Technical Engineering and Safety Assessment:

Routing, Construction, and Operation of the Dakota Access Pipeline in North Dakota

January 5, 2016

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Acronyms and Abbreviations

ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
bbl	Barrel of Oil
BOTAS	Turkish Petroleum Pipeline Corporation
bpd	Barrel per day
BTC	Baku Tbilisi Ceyhan
CEQ	Council on Environmental Quality
DAPL	Dakota Access Pipeline
DOT	Department of Transportation
DSI	General Directorate of State Hydraulic Works
EA	Environmental Assessment
EIA	Environmental Impact Assessment
EIS	Environmental Impact Study/Statement (depending on the definition in applicable country, but generally the same environmental process globally)
EPA	Environmental Protection Agency
ESD	Emergency Shutdown
FEA	Finite Element Analysis
FOC	Fibre Optic Cable
ft	Feet
HDD	Horizontal Directional Drilling
HDPE	High Density Polyethylene
in	Inches
KDHE	Kansas Department of Health and Environment
km	Kilometer
LDS	leak Detection System
m	Meter
NAB	National Energy Board
NDPSC	North Dakota Public Service Commission
NPDES	National Pollution Discharge Elimination System
NWPA	Navigable Waters Protection Act
SCADA	Supervisory Control and Data Acquisition
SPCC	Spill Prevention, Countermeasure and Control (Plan)
US	United States
USACE	United States Army Corps of Engineers
vs	Versus
WCD	Worst Case Discharge

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1 INTRODUCTION

The proposed Dakota Access Pipeline (DAPL) project is an approximately 1,172 miles long crude oil pipeline which would begin near Stanley, North Dakota, and end at Patoka, Illinois. In North Dakota, there are two pipeline segments, including the 148-mile Supply Line and the 210-mile Mainline, which total approximately 358 miles across seven counties (Mountrail, Williams, McKenzie, Dunn, Mercer, Morton, and Emmons).

The diameter of the pipeline increases incrementally at designated tank terminals from 12 inches to 20, 24, and ultimately, 30 inches. The DAPL is co-located with existing pipelines and other linear facilities previously installed on the federal real property interests over which the USACE Omaha District has administrative and regulatory authority. The portion of the DAPL project relevant to the environmental assessment (EA) is the portion that Dakota Access proposes to construct on USACE-administered lands and flowage easements.

Specifically, the DAPL project would cross federal flowage easements near the upper end of Lake Sakakawea, north of the Missouri River in Williams County, North Dakota, and federally-owned property at Lake Oahe in Morton and Emmons counties, North Dakota. Dakota Access proposes the DAPL Project to transport at least 570,000 barrels of crude oil per day (bpd) from the Bakken and Three Forks production region in North Dakota to a crude oil market hub located near Patoka, Illinois.

Horizontal Directional Drilling (HDD), a trenchless construction method, was selected as the preferred construction method to install the pipeline under the upper portion of Lake Sakakawea, north of the Missouri River, and under Lake Oahe, north of the confluence with Cannonball Creek.

On July 25, 2016, the US Army Corps Engineers (USACE) issued a Finding of No Significant Impact (FONSI) for the Environmental Assessment prepared for the DAPL Project under the National Environmental Policy Act (NEPA). In their FONSI, the USACE, stated that with implementation of the mitigation measures and USACE-stipulated conditions, the issuance of permissions under Section 14 of the Rivers and Harbors Act (codified 3 U.S.C. Section 408, “Section 408”) to construct a 30-inch diameter pipeline across federal flowage easements using the planned HDD construction methods does not constitute a major federal action that would significantly affect the quality of the human environment. By issuing a FONSI, the USACE also concluded the preparation of an Environmental Impact Statement (EIS) under NEPA would not be required for the project.

On December 4, 2016, the USACE announced that they would not grant the final easement for the Dakota Access Pipeline (DAPL), and instead will prepare an EIS that considers alternate routes. While the USACE did not deny the final easement or deny the DAPL crossing at Lake Oahe, it announced that it “will not grant an easement to cross Lake Oahe at the current location based on the current record.” In announcing that EIS process would commence in early 2017, the USACE’ stated that EIS would include a “robust consideration of alternative locations for the pipeline crossing the Missouri River, including, but not limited to, more detailed information on the alternative crossing that was considered roughly ten miles north of Bismarck."

Presumably, a "robust consideration" would mean that "state-of-the-art" impact analyses would be conducted using the best, currently available technology, data and knowledge to access the engineering design and construction processes required to successfully cross Lake Sakakawea and Lake Oahe. Similarly, the same rigorous methodologies would be applied to assessing the potential risks and impacts from oil spills and leaks in the short- and long-term. The USACE's December 4th decision also identified the need to evaluate the potential risks of oil spills and impacts to Lake Oahe in the context of the project's potential impact on water intakes downstream, as well as the extent of potential impacts on the water, treaty, and fishing and hunting rights of Tribes historically and currently associated with the Missouri River system.

1.1 Objectives

The objectives of this report are to discuss the following:

1. **HDD**: Review of previous oil pipelines built in HDD bored tunnels under lakes of at least 1 mile long with a large diameter pipe, with reference given to global and US projects and the known engineering design, construction, and operation challenges and issues.
2. **Leak Clean Up Procedures:** Known/proven clean up procedures necessary in case of a leak in the pipe under the lake, the expected status of contaminated soil and aquifers, and the cleaning methods required and necessary.
3. **Global Standards:** Comparison of global standards (US, EU, World Bank/IMF, Turkish, other) surrounding oil pipeline construction under freshwater lakes and reservoirs.
4. **Leak Detection Systems:** Discussion of a normal pipeline leak detection system vs. the one proposed by DAPL.
5. **Geological Risk and Hazards:** A geological analysis of the risks of construction and operation of the pipeline in the local shale formation due to continuous shifting, landslides, and sloughing.
6. **Lake Oahe HDD Risk Analysis Report:** Review of the proposed HDD construction documents proposed as well as the document that was previously withheld from the Cheyenne River Sioux Tribe, as noted in the USACE Memorandum of December 4, 2016.
7. **Routing Analysis:** Indicative sample analysis of three different potential pipeline routes including:
    - Alternative I: a route that does not require any crossing of the Missouri River. This alternative envisions that the route will pass through the east of the River.
    - Alternative II: proposed Route DAPL selected with HDD crossing under Lake Oahe.

- Alternative III: a route crossing Missouri River at North of Bismarck to avoid crossing Lake Oahe

8. **Costs:** Examine the costs associated with rerouting of DAPL to alternative locations as set forth for Alt II and III above and compare such cost to the costs for completion of construction at the current location Alt I for a Lake Oahe crossing

1.2 Limitations

All assessments contained in this report were prepared by utilizing the publicly-available Environmental Assessment (EA) and the USACE"s Administrative Record (AR) as a basis. A third-party contractor and DAPL, under the guidance and authority of the USACE and as allowed under the National Environmental Policy Act (NEPA), prepared the EA. It is unclear whether the USACE or the third-party contractor maintained the AR.

Under a NEPA third-party contract, the federal lead agency, project applicant, and environmental consultant enter into an agreement about how a NEPA document, such as an EA, will be prepared. The applicant pays for the consultant's services, but the federal lead agency is responsible for independently reviewing, analyzing and judging the accuracy and completeness of all information in the NEPA document. Under NEPA regulations, the lead agency is responsible for guiding and participating in the NEPA document preparation, independently evaluating the document prior to its approval, and taking responsibility for the document scope, contents, conclusions reached, and conditions and mitigation measures recommended [40 CFR 1506.4(c)]. Third-party NEPA contracting is commonly used across the nation for applicant projects requiring lead agency approvals. Many lead agencies rely on environmental consultants to assist in NEPA document preparation, often because lead agencies do not have the staff expertise, staff resources or time to conduct the technical analysis necessary to comply with NEPA.

For the record, we note that several portions of documents contained in the aforementioned AR have been redacted. Additionally, key documents used in the EA's impact analysis and by the USACE to justify the issuing of the FONSI were withheld from AR and the public, as claimed by DAPL, for proprietary, sensitivity, and/or security reasons. The documents withheld and specifically referenced by the USACE in their December 4, 2016 memorandum are:

(a) North Dakota Lake Oahe Crossing Spill Model Discussion, prepared by the Wood Group Mustang Engineering;
(b) Lake Oahe HDD Risk Analysis Report; and
(c) DAPL Route Comparison and Environmental Justice Considerations.

It is our understanding that DAPL have made the documents cited above available to Fredericks Peebles & Morgan LLP (FPM), the legal representatives of the Cheyenne River Sioux Tribe, however, DAPL has refused to disclose the documents for review and analysis by the technical experts involved in the preparation of this report under contract to FPM. Therefore, our comments and review do not have the benefit of what would be an otherwise more comprehensive technical engineering review of the methods used, the construction and operating costs associated, and conclusions reached regarding the Lake Sakakawe and Lake Oahe crossings. It is not possible to complete and compile a comprehensive technical and cost review without these key withheld documents. As the technical experts, we, therefore, recommend their release to allow for their review and analysis.

2 HDD CONSTRUCTION METHOD

Transportation of crude oil via pipeline is an effective way to carry fluid (liquid or gaseous) products from one point to destination, depending on the properties and sensitivities of the specific project. In the Bakken and Three Forks region, current alternatives used for transportation include truck and/or rail transportation.

Since, the pipelines generally have very long routes, they cross wetlands, rivers, roads, railways, and other environmental and geographic features, which are named as special crossings, inevitably. DAPL also crosses federal flowage easements near the upper end of Lake Sakakawea, Missouri River and Lake Oahe.

