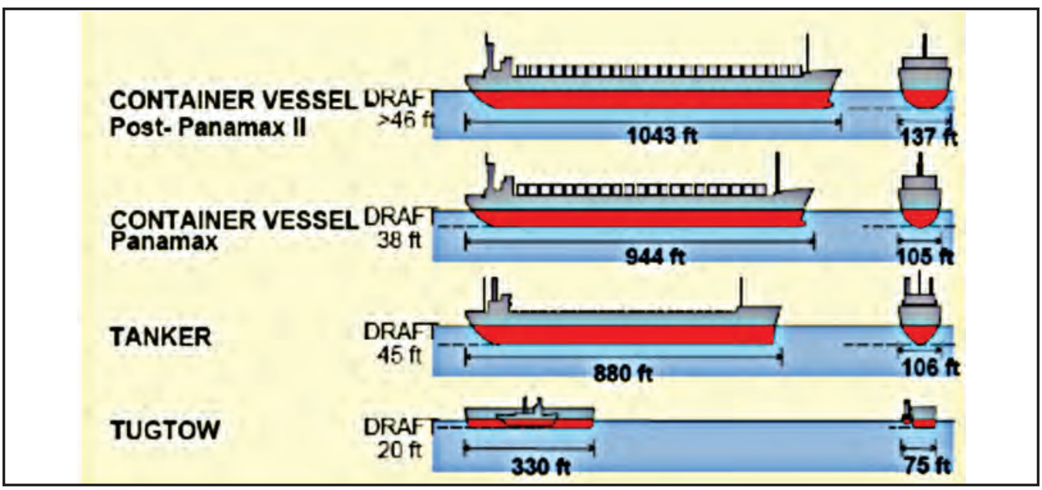
5.9 THIRD PARTY CONSIDERATIONS

Tunnels beneath open water are often subject to long-term operational risks due to activities from third parties. For example, tunnels located in the vicinity of mine tailings dams may be exposed to groundwater containing corrosive agents, and tunnels in saline environments will need to consider the effects of sodium chloride or other dissolved salts. Also, future alterations to the river flow regime, such as dredging and channel navigation improvements, will need to be considered. The following discussion highlights a few of these external considerations.

Dredging and Scour

Future channel development may impact the selected alignment and operation of the tunnel, particularly if this includes dredging or shoreline expansion into previously open water areas. In addition to alignment considerations, design of the tunnel lining will need to consider the full range of loadings anticipated from these future developments if they are applicable. A more rigorous evaluation of future dredging and its impact on a proposed tunnel may be needed if the tunnel alignment is proposed to have minimal soil cover. A preliminary evaluation can be performed by estimating the likely draft needed for the vessels anticipated within the channel. For reference, configurations of current commercial shipping vessels is provided in Figure 26.

Figure 26. Commercial Vessel Dimensions and Estimated Draft



Permanent loads due to placement or removal of dredged material could alter the stress distribution in the ground beneath and within the soil and/or rock mass, thereby potentially affecting underlying tunnels. Activities associated with dredging could load or unload the soils in the channel bed and alter stresses in the tunnel lining. In the extreme, this could lead to a reduction in the tunnel's margin of safety against structural failure. Tunnel design under this scenario will need to consider the anticipated change in ground loads, and also any consolidation settlement that may occur in compressible soils beneath the tunnel.

Anchors

Impacts from ship's anchors may need to be considered for design as they may impact tunnel construction (in the form of subsurface obstructions) or tunnel performance (resulting from increased impact load on tunnel linings in close proximity to the channel bottom). As shown in Figure 27, modern ship anchors can weigh upwards of 20 tons and have the potential to penetrate significant depths below the bottom of the channel if soil conditions are soft.

Most tunnels beneath open water will likely have a depth of cover much greater than the anticipated penetration depth of an anchor, so that the risk of impact from a falling anchor is judged low. However, it may be useful in evaluating the potential for encountering obstructions, particularly if the tunnel crosses beneath an area that was once open water but subsequently in-filled. Historically, anchors may have broken off prior to infilling, and if the historic channel depth is known, the potential depth of these possible obstructions can be estimated.

Figure 27. Photograph of a Modern Cruise Ship Anchor

If conditions do warrant an evaluation of anchor penetration, the following equations can be used as to estimate penetration depth:

$$x = 10 N_{pen} d_e$$

$$N_{pen} = \sqrt{\frac{m_w}{E_r d_e^3}} \cdot v_i$$

$$d_e = \sqrt{\frac{4A}{\pi}}$$

$$A = 0.6 + 0.2\frac{m_a}{1000}$$

where

x	penetration depth (m)
N_{pen}	penetration parameter
d_e	equivalent diameter of striking area of anchor (m)
m_w	mass of anchor reduced by the mass of the displaced water (kg)
m_a	mass of anchor in air (kg)
E_r	modulus of elasticity in the longitudinal direction of the layer (N/m²)
v_i	impact velocity of anchor (m/s)
A	cross-sectional striking area of anchor (m²)

6.0 EXCAVATION TECHNIQUES AND GROUND BEHAVIOR

6.0 EXCAVATION TECHNIQUES AND GROUND BEHAVIOR

In the previous two chapters, the planning and design process for open water tunnels was outlined and important design considerations were discussed. While it is the intent of this monograph to concentrate on site investigations and risk management techniques for open water tunnels, it is important to discuss other construction considerations, in particular the selection of an excavation technique that is suitable to expected ground conditions.

This chapter provides a general background on modern excavation techniques and is intended to provide enough detail to brief project planners and engineers on some of the issues regarding excavation techniques and their relationship to various types of ground conditions. This is not intended to be a thorough discussion of all possible excavation methods and ground types.

6.1 CONSIDERATIONS FOR OPEN WATER

Often the type or method of excavation selected for traditional dry land tunnels is dictated by the required cross section of the tunnel, site conditions overlying the tunnel alignment, length of tunnel drive without access to the ground surface, or the dominant ground conditions along the tunnel alignment. For tunnels beneath open water, the ground characteristics and behavior of ground under excavation is the most important consideration and is most likely to control the selection of excavation method. Where rock conditions are excellent and the likelihood of encountering a large groundwater inflow is minimal, excavation by drill-and-blast may be appropriate. Where groundwater inflow is a concern, or where soft ground requires the ground to be supported as soon as possible after excavation, a closed face tunnel boring machine may be more appropriate.

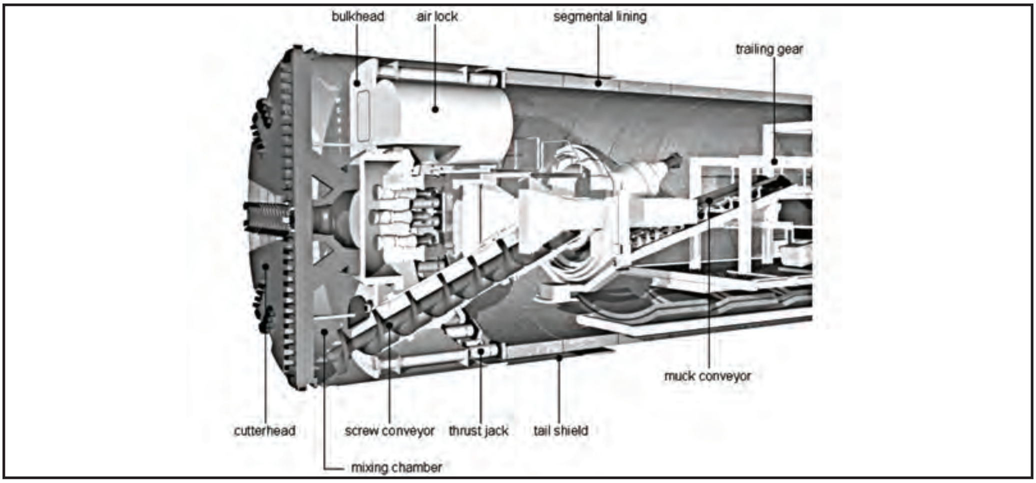
The following sections are intended to provide a brief overview of potential excavation methods for open water tunnels. The reader is advised there is no definitive methodology or standard for selection of excavation methods and the discussion presented herein is not intended to be exhaustive. Final selection must always consider the full range of ground conditions and the ground's behavior in response to the intended excavation method.

6.2 SOFT GROUND TUNNELS

Closed face TBMs are effectively sealed from the full ground and hydrostatic pressures. These TBMs are usually required for soft ground tunnels beneath open water due to their ability to maintain control of the ground, particularly at the face of the excavation, and their effectiveness at minimizing ground loss and reducing the risk of developing a connection to an overlying water body. Closed face TBMs provide positive support of the ground and minimize the potential for problematic groundwater inflows into the tunnel excavation. Closed face TBMs also provide a stable and safe underground work environment and are suitable for varying ground conditions.

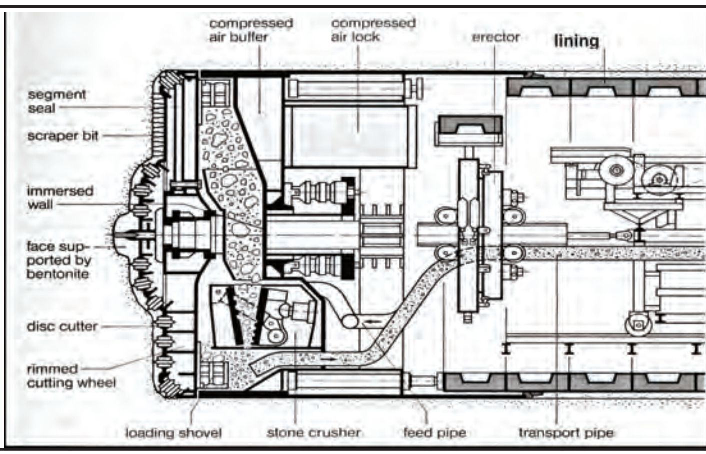
There are essentially two main types of closed face TBMs: (1) Earth Pressure Balance (EPB); and, (2) Slurry (mixshield) TBMs. EPB machines were developed to provide positive face support by allowing the excavation chamber to fill with soil behind a bulkhead or plenum, minimizing the risk of ground loss at the excavation face (Figure 28). EPB machines were designed to work in predominantly cohesive soils where excavated material can readily form a plug in the system's extrusion screw conveyor. Only recently have advances in admixture technology allowed EPB machines to adapt to and better manage cohesionless soils, which have a greater tendency to run or flow into an excavation that is not properly pressurized.

Figure 28. Schematic Section of an EPB TBM



Rather than relying on a soil plug to maintain face pressure, slurry TBMs utilize an entirely sealed excavation and mucking system that is capable of applying positive and active face support through fluid pressure from a bentonite slurry circulated in the excavation chamber (Figure 29). Originally, slurry TBMs were advantageous in submerged ground that was predominantly cohesionless with little or no fines (silt-sized particles or smaller). Now slurry TBMs are sometimes preferred over EPB machines in cohesive ground since they have the capability to provide precise control of face pressure through the use of a compressed air buffer. This design feature can be crucial for tunnels beneath open water where there are high groundwater pressures or risk of heterogeneous geology, since the compressed air buffer can immediately react to pressure changes.

Figure 29. Schematic Section of a Slurry TBM



Machine Selection

For tunnels beneath open water extending through soft ground, selection of an appropriate closed face TBM depends upon a number of factors, including grain size distribution of the soil, presence of gas, presence of boulders, hydrostatic pressures, area available for a mining site, spoil disposal and power requirements. The initial choice of the closed face TBM should be guided by the degree of heterogeneity of the soils and their respective grain size distributions. Figure 30 provides a simplified flow chart of the selection process for closed face TBMs based on anticipated soil types.

When more than 20 percent fines are anticipated, slurry TBMs will have difficulty separating spoil from the slurry, resulting in increased slurry separation time and slower TBM progress. For EPB machines, a fines content of less than 10 percent may cause difficulty in developing an adequate plug in the screw conveyor. Conditioners or positive displacement devices may be required for these soil types.

Typical soil gradations for slurry and EPB TBMs are presented in Figure 31. These guideline values, or zones, are considered generic. Final TBM selection should consider other project requirements such as tunnel length, heterogeneity of soil to be encountered, surface settlement criteria, hydrostatic pressures, and schedule/budget constraints.

Figure 30. Simplified Soft Ground Tunnel Excavation Methodology Flow Chart

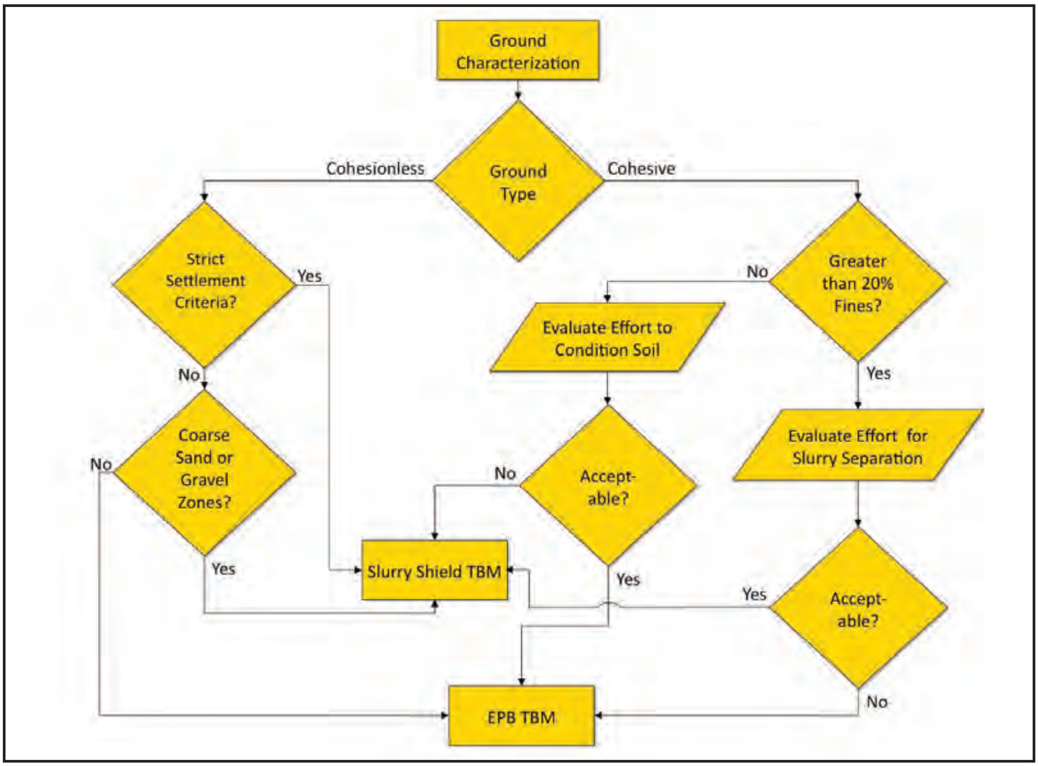
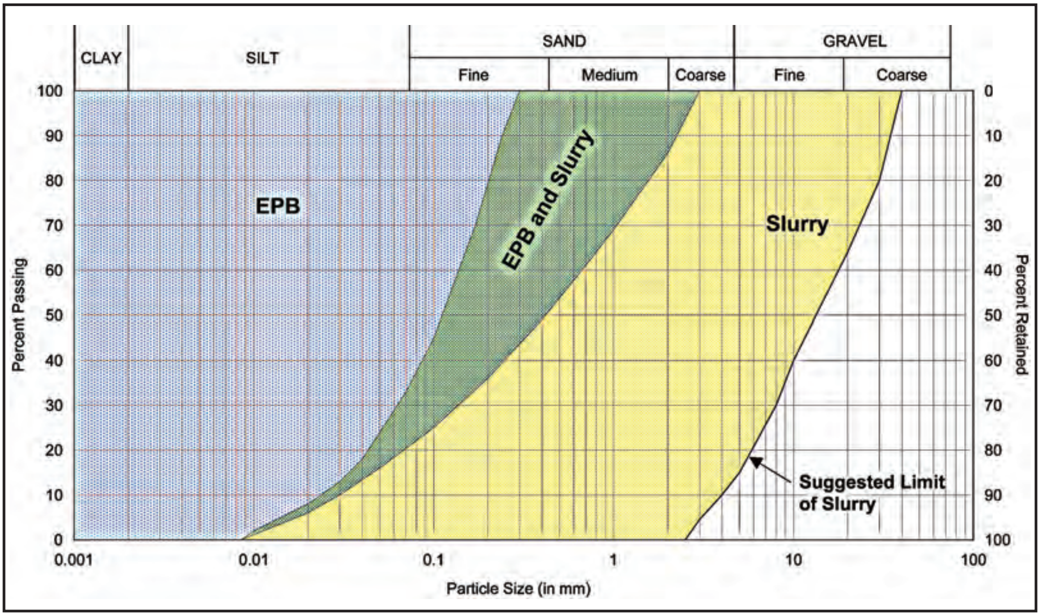


Figure 31. Grain Size Distribution for Closed Face TBMs



Note: Percent passing/percent retained refers to the weight of soil of a given particle size passing or retained on a sieve.

When selecting closed face TBMs for tunneling beneath open water, it is critical to consider the machine's ability to maintain equilibrium between hydrostatic/earth pressures above the tunnel and the applied face pressure. This is especially important where a tunnel is in close proximity to the seabed or channel bed. As many of the historic open water tunnel excavations experienced firsthand, pressure applied to the face of the excavation in excess of the overburden and hydrostatic pressures can result in a blowout and loss of face stability. This is generally a concern for slurry TBMs, since EPB TBMs do not actively apply face pressure.