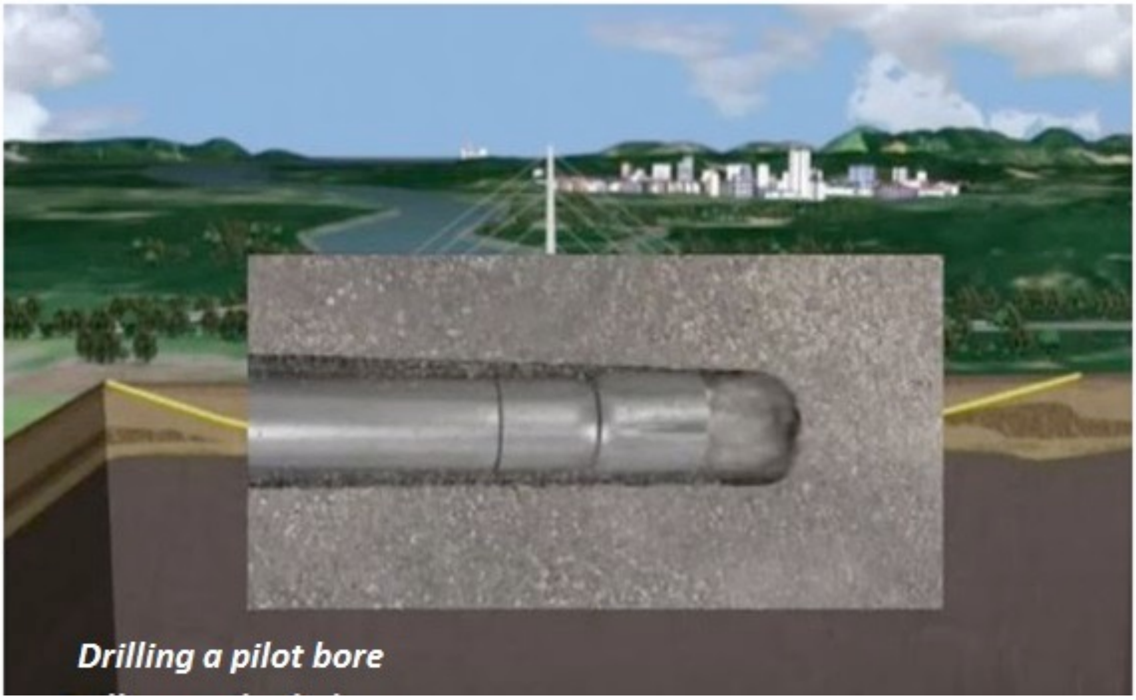
Dry and wet open cut methods which require excavation of a trench, and horizontal drilling from beneath a structure (e.g. railway, road, river, etc.) are methods which are applicable for special crossings In some cases, when it is applicable, overhead pipe crossing method over rivers, roads, etc. are frequently methods applied. Bridges are also used for pipe crossings by mounting/laying pipes to the side of the bridge but this is limited to fluids that comply with various local, regional and federal regulations promulgated and enforced by various regulatory agencies, including the DOT, OSHA, and EPA.

The HDD method involves first drilling a pilot bore in the location(s) as indicated on the plans, and then next enlarging the drilled pilot bore to facilitate the installation/pulling of the required pipe line or bundle, herein referred to as the “product pipe”. [1]

The general steps involved in the HDD construction method are shown in Figure 2.1 - Figure 2.6.

Source: https://www.youtube.com/watch?v=FLUbUUczcsc

Figure 2.1: Overview of an HDD Project Site

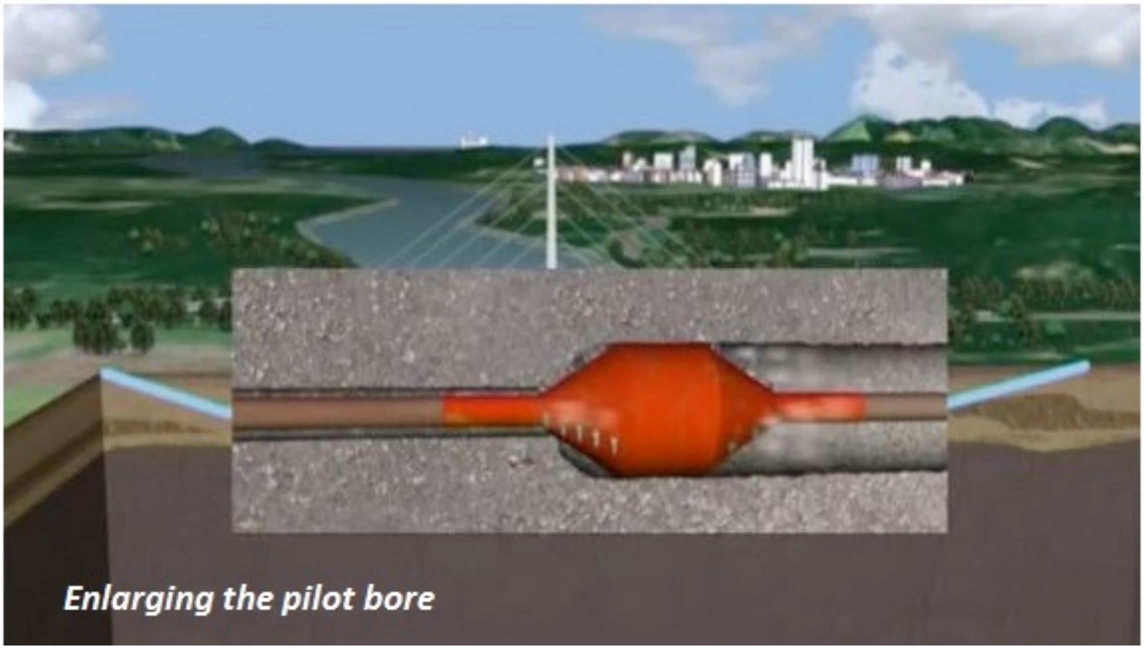


Source: https://www.youtube.com/watch?v=FLUbUUczcsc

Figure 2.2: HDD pilot bore

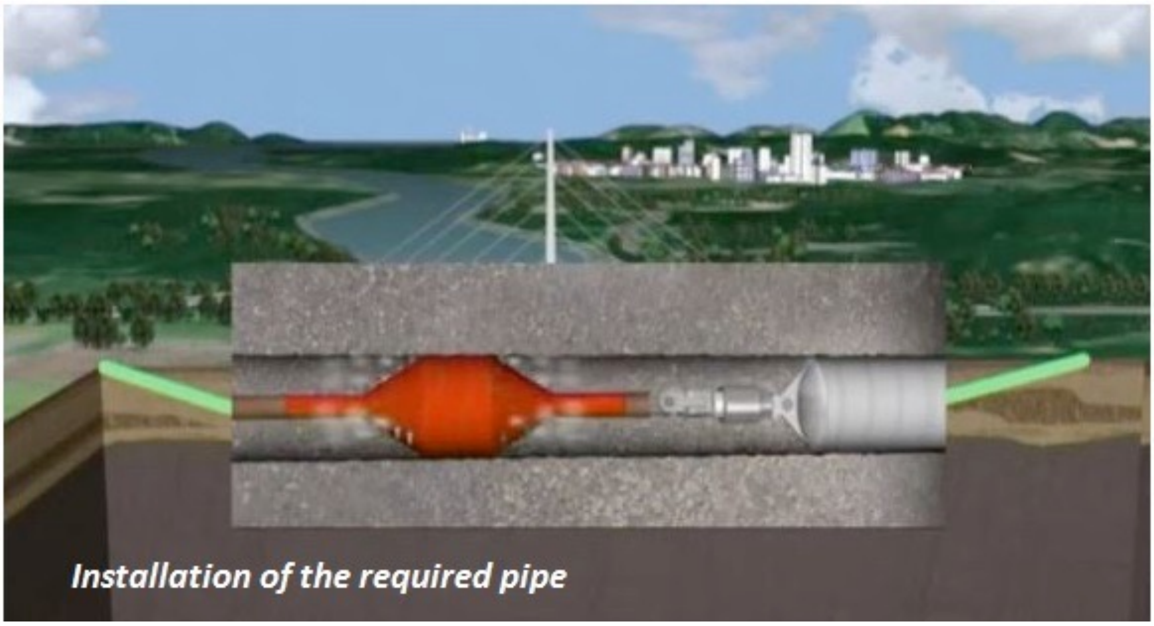
Source: https://www.youtube.com/watch?v=FLUbUUczcsc

Figure 2.3: Completed HDD bore hole



Source: https://www.youtube.com/watch?v=FLUbUUczcsc

Figure 2.4: Enlargement of the HDD pilot bore



Source: https://www.youtube.com/watch?v=FLUbUUczcsc

Figure 2.5: Pipeline installation occurs by pulling the pipeline through the HDD bore

Source: https://www.youtube.com/watch?v=FLUbUUczcsc

Figure 2.6: Pipeline Installation completed.

2.1 Long Distance HDD Crossing Applications in the World

Although our review may not be exhaustive in finding all global references, we specifically looked for similar HDD applications involving crude oil as the product fluid as well as the other applications. We also used as criteria long distance horizontal bores of at least 1 mile in length, and a large bore pipeline of at least 30" diameter. While we were able to find several references involving natural gas as the product fluid, the use of a long HDD to install pipelines carrying crude oil is more limited. The only crude oil applications that we were able to identify crossing long bodies of water were for seawater crossing applications. The references found reveals that ***there are no similar applications to what DAPL have proposed involving crude oil as the product fluid in a long HDD bore in a large diameter/volume pipeline application underneath a wide freshwater waterbody similar to Lake Oahe***. This in itself should have been a red-flag in the review process. Additionally, most global permitting authorities would have seen such a large undertaking as just cause for a more detailed and rigorous assessment of the potentially significant environmental risks. Given that the HDD of Lake Oahe is perhaps the longest and largest diameter HDD efforts under a freshwater body, the USACE should incorporate a detailed and rigorous risk analysis in the proposed EIS.

While any hydrocarbon leak from a pipeline can have significant and catastrophic results, it is our opinion that crude oil presents significantly more risks to soil and water contamination as compared to natural gas. Natural gas clean-up is generally not required as natural gas is of pipeline quality is 85-95% methane – a naturally occurring gas in the earth's crust. In the event that natural gas is released into a waterway, the gas will eventually dissipate into the atmosphere and does not pose a significant risk to the quality of potable water or other life forms in the water. Of course, methane release into the atmosphere poses an entirely different set of environmental risks that are not the subject of this report and shall not be presented here. However, the EIS should follow the Council on Environmental Quality (CEQ) *Guidance On the Consideration of Greenhouse Gas Emissions and the Effect of Climate Change.*

(https://www.whitehouse.gov/sites/whitehouse.gov/files/documents/nepa_final_ghg_guidance.pdf).

Any leakage of crude oil (or similar contaminating product fluid – natural gas is not viewed in the same risk category) into a large body of water has potential catastrophic impact on nature and the environment; however, the risk to freshwater vs salt or sea water is exponentially higher. Both contaminate the aquatic life forms that inhabit the waters contaminated, as well as the shore areas. Contamination of freshwater due to liquid hydrocarbons– like that in the Missouri River and Lake Oahe in particular – are of the most significant consequence that should be considered for project permits as communities are dependent on uncontaminated freshwater sources for safe human consumption, agricultural / irrigation use, domestic and wildlife animal consumption and other public consumption.

One of the key mandates of the USACE is the very protection of these federally regulated freshwater sources & uses, and it appears to be a fatal flaw that they have simply accepted the claim of DAPL of "no significant impact". It is our experience that most other applicable permitting agencies around the World would have rejected this FONSI and required an Environmental Impact Statement (EIS), similar to the NEPA EIS process. Its always best practice to avoid lake or freshwater reservoir pipeline crossings altogether. It is our strong recommendation that USACE should not be granting freshwater lake crossings or even considering them as there is always a better alternative available to project proponents.

The EA references the Garrison Project – Lake Sakakawea Oil and Gas Management Plan, which stipulates that: "oil and gas pipelines should use directional drilling technology to traverse beneath sensitive habitat areas." The DAPL EA incorporates this stipulation to justify this particular application at Lake Oahe.

According to the EA, DAPL's decision to propose a pipeline alignment requiring the crossing of Lake Oahe was based on a fatal flaw analysis as described below:

> Dakota Access utilized a sophisticated and proprietary Geographic Information System (GIS)-based routing program to determine the pipeline route based on multiple publicly available and purchased datasets. Datasets utilized during the Project routing analysis included engineering (e.g., existing pipelines, railroads, karst, powerlines, etc.), environmental (e.g., critical habitat, fault lines, state parks, national forests, brownfields, national registry of historic places, etc.), and land (e.g., fee owned federal lands, federal easements, dams, airports, cemeteries, schools, mining, tribal lands, and military installations, etc.).

> Each of these datasets was weighted based on the risk (e.g., low, moderate, or high based on a scale of 1,000) associated with crossing or following certain features. In general, the route for the pipeline would follow features identified as low risk, avoid or minimize crossing features identified as moderate risk, and exclude features identified as high risk. For example, the existing pipelines dataset was weighted as a low risk feature, so that the routing tool followed existing pipelines to the extent possible to minimize potential impacts. An example of a high risk feature is the national park dataset. Since national parks were weighted for the DAPL Project as high risk, the GIS routing program excluded any national parks from the pipeline route to avoid impacts on these federal lands. In addition, the routing program established a buffer between the proposed route and certain types of land, such as maintaining a 0.5-mile buffer from tribal lands.

We also note the following statement in the EA regarding route selection :

> Early in the routing phase of the DAPL Project, Dakota Access considered but eliminated an alternative centerline that originated in Stanley, North Dakota, within Mountrail County, where it connected to customer receipt points and headed southwest through Williams County and crossed the Missouri River approximately 8.5 miles east of the Yellowstone River and Missouri River confluence (Figure 12 in the EA). The centerline then headed southeast across the state and crossed Lake Oahe approximately 10 miles north of Bismarck (Figure 13 in the EA), where it then headed south again and entered South Dakota approximately 35 miles east of Lake Oahe in McIntosh County. In addition to other evaluation criteria listed in Table 2.1 (of the EA), the route alternative was in proximity to and/or crossing multiple conservation easements, habitat management areas, National Wildlife Refuges, state trust lands, waterfowl production areas, and private tribal lands.
>
> As a result of public input and comment during this EA process, additional desktop evaluation of the North Bismarck alternative portion of the early route (Figure 13 in the EA) was undertaken. The comparison of this alternative to the preferred route is included in Tables 2-1 (in the EA) and 2-2 (in the EA) contained herein. As illustrated in the tables, the data substantiates eliminating this route as a viable alternative. While the alternative does avoid Corps fee owned land at Lake Oahe; therefore, would not require a Corps real estate outgrant or Corps EA review, approximately 11-miles of length would be added to the pipeline route, consisting of roughly 165 additional acres of impact, multiple additional road crossings, waterbody and wetland crossings, etc. In addition to the criteria shown in the tables, due to the proximity to Bismarck, the North Bismarck route alternative crossed through or in close proximity to several wellhead source water protection areas that are identified and avoided in order to protect areas that contribute water to municipal water supply wells. The route was also severely constrained by the North Dakota Public Service Commission's 500-ft residential buffer requirement at multiple locations. Furthermore, this route alternative crossed other populated PHMSA high consequence areas (HCAs), that are not present on the preferred route. Pipeline safety regulations use the concept of HCAs to identify specific locales where a release from a pipeline could have the most significant adverse consequences.

While we acknowledge that a kind of constraints analysis may have been conducted to evaluate the relative risk of the DAPL routes, the conclusions in the EA/FONSI regarding route selection also rely on a vague reference to a qualitative “desktop evaluation” of about 25 elements (see EA, Table 2-1, page 9). Additionally, a comparison of costs, the number of bores, and the number of mainline valves (see EA/FONSI; Table 2-2, page 11) were included in the EA/FONSI to justify selection of the southern route crossing Lake Oahe. We note that the EA/FONSI states that the “desktop evaluation” was conducted *only after* public input was received during the scoping and public comment periods of the EA process. We ask three related questions:

1) Why was the EA/FONSI devoid of a more robust and comparative assessment of the engineering design and safety risks that exist from HDD construction for either the 5,966-ft (1.13 mi) crossing north of Bismarck or the 7,800-ft. (1.47 mi) southern crossing that places the pipeline 92 f below the lakebed of Lake Oahe. The technical risk of crossing a freshwater lake that exceeds one mile is substantially bigger than a 100-200 ft crossing.

2) Why was an engineering design and safety risk assessment not conducted as part of DAPL’s fatal flaw analysis?

3) What specific design and safety response features will DAPL incorporate in the river crossings that demonstrate maximum protection against potentially significant leaks and spills. If DAPL contends they are using “state-of-the-art” technologies, they should disclose and specify what those technologies are to allow the USACE to more rigorously evaluate potential environmental impacts and risks in the EIS.

2.2 HDD Construction Challenges and Issues

In order to lay a pipeline below Lake Oahe, the construction contractor must drill a horizontal lateral that is about 1.5 miles long and then pull a 30-inch diameter. 0.625-inch thick pre-manufactured pipe all the way through the bore hole (Figures 1.1f and 1.1g). A 0.625 inch think pipe is a very thick-walled metal pipe that is extremely heavy and would be hard to pull over a 7,800 ft long bore hole. In addition, metal pipe is subject to additional stresses by having to go around the two corners as depicted in Figure 1-1 above.

Although the pipeline is pre-welded, tested before insertion, and likely fed to the inlet of the bore on a roller system, the real construction risk lies below surface. Theoretically, stresses on the pipeline sections and the pipeline as a whole increase as each welded section goes under ground into the lateral. Considering that each 40 ft. section of metal pipe weighs approximately 7,850 lbs (approximately, 196.26 lbs per foot), or nearly four U.S. tons, the pipe simply becomes dramatically heavier as the welded pipe sections are pulled through the borehole below the surface; thereby, increasing the stresses on the pipe materials and welding workmanship.

To illustrate the magnitude of the forces required to pull the 30-inch diameter pipe weighing approximately four tons, consider that pulling the pipeline through the borehole near its completion point causes the pipe to literally be stretched like an elastic rubber band. Steel pipe has some lateral flexibility and the hope is the material will not exceed its yield strength. Once the pulling stresses are relieved, the any stretch in the pipeline will be reduced to zero and the pipeline can be expected to return to its original shape.

2.3 Finite Element Analysis - Pipeline Weld Flaws and a Construction-Damaged Pipeline

Finite element analysis (FEA) is a computerized simulation method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects. FEA shows whether a product will break, wear out, or work the way it was designed. FEA is used in pipeline construction to test welds that hold the 40 ft. pipeline sections together.

FEA conducted on the assembled pipeline would normally include certain assumptions about the welds, including the PHMSA pipeline safety regulations; ASME, API, and DAPL welding specifications with acceptable tolerances. Tolerances are measured centerline to centerline for each 40 ft section of pipe to match similar accepted tolerances and also include some buffer or factor of safety to account for unknowns. We note that the ***actual welds on aboveground sections along the already-constructed sections of DAPL have been reported to have been spot inspected by independent inspectors, and found to be out of compliance with pipeline standards***.

A weld is considered in spec when approximately a 1/8 inch excessive reinforcement (that is; the weld material that builds up above/below the natural surface of the pipeline) is observed on the topside of the weld and 1/16 inch excessive reinforcement on the inside/bottom of the weld. A stress-riser is a location in an object where stress is concentrated. An object is strongest when force is evenly distributed over its area, so a reduction in area, e.g., caused by a crack, results in a localized increase in stress. A material can fail, via a propagating crack, when a concentrated stress exceeds the material's theoretical cohesive strength. The real fracture strength of a material is always lower than the theoretical value because most materials contain small cracks or contaminants (especially foreign particles) that concentrate stress. Fatigue cracks always start at stress raisers, so removing such defects increases the fatigue strength Actual weld reinforcement variations observed were two times higher for both the top and bottom welds as noted in the required specs above. Significant undercut was also observed. These conditions translates to a ***stress-riser*** along the pipe.

As a pipe is stretched laterally (pulled), torsional stresses occur in the pipe walls. If the pipe were a perfect round cylinder those stresses would be very equally distributed along the pipe and only the material variations in the pipeline material would make one point more susceptible to yielding (stretching beyond the material limits that causes a permanent weakening of the pipe-wall that can lead to leakage) and no stress-risers would be observed.

Any stress-riser that occurs due to welding imperfections, misalignment of 40 ft pipe sections during welding, pipe material imperfections, and/or miscellaneous scaring/bending/denting/damage to pipe during construction will serve as a concentration/collection point of stress. The bigger the stress-riser, the bigger the concentration of stresses that will accumulate there and that single point (or several stress risers along the length of the pipe) become the so called, 'weakest link(s) in the chain' At these weak links, a pipeline rupture during construction underground could occur and the gravity of the impact is magnified because it is no longer possible to visibly or otherwise detect the damage on the outside of the pipeline. Even with a pipeline pig inspection, it is not possible to detect all external wall damage or many internal pipe-wall damages due to stresses from construction. It is inevitable that some of these HDD construction risks will likely result in pipeline damage and that damaged pipe will be installed in the borehole. The extent of the damaged pipe finally installed is nearly impossible to detect or remedy and the only way regulators or the public will ever know is some time has passed after the leak has occurred. Undetectable underground leaks pose as some of the most significant environmental pollution risks throughout the life of the pipeline and potential risks increase over time through corrosion, landslide movement or other disruptive forces.

2.4 Other Considerations for a Construction-Damaged Pipeline

<u>Repair and Replacement</u>

The risks of damage to the pipe due to construction risks are not insignificant; once the pipeline is placed in the bore hole under Lake Oahe, there is little opportunity to remedy major problems that would require replacement of sections. The damage to the pipeline from construction are likely to be exacerbated over the years of operation. Large volumes of fluid flowing through the pipe causes significant friction and stress over time through vibrations, changes in pressure and temperature, and any natural movement of soils and the geologic subsurface.

Compared to a long bore HDD, pipeline repairs and replacement can typically be achieved where relatively short sections are accessible over land or under a short river or stream crossing. However, irreparable damage to the 7,200 ft (1.5 mile) horizontal lateral under Lake Oahe would likely cause the pipeline to be abandoned as it is not practical to remove damaged sections for repair/replacement. Costs associated not only with the repair, but the time the pipeline would be down would result in a considerable loss of revenue. Where leaks occur and repair/replacement costs are high, we are concerned that the pipeline operator would continue operating without redress of the leaks. Past and present evidence exists for pipeline operators continuing to operate leaking pipelines by hiding, masking or downplaying the significance of leaks rather than disclosing and remedying the situation.