For a simplistic example of factors influencing selection of a TBM type, consider an open water tunnel alignment that is anticipated to encounter predominantly clays and silts along its length with fines content greater than 50 percent. Due to alignment restrictions, the tunnel passes below a river channel with less than one tunnel diameter of soil cover. Under normal circumstances, an EPB TBM may be the preferred tunneling method in this ground type due to lower equipment costs and reduced spoil processing and disposal costs (slurry TBMs can require extensive processing time to remove the fines fraction of the excavated soils from the slurry; if fines content is high, this can also result in high bentonite consumption, increasing the cost of tunneling). However, considering that a reduced soil cover above the tunnel may result in higher than normal ground loss during excavation, a slurry TBM may be preferred since it can reduce the risk of ground loss and a potential catastrophic groundwater inflow.

Zones of highly permeable ground, such as gravel lenses with little fines, when encountered at the face of an EPB machine, may make maintaining an impermeable plug in the screw conveyor difficult. The resulting loss of face pressure can result in loss of ground above the machine and loss of ground support. Also, blowouts can occur along or behind a slurry or EPB

TBM shield from excessive tail skin grouting pressure. Injection of backfill grout will need to carefully balance the existing overburden and hydrostatic pressures, while providing sufficient pressure to prevent closure of the surrounding soil prior to backfilling.

Selection of a closed face TBM will also need to consider the need for interventions in order to facilitate maintenance and/or repair. Slurry TBMs provide a unique advantage over EPB TBMs in that they are aided by the presence of the bentonite slurry at the face, which can assist in developing a seal of the excavated face when compressed air is used to provide worker access to the cutterhead.

Overall, slurry TBMs provide an advantage over EPB machines in that they provide a completely closed excavation, minimizing the risk of a sudden influx of soil and/or groundwater. Slurry TBMs generally come at a higher cost and have more logistical requirements, such as a slurry separation plant at the ground surface (a slurry separation plant separates the excavated soil from the slurry which is circulated at the cutterhead and allows the slurry to be reused).

Large Diameter Tunnel Bores in Soft Ground

In the 1990s, technical advancements in soil conditioning agents (additives injected at the cutterhead of EPB machines that improve the workability of excavated soil) led to the design of larger diameter TBMs, up to 31 feet in excavated diameter (for example, at the Second St. Clair River Tunnel discussed in Chapter 3). At that time, one of the main factors limiting TBMs from getting even larger was exponentially increasing torque requirements for larger machines. Recently, advancements have been made in TBM design that allow machines as large as 50 feet to be successfully used. Machines of this size have been used on large soft ground tunnel projects in China and Europe. A listing of these projects is provided in Table 11, along with design details regarding tunnel configuration, ground conditions, TBM design requirements, tunnel lining and waterproofing. This information may be relevant for large diameter TBMs under consideration for new open water tunnel projects.

Table 11. Large Diameter TBMs and Selected Project Details
Mixed Face Excavations

		Tunnel					
		Shanghai Yangtze	Nanjing Yangtze	SMART Malaysia	Westerschelde Holland	Groen-Hart	M30 Madrid (Mitsubishi)
Tunnel Configuration	Open Water Crossing	Yes	Yes	Yes	No	No	No
	Excavated Diameter (ft)	50.6	49	43.5	37.1	48.8	49.2
	Bored Length (miles)	5.6	1.82	2.5 & 3.5	4.1	4.45	3.7
	Maximum Depth (ft)	75	98	65	197	200	Unknown
	Maximum Hydrostatic Pressure (bars)	6	7.5	5	6.5	4.5	Unknown
	Min. Alignment Radius (ft)	N/A	N/A	820	820	N/A	1,148
	Ground Conditions	Sa/Si/Cl	Sa/Si/Cl/Gr	Limestone / Sa	Sa & Cl	Sa	SaCl Cl
TBM	Type	Mixshield	Mixshield	Mixshield	Slurry	Slurry	EPB
	Total Installed Power (kW)	N/A	N/A	8,200	N/A	9,540	14,300
	Cutterhead Power (kW)	3,500	3,750	4,000	2,560	3,500	Unknown
	Torque (kNm)	39,945	34,700	24,400	12,900	30,100	85,700
	Thrust (kN)	203,066	185,000	94,500	120,687	180,737	317,000
	Number of Tail Seals	5	N/A	3	4	4	4
	Number of Grout Pipes	6	N/A	8	N/A	N/A	N/A
Tunnel Lining	Outside Diameter (ft)	49.2	47.6	43.3	36.1	47.6	48.1
	Lining Thickness (ft)	2.13	2	1.64	1.5	2	2
	Number of Segments	10	10	9	8	10	10
	Ring Width (ft)	6.6	6.6	5.6	6.6	6.6	6.6
	Number of Gaskets Used	2	2	1	2	2	Unknown

Cl = clay, Gr = Gravel, Sa = Sand, SaCl = Sandy Clay, Si = Silt

Mixed Face Excavations

Tunnels beneath open water often negotiate layers of both soft ground (soil) and hard rock. When the cutterhead of the tunnel boring machine is cutting through both types of ground at the same time (e.g., as the tunnel alignment transitions from one zone to the next) this is known as operating in a "mixed face" condition. Operating a closed face TBM in this condition is feasible but often extremely difficult, with risks including:

- Overcutting of the softer material (where the actual excavated volume exceeds the planned excavated volume)
- Reduced mucking ability
- Increased wear of cutting tools or even possible cutter damage
- Increased risk of ground loss and possible tunnel lining deformation from groundwater flows.

The following discussion highlights some of the technical considerations of TBM operation in mixed face conditions.

In mixed face conditions, circulating slurry or additives in the cutterhead area are required in order to provide face stability. At the same time, higher thrust is needed to provide ripping and cutting of the rock. Both high thrust and greater circulation of slurry or additives can lead to increased wear and abrasion on the cutterhead (Figure 32). Cutter damage may also result, requiring more frequent tool replacement and interventions.

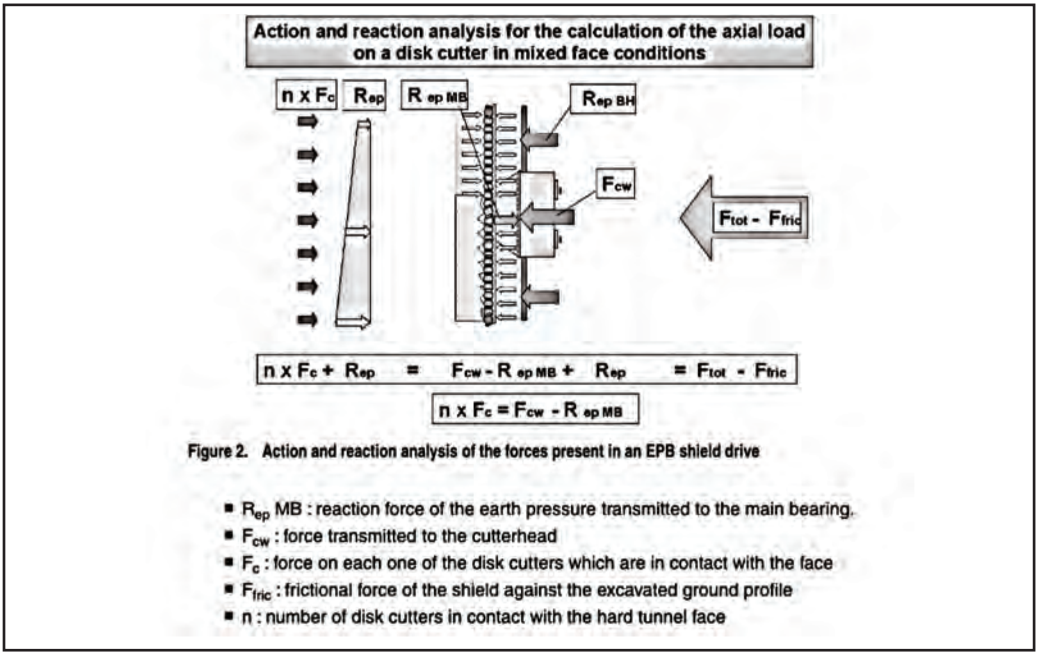
Decreasing thrust or circulation of additives may lead to an increase in face instability. Furthermore, in mixed face conditions only a fraction of the cutters are utilized to cut the rock and overloading of cutters is an important concern, since repair or replacement may be extremely difficult in mixed face conditions. In addition, poor material inflow can lead to secondary wear and clogging of discs. Blocky ground (defined as a rock mass that contains discrete blocks due to the presence and orientation of discontinuities, i.e., joints, bedding planes, etc.) can also reduce cutting effectiveness and decrease overall TBM performance.

Reducing applied thrust is sometimes considered when tool wear becomes excessive and overloading of the TBM cutters occurs. This also carries a negative impact on the excavation process by reducing the confinement pressure at the face and increasing the risk of face instabilities and ground loss. Reduction of face pressure can also allow unwanted ingress of groundwater and related difficulties in several areas, as illustrated in Figure 33.

The area of interface between soil and rock can be a natural conduit for groundwater flow and if face pressure and soil extraction rates are not carefully monitored, the groundwater can erode overlying or underlying soils, reducing their strength and increasing instability. Groundwater flow can occur from the ground around the shield and from behind the tunnel lining, leading to a washing out of backfill grout and erosion of the overlying soils, and possible deformation of the tunnel lining.

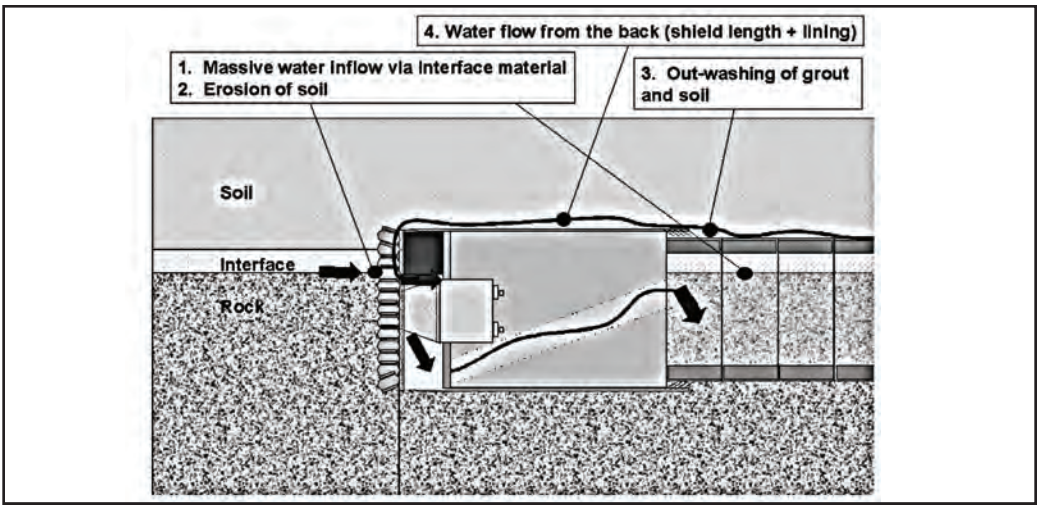
Finally, compressed air interventions are more difficult in mixed face conditions, due to variable conditions at the face and potential for difficulty in controlling applied pressures. The need for interventions in mixed face ground will be a function of the length of the mixed face zone, integrity of the rock being excavated, and how "hard" the TBM is pushed through this zone (the level of thrust).

Figure 32. Cutter Loading in Mixed Face Tunnel Excavation by TBM



(Source: Maidl, 2003)

Figure 33. Groundwater Flowpath for EPB in Mixed Face Condition



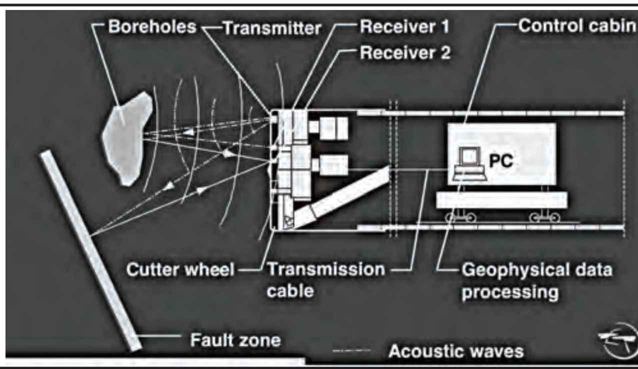
(Source: Maidl, 2003)

Remote Sensing Technology

Often information on ground conditions immediately in front of an excavation can be obtained from probes that are drilled down from the surface or from small bores drilled from the front of the TBM. Open water tunnel excavations often can't utilize probes from above due to lack of access above the tunnel to map or investigate these features in greater detail. Probes dug in front of the excavation take time and usually require excavation to slow down or stop. However, recent advances in remote sensing technology now provide a means to "see" in advance of the tunnel face, thus potentially allowing less reliance on direct investigation methods.

Sonic soft ground probing (SSP) is a proprietary system recently used on a small number of TBM tunnel projects. SSP utilizes acoustic waves with a source and receiver mounted at the TBM face. Potential obstructions and other reflective geologic features can then be mapped by way of seismic reflection (Figure 34) by introducing small vibrations into the ground and interpreting the resulting changes in the reflected signals. What makes this application so powerful is its data acquisition and analysis systems, which are typically fully automated. Potential drawbacks include inability to transmit seismic energy through conditioning or slurry products circulating at the face. Although use of this technology has been limited and not much case history data has been developed, initial studies have concluded that the technology can provide useful real-time information quickly and at relatively little cost.

Figure 34. Detecting Obstructions ahead of the Face



Another system is the Beam Scan developed by Geohydraulik Data of Germany. Beam Scan has been used in hard rock applications to detect shear zones, blocky rock or voids ahead of the excavated face. The cost of installation is approximately $30,000 to set up on the machine (a modification to the TBM head has to be made, and therefore it is important to specify this equipment in advance) and a cost of $10,000 per month to maintain. Beam Scan was installed in a TBM at the request of the owner's engineer on the Vancouver, BC subway extension project.

Other Technical Considerations

Many other TBM design considerations should be evaluated as part of the design process for open water tunnels, but final selection and implementation of these details are often best left to the TBM manufacturer to implement. The following lists can be used as a checklist for evaluating machine-specific requirements. These considerations are based on lessons learned from a number of past tunnel projects, including tunnels beneath open water as well as those under dry land.

Cutterhead and Shield Design

- Cutterhead bearings and seals should be replaceable from within the TBM as access from the ground surface will be extremely difficult, if not impossible
- Multiple wear and abrasion detection/monitoring points on cutterhead and within the mucking system, with associated reporting systems
- Injection ports for soil conditioners
- Stone crusher (if boulders or rock are anticipated)
- Probe, grout/freeze ports and extras on cutterhead for ground stabilization or treatment (to facilitate interventions for maintenance, obstruction removal, etc.)

Tail Seals and Annular Grouting

- Tail shield seals with grease injection system; repairable and maintainable from within the machine
- Computer operated and integrated grouting system which accounts for rate of advance, grout quantities, external pressure and related variables

Miscellaneous

- Screw and ribbon conveyors are replaceable from within shield
- Man and equipment lock for entrance in front of the pressure bulkhead for obstruction removal and cutterhead maintenance
- Positive displacement or positive lockout device on muck discharge
- Hyperbaric chamber for tool replacement, repairs, and removal of obstructions
- Real-time face pressure monitoring and muck weighing system to verify excavated volumes

Construction Issues

Even if appropriate construction equipment and methods are selected, errors can occur, or equipment can malfunction, resulting in increased cost, delay or unsafe conditions. Errors and other construction-related issues can be made regardless of the degree of controls and automation employed, the diligence of the construction manager and/or contractor's personnel, and the safeguards taken by the contractor. Examples of potential issues include:

- Over-excavation of soil material not matched by shield advance can result in excessive ground surface settlement
- Excessive pressure in sealed front compartment of shield can result in heave in soft or loose soil conditions and subsequent reconsolidation of disturbed soil, resulting in long-term settlement
- Malfunction of tail void filling system, or negligence in its operation, can result in closure of the tail void with soil before grout placement, with resulting ground loss and additional settlement
- Steering errors can result in the tunnel being off-line or grade
- Construction errors or operator negligence that can cause loss of life or injury to construction workers, such as electrical hazards, moving vehicle events, moving components events (conveyors, erector arms), trips and falls, etc.
- Major equipment malfunction or failure, such as main bearing failure

Remedies against these types of errors and construction-related issues can be reduced by increasing the degree of controls and automation, adding additional safeguards, and hiring experienced, diligent personnel. Potential remedies include:

- Selection of a qualified, experienced contractor
- Employment of experienced contractor supervisory staff
- Employment of experienced TBM operators
- Employment of an experienced geotechnical engineer to promptly review subsurface conditions and to analyze settlement and instrumentation data, and TBM records during tunneling
- Preparation and submittal of contingency plans to mitigate high-risk events
- Preparation and adherence to rigorous operations and safety rules
- Regular safety meetings of all contractor and CM staff
- Appointment of a responsible, trained safety officer by contractor
- Requirements for quality of TBM provided, such as all-new main bearing seals, new hydraulic system components and other critical items whose failure may have a significant effect on schedule
- Installation of operational controls on tunneling equipment that do not permit advancing of the TBM unless all critical elements are functioning (e.g., no advance if the grout backfill system is not operating under proper pressure; and no advance if muck intake does not match advance rate)
- Real-time and continuous monitoring of TBM operational parameters, including annulus grout pressure and volume, thrust, lining erection time, any delays incurred during shoving or ring erection, and tunnel alignment data (horizontal and vertical attitude of TBM compared to theoretical)
- Prompt analysis of all settlement monitoring and observation data, and TBM operation records, subject to verification by the owner's representative
- Prompt reaction to adverse observations and implementation of prepared contingency plans
- Preparation of contract documents that assign responsibility for safety and property damage to the contractor
- Rigorous supervision by construction management staff to verify that specifications and rules are followed and any adverse trends are arrested by appropriate action
- Adequate spare parts on-site or readily available
- Adequate compensation to attract and maintain experienced personnel

Precast Concrete Linings and Constructability Issues

For open water tunnels with tunneling linings constructed with a precast concrete segmental lining erected behind a TBM, close monitoring of segment and ring build issues is critical to the long-term performance of the tunnel. The tunnel lining will likely be required to provide support for the following loading conditions:

- Full ground and hydrostatic loads
- Thrust jack loads (from the TBM advancing itself forward)

- Self weight of the machine and trailing gear
- Annulus grouting pressures
- Additional loads from external structures
- Uplift due to buoyancy (if applicable)

Since access above the tunnel will be limited, any repairs to the lining will likely need to be performed from within the tunnel, which can be a costly and time consuming endeavor. Therefore, it is important that close monitoring of the segment manufacturing, transport, and ring building processes be performed to identify potential issues, particularly related to concrete durability, ring build tolerances, and the required watertightness of the lining. Common ring building issues related to precast concrete linings installed behind a TBM are presented below in Table 12.