If the mitigation requires repair or replacement (not just monitoring) the entire HDD construction must be abandoned and a new pipeline built. One cannot replace only a section of damaged pipe as can be done in a pipeline constructed in a trench. The success/failure of any HDD this long relies too heavily on a risky construction method that doesn't allow for an expedient, environmentally- and mechanically-sound repair or replacement to any section of the pipeline at Lake Oahe which will bring up the new construction challenges and environmental risks.

Soil Contamination

Subsurface pipeline leaks occurring 92 ft. below and in the HDD bore of Lake Oahe, would be complicated if not impossible to clean up and likely would have significant impacts on soils and the Hall Creek and Fox Hills aquifers underlying Lake Oahe. The depth of the contamination would likely make clean-up of contaminated soil impossible. Contaminants in the soil from any leak or spill could easily travel from 92' below the surface to the freshwater Hall Creek and Fox Hills aquifers present below Lake Oahe and located just above the proposed HDD tunnel. The Hell Creek and Fox Hills formations are the major aquifers in the state and many residents depend on these formations for the water usage. These are also regional aquifers for not only North Dakota but also other surrounding states.

We note that the EA does not specify mitigation measures or specific pre-construction and construction prevention actions that would be implemented in a Spill Prevention, Countermeasure and Control (SPCC) Plan in the event of a leak in the HDD bore. We also note the EA did not adequately address how contaminants would travel up and through naturally-occurring geological cracks in the Hall Creek and Fox Hill formations; thereby, allowing shallow fluids to intermingle in the 92 ft wide zone between the lake and the horizontal HDD bore area. NIntey-two feet is an insignificant distance for fluids to travel over time. Naturally-occurring Thermal stresses from ground / lake freezing can also exacerbate the conditions by creating additional fluid communication channels for contaminants from the leaking pipeline to enter the Hall Creek and Fox Hill aquifers, and ultimately, Lake Oahe.

Bore Hole Integrity and Geological Hazards

HDD considerations must include its application in the context of pipeline safety. Pipeline safety is directly proportional to the length, diameter, and weight of the pipeline. The geological conditions as well as the straightness of the original borehole are also important safety factors that must be considered. Based on our experience in the field and the existing information globally and in North America, we are confident in saying that ***the longer the HDD, the higher the risk***.

Construction technologies and methodologies used to construct the initial small-diameter pilot bore hole do not actually result in a point-to-point, straight-line hole, in part, because the borehole requires the HDD drill bit to navigate two curves (Figure 1.1a-f). The resultant bore hole behaves more like long cork-screw that also 'dolphins' up and down, as well as left and right. The same HDD steering technology is usually applied to shale or coalbed methane oil and gas production wells. Actual observed results have shown the HDD borehole centerline to move vertically and horizontally by as much as 20-30' before the directional driller is even made aware that the drill bit has strayed from the intended tracking and correction is made to bring it back. Rather than a straight line, one could liken the boring to be more like an uncontrolled squiggle that more closely resembles an uncontrollable corkscrew moving vertically, horizontally as well as rotationally. This is not a result of poor drilling practices; rather, it is an accepted variance of the technology.

When this 12-3/4" horizontal bore hole is eventually reamed out to 48" diameter, and the reamed hole will also follow the same non-linear centerline of the original borehole resulting in a non-linear hole as described above. The excessive clearance between the 30" pipeline and the 48" reamed hole is intended to be the mitigation measure to allow the pipeline to slide in unobstructed by the walls of the borehole. However, this mechanical variance in the holes centerline as a result of the limits on steering control, compounds when considering the geologic hazards present in the borehole. Clays in the borehole are subject to swelling, and sloughing and are likely to compromise bore hole integrity, even where the appropriate drilling muds are deployed to mitigate this. Compromising bore hole integrity creates higher risk conditions for the construction and operation of the pipeline due to the increased potential for caving and the presence of swollen clays. And compromised bore hole integrity due to the hazards present under natural geologic conditions further reducing pipeline safety by increasing stress calculators (e.g., stress and force) on the pipeline and along stress-risers.

We also assume that DAPL will incorporate centerline stabilizers installed on the pipeline so that the pipeline with stay near the centerline of the borehole and not drag on the sides (top, bottom or sides) of the bore hole. It is impossible to keep the stabilizers from contacting the open borehole but the pipe itself should 'theoretically' be kept from contact with the open bore hole. In practice, due to the issues raised above, the pipeline will also drag along some of the bore-hole surfaces during installation. Stabilizers and the pipeline itself may actually scrape the open bore-hole causing further damage to both the pipeline and bore-hole during construction. In other situations, the entire pipeline could get stuck in the bore hole. While It is possible to eventually get the pipeline moving again, the ***initial forces to break the pipeline free will be another incredible force that cannot be accurately calculated and modeled to ensure a safe pipeline design. This is one of the most significant construction risks with the potential to leave the pipeline unsuitable for use, even though the pipeline is eventually freed and completed.***

Considering the potential damage to the pipeline during the construction of the long horizontal section under Lake Oahe, together with the long term operational risks stated above, we believe that DAPL and its principal, Energy Transfer Partners (ETP), have not fully and sufficiently evaluated the range of geologic and subsurface hazards factors that would likely preclude the proposed Lake Oahe crossing in favor of using a less risky route alternative.

2.5 Summary of Other Global and North American Long-Range HDD Construction Crossings

On paper, it seems a well-equipped project that includes a SCADA system (supervisory control and data acquisition; the computer controls and communication system for pipelines), leak detection system, cathodic protection system, qualified personnel, trainings, the application of global standards, and best available technologies would significantly reduce the risk potential for major and minor spills and leaks. However, as indicated by the recent 4,200 bbl (176,400 gallons) Belle Fourche leak - located 150 miles west of Lake Oahe in North Dakota - significant accidents can and do occur any time, and response time for remediation is an important factor as well as detection systems functioning as intended. As the Belle Fourche leak demonstrates, leak detection systems, even those that are deemed “state-of-the-art” can and do fail. At best, all we can hope for is that nothing ever happens. However, the most critical step is to avoid planning construction where the risk potential is highest.

Despite DAPL’s assertion that “state-of-the-art” construction techniques, pipeline technologies and controls, leak detections systems would be used, and that a rigorous SPCC plan (EA, Appendix L) would be prepared and submitted by DAPL for review and approval by the USACE to protect the environment and public safety, we remain unconvinced that such assertions can be made without first conducting a more robust engineering risk analysis for a 7,800-ft long HDD below Lake Oahe. We are further unconvinced where the USACE and DAPL also relied heavily on a qualitative assessment that compared relative physical features and elements (e.g., co-location of routes in existing rights-of-way, number of road and stream crossings, length of pipeline route, and costs; EA, Tables 2.1 and 2.2) without giving greater weight to construction risk considerations, as described throughout Section 2 of this report. In short, it is unconscionable, as well as mystifying to our engineering technical team how a more rigorous analysis of one the longest bore HDDs ever attempted was ignored. The DAPL project cannot justify any scenario whereby long distance HDD can be considered more safe than a much shorter HDD bore under a river, or where a pipeline route avoids the crossing of a significant river or lake altogether.

While a comparative analysis of long bore issues and challenges is beyond the scope of this report, we have conducted some cursory research on long distance HDDs. We sought to explore examples of various long distance HDD drilling without considering the purpose of the drilling (e.g,, natural gas, chemical, oil, electrical) and other factors such as pipe diameter and width, substrates bored, and latitude/location of the project:

1. England: The Pipeline Industries Guild reports completing a 3,005 m (9,860 ft) long drilling under Milford Haven Waterway in South Wales by LMR Drilling. The drilling allowed for the installation of a 457 mm (18 in) gas pipeline connecting the north side of the Milford Haven Waterway to the Pembroke Power Station on the south side. The project was completed in two phases. Initially a 1,980 m (6,500 ft) long x 16 in pilot hole

was drilled to assess ground conditions and prove viability. A second pilot hole was drilled from the opposite end of the crossing, intercepting the Phase 1 pilot hole, to form a single, 3,000m (9,840 ft) long hole. [2]

2. Netherland: The trace for a new gas pipe was divided in two parts to span the distance. Two joining 1450 m (4,760 ft) drills allowed the installation of a 48-inch gas pipeline under the Westerschelde river. At the deepest point the pipeline was at a depth of 50 meters (164 ft) below ground level. In the middle of the Westerschelde an artificial island was constructed so that the two pipelines could be connected. [3]

3. Greenland: Every year communication lines were damaged by icebergs. To prevent reoccurrence, two conduits were installed by drilling through 1150 meters (3,775 ft) of granite . The exit points were at the sea bottom, 200 meters (656 ft) beneath the water surface. [3]

4. Australia: HDD Bay crossing in Gladstone. Length 2 × 2125 m (6,970 ft), depth 78 m (256 ft). The drills were made to connect the Compigne Island to the shore. 95% of this trajectory is underneath the bay. [3]

5. Germany: Elbe river crossing. Length 1080 m (3,540 ft), depth 25 m (82 ft). It is reported as HDD drilling record in Europe. To get the 56-inch pipeline installed, Europe’s largest underground drill channel had to be made. It runs under the two embankments from the river banks in Lower Saxony at Barförde to the other side at Boizenburg in Mecklenburg, where the Elbe river is 300 meters (985 ft) wide.