Table 12. Summary of Potential Issues During Ring Building for Precast Concrete Segments

Ring Build Issue	Preventative/Corrective Action
Incorrect gasket installation	• Inspection by design and construction management personnel. • If installed, observe lining and if leaking, evaluate need for post-grouting or other remedial measures.
Segment cracks or damage prior to installation	• Visually check for signs of damage after segment delivery to the mining shaft. Segments with damage should be rejected and returned to the segment plant for repair. • If damage continues to occur, review quality control processes during segment manufacture. • Document location of repaired segments within the tunnel and monitor.
Ring build not in compliance	• Check ring build by measuring ring non-planarity and/or non-circularity that may cause segment damage or gasket leakage. • Ring and segment offset should be checked to verify gasket tightness. • Issues with ring build are best addressed during installation since disassembly will be difficult. Guide rods and ring dowels can be used to help guide each segment into its proper position. • If gaps and offsets exceed the specified requirements, the ring should be rebuilt or injections and repair will be needed before the drive can continue.
Segment manufacture out of tolerance	• Check regularly and at short intervals the segment measurements - external width, internal width, radial ends, and circumferential sides – for conformance with tolerances in specifications.
Post-installation ring and/or segment damage (within and outside the shield)	• Recurring segment damage may be due to an improperly designed segment joint. Review of the segment design should include a review of the position of the gasket groove within the segment and the gasket type, width and thickness. Corrective measures include redesign of the segment or adjustment to the installation and mining procedures (if cost effective and technically possible).

Table 12. (Continued) Summary of Potential Issues During Ring Building for Precast Concrete Segments

Ring Build Issue	Preventative/Corrective Action
Post-installation ring and/or segment damage (within and outside the shield)	• Segment damage can result from high contact stresses from advancing the TBM, misalignment of the thrust jacks, and/or excessive segment deflection (movement of the segments that occurs as a result of the pressure applied from the thrust jacks). The positions of the thrust jacks must be routinely checked to ensure they are kept in their intended position on the segment. Any misalignment should be corrected immediately. TBM "roling" should also be monitored, as this can also be a cause of thrust jack misalignment. Changing the direction of the cutterhead rotation (if using a bi-directional cutterhead) can help correct TBM rolling. • For damage caused by improper handling of the segments, corrective measures should include reviewing installation procedures, reviewing the sequence of segment compression, confirming that segments are built within specified tolerances, and confirming segment bolts are sufficiently tight and secure. These procedures may require modification depending on the type and location of the segment damage. • Eccentric rings can cause concentrated loads on the lining that may result in damage at segment interfaces, i.e., bolt pockets. Preventative action includes careful monitoring of the shield tail offset and continuous checking of the ring build and supervision of the installation process. • Excessive annulus grouting pressures can sometimes be the highest load experienced by the tunnel lining. Twisting of ungrouted segments inside the shield can sometimes occur upon leaving the shield and can cause damage at the segment corners. These deformations can be limited by careful monitoring of annulus grouting pressures to ensure simultaneous grouting and by maintaining compression of longitudinal joints at the end of the shield. • Insufficient annulus grout hardening or insufficient annulus grout volumes can result in lining deformations outside of the shield under buoyant pressures and can cause segment spalling (e.g., concrete chipping). Under this circumstance the grout mix design should be reviewed to ensure hardening is occurring quickly enough to minimize distortions. Insufficiently hardened annulus grout can also result in lining deformations and segment damage as a result of wheel loading from segment delivery cars and the TBM trailing gear. Loading from the first delivery car should be distributed as much as possible to minimize concentrated loads and deflections.

6.3 HARD ROCK TUNNELS

Excavation of open water tunnels in hard rock can be done with either drill-and-blast or mechanical (TBM or roadheader) techniques. It is likely these methods will be carried out under free air, unless other factors dictate the use of a closed face TBM. Potential conditions that restrict open water tunnels from being excavated in free-air are:

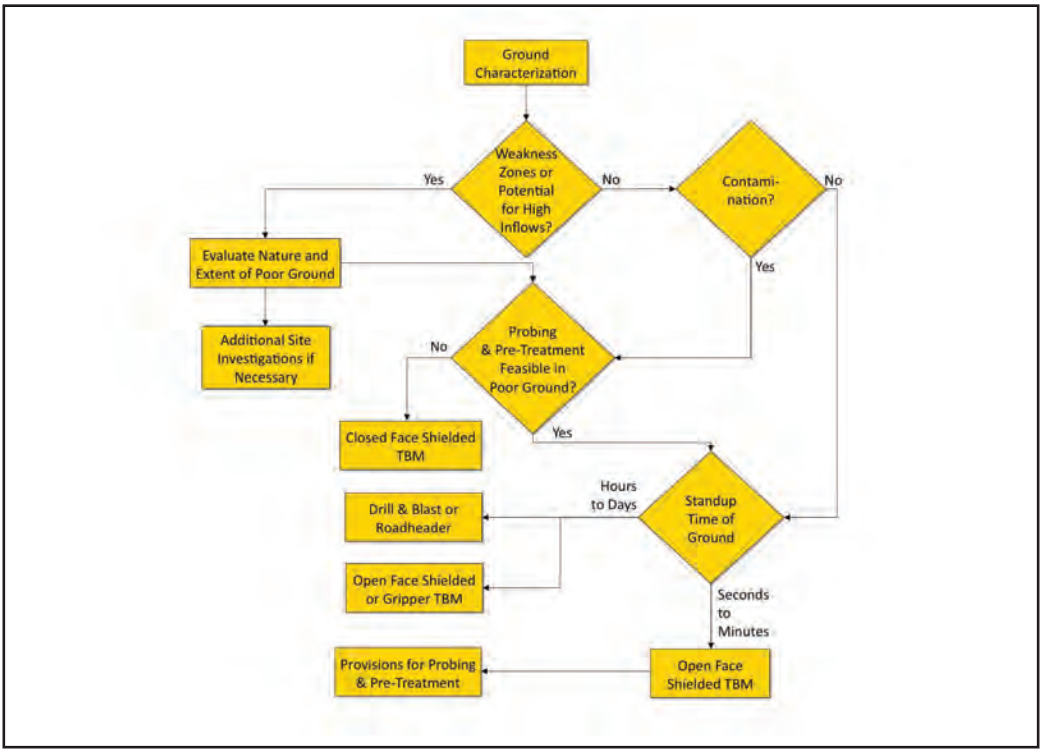
- Potential for high and uncontrollable groundwater inflows
- Presence of gas or contaminated groundwater in soil or rock
- Poor rock conditions and potential for unstable excavation

Often, the most efficient method to control groundwater in the excavation is to select the most favorable geology to excavate within and adjusting the tunnel alignment accordingly. This was the case for the Channel Tunnel (Chapter 3) where project designers anticipated most favorable tunneling conditions would occur within the Chalk Marl. The tunnel alignment was ultimately selected to coincide with a relatively flat-lying geologic stratum that was predicted to minimize the risk of groundwater inflows and ground instability.

For hard rock tunnels beneath open water, selection of an appropriate excavation technique depends on a number of factors. A simplified flow chart outlining the selection process for rock tunnels beneath open water is presented in Figure 35.

A unique advantage for some open water tunnels in hard rock is the ability to construct a smaller diameter pilot tunnel, or pilot heading, to test excavation techniques and confirm predictions of ground conditions. A pilot tunnel can also be used to detect localized geologic defects that may have considerable consequences for the larger primary excavation, such as open joints with high groundwater inflows, zones of weak or poor quality rock, and variation in rock type. Where a pilot tunnel or heading is deemed impractical or infeasible, probe drilling ahead of the excavation is a simpler option to detect and pre-empt difficulties with excavation due to unexpected geologic conditions.

Figure 35. Simplified Hard Rock Tunnel Excavation Methodology Flow Chart



Geologic Weakness Zones and Groundwater Inflows

During site investigations, geologic weakness zones are often detected by geophysical surveying, core drilling, analysis of core samples, and observations made in the field during drilling and sampling. Where investigations indicate reduced seismic velocity, low rock quality, low core recovery, or loss of water circulation during drilling, these areas should be considered critical during the site investigation stage and additional effort should be extended in order to identify and characterize these zones.

During the design phase, the potential for encountering these zones will need to be assessed by a thorough geologic investigation, including use of geophysical techniques and interpretations by skilled and experienced geologists and engineers. Common geologic features that require investigation for characterizing weakness zones and areas of high groundwater inflow include:

- Contacts between rock types or geologic formations
- Geologic structure and orientation of beds or folds
- Fault and shear zones
- Intersections between rock mass discontinuities (i.e., joints and fractures)

Where geologic weakness zones or localized areas of poor or reduced quality rock are anticipated beneath a water crossing, prescriptions for how to treat these areas must be developed. These prescriptions will vary depending on the excavation technique and what impacts the weakness zone will have on construction. Determining what design or construction measures should be implemented is particularly challenging where access from above the tunnel is restricted or not available at all, as most treatment activities can only be accomplished from inside the confines of the excavation.

In addition, contingency plans should be developed and ready to implement in the event undiscovered or unanticipated weakness zones are encountered during construction. Detecting these zones in advance can be done using probe holes ahead of the excavation face, and careful geologic mapping to confirm assumptions made during design. Contingency plans, including ground stabilization, ground treatment and groundwater inflow control strategies, will vary depending on the type of problem encountered as well as the excavation method selected, but at a minimum should include keeping supplemental and emergency equipment readily available on site.

Probing, Pre-Excavation Grouting, and Groundwater Control

Pre-excavation grouting is often performed ahead of the excavation face to stabilize or improve the ground, or to cut-off groundwater inflows so that the advancement of the excavation can proceed with as little delay as possible. Typically, probe holes are advanced ahead of the tunnel excavation to detect weakness zones and areas of high groundwater flows before they are fully encountered by the excavation. The grouting is then injected from these same probe holes.

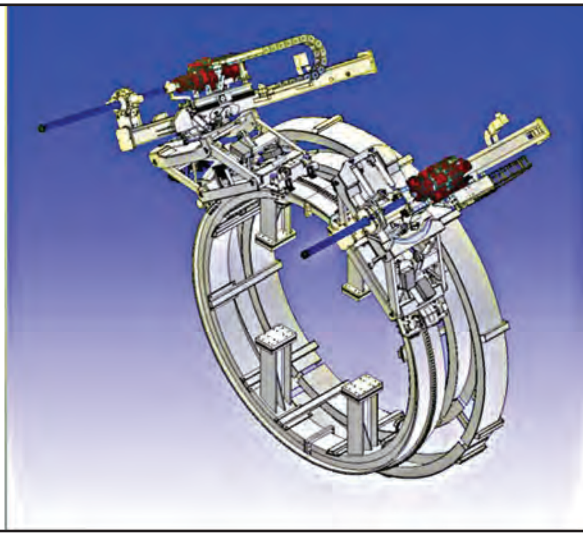
For open water tunnels in hard rock, multiple probe holes are recommended with the length, position and orientation controlled by the, tunnel size, surrounding geologic conditions, and the excavation type (TBM vs. drill-and-blast). For TBM excavated tunnels, fewer probe holes may be preferred since access to the face is more difficult and probing significantly disrupts TBM operation and the excavation process, slowing advance rates. Consideration should always be given to probing during TBM downtime, i.e., during maintenance or other planned stoppages.

The length of probe holes should range from 20 to 50 feet and should be adjusted based on the geologic conditions. For drill-and-blast excavations, probe holes should be advanced prior to each round. In drill-and-blast tunnels, a round of excavation commonly refers to the length of rock removed during each blast and is equivalent to the blasthole length. A blast round typically ranges from a few feet to several feet. For TBM excavations, the distance between probe holes can be longer, provided that a minimum length of probe is maintained ahead of the excavation at all times.

Types of grout used for pre-excavation grouting applications vary significantly and will need to be custom tailored to meet the demands of each project. Grout types can range from quick setting gels to low viscosity fluids that can sometimes penetrate great distances. In general, grouts used for waterproofing will contain some portion of bentonite or other expansive chemicals, which swell to many times their original size when they come in contact with water, rapidly forming a plug, or helping to stiffen fluid soils. Chemical grouts can also be advantageous for water cut-off when quick gel times are required or washout is a concern due to high groundwater flows.

It is important to note that most probe hole drilling (Figure 36) does not retrieve core samples; only drilling rates, penetration, torque, drilling pressure, drilling fluid pressure, and water loss can be recorded. Therefore, geologic interpretation of this data will be needed when making predictions regarding the possible presence of weak or water-bearing zones. Drilling systems with core recovery can be considered but are less common and will likely require mobilization of a drill rig to the tunnel face that is independent of any drilling equipment within the TBM. For closed face TBMs where there is a risk of groundwater or soil entering the cutterhead, openings in the bulkhead for a probe hole will need to have a “preventer” system or “stuffing box.” Geophysical surveying, such as seismic velocity logging or ground penetrating radar, can also be performed along the length of the open probe holes provided the diameter is sufficiently large to accommodate insertion of the geophysical instruments..

Figure 36. Probe Drills Mounted on a Hard Rock TBM



Selection and implementation of the means and methods used to control groundwater inflows will heavily influence project schedule and cost. Most groundwater inflows below 100 gallons per minute can be managed with little impact to construction operations. However, larger groundwater inflows can significantly impact equipment downtime, worker efficiency, and the ability to treat or mitigate the inflow. For tunnels where a prefabricated liner, such as concrete segments or steel liner plates, is specified, the presence of relatively minor groundwater inflows can be problematic. Where these liner systems are installed immediately behind the TBM, groundwater inflows are forced to the heading of the excavation and can unexpectedly impact TBM progress if not planned for. If not controlled, these "shunt" flows can wash out tailskin (annulus) grout and be difficult to stem.

6.4 HARD ROCK TUNNEL CASE STUDY – TUNNEL F, SSDS, HONG KONG, CHINA

Tunnel "F" of the Strategic Sewage Disposal System (SSDS) extends from Tsing Yi Island to Stone Cutters Island near the Kowloon side of Hong Kong Harbor in China. This open water tunnel is described as a case study by Barton (2006) and McLearie et al. (2001). The open water portion of the tunnel extends for a distance of about 1.8 miles and up to 475 feet below sea level, a portion of which passes beneath the world's second largest container port. Unfortunately, contract consultants failed to properly characterize a large fault zone within the limits of the tunnel alignment, the Tolo Channel Fault Zone. This zone was not explored or investigated in sufficient detail in large part due to difficulties in performing site investigations within the channel (due to the heavy ship traffic and the presence of man-made filling associated with the port construction). Seismic profiling was performed but did not detect the low velocity areas associated with the fault zone.

Tunnel excavation was carried out by an open face, main beam type TBM. During initial tunneling three faults were crossed, ranging in length from about 50 feet to 900 feet in length (Figure 37). Excavation through each of these zones lasted between 4 and 10 months and required extensive pre-treatment, primarily in the form of grouting. Significant delays to the project were incurred as a result of the reduced tunneling productivity. Overall the tunneling advance rate was about one tenth of the rate anticipated by the contract consultants.

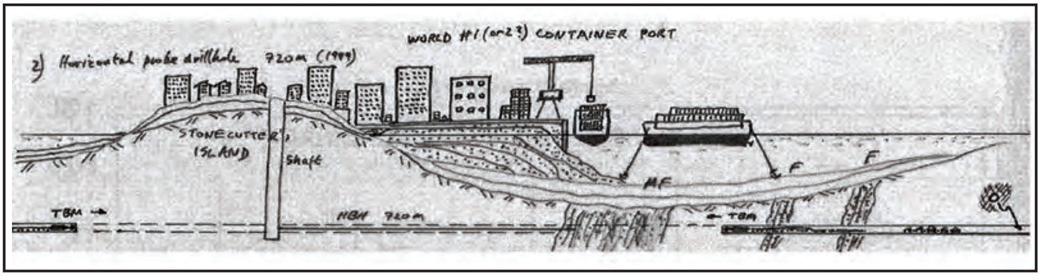
In the longest fault zone, the Tolo Channel Fault Zone, geologic conditions were highly variable and consisted of decomposed and poor quality rock, and areas of high groundwater inflows (up to 3,500 liters/min). Conditions were in fact so poor that the contractor attempted to advance a horizontal exploratory borehole from the forward (receiving) shaft in an attempt to map and characterize the nature of the fault zone; however the borehole could not even penetrate into the fault zone.

Part of the difficulty in mining through these fault zones with a TBM was the limitations imposed by the confined working environment within the TBM itself. Probe hole drilling from within the TBM was extremely limited since holes had to be positioned through openings in the cutterhead, which were few, and there was only room for two rock drills to operate within the TBM. Pre-treatment, or pre-excavation grouting within a tunnel is often most efficient during drill-and-blast type operations, as grout holes can be drilled more frequently for each excavation round and can also be placed at more effective grouting locations.

Although some of the fault zones were anticipated along the tunnel alignment, the slow progress and difficulty in advancing the TBM through these zones was not expected. In retrospect, the delays mentioned above can be partially attributed to the machine selection, as better progress through the fault zones might have been achieved with a drill-and-blast type excavation. It is arguable that drill-and-blast would have provided a more flexible construction environment and perhaps even provided a more efficient excavation since pre-treatment of the ground and pre-support measures (spiling) could have been implemented more easily. However, given the extreme depth of the tunnel within the channel, pre-treatment would have been problematical and the difficult conditions ultimately would have had to be addressed from within the tunnel excavation.

An important lesson learned from this project is the concept that fault zones, or other weakness zones, often represent an extreme condition. Proper characterization of these zones requires an evaluation that extends far beyond the central tendency of rock qualities along the tunnel alignment. Evaluation of the ground and its likely behavior during excavation should consider the overall length of tunnel, and the location of the anticipated fault zones, since any fault zone expected at a great distance from a launching or mining shaft will only magnify the difficulty of extending the tunnel through this zone.

Figure 37. Schematic of Tunnel "F" Excavation Through Fault Zones



(Source: Barton, 2006)

7.0 SITE INVESTIGATIONS FOR OPEN WATER

7.0 SITE INVESTIGATIONS FOR OPEN WATER

Site investigations for open water tunnels are an integral component of the risk management process; a tool that, when implemented properly by experienced geo-professionals, will have a positive impact in reducing one of the most import project risks: ground conditions. A high-quality site investigation provides data along the entire project corridor to characterize ground conditions, define the groundwater regime, identify areas of potential contamination, and assess potential impacts to the project from previous site use.

While some unknowns will remain under the best of circumstances, a properly designed and implemented site investigation will:

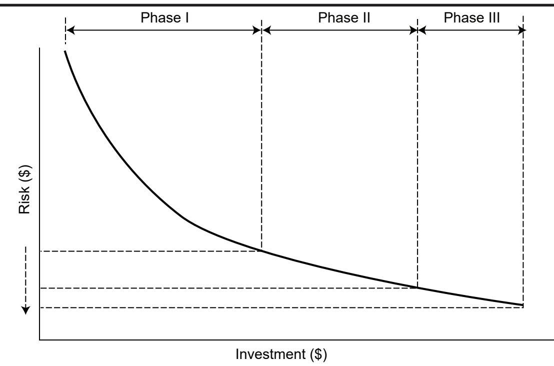
- Determine construction feasibility
- Assist with determining the best horizontal and vertical location of the tunnel
- Provide engineering parameters needed for selection of a safe and economical construction method (drill-and-blast, roadheader, closed face TBM or open face TBM)
- Provide data needed for a safe and economical tunnel design (e.g., pre-fabricated concrete rings vs. cast-in-place or metal rings, type of waterproofing to be used, etc.)
- Reduce occurrence and impact of unforeseen conditions
- Provide a basis for identification of ground-related risks and selection of contingency measures or other means of risk mitigation

The following sections provide general considerations and recommendations for site investigations as they relate to open water tunnels and risk management. Further guidance relating to site investigations for underground projects can also be found in *Study of the Efficiency of Site Investigation Practices* (Mott MacDonald and Soil Mechanics Ltd., 1994), *Engineering and Design: Tunnels and Shafts in Rock* (US Army Corps of Engineers, 1997), and *Geotechnical Site Investigations for Underground Projects* (US National Committee on Tunneling Technology, 1984).

7.1 SITE INVESTIGATION PLANNING

A typical site investigation process for open water tunnels can be divided into three phases: (1) Desk Study, (2) Design Level Study, and (3) Contingency Study. As each phase is completed, additional information regarding the ground is obtained and geotechnical risk – which can substantially impact costs – is reduced (Figure 38).

Figure 38. Level of Risk as a Function of Investment in a Site Investigation Program



Site investigations do not necessarily stop when various stages of the design are complete. Ideally, a site investigation program should be ongoing throughout the planning and design process, and, in fact, should continue during construction as well, through interpretation of probe and borehole drilling data. As detailed below, significant investment (schedule, financial and interpretive) should be expended early and continued as the geotechnical and geologic and geotechnical model is advanced.

Stage I – Desk Study

All open water tunnels should begin with a desk study to provide data to determine viability or feasibility of a proposed project or to provide background and historical data to supplement future design level studies. Data collected during this stage may not relate specifically to the tunnel, or the portion of the tunnel beneath open water, but rather will allow a confident selection of project alignment and the likely methods of construction and cost. This effort would typically be considered prior to preliminary design (up to approximately 15 percent of the total design effort).

Stage II – Design Level Study

Investigations for this stage will generally be conducted in greater detail than the desk study stage and provide data for design of the tunnel and temporary works, selection of appropriate means and methods, and to identify difficulties that may be encountered during construction. Likely investigation methods will include drilling and sampling along the project alignment, in-situ testing, laboratory testing, and geophysical surveys.

Stage III – Contingency Study

A contingency plan may be considered depending on the project and the complexity of the geologic conditions identified along the project alignment in Stage I or II. The Contingency Study would be used to help determine detailed prescriptions for high-risk situations likely to be encountered during excavation, as well as identifying the associated financial risks. If ground conditions are anticipated to be especially difficult, it is recommended that a contingency fund be set aside in the event the design level study does not completely characterize ground conditions, or in the event subsurface risks can be mitigated by the implementation of additional exploration during construction. For example, a full-scale on-site pump test at the start of excavation could determine the viability of dewatering when the pre-construction borings indicate a potential for high groundwater flow.

7.2 GEOTECHNICAL BASELINES

In the US, a Geotechnical Baseline Report (GBR) is becoming the preferred method for defining and sharing underground risks in construction. The GBR provides an interpretation of the geotechnical data, subsurface and site conditions and ground behavior likely to be encountered during the performance of the work. These reports also include discussions of potential geologic and man-made obstructions or other features that may impact construction. Guidelines for preparation of GBRs have been published by ASCE in *Geotechnical Baseline Reports for Construction: Suggested Guidelines* (Essex, 2007).

Conclusions regarding the subsurface and site conditions and the anticipated ground behavior are derived from geotechnical information and data gathered from the borings. While this information is based on substantial geotechnical investigations and analyses, because of the natural heterogeneity of subsurface conditions, the GBR cannot be a guarantee or warranty that the conditions encountered during construction will be exactly as described. Ground behavior will vary and will also significantly depend upon and be influenced by the construction methods used by the contractor.

The objectives for establishing the baselines are to provide a basis for reducing uncertainty and the degree of contingency in contractor bids, and to assist in the administration of the differing site conditions clauses contained in the contract documents. As part of the contract documents, the GBR, as used in underground construction projects, establishes a contractual statement of the geotechnical conditions anticipated to be encountered during construction. It provides a definition (qualitative and quantitative) of the physical site conditions, so as to provide a "level playing field" upon which all bidders will base their proposals.

It is important for the planners of site investigations to consider how geotechnical baselines will be established and to implement exploration techniques to provide robust and defendable data. Furthermore, the exploration methods selected to investigate baseline parameters should be similar to techniques the contractor would use under reasonable circumstances.

7.3 GEOMORPHOLOGY

Geomorphology is the study of the earth, its landforms, and their relation to geologic structure. It is important to understand geomorphologic processes and the results of these processes, as they can provide useful interpretation of subsurface conditions, without the need for more expensive site investigations. Simple geologic considerations such as the age of a river channel, rate of flow, geologic structure underlying a body of water, or location of major faults and geologic contacts, all can have an impact on the planning, design, and ultimately, construction of an open water tunnel.

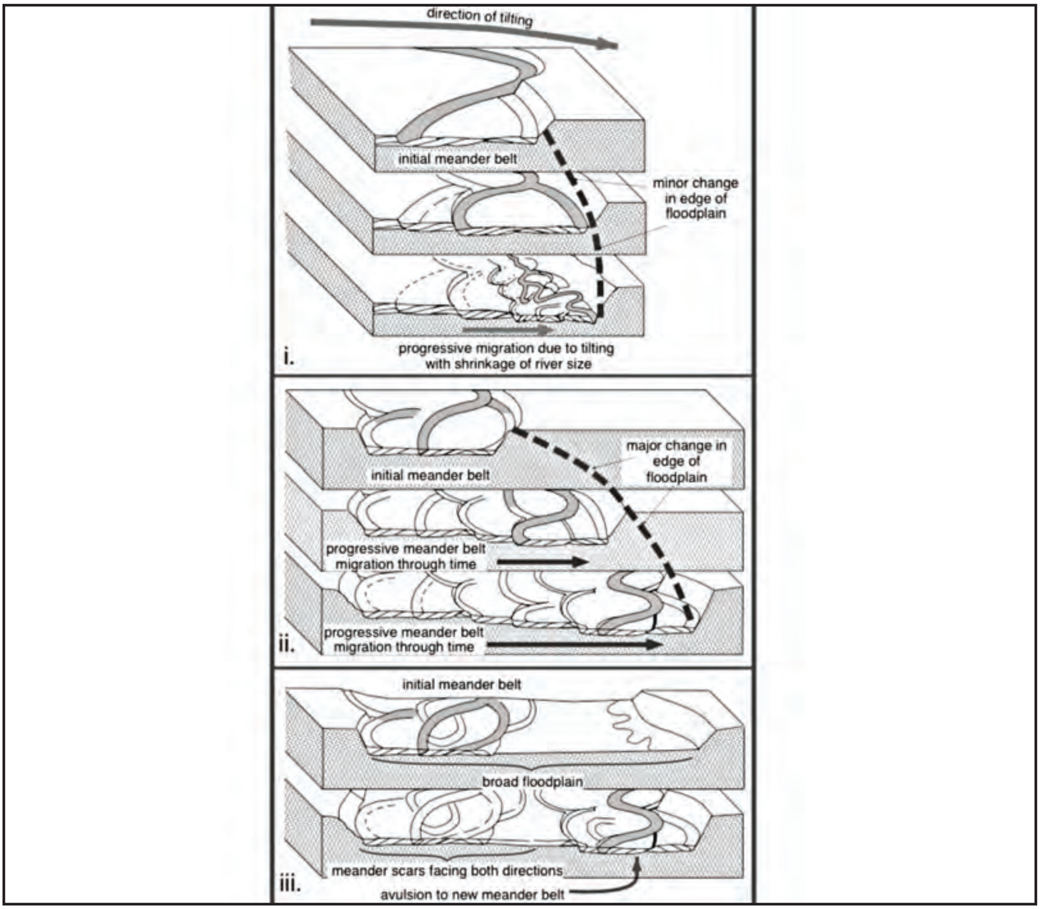
This monograph will not provide a detailed discussion on the science of geomorphology, but rather highlight a few of the unique processes that, when fully understood in terms of the geologic or geomechanical model, may have a direct impact on open water tunnels and should be captured by the geotechnical site investigation. For example, bedrock structure can play a key role in the width of a fluvial channel, and perhaps the length of soft sediments anticipated to be excavated at the tunnel horizon. Figure 39 shows how tilting of the underlying bedrock (which can be detected by core samples and geologic interpretation) can indicate locations of historic river channels that may be present outside the present day location of the river channel. Alternatively, the presence of faulted rock structure may indicate the potential for weakness zones at the tunnel depth, and investigations should attempt to detect and map these features to the fullest extent possible. Figure 40 shows areas of low seismic velocity that have been inferred to be faults and then projected as possible weakness zones at the level of the proposed tunnel.

Geologic conditions and processes specific to open water tunnels can be categorized by the geomorphology by which the bodies of water have formed. Understanding the geologic process that formed the bodies of water can identify typical subsurface conditions and geotechnical risks.

To assist in identifying and planning for subsurface risks, two types of geomorphology are likely to be encountered for open water tunnel crossings:

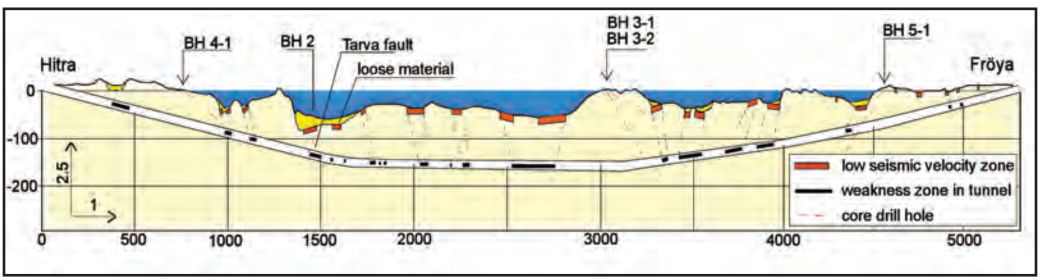
1) **Fluvial:** Body of water that flows and transports sediment over a channel bed, includes lakes, rivers and streams and other conduits of surface water
2) **Oceanic:** Area of oceanic crust covered by water, includes bays, seas, fjords, straits, and archipelagos

Figure 39. Channel Development for a Meandering River on a Tilted Floodplain



(Source: Burbank & Anderson, 2000)

Figure 40. Potential Faults and Weakness Zones Along a Tunnel Alignment



(Source: Nilsen & Palmstrøm, 2001)

Each of these geomorphologic types typically exhibits geologic traits at the surface that can be used to anticipate common subsurface features for open water tunnel crossings. These conditions are summarized below in Table 13.

Table 13. Common Geologic Conditions for Open Water Tunnels

FLUVIAL		OCEANIC	
Water Body	**Geologic Condition**	**Water Body**	**Geologic Condition**
Rivers Streams Lakes	• Rapid changes in soil stratigraphy • Potential for large clasts (cobbles & boulders) • Buried channels • Soft sediments along channel bed • Changing channel depth due to scour	Fjords Straits Bays Seas Ocean	• Major faults or zones of weakness where deepest part of channel coincides with weak zones or faults • Saline water - impact to equipment and long term performance • Soft sediments along channel bed • Commonly flat lying sedimentary rock deposits

For hard rock tunnels, weakness zones in the rock mass can sometimes be found along topographic lineaments (observable linear features at the surface which are often expressions of crustal structure, such as fault lines and highly fractured zones). Since these features frequently present the most significant risk elements for open water tunnels, site investigations should target these features to better characterize the extent of the potential weakness zone and evaluate the impact to the selected tunnel excavation methods.

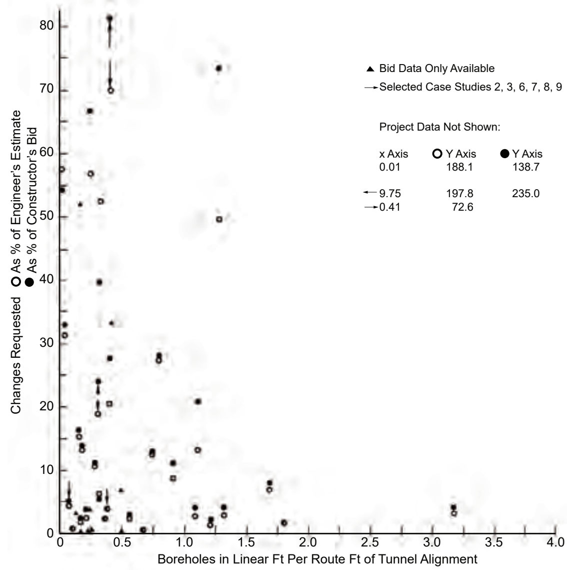
Soft ground tunnels will need to consider the depositional environment of the soils within the area of open water being traversed. Often open water tunnels are situated in fluvial environments where minor changes in the depositional environment (combination of physical, chemical, and biological processes associated with a given sedimentary rock type) indicate the presence of variable soil types and soil properties underneath.

7.4 PLANNING THE INVESTIGATION

Open water tunneling makes the typically arduous process of selecting borehole locations and exploration techniques more complicated, as the ground surface itself becomes difficult to access. Early in the design process, site investigations should be selected to provide sufficient data to evaluate feasibility of design concepts and alignment alternatives. In areas with a long history of shoreline development, such as the harbors and shorelines of many major urban centers, the configuration of the shoreline has likely been transformed numerous times. Gathering historic data on this historic transformation can require a significant effort of time and resources, but is generally less expensive than additional borehole drilling and analysis. Gathering historical data is most effective when started early in the design phase or earlier if possible (e.g., before alignment selection).

Previous studies on the relationship between site investigation investment and construction costs suggest that as site investigation increases, the number of construction claims and the overall construction cost decrease (USNCTT, 1984). This is an intuitive relationship, as the more subsurface data that is acquired, the greater the reduction in unforeseen conditions, and hence, uncertainty and risk, resulting in fewer claims (Figure 41) and possibly lower construction bids as well.

Figure 41. Comparison of Construction Claims Based on Cumulative Borehole Length



(Source: US National Committee on Tunneling Technology, 1984)

This still leaves open the question of how much site investigation is enough. The USNCTT report on site investigations for underground projects recommends that average site investigation costs should be 3.0 percent of the project cost. Other sources recommend a "rule-of-thumb" for total length of exploratory boreholes (advanced vertically) equal to 1.5 times the length of the tunnel, which should be considered a bare minimum for shallow alignments with "very favorable conditions" (Oregon DOT, 2007).

For planning purposes, the recommended borehole spacing in Table 14 can be used as a rough guide for open water tunnels. These guidelines should not be viewed as fixed rules for open water tunnels, or any tunnels. Rather, they should be viewed as approximate benchmarks, representative of the level of effort expended on previous tunnel projects. Actual investment for the site investigation should be a function of several factors, including geology, size and length of tunnel, location and terrain. In the end, it is best to let the judgment and experience of the geotechnical engineer or engineering geologist determine the final scope of the site investigation program, using past experience as a guide whenever possible.

Table 14. Recommended Borehole Spacing for Overland and Open Water Tunnels

	Overland	Open Water
Soft Ground		
Adverse conditions	50 – 100 ft	100 – 200 ft
Favorable conditions	200 – 300 ft	300 – 500 ft
Mixed Face	25 – 75 ft	50 – 100 ft
Hard Rock		
Adverse conditions	50 – 100 ft	100 – 200 ft
Favorable conditions	200 – 500 ft	300 – 500 ft

7.5 MANAGEMENT

All disciplines involved in an open water tunnel project should take part in the assessment of geotechnical and geological conditions, as design decisions made without consideration of the ground can carry significant risks. All project participants should be aware of these risks and the attempts made at assessing them. It is useful during implementation of the site investigation program to hold regular meetings with project staff to provide updates on the status of the investigation and to discuss the results, particularly where subsurface conditions have deviated from previous interpretations. The geologic risks should also be well documented as part of the project risk management strategy, including updating geologic models and subsurface risks in the risk register and risk analyses.