6. Russia: Crossing the Naiba River in Dolinsk was a particularly complex task for Sakhalin Energy's HDD contractor DrillTec Russia and its team. At almost 1.15 km (3,770 ft), it was one of the longest HDD crossings ever completed, with the 48" pipeline actually pulled deep underneath the riverbed. The whole drilling operation takes several months for each river. [4]

7. Germany: The paper which is reprinted from World Pipeline indicates that the longest underwater crossings were carried out in 2004 and 2005 for an ethylene pipeline to two chemical plants when crossing the river Wolga in the river Elbe at a length of 2.2 km (7,217 ft) and 2.6 km (8,530 ft). In addition, it reports a crossing underneath the Wolga dam lake but no details. [5] and [19]

8. India: Indian River HDD Crossing. The project was part of a much larger endeavor to secure electrical infrastructure for some 4.8 million customers. The project involves the installation of two parallel 32-in., 7,020-ft bores 60 ft below river bottom in an environmentally sensitive area in order to ultimately install underground electric lines. [6]

9. Saudi Arabia: To feed the oil from the offshore oil field safely to the refinery on land, two parallel pipelines, each with a length of 3,048 meters (10,000 ft), had to be laid beneath the seabed – the longest crossing ever to have been completed using the HDD procedure until then. It completed both the subsequent reaming step and the pull-back of

the complete 3,048 m (10,000 ft) long pipeline along the entire route, although the weight of the pipelines was around 1,500 tonnes, with diameters of 24 and 30 inches. [7]

10. US: Michels, which is the proposed company for HDD for Dakota Pipeline, reports that on November 21, 2015, they utilized HDD to drill beneath the Athabasca River and completed an HDD for transportation of bitumen and diluent products between the Fort Hills Mine and Bitumen Extraction Facility. An installation of a 42-inch 7,200-foot (2,195 meters) crossing near Fort MacKay which is about one hour north of Fort McMurray, Alberta. The 1.36 miles (2,195 m) of 42-inch pipe is a new record for Michels and the longest in North America. [8]
11. US: Michels Directional Crossings completed the technically challenging crossing that stretched between the bordering states of Missouri and Illinois, and crossed under the Mississippi River and two associated levees. The installation spanned 9,038 ft, and was part of Enbridge's 593-mile Flanagan South Pipeline. [9]

From a technical standpoint, and given the preceding examples, it seems placing a 30-inch pipe at 92 ft below the lake bed, and spanning 7,800' (2,378 m) across Lake Oahe using an HDD construction method is achievable. However, we caution that the application of an HDD construction method for distances exceeding one mile (5,280 ft) is not a standard application. As we have repeatedly pointed out, many factors have to be carefully taken into consideration, including but not limited to: the diameter and wall thickness of the pipe, technology used for directing the drilling, soil conditions and substrates, and the pipe pulling technology used. In addition, other project specific constraints such as environmental, geological, sludge (water and bentonite) handling, risk of drilling fluid escape, landslide risk and other earth movement risk, such as tectonic or other, should be considered before making HDD application decisions.

We discuss the standards for applying HDD in Section 3 below.

3 STANDARDS FOR HDD APPLICATION

HDD construction applications are performed as per the specifications set by the related authorities, manuals and guidelines by considering the environmental legislation. The following information is collected through internet review.

3.1 Turkish Petroleum Pipeline Corporation (BOTAS) - Specifications In Turkey:

- HDD construction is a preferred method for natural gas and crude oil pipelines to cross large water courses, highways and railways;
- The water courses having widths >30 m (98.5 ft), highways and railways are crossed by HDD construction method. When applicable, the rivers can be crossed by wet or dry open cut method as depending on the amount of water in the river;
- There is no upper limit (maximum crossing length and depth) set for crossings. Although there is no upper limit that specifically excludes the crossing of a lake, it is well known throughout the industry that no approvals for HDD pipe application for lake crosings have occurred to date;
- In the river crossings, the minimum distance between bottom of the river and top of the pipe should be 1.20 m (4.0 ft);
- If a river will be crossed with an open-cut method, the pipe section beneath the river should be coated with concrete. By this way, both the contamination of soil and water table are prevented and negative buoyancy is provided;
- Highways and railways crossings should be performed via casing pipe without any exception. For example, 30" pipe should be placed in a 36" casing pipe beneath the structure. Casing pipe has several advantages as follows:
  - when a leakage occurs, it is kept in casing pipe, and soil and water contamination is prohibited,
  - no excavation is required for cleaning,
  - it is easy to clean casing pipe after leakage via inner pipe equipment.
- HDD waterway crossings do not require a casing pipe like the highways and railway crossings because it is not as practical. A pipeline is installed in an open bore-hole and then cement is pumped into the annular section between the outer surface of the pipeline and the inner 'earth' surface of the HDD bore-hole.
- Project owners shall prepare and submit their own crossing application plan including drilling sludge handling plan to the related authority (i.e. DSI (State Water Works), General Directorate of Railways, General Directorate of Highways) prior to construction, and similarly as-built project after the construction. Project owners are obliged to secure permit for all the works
- Project owners shall apply rehabilitation for the disturbed areas at the both side of the crossed structure;

- Project owners shall compensate all damages to properties during construction and operation (i.e. due to repair and maintenance);
- Project owners shall apply the precautions set by Water Pollution Control Regulation, Groundwater Pollution Control Regulation and Solid Waste Control regulation,

3.2 Evaluation of Horizontal Directional Drilling By State - University of Illinois - Illinois Center for Transportation

This document includes factors concerning HDD such as Drilling Fluids and Reamer Types. The document also mentions various Recommended Regulations By The American Society of Civil Engineers (ASCE) and State Regulations:

- **ASCE:** Pipeline Design for Installation by Horizontal Directional Drilling published by ASCE goes into detail about HDD pipe installation and gives specifications about practice.
- **ARIZONA:** The preferred trenchless technology is jack and bore, but it does provide depth of coverage that can be applied to either HDD or jack and bore. (Policy for Accommodating Utilities on Highway Rights of Way, 2009). The depth is dependent on whether there is a conduit present for the utility cable.
- **ARKANSAS:** Arkansas focuses most of its regulation on the depth of cover for different pipeline.
- **NEW YORK:** The New York manual, Requirements for the Design and Construction of Underground Utility Installations Within the State Highway Right-Of-Way, 1997, provides very general information about HDD.
- **CALIFORNIA**: In California's Guidelines and Specifications for Trenchless Technology Projects, 2008, the only specific requirement addressed was a minimum depth of cover depending on the pipe or product diameter.
- **IOWA:** Iowa's Requirements for the Design and Construction of Underground Utility Installations Within the State Highway Right-Of-Way, 1997, provides guidelines for deviation tolerances and depth of cover for utilities.
- **KANSAS:** Kansas has detailed pipe requirements depending on the kind of product being transported. Depth of cover varies for when the pipe is below the crown grade and when it is below the ditch grade. KDOT also has specifications on the hole diameter in relation to the pipe diameter (KDOT Utility Accommodation Policy, 2007).
- **MARYLAND:** Maryland's guidelines come from a source other than its department of transportation. The guidelines come from the Washington Suburban Sanitary Commission (WSSC) which uses HDD in the installation of its water mains. The WSSC has general rules, but pays special attention to the relation between pipe diameter and boring distance.
- **FLORIDA:** Florida's utility guide, Utility Specification- Quality Control, 2004, specifically prefers HDD for installations.

- **INDIANA:** Indiana focuses on the initial investigation of geologic properties as opposed to the actual boring process. Indiana most likely relies on judgment of the contractor after a through ground investigation.
- **OREGON:** HDD is used for smaller projects. Therefore, contactor makes decisions for individual projects. Like Indiana, only thing regulated is the initial investigation of geologic properties.
- **NORTH DAKOTA:** HDD regulations do not exist; however,North Dakota relies on the USACE Guidelines for installation of Utilities Beneath Corps of Engineers Levees Using Horizontal Directional Drilling.

3.3 Guidelines: Planning Horizontal Directional Drilling for Pipeline Construction-Canadian Association of Petroleum Producers

- Regulatory And Compliance Information Requirements:
  - *Fisheries Act :* The Fisheries Act was enacted to protect fish, fish habitat and water frequented by fish, and to provide for sustainable fisheries in Canada.
  - *Navigable Waters Protection Act* (*NWPA*): The *NWPA* provides a legislative mechanism for the protection of the public right of marine navigation on all navigable waterways of Canada.
  - HDD watercourse crossings which are part of an international or interprovincial pipeline are subject to review under the *National Energy Board Act* (*NEB Act*) and are also subject to approval by CCG, under Section 108 of that Act and the *NWPA*.
  - Guidance documents
    - Directional Crossing Contractors Association. Guidelines for a Successful Directional Crossing Bid Package. 1995.
    - Watercourse Crossings, Second Edition. Canadian Pipeline Water Crossing Committee. November, 1999.
    - Horizontal Directional Drilling Best Management Practices Manual, Topical Report. Gas Research Institute. May, 2002.
    - Horizontal Directional Drilling Practices Guidelines. HDD Consortium. 2004
    - Alberta Energy and Utilities Board (EUB) Guide 50; Drilling Waste Management, Interim Directive ID 99-05
- Selection Of HDD as The Preferred Crossing Method
  - overall pipeline route selection
  - crossing location selection;
  - crossing method selection;

  - other selection criteria such as:
    - availability of access,
    - need for and suitability of vehicle crossings,
    - siting of entry and exit points,
    - dimensions of the No Drill Zone, and
    - availability of a water source.
- Risk Considerations: Risk can generally be divided into three types: regulatory risks; construction risks; and operations risks
  - Regulatory Risk: During the application and approvals stage, the project may be delayed or rejected if insufficient information is submitted for regulator review. During construction, an inadvertent release of drilling fluid to the environment or other contravention of an act may result in possible charges being laid by the regulatory agencies.
  - Construction Risk: Construction risk on a project can be minimized by ensuring that sufficient planning is conducted and an adequate geotechnical investigation is carried out.
  - Operations Risk: Operation risk include:
    - pipe is inaccessible for repairs due to depth of cover;
    - corrosion due to undetected damage to pipe coating;
    - subsidence at entry and exit points; and
    - visual leak detection is not possible.
- Economic Considerations
- Geotechnical Considerations: The design drill path must be developed taking into account the geological setting for the project and geotechnical and hydrogeological issues at the crossing site.
- Environmental Considerations: HDD crossings are often undertaken to minimize the adverse environmental effects at watercourse crossings. Nevertheless, an HDD does not guarantee that all adverse environmental effects will be prevented. Common adverse effects are the result of:
  - inadvertent returns of drilling fluids into the aquatic, terrestrial or social/cultural environments; and, to a lesser extent,
  - disturbance of soils, vegetation, wildlife and social/cultural elements arising from either construction of drill sites, exit areas, access roads and temporary vehicle crossings, or the HDD activity
- Engineering Design Considerations
  - Design of Drill Path: of the drill path design.

  - Land Issues
  - Casing
  - Pipe
  - Drilling
  - Testing
- Contractual Considerations
- Construction Considerations
  - Drilling
    - Types and Sizes of Rigs
    - Casing
    - Drag Section: The pipe installation should be designed so that, wherever possible, the pipe string or drag section can be laid out and pulled back in one continuous section.
    - Steering / Survey of Drill Head
    - Drilling Fluids: A drilling fluid design plan should be established before the start of the project. This plan should also be modified, when warranted, throughout the project to ensure the drilling fluid is fulfilling its function
    - Drilling Fluid Disposal: Samples should be acquired of the drilling fluid/cuttings and analyzed for contamination before disposal. Permits/approvals are required in some provinces and territories for the disposal of drilling wastes.
    - Buoyancy Control
  - Monitoring: Drilling and Environment should be monitored. Typical failures and causes are given in the document. A site-specific contingency plan should be prepared by the project team for each HDD. Alternatives that may be available to allow continued use of an HDD method following an initial failure. Clean-up and remediation of the drilling mud shall be decided.