Ideally, the site investigation program should be outlined in a formal document, such as an exploration plan. The plan should be drafted, reviewed, and executed by an experienced engineering geologist or geotechnical engineer. The purpose of the plan should be to ensure that the properties of the subsurface material are adequately captured. The goals of the plan should be to extract the maximum amount of information from the fewest number of borings and tests, while at the same time being flexible enough so that adjustments can be made as necessary.

7.6 INVESTIGATION TECHNIQUES

As previously discussed, the primary purpose of the site investigation is to ascertain the ground conditions and relate these findings in terms of their impacts on project design and constructability. Numerous techniques are available to investigate the nature and consistency of the ground through which the open water tunnel will be constructed, and there are no clear cut rules for investigations that are best suited for a given ground condition. Generally, the decision of which investigation method to use should be based on the value of the anticipated data and its ability to help determine subsurface conditions that will impact the project, such as the location of major geologic features. For example, a detailed geophysical survey can provide extensive data at relatively little cost, but without physical samples to confirm observations from the geophysics, considerable uncertainty may remain in the subsequent geological or geotechnical interpretation.

A general summary of investigative techniques and their key functions and/or limitations is provided in Table 15.

Table 15. Summary of Site Investigation Techniques for Open Water Tunnels

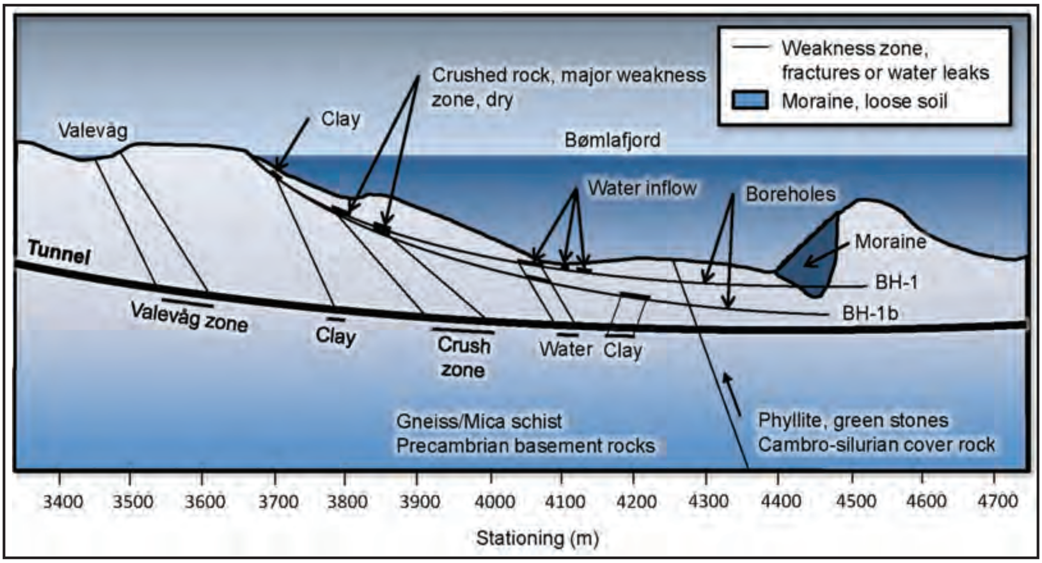
Investigative Technique		Key Functions
Boreholes (Inclined & Vertical)	• Auger • Rotary Wash • Sonic • Core Drilling	• Delineate horizontal strata • Identify zones of weakness • Obtain samples for laboratory testing • Allow access for in-situ testing, e.g. packer tests, pressuremeter and vane shear tests
Cone Penetration Test (CPT)		• Continuous profiling of sediments (pore pressure dissipation, shear strength)
Geophysical (surface)	• Seismic Reflection • Seismic Refraction	• Mapping shallow reflectors, i.e., bedrock surface
	• Radar • Gradiometer	• Shallow anomalies or obstructions
Geophysical (airborne)	• Magnetic • Electromagnetic • Gamma-Ray Spectrometry • Gravity	• Mapping of regional geology and large-scale structural features • Overburden mapping • Identify soil types (conductive soil only) • Identifying aggregate sources
Geophysical (downhole)	Ground Penetrating Radar	• Mapping of local anomalies, geologic structures or potential obstructions
	Side Scan Sonar	• Identifying surface features
	Acoustic Imaging	• Large and small scale geologic structure
	Gamma Logging	• Identify clay/shale zones
	Electrical Resistivity	• Identifies variations between fine (clay, shale) and coarse grained (sandstone, gravel) sediments
	Video Logging	• Visual identification of geologic features

Commonly, site investigations for any tunnel project should extend a minimum of 1.5 times the tunnel diameter below the proposed invert. If the alignment has not been finalized, it is recommended explorations extend deeper, possibly up to three times the proposed tunnel diameter.

7.7 LAND-BASED INVESTIGATIONS

One of the most effective investigation tools for an open water tunnel are horizontal or directional boreholes advanced from the shore that extend along the anticipated tunnel alignment (Figure 42). Not only does this exploration technique save the time and expense of mobilizing barges or ships in order to advance borings from above the tunnel alignment, horizontal or directional boreholes can often provide continuous sampling of the geologic horizon through which the tunnel will be excavated; thus eliminating the need for extrapolation between widely-spaced vertical explorations.

Figure 42. Directional Boreholes (BH-1 and BH-1b) for a Tunnel Crossing in Norway



Depending on site access and the geometry of the proposed tunnel crossing, a temporary access shaft may be needed in order to perform horizontal boreholes. Although the cost of this excavation may come at a considerable expense, it will provide valuable subsurface data and may even offset the cost of vertical drilling from the water surface.

The DeviDrill™ system (Figure 43) is a proprietary directional drilling technique that utilizes steerable wireline coring. The "core" in this system refers to a narrow tube containing equipment that can be used to retrieve samples along the drilling path. Combined with powerful software used to survey and monitor drilling activities, this system is capable of investigating long sections of the tunnel alignment where access from above the water is difficult. As with other drilling techniques, there is no limit to where the borehole can go (outside of curvature and surface constraints). The DeviDrill™ system can be advanced from the ground surface, such as during preliminary investigations for a tunnel, or also from within the tunnel, provided the tunnel is wide enough to accept the 12 to 15-foot wide drill rig and supporting equipment.

Figure 43. DeviDrill™ Directional Drilling System

Recent applications of the DeviDrill™ system suggest practical investigation limits for steerable wireline coring are about 4,000 feet in total drilling length, somewhat less than traditional (non-steerable) wireline coring. Ranges of available core diameters are also reduced when compared to traditional wireline coring methods, to allow for negotiation of the core through the articulated core barrel and drill stem. However, core diameters up to about two inches have been used with this system. Costs for the DeviDrill™ vary with core diameter, length of drill, and the accuracy of the borehole required (greater accuracy requires more frequent surveys and secondary confirmation from adjacent boreholes). As with traditional wireline coring systems, larger core diameters often result in greater core recoveries and better sample quality, which can facilitate a greater range of laboratory tests.

7.8 OPEN WATER INVESTIGATIONS

Explorations performed in open water are much more complicated than traditional overland methods. A lack of a stable work platform on which to work can have a substantial impact on the ability of drilling equipment to work efficiently. Rough seas or high winds can also shut down drilling operations and impact the design schedule. Maritime traffic (shipping, fishing, cruise vessels, etc.) can also impact schedule and the ability to explore to sufficient depths.

As noted in Section 5.6, permitting is another complication. In the US, permits may be required from the US Army Corps of Engineers and/or other agencies, depending on the drill location. Often a certified Marine Surveyor will be required to examine the drilling operations and make recommendations regarding equipment, personnel, and safety. In addition, permission may be required from the local port authority or harbormaster with jurisdiction over the waters where the explorations will occur.

Staging and launch areas for barges or drilling platforms will also need to be considered. These must be capable of handling the drilling equipment, including safe loading and unload-ing. In addition, the barge or platform will need to be accessed on a daily basis. Coordination with the loading facility may therefore be important, as some ports and harbors are only available during certain times of the day or year, depending on their operations.

Shallow Water Considerations (depths less than 100 feet)

In water up to about 100 feet in depth, investigations can typically utilize over-land exploration equipment, such as a truck-mounted drill or cone penetration test (CPT) rig, which can be mobilized to the drill location using a barge or jack-up platform secured to the sea bed (Figure 44). Despite the barge or platform used to access the drill location, the drilling equipment is generally the same as that used for over-land drilling. Often larger casing, and sometimes double casing, is required to maintain fluid circulation and minimize the potential for leakage into the water body.

When planning in-water explorations, several additional factors need to be considered beyond those normally considered for over-land drilling. Jack-up platforms will need to consider the foundation conditions surrounding the location of the proposed exploration. The drilling barge should also be sufficiently large to accommodate all required drilling equipment, including in-situ testing and specialized sampling equipment. Environmental restrictions, weather and sea traffic are all likely to impact the schedule and progress of drilling, so the timing of the explorations will need to be considered as well.

Figure 44. Jack-Up Barge with Truck-Mounted Drill Rig

Support of the drilling platform will need to consider the range of environmental conditions likely to be encountered while performing the drilling, including:

- Tidal fluctuations and currents
- Anchoring zones (suitable foundation support with anchors sufficiently long)
- Weather (tropical storms, hurricanes, etc.)

- Biological, ecological constraints (sensitive habitat)

The selection of borehole locations requires consideration of the future tunnel alignment, as there is always the potential that drilling equipment may fail, break, or become lodged in the borehole. Since it is likely the borehole will extend to the planned tunnel depth, drill tooling left behind or stuck in the borehole may pose significant problems for the future tunnel construction. The potential for borehole deviation will also need to be considered. Ultimately, care and judgment should be exercised when selecting borehole locations and performing boreholes in close proximity to the tunnel alignment.

Deep Water Considerations (depths greater than 100 feet)

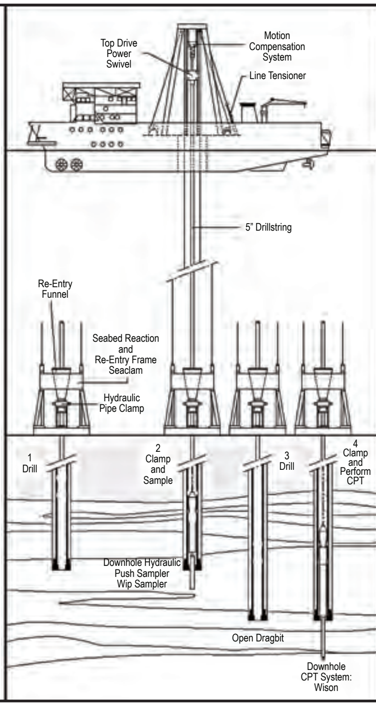
Deep water investigations can require the use of large offshore exploration vessels (Figure 45). These vessels are equipped to explore to great depths (some have the capacity to explore to depths greater than 6,500 feet). Although typically used for mineral extraction such as deep sea oil drilling, they can, on certain occasion, be considered for civil engineering purposes.

Rotary drilling methods are typically used from these vessels, with sampling performed by wireline methods. In-situ testing is typically performed with standard downhole apparatus, such as those shown in Figure 46. Drilling costs for explorations vary widely and depend on vessel availability, project location, and the scope of the exploration. Typical daily costs can range from $30,000 to $150,000, with mobilization costs ranging from $250,000 to $1 million.

In addition to the above costs, delays and downtime due to adverse weather and sea conditions are important considerations for drilling in deep water where offshore exploration vessels are used.

Figure 45. Deep Water Drilling Vessel

Figure 46. Typical Downhole Equipment Used for Drilling, Push Sampling, and In-Situ Testing from Offshore Vessels



(Source: ISSMGE, 2005)

Sampling and in-situ testing during deep water drilling is performed using similar techniques to those used in shallow water and over-land, with limitations to depth, penetration, and sample quality dependent on the various systems involved. Standard Penetration Tests (SPTs) may be used for sampling in soils, but caution should be used when estimating strength parameters by converting blow-counts since energy losses in the drill rod can be high over such great distances. Vane shear tests can also be performed in boreholes either from vessels or from stand-alone units resting on the sea bed, and provide a relatively accurate means of estimating in-situ shear strength. Capabilities of other sampling techniques are described in Table 16 and Table 17.

Penetration tests can also be performed to a wide range of depths, from vessels or from units that rest on the seafloor (Table 18). CPTs in deep water are useful in that they can provide reliable engineering data on soft soils without the expense of mobilizing a drilling vessel (as is required for SPTs and vane shear tests).

Table 16. Water Depth and Penetration of Drilling, Sampling and Coring Systems

Type of Equipment	Maximum Water Depth	Penetration
Drill mode borings from vessels	Unlimited*	Unlimited*
Rock corer (seabed unit)	600 ft	6 to 20 ft
PROD™ seabed drilling/coring	60 to 6,500 ft	6 to 325 ft
Basic gravity corer	Unlimited*	3 to 25 ft
Piston corer	Unlimited*	10 to 100 ft
Vibrocorer	3,250 ft	10 to 25 ft
Box Corer	Unlimited*	1 to 1.5 ft
Seabed push-in sampler	825 ft	3 to 6 ft
Grab sampler (mechanical)	Unlimited*	0.3 to 1.5 ft
Grab sampler (hydraulic)	600 ft	1 to 1.5 ft

*Depth limited by deployment winch and handling capabilities.

(Source: ISSMGE, 2005)

Table 17. Sampling Equipment and Effectiveness in Various Ground Types

Type of Equipment	Sample Quality			Recovery (relative to length of sample tube)		
	sand	clay	rock	sand	clay	rock
Hydraulic piston sampler	3 to 4	5	1	3	5	1
Hydraulic push sampler	3 to 4	4 to 5	1	3	5	1
Hammer sampler	2 to 3	2 to 3	1	3 to 4	3 to 4	1
Rotary coring	1	2	3 to 4	1	3	3 to 4

(Source: ISSMGE, 2005)

Where:

1 = Poor or inappropriate
2 = Acceptable for non-critical analyses
3 = Moderately good
4 = Good
5 = Very good

Table 18. Water Depth and Penetration Capabilities of In-Situ Testing Systems

Type of Test	Maximum Water Depth	Penetration
Deck- or frame-operated penetration tests	60 ft	6 to 200 ft
Seabed wheeldrive penetration tests	1,600 to 10,000 ft	6 to 200 ft
Drilling mode downhole penetration tests	Unlimited*	Unlimited*
PROD™ seabed penetration tests	60 to 6,500 ft	6 to 325 ft
Light weight wheeldrive penetration tests	6,500 ft	6 to 16 ft
ROV penetration tests	1,000 to 6,500 ft	3 to 6 ft
Minicone penetration tests	800 to 8,000 ft	16 to 20 ft
Seabed vane test	800 to 8,000 ft	16 to 80 ft

*Depth limited by deployment winch and handling capabilities

(Source: ISSMGE, 2005)

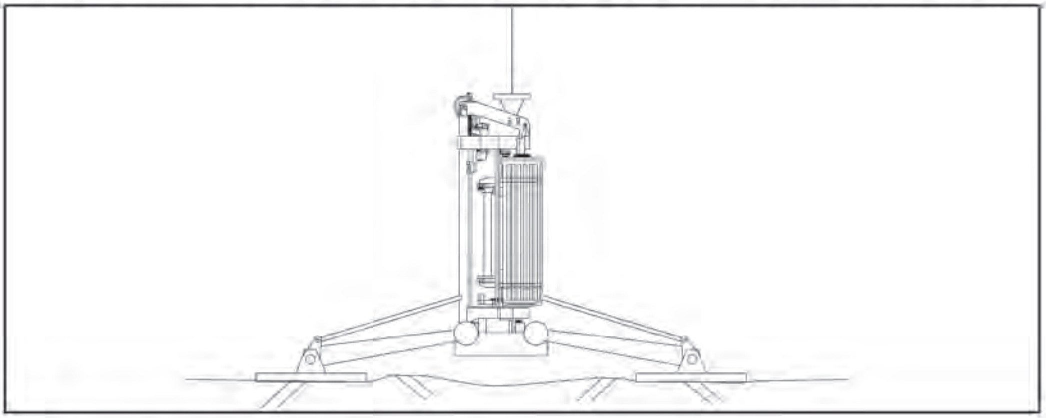
Where equipment availability, surface constraints, or high costs make drilling from a vessel or platform infeasible, another option is a submerged, remotely operated drill unit. A few variations of this equipment are currently available, including the PROD™ (Portable Remotely Operated Drill) (Figure 47), and the BMS (Benthic Multicoring System) unit, or "MeBo" ("Meeresboden-Bohrgerät," which is German for "sea floor drill rig").

Both the PROD and the MeBo can utilize rock coring and soil sampling techniques in water up to 6,500 feet in depth, and are capable of penetrating about 400 feet below the seabed. The main advantage of remotely-operated drill units is their portability. These units can be operated from a wide range of vessel types, rather than solely from drilling vessels, making them advantageous when schedule is a priority. The PROD™ unit also has the unique capability of alternating rock coring and CPT techniques (seismic cone, T-bar and ball penetration tests) for both hard and soft ground types.

Costs for remotely operated units are high due to the limited availability of the technology and the high demand for their use in seafloor exploration in the mining industry; and they generally cannot compete with drilling vessels. Rental fees for the units are about $35,000/day which includes support crew and operation, but does not include vessel rental to transport the unit to the project site. Savings may be realized if the equipment is being used in a nearby area, which can reduce the mobilization fee considerably.

Drilling from ships in deep water is seldom cost efficient, even for large tunnel projects. The quality of core samples and the limitations on interpretation (extrapolating conditions from vertical cores for a predominantly horizontal structure) are significant drawbacks to these types of investigations, and the value of these methods needs to be carefully considered. Directional drilling from the shore or from shallower waters, combined with the use of geophysical analysis methods, such as seismic reflection and refraction, is frequently more cost-effective, and provides greater amounts of data at a fraction of the cost of deep water drilling.

Figure 47. Submerged, Remotely Operated Drilling Unit (PROD™)



7.9 AIRBORNE GEOPHYSICAL TECHNIQUES

Airborne geophysical surveying techniques lend themselves well to tunnels beneath open water as they generally can be readily mobilized and can provide data over a large area, including areas submerged beneath the water. Airborne surveys can provide indications of the nature of the seabed, such as contours (bathymetry), identification of significant features or hazards, and delineation of geologic strata over large areas.

Airborne geophysical surveys are ideal for capturing geologic data on a regional scale and are best suited for larger projects where the tunnel length is great (on the order of miles or tens of miles), or if the tunnel location is remote. Airborne surveys can provide sufficient resolution to allow detection of large-scale geologic features, such as location and planar orientation geologic structure (dikes, faults, ore bodies, etc) and can often be performed at a fraction of the cost of surface geophysical surveys or drilling.

Costs of airborne surveys vary depending on the size and location of the area of analysis as well as terrain, built environment (power lines, roadways, buildings, etc.), and availability of aircraft. Minimum costs for airborne surveys start around $150,000 and can range from $3/mile to $40/mile. As technology advances in remote control aircraft, it is likely airborne surveys will become even more cost competitive when compared to traditional surface geophysics and drilling.

7.10 SEISMIC REFLECTION AND REFRACTION SURVEYS

Seismic surveying has been used extensively in engineering applications for many years. It involves introducing vibrations into the ground and interpreting the resulting changes in the reflected signals as perceived by an array of geophones set out on the surrounding land or seafloor. Different ground types have different impacts on the returning energy flow.

Seismic surveying is particularly useful for open water tunnels as seismic techniques can be used to readily evaluate the nature of the channel bottom. Through refraction or reflection surveys, models of rock structure, sediment layering, bathymetry, and weakness zones can be detailed.

Seismic refraction surveys also allow mapping of varying seismic velocities in hard rock, which can be useful for identifying low velocity zones like faults or weakness zones. Typical seismic velocities for various materials are provided for reference in Table 19.

Seismic refraction surveys are best used for mapping of hard rock tunnels where seismic velocities increase with depth. The depth of exploration is often limited by equipment, since longer geophone array lengths are generally required for greater depth of exploration. Also, the resolution of refraction data decreases with increasing array length. One advantage of seismic refraction surveys is the increase in vertical resolution when compared to seismic reflection. This is useful where shallow bedrock is expected along the seabed and a detailed mapping of the bedrock surface is required.

Table 19. Typical Field Values for Seismic P-Waves (V_P), Density ($P_{b,\ dry}$) and Poisson's Ratio (υ) for Various Materials

Material	V_P (m/s)	$P_{b,dry}$ (mg/m³)	υ
Air	330		
Damp loam	300-750		
Dry sand	450-900	1.6-2.0	0.3-0.35
Clay	900-1,800	1.3-1.8	~0.5
Fresh, shallow water	1,430-1,490	1.0	
Saturated, loose sand	1,500		
Basal/lodgement till	1,700-2,300	2.3	
Rock			0.15-0.25
Weathered igneous and metamorphic rock	450-3,700		
Weathered sedimentary rock	600-3,000		
Shale	800-3,700		
Sandstone	2,200-4,000	1.9-2.7	
Metamorphic rock	2,400-6,000		
Unweathered basalt	2,600-4,300	2.2-3.0	
Dolostone and limestone	4,300-6,700	2.5-3.0	
Unweathered granite	4,800-6,700	2.6-3.1	
Steel	6,000		

(Source: US Army Corps of Engineers, 1995)

Seismic reflection surveys use similar equipment to seismic refraction but the direction of energy wave detected by the receiver is different. Energy from the source travels through the surface and is reflected directly to the receiver. The travel time required for the wave to "bounce" back from a given layer then provides information on the depth profile of the underground surface or layer being surveyed. Seismic reflection is best at detecting material boundaries and voids, and can occasionally be used to map large-scale underground rock structures, such as the dip of major features.

Refraction surveys require greater field and data processing efforts in order to maximize energy reflected along near vertical ray paths. This results in a more expensive survey compared to seismic reflection, but allows a deeper exploration and greater resolution of deep subsurface structures and features. Seismic refraction works well for detecting changes in seismic velocity, mapping of rock weakness zones, and detecting the top of bedrock. However, if weaknesses are detected in the vicinity of the tunnel as a result of the refraction surveys, additional investigations are often needed to better define the extent and proximity of these zones to the proposed tunnel works.

Seismic reflection and refraction surveys are better suited to investigations for long tunnels in open water, particularly where there is a need to penetrate deep into the seabed or where water depth is great and direct investigation through drilling is costly.

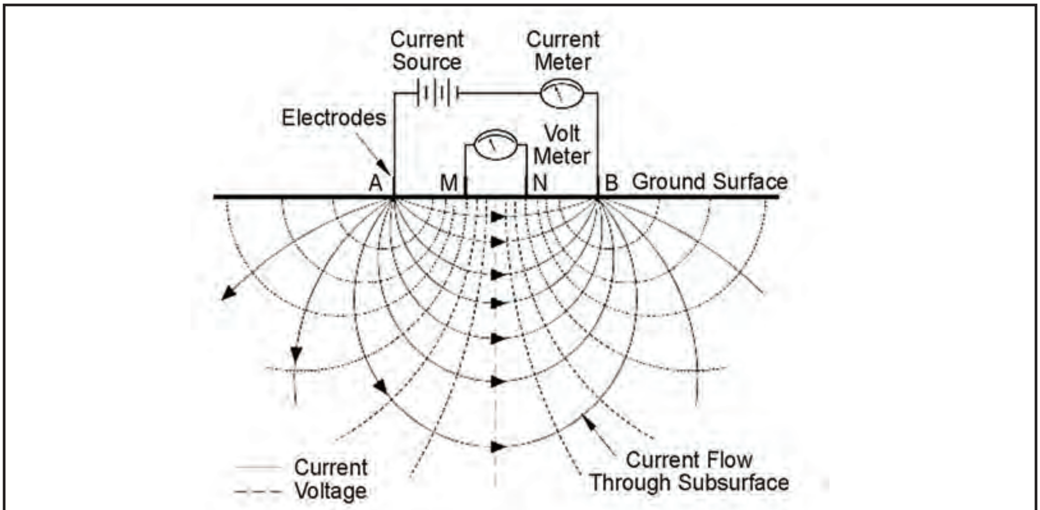
7.11 ELECTRICAL RESISTIVITY IMAGING

Electrical Resistivity Imaging (ERI) is a geophysical technique that maps variations in the electrical properties of geologic materials. The method involves transmitting an electric current (DC) into the ground between two electrodes and measuring the voltage drop as the current travels through the ground. The changes in the voltage are measured using additional electrodes inserted along the path of the current (Figure 48). The resulting measurement is the apparent resistivity of the area beneath the electrodes, and can include deeper layers as the electrode spacing is increased.

Common applications of the DC resistivity method include: delineation of aggregate deposits for quarry operations, measuring earth impedance or resistance for electrical grounding circuits or for cathodic protection, estimating depth to bedrock, to the water table, or to other geoelectric boundaries, and mapping and/or detecting other geologic features.

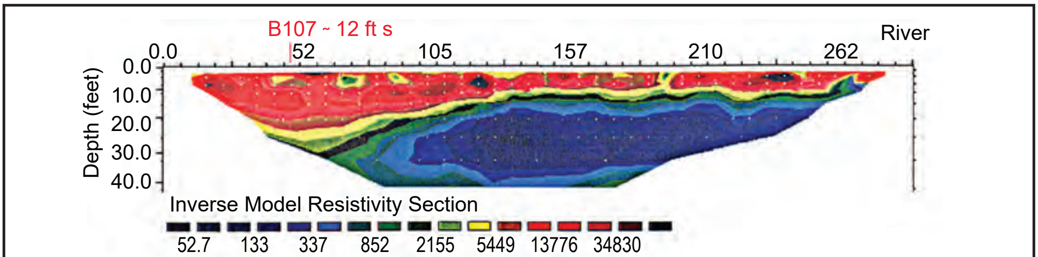
Data collected from the electrodes is processed and interpreted using specialized inversion software. Software is available to create 2-D or 3-D geo-electric profiles that are useful for mapping vertical and horizontal variations in the resistivity of the subsurface strata (Figure 49). Caution should be exercised when interpreting resistivity measurements since resistivity cannot discriminate between all possible geologic conditions. It is important to supplement resistivity measurements with other geotechnical field data.

Figure 48. Electrical Resistivity Imaging



ERI techniques can be applied either over-land with an array of electrodes spaced along the survey boundary or along the sea bed using a towed sled with a multi-electrode “streamer” cable attached. Typically, the deeper the penetration desired, the longer the electrode array or streamer cable will need to be. Penetration depths are generally on the order of about 15 feet. Greater depths are possible, but at the expense of decreased accuracy and resolution.

Figure 49. Results from an ERI Survey to Detect Bedrock Surface Below Water Line



(Top of bedrock indicated by darker shading on bottom of profile)

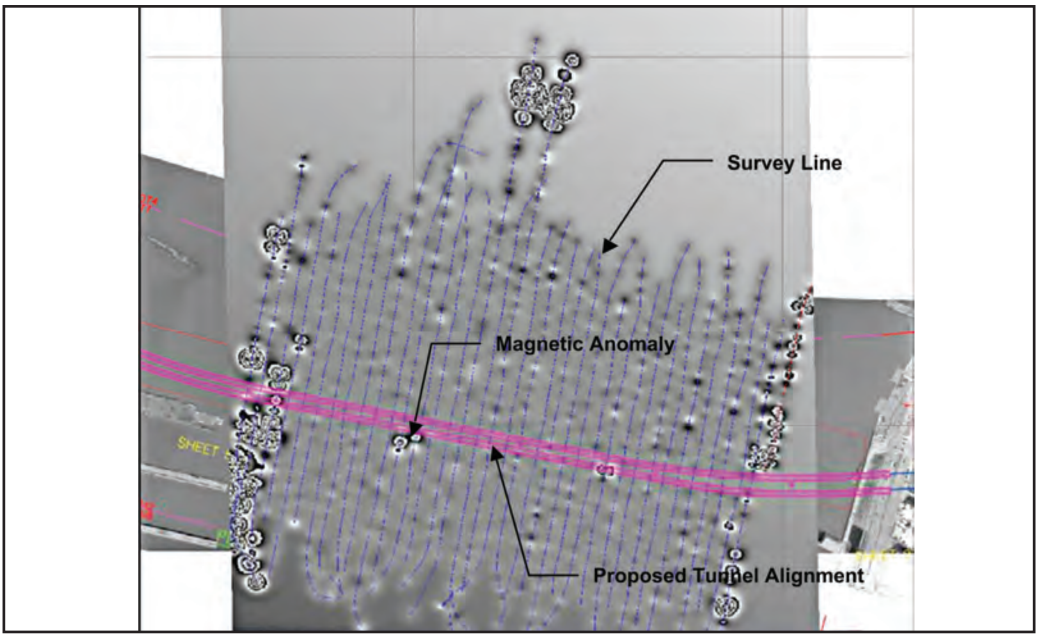
7.12 MAGNETIC METHODS

Several magnetic methods can be applied to open water tunnel investigations. These methods vary in both cost and level of effort depending on the desired accuracy of the results, the size and location of the area requiring mapping, and the type of mapping needed. Magnetic surveys can be used to perform geologic mapping, as well as to locate karst features, sinkholes, mineshafts, buried utilities, abandoned drill casings, and underground storage tanks.

Two types of magnetic surveys are described in this section, magnetometer surveys and magnetic gradiometer surveys. Magnetometer surveys typically measure the strength of magnetic energy and can detect the presence of magnetic objects and large-scale geologic features such as a major fault or geologic weakness zone. Magnetic gradiometer surveys measure the change in magnetic energy across a horizontal distance, and are often best suited for near-surface investigations where the target is at shallow depth, and slight changes in magnetic signature can be easily detected.

Large-scale total field magnetometer surveys can typically be performed by one mobile reading instrument and a base station unit. The survey is generally intended for mapping of rock units, either by surface, marine, or airborne survey. This method requires magnetic measurements at regular intervals over the desired survey area. Since only certain rocks contain a magnetic signature (i.e., ferrous rocks which originate from the earth's core, such as gabbros, basalts, and andesites), sedimentary and some metamorphic rocks may not show sufficient contrast during surveying. A sample interpretation of a magnetic survey conducted in a river channel is presented in Figure 50.

Figure 50. Results of a Marine Magnetometer Survey



Gradiometer surveys use the same principles of magnetometer surveys but can utilize multiple magnetic instruments coupled with powerful software to locate magnetic anomalies by triangulation. Gradiometer instruments are capable of filtering background "noise" such as diurnal effects and influences from surface debris. Several types of gradiometer instruments are available and their application varies depending on the type of anomaly being investigated as well as other environmental factors.

When considering magnetic surveys, be aware of the presence of large man-made metal objects (e.g., steel pile supported pier structures, power lines, and the presence of low frequency fields such as pipelines carrying alternating or direct currents) as these will cause interference to the survey. It is possible to correct for this if the location of the interference sources can be confirmed by field observations or existing maps.

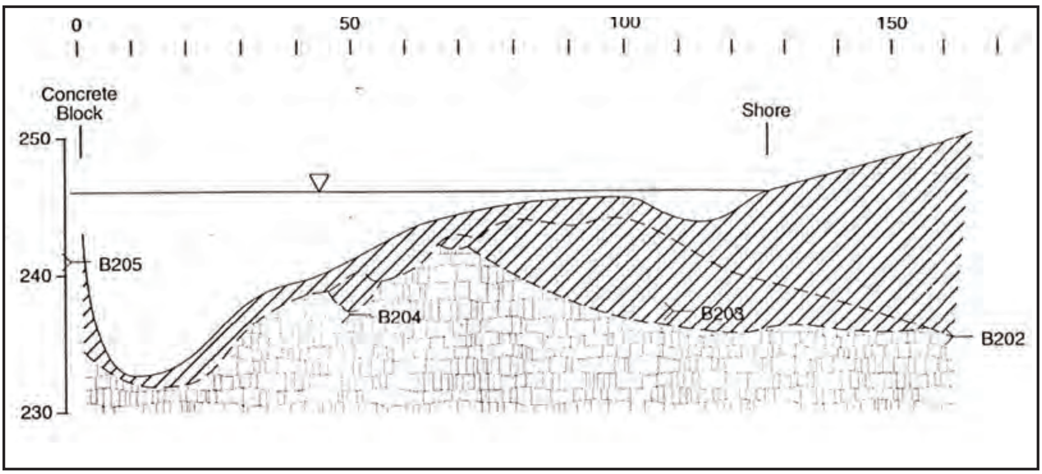
7.13 GROUND PENETRATING RADAR

Ground Penetrating Radar (GPR) uses electromagnetic pulses directed into the ground to map subsurface conditions. Pulses are continuously transmitted and then reflected back to an antenna. Reflections occur where there are changes in the electrical properties of the material, such as at the interface between two soil types, at the water table, or at objects like buried debris or boulders.

The maximum depth of penetration of GPR is dependent on the frequency of the pulses used and the electrical properties of the material being investigated. Penetration depths of up to 50 feet can be obtained in coarse-grained soils. In fine-grained soils, such as clay, GPR is generally limited to less than five feet of penetration.

GPR can also be used downhole in cased boreholes, or when surveying in open water, can be run along the water surface to detect the underwater ground surface and top of bedrock (Figure 51). This technique is primarily limited to shallow water where the water is less than 30 feet deep.

Figure 51. Interpreted Channel Dimension and Bedrock Profile from GPR



8.0 RISK MANAGEMENT STRATEGIES

8.0 RISK MANAGEMENT STRATEGIES

"I am more and more amazed about the blind optimism with which the younger generation invades this field, without paying attention to the inevitable uncertainties in the data on which their theoretical reasoning is based and without making serious attempts to evaluate the resulting errors."

- Karl Terzaghi (1883-1963), "The Founder of Soil Mechanics"

The greatest technical and financial risks for any tunnel project can almost always be traced to the variability and uncertainty associated with the ground. An underwater location can compound and amplify these risks if not properly managed. Given the magnitude of tunnel projects and the amount of capital investment often required, it is only prudent to consider a formalized risk management approach to improve planning and cost estimating practices, while providing important guidance for safer design and construction.

The preceding chapters discussed technical risks commonly encountered in open water tunnels. While this information is useful for project managers, designers and construction engineers, this knowledge should be captured in a formal risk management process in order to be incorporated effectively into project decision-making. It is therefore the intent of this chapter to provide the framework through which these risks can be assessed in a structured format relevant to open water tunnel projects.

A formalized risk management system, when executed properly, should:

- Identify potential hazards to construction
- Reduce the likelihood of risk events occurring
- Reduce the consequences of damage should an event occur

8.1 RISK TERMINOLOGY

Risk, in general terms, can be defined as an uncertainty or variability in the outcome of a decision or event. Often in risk management, risk is expressed as the combination of the frequency (or likelihood) of an event's occurrence, and the consequence of that occurrence, whereby frequency and consequence are quantified in accordance with a predefined classification system. Risks on a construction project are typically evaluated in terms of cost, schedule, and health and safety.

Risk assessment and risk analysis are terms used to describe the methodology employed to evaluate, often by way of engineering judgment, a risk or series of risks. Risk assessments can be qualitative as well as quantitative. The outcome of a risk assessment is typically provided in terms of cost, time, or other user-defined variable.