3.4 Horizontal Directional Drilling Guidelines Handbook - City of Overland Park - Kansas

- Before submitting an application for a Right-of-Way Permit, design process shall be undergone and following tasks shall be completed.
  - Prepare or obtain scaled mapping for the planned installation
  - Collect existing underground utility information

- Obtain Right-of-Way information through AIMS, survey records, or other sources
- Obtain general and/or specific geotechnical information
- Prepare Construction Plans using the information noted above
- Consider the minimum horizontal and vertical clearance requirements
- Consider product pipe and reamer diameter requirements
- Consider the bore geometry for the given ground profile
- Consider drilling equipment requirements for the given geotechnical conditions, geometry and final product diameter
- Consider equipment and material handling requirements
- Consider material strengths, capacities, and coupling methods

- In order to do Right-of-Way Permit Application, Project Information, Construction Plans, facility information, specific installation requirements, subsurface geotechnical conditions, Traffic Control Plan, Storm Water Pollution Prevention Plan and Construction Schedule shall be provided.
- Construction Safety Guidelines shall be followed.
- Drilling fluid shall be handled, collected and disposed in accordance with Drilling Fluid Containment and Disposal Requirements
- All construction work shall be performed in accordance with the Overland Park Municipal Code, Chapter 13, and as outlined Construction Requirements.
- All construction activities shall be performed in accordance with the National Pollution Discharge Elimination System (NPDES) as regulated by the Environmental Protection Agency (EPA), the Kansas Department of Health and Environment (KDHE), and the City of Overland Park.
- The Permittee (or its Contractor) shall implement Best Management Practices to insure that storm water runoff is not contaminated by sediment caused by land disturbances associated with construction activities.
- The HDD Contractor shall keep detailed and accurate records of all activities associated with the HDD process. Upon completion of HDD installations, As Built plans and any supporting documents shall be provided to the city of Overland Park.

3.5 Horizontal Directional Drilling - US Fish and Wildlife Service (fws.gov)

This document describes three stages of installation of a pipeline by HDD. The first stage consists of directionally drilling a small diameter pilot hole along a designed directional path. The second stage involves enlarging this pilot hole to a diameter suitable for installation of the pipeline. The third stage consists of pulling the pipeline back into the enlarged hole

This document is also gives site investigation requirements for large diameter HDD projects. General requirements are summarized as follows:

- Site investigation Overview
  - Obstacle Definition
  - Site Conditions Determination
- Passive Conditions
  - Geological Factors
  - Topographical / Hydrographical Data
  - Geotechnical Aspects

3.6 USACE Guidelines for installation of Utilities Beneath Corps of Engineers Levees Using Horizontal Directional Drilling - USACE

- Permit application, which include location information about drilling, layout, proposed drill path and cover depth, soil analysis, pipe information and detailed pipe calculations, information about proposed drilling fluid, information about tracking method and work plan, should be submitted.
- Soil investigation should be carried out.
- Appropriate equipment to facilitate the installation provision shall be ensured as a part of installation requirements and continuous monitoring of progress shall be undertaken.
- Additional permits such as obtaining water, water disposal, etc. and bonding and certification such as payment bond, certificate of insurance shall be submitted if required.
- Drilling operations shall be undertaken in accordance with general remarks, equipment setup and site layout remarks and drilling and back-reaming remarks.
- Drilling fluids shall be collected and handled in accordance with the standard and drilling fluids shall be kept out of streams, streets, and municipal sewer lines.
- Trenching may be used to connect sections installed by the directional boring method with other parts of the pipeline.
- The product should be installed to the alignment and elevations shown on the drawings within the pre-specified tolerances
- In order to prevent failures, deformations during installation, mitigation measures given in the standard shall be applied.
- A form of coating which provides a corrosion barrier as well as an abrasion barrier is recommended during the operation.
- All surfaces affected by the work shall be restored to their pre-construction conditions.

Based on our review of the various HDD standards and guidelines, we note that there is no restriction on HDD based on restrictions in pipe size, length, depth and lake crossing. Although as a general approach, the regulatory authorities always prefer selection of routes that avoid lake crossings. Depending on the route alternatives, they may allow lake crossings for water transportation, energy transmission, gas pipeline and even crude oil pipelines.

In Turkey for example, the Ministry of Forestry and Water Affairs, General Directorate of State Hydraulic Works (DSI) is the owner of all surface and groundwater of Turkey, ***and no lake crossings of any kind are allowed***, although it is not a written legal rule. The Ministry requires that pipelines be routed around lakes.

In the United States, interstate pipelines are governed by a number of different regulations and agencies. First and foremost, the Pipeline Safety Act (PSA) grants to the U.S. Department of Transportation (U.S. DOT) regulatory authority over the safety of hazardous liquid pipelines, which may transport oil. Within U.S. DOT, the Pipeline and Hazardous Material Safety Administration (PHMSA) administers the program through U.S. DOT's Office of Pipeline Safety (OPS). OPS implements pipeline design, construction, operation, maintenance and spill response planning provisions. Federal pipeline safety requirements are enforced by three primary mechanisms: PHMSA administrative orders, and civil and criminal sanctions pursued in court or citizen suits. PHMSA is the only agency authorized to prescribe safety standards for interstate pipelines. However, it does not have the authority to prescribe the location or routing of a pipeline. This gap in federal power allows the states an opportunity to become directly involved as they may exercise authority over the selection of pipeline routes within their state. Only three Great Lakes states have exercised their authority: Michigan, Minnesota and Illinois. All three states require permits for new oil pipeline construction. Proposed standards must be compatible with federal regulations. Furthermore, states may take a leadership role in the oversight of pipeline safety by state assuming intrastate regulation, inspection and enforcement responsibilities under an annual certification issued by PHMSA. Three states in the Great Lakes basin (Minnesota, New York and Indiana) have certified programs. Despite their certification, none of these states impose a requirement on pipelines that is stricter than the federal government standards. [13]

From the above review, it is clear that the US lags behind other nations in its regulations and standards regarding the transport of crude oil and the protection of the environment and public safety. There is no significantly impactful HDD regulation, authority and/or guidelines in the US compared to Canada, the nation most like the US. The lack of regulation, authority, and guidance in the U.,S. over crude oil pipelines suggests that further policy and regulatory development by the USACE, PHMSA (DOT) and state regulatory bodies would bring US compliance standards to a higher level and on par with protection and safety approaches found in other parts of the world.

4 ASSESSMENT OF PIPELINE ALTERNATIVES

4.1 Background and Issues Warranting an Alternatives Assessment

The proposed Dakota Access Pipeline (DAPL) Project would construct a 30-inch steel pipeline with a 7,800 ft long horizontally directionally drilled segment placed 92 ft depth beneath the southern end of Lake Oahe, north of Cannonball Creek. The length of the crossing is 7,500' (2,378 m). Other than the normal pipeline construction challenges, the long length of the HDD construction, and operation and maintenance of segment 92 feet below the bed of Lake Oahe presents other significant issues, many of which were discussed in Sections 2 and above.

Pipeline accidents can occur any time and response time for remediation is an important consideration when routing a pipeline. Particularly, pipelines that transport large volumes of liquid fuels. Under normal operating conditions, it is not expected/hoped that incidents involving spills and leaks ever happen. When considering pipeline routes, operators must be careful to not only weigh the environmental and cultural elements that may be impacted from construction, but also the suitability of a route and its alternatives based on safe engineering design. No matter the route selected, routinely plan for the worst case is good and responsible engineering and operating practice, bearing in mind that there is a likelihood that some event (e.g., ruptures and leaks) with negative consequences will happen. In the case of the Lake Oahe HDD crossing, if / when a negative event/situation arises, Dakota Access will have to deal with what may be more than 9,000 barrel of crude oil (estimated volume for the 7,800 ft long pipeline section).

The DAPL EA also discusses the spill prevention, leak detection and spill response mitigation measures that would be implemented. Specifically, the document states,

> "Based on a worst case discharge (WCD) scenario specific to Lake Sakakawea and Lake Oahe, a largest possible release volume was determined specific to the segment of the pipeline that would cross Corps-managed lands. It is important to note, this WCD scenario is also calculated on the assumption that the pipeline is on top of the river verses down in the horizontal lateral 92 ft below the lake. Because the proposed pipeline would be installed at a minimum depth 92 feet below the lakebed of Lake Oahe and ***there would be greater response time inevitably, and this could likely result in much more significant leakage/damage. While the potential risk for a WCD scenario could not be verified, such a spill would result in extremely high consequences for a fresh water lake***.

Section 2 discusses the issues and challenges with HDD and replacing and/or repairing the pipeline at the Lake Oahe crossing. In summary of those issues, problems with the pipeline may start from the beginning of the construction phase due to the stresses on the pipe resulting from pulling welded sections of the pipe using HDD construction methods across an exceedingly long crossing. Problems may be compounded where pipeline sections are either over- or underwelded. Pulling an increasingly heavy pipeline through the HDD bore hole strains the pipe and the welds holding the heavy sections together. Compromised portions of the pipe may go undetected and could result in leaks that contaminate the associated aquifers and soils. Clean-up of the contaminated aquifer and soils would not only be problematic because of deep depth of the contamination, but the clean-up is also unlikely to be successful at remediating the long-term environmental damage and impacts to the downstream fish, wildlife, plant, agricultural resources, as well as the various Native and non-Native communities dependent on the Missouri River. Should the pipe require a major replacement of that portion under Lake Oahe, the situation will be significantly more problematic than a pipeline trenched on land surface or a more narrow and shallower river or stream crossing.

Alarms signaling the detection of a major leak are also not fail-safe measures. While the triggering of some of these alarms is attributable to false positive signals on conventional pipeline control systems, human error and negligence are known to occur where operators turn off, override, or simply choose to ignore alarms. For example, while over 1,000,000 gallons of tar sands (bitumen) oil were spilling into the Kalamazoo River in Michigan, three consecutive Enbridge shifts ignored repeated warning signals. It took an emergency call from an electric utility field worker before the pipeline was closed—17.5 hours after the spill began. [9] Pipeline inspection tools may also be problematic, and similar to leak detection alarms, are not fail-safe measures. Human error will always be an issue when interpreting the technology. In many cases, landowners are the principal source for reporting a breech of the pipeline.

Nobody can guarantee that DAPL will not face similar operational challenges. With responsibility for maintaining more than 5,000 miles of pipeline, ETP, according to their own 2013 annual report, may not have enough cash reserves to cover damages from a significant oil leak or spill. Given ETP's 2013 annual report, the costs for the clean up of leaks, spills and explosions will likely be passed on to local landowners and federal taxpayers [9].

Typically, longer pipelines follow routes that cross many topographic features, including but not limited to rivers, roads, railways, wetlands, sensitive plant and wildlife habitats, agricultural irrigation, and sensitive visual features. Many long distance pipelines, including DAPL, also cross federal flowage easements managed by the USACE under various federal regulations and laws. Crossing flowage easements like other special crossing types (highways, railways, wetlands) typically carry more risk than a pipeline placed in trench in upland or forest. Thus, project proponents and decision-makers have the duty and obligation to plan early and diligently to ensure that the proposed alternative is selected using the best available engineering, environmental and cultural data to support the ultimate route selection.

In reviewing the DAPL EA and based on our professional engineering experience in global energy infrastructure development, our team was struck by the obvious risks associated with selecting a pipeline route requiring a deep and long HDD water crossing. We again question here, as we discussed in Sections 2 and 3 above: Why choose a route with such a high degree of risk and that is longer than a better alternative and involves the deep crossing at Lake Oahe when other more appropriate routes that are less risky and more manageable routes are available?

From our global professional engineering perspective, crossing a large freshwater waterbody, especially one that it is the fourth largest reservoir in the U.S., does not comply with the current best engineering practices and policies in most of the developed and undeveloped countries of the world. Aside from being a large and important freshwater waterbody, the proposed Lake Oahe crossing is neither the best alternative from an obvious engineering and construction risk potential nor an alternative that should be considered as part of the proposed project due to potential to leak and cause irreparable environmental damage.

The EA discusses two potential pipeline route alternatives with only limited and vague reference, information, and data regarding the selection criteria. As we have noted elsewhere in this report, there is seemingly a dearth of rigor in comparing the inherent risks of the engineering and construction design that compares the proposed route crossing at the south of Lake Oahe to either crossings that avoid flowage easements altogether or would occur at a narrower and presumably shallower point ten miles north of Bismarck. We have also discussed previously the USACE's and DAPL's reliance on a qualitative comparison of such features as the length of the pipeline, number of road crossings, and costs (EA, Tables 2.1 and 2.2)..

The NEPA process and the nearly non-existent federal regulatory oversight for oil pipelines notwithstanding, big projects like DAPL should logically consider a comprehensive comparison and evaluation of a broader range of alternatives. In a general review of the topographic and Google Earth maps available in the public domain, the project area's topography is almost flat and would be suitable for a large pipeline. We acknowledge that a pipeline project proponent in North Dakota could be complicated by large private land ownership, and depending on the route, could require a greater number of negotiated easements and condemnations. This is beyond the discussion of this report. However, we feel it necessary to note that the high engineering risks could be reduced substantially were DAPL to have chosen a longer and less direct pipeline to the north of Bismarck, North Dakota. One alternative could effectively be routed to pass east of the Missouri River without any river or stream crossing. From a purely engineering perspective, the EA does a poor job of conducting a comparative analysis of potentially viable pipeline routes.

The EA states that DAPL used a proprietary fatal flaw analysis to help select the pipeline alternative, We note, however, that the EA also is largely reliant on Tables 2.1 and 2.2. We contend that the comparison of the criteria listed in the tables was not done appropriately.

Though ranking the alternatives as minus (-) or plus (+) may be generally acceptable for comparing simple differences, such as the number of miles of collocated pipe, or the number of waterbodies crossed; such a ranking was done without the attention to weighting the value of certain selection criteria. By applying more rigor to the pipeline selection process, we believe that the route crossing the southern end of Lake Oahe would have ranked as worst potential alternative.

We contemplate whether the ranking was done with some degree of bias or arbitrariness. For example, the Lake Oahe is ranked as zero (0) and (+1) for alternative 2 and 3, respectively. The lack of consistency in ranking criteria is demonstrated where the EA states that "while the potential risk for a WCD scenario may be relatively low, such a spill would result in extremely high consequences." We could not find any analysis in the EA that evaluates the "potential risk for a WCD scenario." The EA (Section 2.1.4) also states that "national parks were weighted for the DAPL Project as high risk, the GIS routing program excluded any national parks from the pipeline route." We wonder why the potential risk to national parks were considered a criteria but a similar risk and ranking was not applied to the Lake Oahe crossing where the risk of potential environmental from engineering design is very high.

The EA (Table 2-2) considers the route crossing Lake Oahe to be the more preferable alternative compared to the route north of Bismarck. The conclusion is reached, in part, based on the comparative lower overall costs ($22,556,880) associated with Lake Oahe crossing. Like Table 2-1, the EA fails to evaluate the potential catastrophic risks and high costs that could result from operational failures due to an accident, leak or spill. Due to time constraints, this report did not analyze the cost values for the additional elements needed to assess the potential costs associated with the engineering risks at each of the crossings. We note, however, that based on the figures presented in the EA (Table 2-2), the overall cost difference between the Bismarck and Lake Oahe alternatives is 9 percent; an amount that we do consider significant especially when weighed against the higher risks of pipeline failure at Lake Oahe.

4.2 Indicative Assessment of the Route Alternatives

4.2.1 Methodology

In order to perform a good and acceptable comparison, the route optimization should be performed as an iterative process. The process weighs and balances several different factors that are encountered on a route, particularly those elements causing either deviations of the initial line or the need for the implementation of specific construction or engineering design methods. The objective of this process is to select a technically feasible route that also provides the most cost-efficient solution with minimum damage to the environment.

Although an indicative assessment differs in the characterization and weighting of the particular project elements included in the assessment, there are some basic criteria should be considered in route selection. These include pipeline length, accessibility to the route, topographical conditions, soil conditions, seismicity characteristics, special crossings, environmental aspects (forestry areas, dams, reservoirs and lakes, wetlands, protected areas, climatic conditions), and social aspects, etc. During the comparison, the route evaluation criteria are scored. For example, environmental aspects can be scored as 1 (low), 2 (moderate), and 3 (high). Then, the weighting percentage of each route evaluation criteria is determined according to their significance in the selection process. For example, while environmental impacts may have 10% weighting, soil conditions may have 12%. A total weighted score is calculated by multiplying score and weighing percentage for each evaluation criteria. The route having the minimum weighted score is the preference.

A proper assessment of route alternatives requires a desktop study followed by reconnaissance survey at site. A desktop study needs the followings to help establish constraints at the beginning of the analysis:

- 1/25000 scaled topographical map;
- Active fault and earthquake maps;
- Existing infrastructure maps;
- Maps showing the locations of dams, reservoirs, and lakes;
- Wetland maps,
- Map showing the location of protected areas, environmentally sensitive areas, crossings;
- Wildlife maps;
- Map showing soil conditions; and
- Map indicating socially sensitive areas.

For this report, three alternatives were compared. Pipeline route locations were approximated and placed on Google Earth maps. At this time, DAPL has been unwilling to release digital files to technical engineering team. Without digital data, we cannot: therefore, accurately and precisely confirm the DAPL route and route alternatives.

The alternatives are as follows:

- Alternative I: a route that does not require any crossing of the Missouri River. This alternative envisages that the route will pass east of the Missouri River.
- Alternative II: Existing Route DAPL selected with HDD crossing under Lake Oahe.
- Alternative III: a route crossing Missouri River at North of Bismarck to avoid crossing Lake Oahe.

The route analysis was performed using limited parameters, focusing on the most basic data elements available to us in the short timeframe allocated to prepare this report. The parameters used in the analysis include:

- approximate pipeline length,
- using an existing pipeline corridor,
- number of main crossings considering rivers, highways, etc.
- constructional and operational challenges,
- social sensitivities, and
- environmental aspects considering lake, river and wetland crossings.

it is assumed that other evaluation parameters such as accessibility to the route, topographical conditions, soil conditions/land use, seismicity characteristics, social aspects are same for all the alternatives.

During comparison, the route evaluation criteria are scored and are presented in Table 4.1.

Table 4.1: Route Evaluation Criteria Rank Scoring Based on Defined Limits

Route Evaluation Criteria	Defined Limits	Scores
Approximate Pipeline Length	0-300 miles	1
	300-600 miles	2
	>600 miles	3
Using an existing pipeline corridor	>50%	1
	25-50%	2
	0-25%	3
Number of Main Crossings	0-10	1
	10-20	2
	>20	3
Constructional and operational challenges	Relatively Low	1
	Moderate	2
	Relatively High	3
Social sensitivities	Relatively Low	1
	Moderate	2
	Relatively High	3
Environmental Aspects	Relatively Low	1
	Moderate	2
	Relatively High	3

Following the scoring process, the weighted percentage of each route evaluation criteria is determined based on their significance.

Table 4.2: Weighted Percentage Used for Route Evaluation Criteria

Route Evaluation Criteria	Weighted Percentage (%)
Pipeline Length	0.25
Using of existing pipeline corridor	0.10
Number of Main Crossings	0.10
Constructional and operational challenges	0.10
Social sensitivities	0.20
Environmental Aspects	0.25
TOTAL	**1.00**

The following equation is used for the calculation of the route evaluation criteria using the scores and the weighted percentage in the evaluation:

Total Weighted Score = score x weighting percentage

Figure 4.1 is the base map used so to compare the route alternatives.

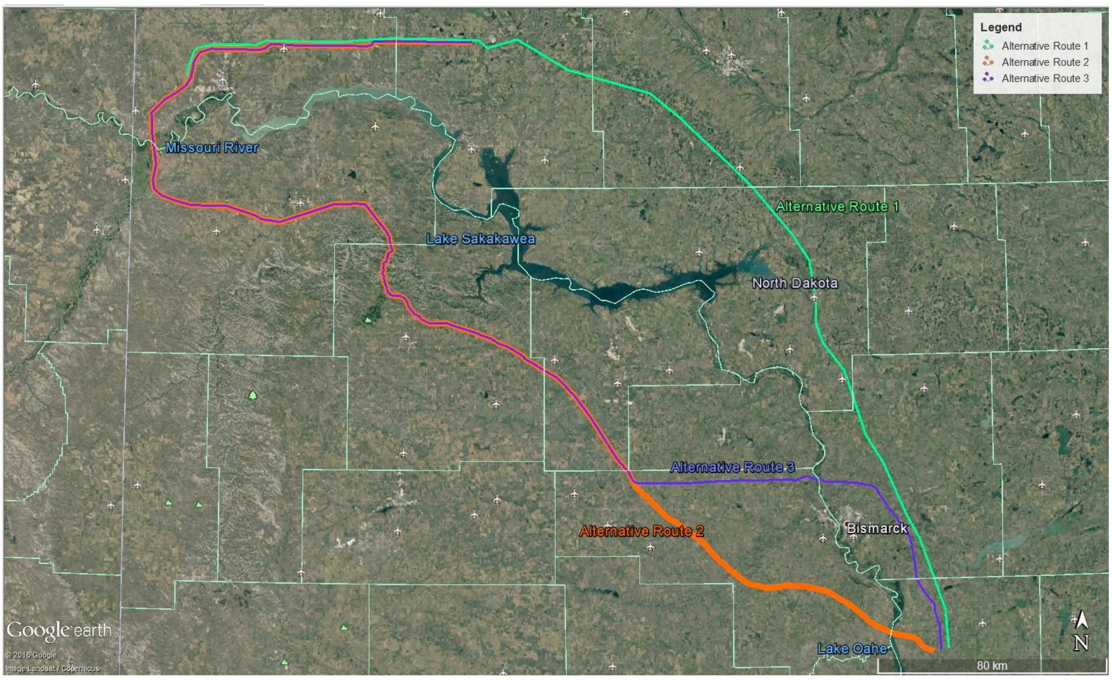


Figure 4.1: Map Showing the Alternative DAPL Routes

The information on each route evaluation criteria for all alternatives is summarized in Table 4.3 and the overall assessment for the three alternatives is given in Table 4.4. in Section 4.2.2.