Risk management refers to the overall process, or strategy, of analyzing risks, their impact on the project, and determining how to control, mitigate or eliminate unacceptable risks. Specific tasks required as part of the risk management process include: risk identification, risk analysis, and risk control (i.e., mitigation or allocation). Individual components of the risk management process are detailed in the following sections.

8.2 DEVELOPMENT OF RISK MANAGEMENT FOR OPEN WATER TUNNELS

Historically, risks on tunnel projects have been managed through engineering decisions made during project development, often during construction. Not until the 1990s did attempts begin at formally implementing a structured risk management process for tunnel projects. In 2003, a risk management code for tunnels was developed in the UK at the behest of the insurance industry. Shortly thereafter, the International Tunnelling Society (ITA) issued a guideline document on risk management in tunneling (Eskesen et al., 2004). In 2006, the International Tunneling Insurance Group followed with a code of practice for risk management of tunnel works which was in large part based on the UK code developed a few years earlier (ITIG, 2006).

Risk assessment and the quantitative modeling of risks are being used more frequently as part of the overall risk management philosophy for tunnel projects, particularly for high profile and high risk tunnel projects. The tunneling industry has in large part embraced these techniques, especially in the US where the American Society of Civil Engineers now offers a seminar on risk management specific to tunnel projects. The wide acceptance of risk management and its implementation on tunnel projects is generally viewed as a positive step for the tunnel industry.

As the risk management process becomes an integral component of tunnel design and construction, its application to tunnels beneath open water becomes even more appropriate. As noted in earlier chapters, tunnels beneath open water carry many of the risks common to conventional tunnels, but can also carry greater consequences to cost, schedule and safety when these risks are realized, whether during the planning, design, construction or operational stages. A systematic approach to risk management can help address these risks and provide a greater overall level of confidence to project owners.

8.3 RISK MANAGEMENT IMPLEMENTATION FOR OPEN WATER TUNNELS

The most effective approach for managing risks for open water tunnels is to designate a task leader, or task force, responsible for developing, implementing, and maintaining the project risk management strategy throughout the life of the project, including the planning, design and construction phases. Ideally, the risk management task leader will be a representative from the project owner or designer with previous design and construction experience, who is familiar with implementing risk management strategies for tunnels or other underground projects. Previous experience with open water tunnels is highly desirable, but this may not always be possible.

A properly planned risk management strategy for open water tunnels should, at a minimum, include the following:

- Delegation of roles and responsibilities among the project team, i.e., different departments within the owner's organization, consultants and contractors.
- Description of the risk management and risk assessment activities to be carried out at different stages of the project in order to achieve the objectives.

- Documentation of the risk management process. This could be accomplished by establishing some type of risk register.
- Identification of risk assessment and analysis methods to be used.

For an open water tunnel project, risks should be identified, assessed and updated as the tunnel project evolves through the conceptual, planning, design, construction and ultimately, the operational phases. In particular, risks should be re-evaluated as subsurface information is obtained from the site investigations. A general risk management flow chart is provided in Figure 52.

Figure 52. Risk Management Flow Chart for Open Water Tunnels

8.4 RISK REGISTERS

Good risk management requires a clear, structured and ordered approach. One of the simplest and most efficient methods for documenting the risk management process is to develop a risk register which consists of a simple table summarizing all risks identified for the project. Risk registers appear to be gaining wider acceptance overall within the tunneling industry, particularly for larger tunnel projects.

A risk register should be a "living" document which is continually reviewed and updated as the project evolves from the early planning stages into construction. Ideally, the register should include:

- Detailed description of identified hazard
- Class of risk (or risk identification number)

- Possible consequences of hazard occurring (on cost, schedule or safety)
- Pre-mitigation risk rating
- Mitigation reference (document which contains the full description of the risk mitigation or control measure)
- Identification of the risk owner
- Post-mitigation risk rating (re-assessment of frequency and consequences with mitigation in place)

To facilitate development of the risk register, risk codes can be developed to readily identify and sort risks according to the appropriate area of impact or discipline. An example of risk codes and corresponding areas of impact that may be used for an open water tunnel project are provided below. Modifiers such as "T" for tunnel risk or "G" for geologic hazard can be added to the risk code to assist in sorting.

- Series 100: Project Wide Risks: permitting, easements, property acquisitions, construction scheduling (i.e., risks impacting activities on critical path), project funding
- Series 200, General Risks: construction management, federal, state, or local regulations, coordination with various agencies
- Series 300, 400, and 500, Construction Risks: numbered according to the location along particular geologic units ("reaches") of the tunnel alignment, these risks include design risks, geologic uncertainty, safety, third party coordination, and structural impacts to existing infrastructure
- Series 600, Environmental Risks: ground contamination, noise and vibration impacts, impacts to hydrology and groundwater, impacts to underwater habitat

Once risks are identified and placed in the risk register, they are then evaluated by the risk management task leader or through a risk management workshop with the participation of relevant project disciplines. Each risk is given a risk rating (R) equal to the product of frequency (F) and consequence (C). Where quantification is impractical, judgment can be used to assess how frequently a risk is likely to occur and evaluate its likely impact, or consequence. The risk rating criteria outlined in Table 20 provide an example of qualitative criteria that can be used quantitatively to assess each of the risks identified in a risk register.

Table 20. Risk Rating System

Frequency (F)		
Rating		Occurrence Interval
1 = Improbable, extremely unlikely to occur		Improbable
2 = Remote chance of occurrence		1 in 1000 projects
3 = Occasional, or likely to occur		1 in 100 projects
4 = Probable, multiple occurrences		1 in 10 projects
5 = Frequent occurrences likely		Occurs every project
Consequence (C)		
Rating	Impact	
1 = Minor	Negligible costs, delays, no injuries expected	
2 = Moderate	Delays of hours expected, costs can be accommodated, potential for serious injury	
3 = Serious	Delay < 1 week expected, costs may be significant, potential for fatality	
4 = Major	Delay > 1 month expected, substantial cost impact likely, single fatality likely	
5 = Catastrophic	Delay of months, cost impact excessive, multiple fatalities likely	

(Source: Clayton, 2001 and Nicholson, 1999)

The resulting risk rating (R) is calculated and categorized based on relative seriousness, as shown in Table 21. A risk score of 1 to 6 is considered a typical level of risk and generally does not require additional risk mitigation measures. As low as reasonably practicable (ALARP) and intolerable risks often require some form of mitigation or allocation, depending on the risk preferences of the client or party impacted by the risk.

Table 21. Risk Classification According to Risk Score

Risk Score (R)	Category
1 – 6	Tolerable
8 – 12	ALARP
15 – 25	Intolerable

A sample risk register for an open water tunnel in soft ground is presented in Table 22. A useful method of summarizing the results of the risk register and risk assessment is to develop a risk distribution worksheet. The worksheet clearly summarizes the number of risks in each category and is helpful when presenting the efficacy of risk mitigation measures on the risk assessment process. A sample risk distribution worksheet is shown in Figure 53.

It is generally accepted that the risk register is an inherently subjective process in that the components and the criteria presented in Table 20 and Table 21 above may not translate well to other tunnel projects. For smaller projects, it is acceptable to modify risk scoring and rating to suit the needs of project risks.

Alternative risk analyses, such as those described in the following sections, may also be considered and may be more adaptable to various open water tunnel projects.

Table 22. Sample Risk Register for a Soft Ground Tunnel Beneath Open Water

Number	Hazard	Consequences	Initial Rating			Estimated Impact		Mitigation Measures	Party Responsible for Action	Action / Documentation	Final Rating		
			C	F	R	Cost	Schedule				C	F	R
300T	Excessive groundwater inflow at TBM heading	Work stoppage, delays, damage to equipment	3	4	12	$300,000/day	1-4 weeks	Specify grouting ahead of TBM heading in areas where potential for excessive inflow exist	ABC, Inc.	Incorporated limits of inflow risk in contract documents	2	2	4
301T	Higher than anticipated abrasivity of ground	More frequent interventions to cutterhead	3	3	9	$50,000 per occurrence	1 week per occurrence	None. Plan for increase in cost and schedule	TSE Corp.	None	3	3	9
302T	Subsurface obstruction (from historic wharf structure)	Intervention to remove obstruction	5	4	20	$100,000 per obstruction	5 days per occurrence	Adjust tunnel alignment/profile to minimize obstruction potential. Additional investigations to determine locations of obstructions	ABC, Inc.	Increased tunnel grade (Subsurface Obstructions Memo)	5	2	10
303T	Unanticipated fault zone along tunnel alignment	Work stoppage, delays	4	3	12	$300,000/day	1-4 weeks	Additional subsurface exploration	Underwater Consultants	Borehole and geophysical logging completed on 8/2/07 (Supplemental Geotechnical Data Report)	4	2	8
304T	Open zone encountered	Excessive slurry loss, delays due to inadequate slurry supply, blowout of seabed	3	3	9	$75,000	1 week	Specify probing ahead of TBM. Pre-treat open zones as necessary	ABC, Inc.	Specifications require probing ahead of TBM Included 4 pre-treatment occurrences in cost estimate	1	3	3
400T	Elevated sea level due to hurricane	Flooding of mining shaft, increase hydrostatic load on tunnel lining	5	3	15	$1,000,000+	1-4 months	Provide storm surge protection for mining shaft. Include storm surge loading case for tunnel lining analysis	ABC, Inc.	Shaft collar raised 5 feet above storm surge level. Lining design incorporated storm surge loading case.	4	2	8
401T	Higher than anticipated scour above tunnel after construction complete	Distortion and breaching of tunnel lining	5	3	15	$1,000,000+	> 6 months	Implement scour monitoring program as part of O&M plan.	Owner	O&M plan identifies protocol for monitoring scour above tunnel	5	1	5

Key: F = Frequency of Occurrence
C = Consequences of Occurrence
R = Risk Rating

NOTE: The author is no longer employed with Parsons Brinckerhoff. This monograph is for reference/research purposes only and not for distribution.

Figure 53. Sample Risk Distribution Worksheet for Pre- and Post-Mitigation Risk Evaluation

	Distribution within Category
Frequency	
Frequent	12
Probable	33
Occasional	48
Remote	44
Improbable	7
Consequence	
Minor	6
Moderate	31
Serious	50
Major	37
Catastrophic	20
Total	

Risk Distribution (Pre-Mitigation)

Frequency (F)	Minor <2 Hrs $10,000	Moderate <1 day $100,000	Serious <1 week $700,000	Major <1 month $3,000,000	Catastrophic <3 months $10,000,000
Frequent (100%)	1	3	8		
Probable (11-99%)	2	9	8	11	3
Occasional (2-10%)		8	17	9	14
Remote (0.1-1%)		11	14	16	3
Improbable (<0.1%)	3		3	1	

Consequence (C)

Tolerable = 43 ALARP = 65 Intolerable = 36

	Distribution within Category
Frequency	
Frequent	2
Probable	7
Occasional	50
Remote	77
Improbable	7
Consequence	
Minor	8
Moderate	68
Serious	61
Major	6
Catastrophic	0
Total	

Risk Distribution (Post-Mitigation)

Frequency (F)	Minor <2 Hrs $10,000	Moderate <1 day $100,000	Serious <1 week $700,000	Major <1 month $3,000,000	Catastrophic <3 months $10,000,000
Frequent (100%)	1	1			
Probable (11-99%)	3	3	1		
Occasional (2-10%)	1	34	15		
Remote (0.1-1%)		30	42	5	
Improbable (<0.1%)	3		3	1	

Consequence (C)

Tolerable = 118 ALARP = 25 Intolerable = 0

8.5 STATISTICAL ASSESSMENT OF RISK

The variable nature of the ground and inherent uncertainty in predicting construction behavior and performance make geotechnical engineering a most challenging endeavor. It is surprising that probabilistic methods have not been more widely used or accepted in tunneling, an industry where there is a greater tendency for designers to accept variability and uncertainty as a matter of course. It only seems logical that some form of statistical analysis should be considered when evaluating geotechnical risk, such as the chance of variation in the ground and its likely impact on construction.

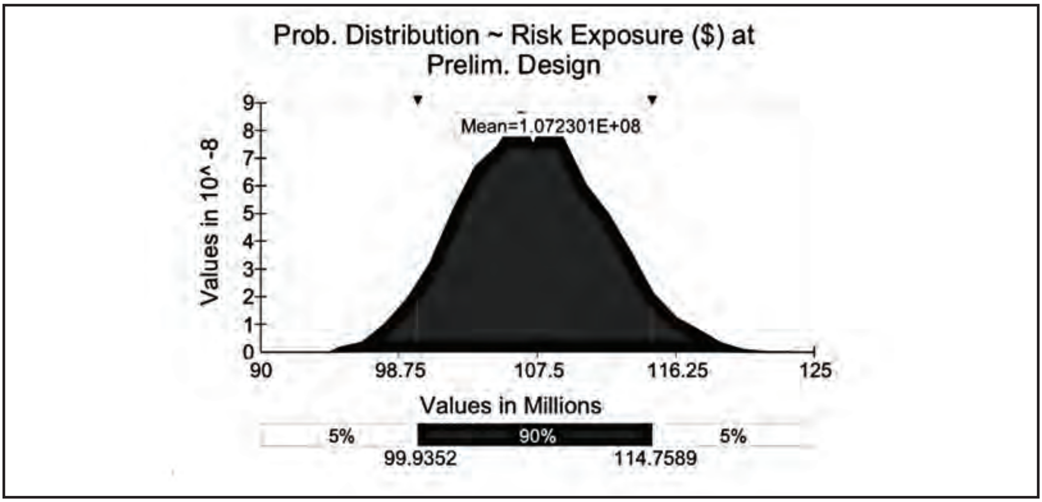
Probabilistic tools can be useful for assessing and analyzing geotechnical risk, particularly for complex risks, or when the outcome of a given event is difficult to predict. In the tunneling industry, these types of risks are ever-present and logic or probabilistic techniques can offer an alternative approach to a problem where traditional deterministic analyses are either unreliable or impractical.

Once the risk, or series of risks, is defined, there are several analysis methods that can be applied. These include the Cumulative Risk Model, Geologic Models, and Decision Tree Analyses. These methods are discussed individually in the following sections.

Cumulative Risk Model Simulation

Using the framework of the risk register, the cumulative risk model simulation incorporates the uncertainty of each risk in terms of previously defined variables, e.g., cost, schedule, etc. This uncertainty can be directly incorporated into spreadsheet models such as the @Risk software program. A Monte Carlo simulation can then be performed, which generates random variables from the pre-defined probability distributions. Each iteration of the analysis represents completion of the project with differing occurrences of risks based on their respective probability. The analysis thereby accounts for all defined risks, and typically produces a range of costs or schedule outcomes (Figure 54).

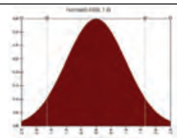
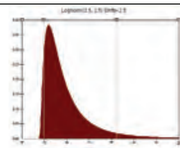
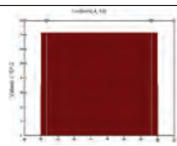
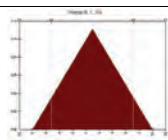
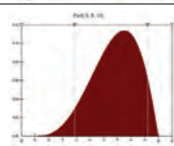
Figure 54. Distribution of Cost Exposure from a Monte Carlo Simulation



In this way the uncertainty of each risk on the risk register is quantified through probability distributions. Example probability distributions specific to open water tunnels are listed in Table 23. The selection of an appropriate probability distribution is a key decision in performing the risk model simulation. If there is no historical data regarding the specific risk or no industry standard distribution and a judgment can be made of the maximum and minimum values and an indication of the skew towards these values, then the PERT (Project Evaluation and Review

Technique) is a reasonable choice. The PERT distribution is generally considered suitable for capturing 'expert' judgment when historical data is not available. It requires only three input values to define it, minimum, "most likely" and maximum, and can be made positively or negatively skewed.

Table 23. Select Probability Distributions and Applications

Distribution Type	Common Risk Variables	Approximate Distribution Shape	Remarks
Normal	• Tunnel lining repair costs • Slurry/conditioner consumption		Appropriate for variables with large existing data sets and when variable is sum or average of large number of independent random quantities. Requires definitive distribution parameters, i.e. mean, standard deviation.
Lognormal	• Excavation advance rate • Hydraulic conductivity of fractured rock mass • Intact rock strength		Appropriate when variable has sharp lower bound, but no sharp upper bound. Typically variable is a product of many small independent factors.
Uniform Distribution	• Delay due to mechanical failure of TBM components • Delays costs from environmental impacts		Use when maximum and minimum is known and no "most likely" (mode) value is available.
Triangular	• Cost of emergency recovery of TBM • Occurrence of fault/weakness zones in rock mass		Use when no data is available but maximum, minimum, and mode value is known. Note mode value may place too much influence on distribution.
PERT (Project Evaluation and Review Technique)	• Permitting costs • Distribution of boulders, voids, etc. • Cost of emergency recovery of TBM		Similar to triangular but places more emphasis on values around mode. Better for data where normal distribution may be more appropriate, but precise parameters are not available.

Geologic Models

For open water tunnels, a key consideration during the risk assessment process may be the geologic setting within which the tunnel will be constructed. Part of the understanding must include knowledge of the variability of the ground and variability of geotechnical parameters. Subsurface data beneath the water generally comes at a high cost. However, this cost should be evaluated against the benefit it brings to the project in terms of revealing additional subsurface data, particularly the potential cost of a differing or unforeseen condition that impacts the tunnel construction.

TBM advance rates can be readily modeled for different geologic units along a tunnel alignment (known as "reaches"). An example of this technique is shown in Figure 55. If historical TBM mining data is available, probability distributions can also be custom-fit. These distribution curves can then be used as input into a risk model to estimate the cumulative distribution of mining schedule duration for the project. Supplemental risks can also be input into the model, such as a learning curve, slower progress in fault or weakness zones, etc. After simulation, the cumulative distribution curve provides a full range of mining schedule durations, incorporating the uncertain nature of the geologic and mechanical risk input (Figure 56).

Figure 55. Geologic Model for a Tunnel in Variable Geology

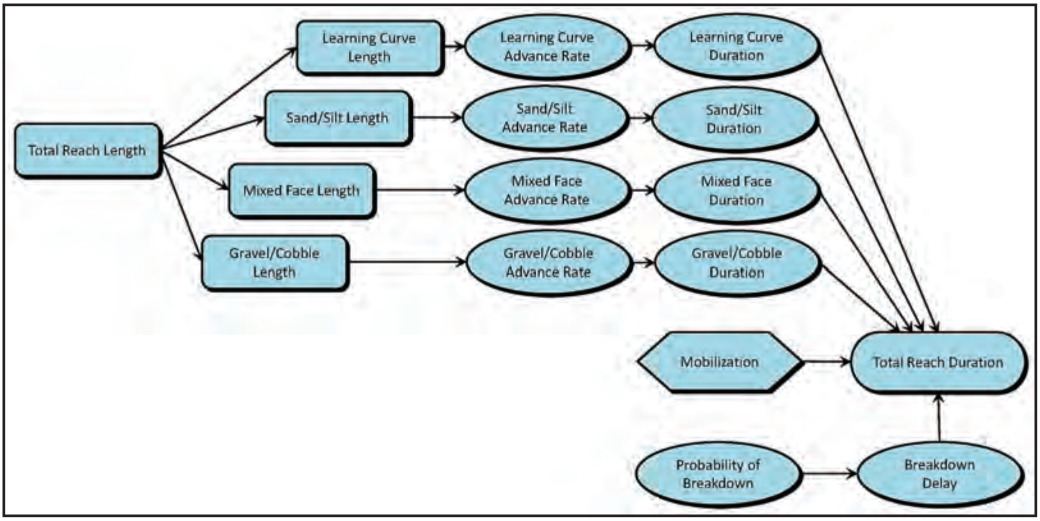
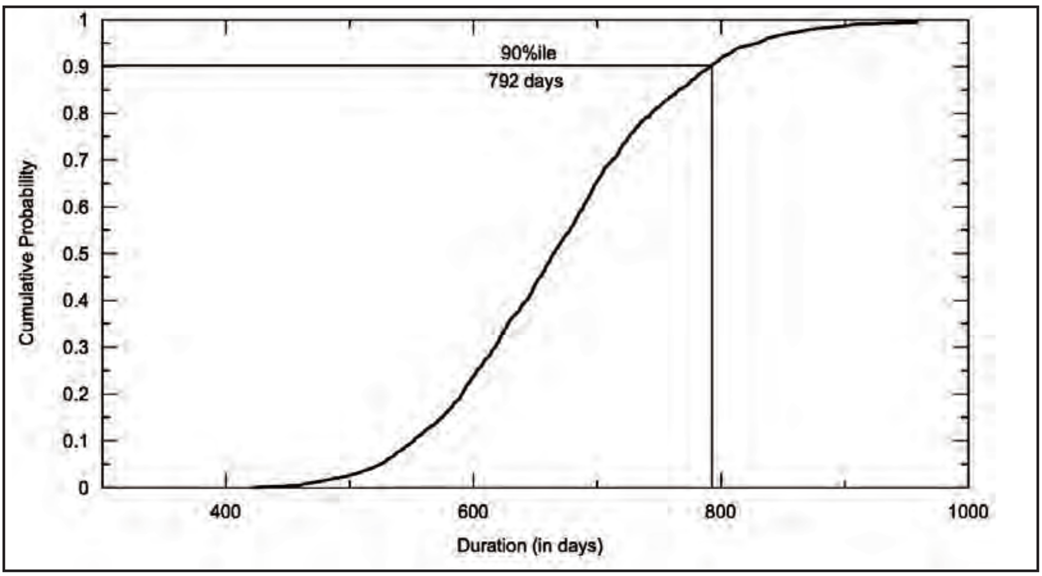


Figure 56. Cumulative Distribution for Total Duration of Mining



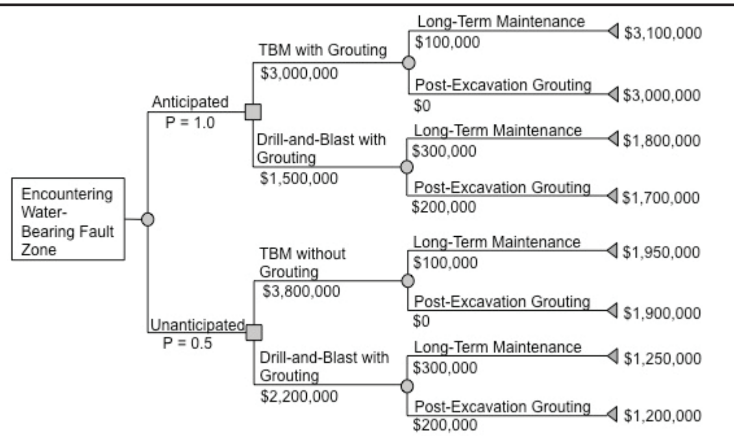
Decision Tree Analysis

Decision tree models, or tree diagrams, are risk models that are based on a singular, or series of, scenarios. These models are useful tools because they are readily developed, and can use quantitative, qualitative, binary, or nominal means to model decisions and their possible consequences. In addition, as with other risk assessment techniques, decision tree models benefit engineers by allowing a structured format for evaluating a risk, or series of risks.

An example of a decision tree model for tunnel grouting within a water-bearing fault zone in a hard rock subsea tunnel is presented in Figure 57. This model determines the relative cost risk for two excavation alternatives and the impact of groundwater inflow.

The Decision Tree model can be easily adapted to various risks for open water tunnels. If these models are used for planning and engineering purposes, it is recommended that overly generalized events, or risks, be avoided to maximize utilization and application of the model, and the resulting output. In addition, risks that can be quantified based on existing information or historical data will provide the most reliable results from the risk analysis.

Figure 57. Decision Tree Model to Evaluate the Cost of Tunnel Grouting for Groundwater Inflow Control



Excavation Method	Remediation	Cost
TBM	Long-term leak maintenance	3,100,000 + 1,950,000 = **$5,050,000**
	Post excavation grouting	3,000,000 + 1,900,000 = **$4,900,000**
Drill-and-Blast	Long-term leak maintenance	1,800,000 + 1,250,000 = **$3,050,000**
	Post excavation grouting	1,700,000 + 1,200,000 = **$2,900,000**

8.6 RISK MANAGEMENT DURING CONTRACT PROCUREMENT AND CONSTRUCTION

Part of an effective risk management plan involves the communication of risk to potential contracting parties during the procurement stage. There are multitudes of risk management techniques available during preparation of the procurement documents. The following list represents a summary of information that should be provided by the bidder during this stage:

- Contractor's risk management strategy and objectives
- Proposed strategy for management of major risk items
- Contractor's experience with proposed risk management techniques on similar projects and the related outcome

A key component to the overall project risk management strategy is the definition and delineation of the owner's risk policy, risk acceptance criteria, and risk classification system. Any follow-on risk management by the contractor during design and/or construction can therefore be communicated on a common and clearly defined basis. Procurement documents should clearly state what is expected of the contractor as part of the risk management strategy. Requirements for participation from the owner and other stakeholders are an important part of the risk management program, and should be included as a high priority.

During construction, the contractor should be responsible for satisfying the owner's risk policy. The contractor's process for identifying hazards, classifying risks, and taking action on risks, should be understood and implemented by appropriate personnel. Likewise, the owner should take proactive steps to monitor and enforce the contractor's risk management strategy.

8.7 CONTRACTING PRACTICES FOR OPEN WATER TUNNELS

For most public works construction projects, current practice in the US is to use competitively bid (tendered) fixed price contracts. This type of contracting generally requires that all work be specified in great detail prior to the award and that the bidder assign a cost to each of the detailed work items. Rarely in underground work can this detail be fully realized. Tunneling work changes as it progresses and the actual subsurface conditions become known. Changes after work starts can be costly and result in claims, disputes and litigation.

In an effort to eliminate some of these costly disputes, several alternative contracting practices were explored by industry groups. The US National Committee on Tunneling Technology (USNCTT) published *Better Contracting for Underground Construction* in 1974 to address the rising costs of underground construction. This document, which had a profound and positive influence on the tunneling industry, identified the fundamental need to improve the overall approach to contracting for underground construction projects. The idea of pre-qualifying bidders was one of the recommendations found in this report. Subsequently the Underground Technology Research Council's (UTRC's) Technical Committee on Better Contracting Practices published a booklet entitled *Avoiding and Resolving Disputes in Underground Construction*. The UTRC, sponsored by ASCE, published an updated edition in 1991. Specific recommendations to more equitably share risks and resolve disputes between owners and their contractors include:

- **Full Disclosure of all Subsurface and Geotechnical Information:** All factual subsurface data, professional interpretations thereof, and design considerations thereby raised should be made available to bidders, but with a careful distinction drawn between factual data and interpretation or opinion. This disclosure of geotechnical information would consist of two reports, the first being the results of the geotechnical investigations contained in the Geotechnical Data Report (GDR), and the second, the geotechnical basis, including professional interpretation and assumptions used in design – the Geotechnical Baseline Report – (GBR).
- **Include a Differing Site Conditions Clause:** A differing site conditions clause provides, in essence, an assumption by the owner of certain risks concerning unknowns in subsurface physical conditions. Thus bidders need not weigh the risk of encountering an unknown adverse subsurface condition and they need not consider how large a contingency should be added to their bid to cover the risk. This clause, preferably with wording similar to the federal differing site conditions clause, should be included in all contracts involving subsurface construction. This practice has come to be recognized as the owner "owning the ground."
- **Pre-qualification of Bidders, Specialty Subcontractors and Suppliers:** For items of work requiring performance by specialty subcontractors or suppliers, a determination of qualification prior to bidding ensures that the personnel on the project and the provider as a company have the appropriate education and experience, and are engaged in similar work on projects of similar complexity and size.
- **Use of Contingent Bid Items and Change Negotiations:** Contract unit price and specification provisions should be included in the contract documents for contingent and variable work items to allow fair and equitable payment for the contingent or extra work performed without protracted negotiations of contract price adjustments. Examples include unit prices for pre-excavation grouting (per bag of cement) or for various types of ground support.
- **Dispute Review Board:** A board of independent, experienced, and impartial members, one appointed by each of the parties and a third selected by the two board members with the approval of both parties, who would hear and make recommendations regarding any disputes that the participants themselves are unable to resolve.
- **Escrow Bid Documents:** The bid documents from all bidders are placed in escrow (i.e., they are held by a third party so that the winning contractor cannot view the proprietary information in a competitor's bid document). These documents could be utilized in the future to establish fair adjustments for extra work, differing site conditions issues and the like.
- **Bid Pricing:** Contracts should be broken up into separate bid items in such a way that contractors will not need to unbalance bids to obtain early recovery of capital, investments, and to provide for possible variations required in the work. For example, the work should be broken out into categories that fit the planned expenditures, like "Procurement and Delivery of TBM," which is a high cost up-front item; "Setup of Water and Spoil Treatment Facilities" "Main Tunnel Drive" and "Treatment of Removed Earth" "Purchase of Tunnel Lining Rings", and so on, ending with "Removal of Equipment and Site Clean-Up."

- **Value Engineering (VE):** Provide a contractual means for the contractor to propose less expensive but equally acceptable alternatives to the design given in the contract documents. After deduction of applicable expenses by both the owner and the contractor, the net cost savings are then shared between owner and contractor. A VE clause can create an effective incentive for the contractor to use its expertise and ingenuity to share cost savings with the owner.

Partnering during construction has also been used successfully in recent years on all types of construction projects. This practice consists of an informal, non-contractual agreement between the owner, construction manager, designer, and contractor that is developed jointly by a representative team working together to establish a mutual mission statement and objectives that define a successful project. It has been particularly successful in fostering better communication, developing trust, and more efficiently managing disputes and resolving potential litigation issues. Success of partnering is highly dependent on the participation and spirit of all parties involved, including the funders of the project.

9.0 CONCLUSION

9.0 CONCLUSION

Open water tunnels are risky enterprises, where the difficulties of characterizing the unknown and preparing for the unforeseen present tremendous challenges. It is the intent of this monograph to provide design practitioners and engineers for these projects with tools to best manage these risks.

As described in the early chapters of this monograph, the uncertainties and risks inherent to open water tunnels have changed very little over the last 100 years. What has changed however is the high cost of modern excavation techniques, coupled with increasingly aggressive schedule requirements, which can increase the cost of risk exposure.

The following list provides a brief summary of some of this monograph's key guidelines and lessons learned for open water tunneling:

- The extent and planning of site investigations should always reflect the complexity of the geology, the type of project, and the degree of risk. Sufficient time and resources must be allocated for investigations and testing.
- The results from site investigations should be properly documented and their use in calculations and assessments shown.
- Construction contracts where the contractor is responsible for the site investigation plan may result in reduced availability of vital information, leading to increased project risks, and should be avoided.
- Risk assessment should start in the planning phase and carry on through design and construction. Clear communication of risks, internally, externally, and within the contract documents is critical.
- The ground investigations should continue through the entire construction period. Tunnel mapping and follow up should be done by experienced engineering geologists representing the owner as well as the contractor.
- Risk assessment and detailed analyses of all project uncertainties are critical. Development of appropriate mitigation measures, suited to the anticipated subsurface conditions, is also crucial.
- An independent, experienced, and well-qualified oversight, or advisory, committee should always be considered for high-risk, high-profile open water tunnel projects.

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ACRONYMS

ASCE	American Society of Civil Engineers
CM	Construction management
CPT	Cone penetration test
DC	Direct current
EPB	Earth Pressure Balance TBM (described in Sections 3.2 and 6.2)
EPDM	Ethylene, polymer, diene, monomer
ERI	Electrical resistivity imaging
gpm	Gallons per minute (measure of water flow)
GBR	Geotechnical baseline report
GPR	Ground penetrating radar
psi	Pounds per square inch (measure of pressure)
PVC	Polyvinyl chloride
SPT	Standard penetration test
SSP	Sonic soft ground probing
TBM	Tunnel boring machine
USD	United States dollars

GLOSSARY

Advance rate	Distance excavated during a given period of time (minute, hour or day).
Annulus	Area between the excavated surface of a tunnel and the exterior surface of the tunnel lining.
Bentonite	Clay mineral that swells as it absorbs water. In tunneling, bentonite is often used to help provide support of an excavated surface by forming a "mud cake."
Blowout	Rapid escape of compressed air due to pressure in excess of the surrounding hydrostatic and earth pressure.
Borehole	Small diameter exploratory hole drilled into the ground to collect geologic or hydrologic data.
Compressed air	Air supplied to the tunnel by mechanical means that is at a greater pressure than atmospheric pressure. Some tunnels are excavated using compressed air instead of free air to support the ground and prevent water and loose ground from entering the tunnel.
Cone penetration test (CPT)	Continuous in-situ soil test performed by hydraulically pushing an instrumented probe into the ground.
Cover	Amount of soil or rock that overlies a tunnel.
Cutterhead	Rotating front end of a TBM that cuts through the ground. See Figure 28.
Cutter/Cutting disc	Roller type cutter, typically mounted at the cutterhead, which rotates freely about a bearing and penetrates the rock to fracture and cut the rock. See Figure 29.
Earth Pressure Balance TBM	Type of TBM that provides positive support to the tunnel face by balancing the external earth pressure and water pressure against the thrust pressure and rate of soil extraction from the cutterhead. Described in Sections 3.2 and 6.2, and shown in Figure 28.
Face	Refers to the front of the excavation where work is advancing.
Gasket	Device that acts as a seal between two contacting surfaces.
Ground loss	Movement of ground (soil or rock) into an excavation as a result of excavation in excess of the theoretical excavated volume.
Heading	Horizontal excavation where active excavation is taking place.
Hydrostatic head	Height of a column of water that exerts pressure at a given depth. Often this is expressed as a force applied to a unit area of surface (bars, psi, pascals, etc.).
Invert	Bottom or "floor" of the tunnel.
Muck	Excavated soil or rock that is removed from the tunnel.
Mucking	Process of removing soil or rock from an excavation.

Overbreak Rock excavated in excess of the neat lines of a tunnel excavation.

Overburden Rock or soil that overlies an excavation.

Packer test In-situ water test performed in boreholes and used for estimating the permeability of soil or rock.

Pilot tunnel Small excavation advanced ahead of the main excavation to gather information about the ground.

Positive support Refers to pressure applied to the face of an excavation that is in excess of the required pressure needed to maintain excavation stability (that is, in excess of what is needed to counteract earth or hydrostatic pressures).

Pressuremeter testing In-situ test performed by applying pressure to the sidewalls of a borehole.

Soil conditioning agents Additives used in EPB TBMs to alter the properties of the spoil being excavated.

Spiling Ground support measures typically in the form of steel bars, strands or pipes, advanced horizontally ahead of the excavation to assist with roof support.

Spoil Soil or rock material excavated from a tunnel or shaft.

Tail skin/Tail shield Steel cylinder at the rear of a TBM shield, where typically the segmental lining is erected. See Figure 28.

Tail skin grouting Process of injecting grout around the tail skin of a TBM to provide full contact between the tunnel lining and the surrounding ground.

Trailing gear Series of equipment platforms behind a TBM shield that provide mechanical support for TBM operations.

Tunnel lining Layer of concrete, shotcrete, or steel, etc., used in tunnels to prevent groundwater leakage and/or to support the surrounding ground from collapse.

Tunnel ring Circular segment of tunnel lining that provides circumferential support of the excavated ground.

Vane shear test In-situ test performed in boreholes and used to estimate undrained shear strength of soil.

Wireline coring Method of advancing exploratory boreholes, typically in rock, to obtain samples for recording subsurface conditions, such as geological and engineering properties. Samples are obtained from within the drill string through an inner core barrel that is attached to the drill rig via a "wireline" that is used to bring the sample to the surface through the drill string.