Table 4.3: Summary or Route Evaluation Criteria for the DAPL Route Alternatives

Route Evaluation Criteria	Alternative 01 (east of Missouri River)	Alternative 02 (crossing at Lake Oahe)	Alternative 03 (crossing North of Bismarck)
Pipeline Length	245 miles	309 miles	322 miles
Using existing pipeline corridor	3%	41%	3%
Number of Main Crossings	28 (main road crossing)	17 (Lake Oahe, Two tributaries of Missouri River, Heart River, Missouri River at Williams County, 11 main road crossing)	23 (Missouri River at North of Bismarck, Heart River, Missouri River at Williams County, 20 main road crossing)
Constructional and operational challenges	Land buried pipe but in wetland	Deep and long horizontal drillings	Horizontal drillings
Social sensitivities	Relatively low crossing only agricultural lands	High due to freshwater Lake Oahe crossings and Oglala Sioux Tribe has both treaty-based and statutory rights to the waters of Lake Oahe, which are considered sacred by the Tribe and the Oceti Sakowin	Relatively moderate due to almost same route with Alternative 02
Environmental Sensitivity	Crossing wetlands	Crossing rivers including Lake Oahe	Crossing rivers

4.2.2 Results and Discussion

The overall assessment evaluation of the six criteria presented in Table 4.4 and the table is arranged in a way that the route which has the minimum score is the favorable one.

Table 4.4: Overall Assessment of DAPL Route Alternatives Based on Six Evaluation Criteria

Route Evaluation Criteria	Defined Limits	Scores	Weighting Percentage (%)	Alternative 01 (east of Missouri River)	Alternative 02 (proposed DAPL, crossing at Lake Oahe)	Alternative 03 (crossing North of Bismarck)
Approximate Pipeline Length	0-300 miles	1	0.25	0.25		
	300-600 miles	2			0.50	0.50
	>600 miles	3				
Using an existing pipeline corridor	>50%	1	0.10			
	25-50%	2			0.20	
	0-25%	3		0.30		0.30
Number of Main Crossing	0-10	1	0.10			
	10-20	2			0.20	
	>20	3		0.30		0,30

Route Evaluation Criteria	Defined Limits	Scores	Weighting Percentage (%)	Alternative 01 (east of Missouri River)	Alternative 02 (proposed DAPL, crossing at Lake Oahe)	Alternative 03 (crossing North of Bismarck)
Constructional and operational challenges	Relatively Low	1	0.10			
	Moderate	2		0.20		0.20
	Relatively High	3			0.30	
Social sensitivities	Relatively Low	1	0.20	0.20		
	Moderate	2				0.40
	Relatively High	3			0.60	
Environmental Sensitivity	Relatively Low	1	0.25	0.25		
	Moderate	2				0.50
	Relatively High	3			0.75	
Total Weighted Score				**1.50**	**2.55**	**2.20**

The most favorable alternative is Alternative 1. While using an existing pipeline corridor is relatively disadvantageous for this alternative, it is only 3%, pipeline length, constructional and operational challenges, because it crosses only wetlands and roads, social and environmental sensitivities become advantages for Alternative 01. On the other hand, although using an existing pipeline corridor is an advantage for Alternative 02, it is 41%, pipeline length, constructional and operational challenges, because it propose very long and deep HDD drilling beneath the Lake Oahe which supply drinking water to individuals, social and environmental sensitivity is the most disadvantages. Because Oglala Sioux Tribe has both treaty-based and statutory rights to the waters of Lake Oahe, which are considered sacred by the Tribe and the Oceti Sakowin. Alternative 03 has moderate score among the other alternatives. The rate of Alternative 02 is closer to Alternative 02 than Alternative 01, this alternative has an advantage of no crossing of the Lake Oahe. This circumstance decreases the rate of social and environmental sensitivities.

4.2.3 Construction Cost Comparison of the Alternatives Routes

Table 4.5 shows the unit construction costs that were stated in the DAPL EA comparison of the three alternative routes are performed as depending on the unit costs represented in the EA.

Table 4.5: Unit Construction Costs (Source: DAPL Environmental Assessment)

Description	Unit Cost
Road/Railroad Bores	34,600 USD/bore
Installation for Non-HDD Areas	1,809,190 USD/mile
Horizontal Directional Drilling (HDD)	1,290 USD/feet
Cost of Geotechnical Investigation	1,150 USD/mile

Description	Unit Cost
Mainline Valves	450,000 USD
Right of Way Acquisition Cost	195,345 USD/mile
Additional Cost Including Engineering and Consultants	131,000 USD/mile

(1) It is assumed that the units costs for Alternative 01 and 02 would be the same.

Table 4.6 shows the parameters used to calculate the relative costs for the three DAPL route alternatives. Construction costs were calculated for only a portion of pipe line alternatives depicted in Figure 4.1.

Table 4.6: DAPL Route Alternative Parameters

Description	Alternative Route 01 (east of Missouri river)	Alternative 02 (crossing at Lake Oahe)	Alternative 03 (crossing North of Bismarck)
Road Bores [1]	28	11	20
Installation for Non-HDD Areas	245 miles	307.3 miles[2]	320.6 miles[2]
Horizontal Directional Drilling (HDD)	0 feet	7,500 feet at Lake Oahe 1,400 feet at Missouri River in Williams County TOTAL: 8,900 feet	5,966 feet at Lake Oahe 1,400 feet at Missouri River in Williams County TOTAL: 7,366 feet
Geotechnical Investigation	245 miles	309 miles	322 miles
Mainline Valves (one valve per each 10 mile segment)	25	31	33
Right of Way Acquisition	245 miles	309 miles	322 miles
Additional Cost Including Engineering and Consultants	245 miles	309 miles	322 miles

(1) only main roads are considered and counted from Google earth map
(2) The lengths of HDD are subtracted.

Table 4.7 is a comparison of the relative construction costs associated for three DAPL alternatives using the limited set of criteria.

Table 4.7: Construction Cost Comparison of Three Route Alternatives

Description	Alternative Route 01 (east of Missouri river)	Alternative 02 (crossing at Lake Oahe)	Alternative 03 (crossing North of Bismarck)
Road/Railroad Bores	968.800	380.600	692.000
Installation for Non-HDD Areas	443.251.550	555.964.087	580.026.314
Horizontal Directional Drilling (HDD)	--	11.481.000	9.502.140
Cost of Geotechnical Investigation	281.750	355.350	370.300
Mainline Valves (one valve per each 10 mile segment)	11.250.000	13.950.000	14.850.000
Right of Way Acquisition Cost	47.859.525	60.361.605	62.901.090
Additional Cost Including Engineering and Consultants	32.095.000	40.479.000	42.182.000
TOTAL COST	**535.706.625**	**682.971.642**	**710.523.844**

(1) only main roads are considered and counted from Google earth map
(2) HDD distances are subtracted.

As seen from Table 4.5, the Alternative Route 01 which is proposed to follow east of Missouri River would has the minimum construction cost. As remembered Table 4.4, Alternative 01 is also the most favorable option with 1.50 rank.

The most important advantage of Alternative 01 is gained due to its length. It is the shortest option among the alternatives with 245 miles. It is obvious that the length and construction cost is very interrelated each other. When the comparison parameters is considered, most of them depend on the length of pipeline except number of crossings such as pipeline itself, number of valves, investigations, permits, etc., and the construction cost goes up as the length increases. On the other hand, the number of crossings is a parameter which is free of length, but the route characteristics. As seen from Table 4.5, Alternative 01, it is only 245 miles in length, has the highest number of road crossings.

5 PROPOSED HDD CONSTRUCTION FOR DAPL PROJECT

An HDD construction method is proposed for the crossing at Lake Oahe. Installation of 30" steel pipe, for DAPL Project. The pipeline will be placed in a 48" tunnel opened with HDD method, and 30" pipeline pulled into the tunnel and left in an open-hole state without being encased by injected concrete. The length of the crossing is 7,500' (2,290 m), of which approximately 5,420 ft (1650 m) b beneath the bed of Lake Oahe, the crossing depth is 92 ft.

The method of HDD construction is described as follows in the DAPL EA: "the directional drilling rig would drill a small diameter pilot hole along the prescribed profile. Following the completion of the pilot hole, reaming tools would be utilized to enlarge the hole to accommodate the pipeline diameter. The reaming tools would be attached to the drill string at the exit point and would then be rotated and drawn back to incrementally enlarge the pilot hole. During this process, drilling fluid consisting of primarily bentonite clay and water would be continuously pumped into the pilot hole to remove cuttings and maintain the integrity of the hole. When the hole has been sufficiently enlarged, a prefabricated segment of pipe would be attached behind the reaming tool on the exit side of the crossing and pulled back through the drill hole towards the drill rig" [11]

The cross section diagram of Lake Oahe HDD crossing is represented in Figure 5.1.

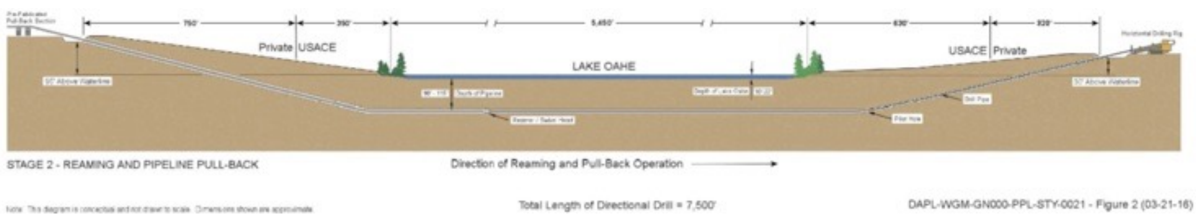


Figure 5.1: Cross-section Diagram of Lake Oahe HDD Crossing

Bearing in mind Guidelines for Installation of Utilities Beneath Corps of Engineers Levees Using Horizontal Directional Drilling by USACE, June 2002 mentions that "Although horizontal directional drilling could offer cost-effective, safe alternatives to installing pipelines with open trenching, the Corps Engineer has no standard guidelines allowing the installation of pipelines with this construction method. As a result, permitting policies are extremely varied and some districts strictly prohibit the use of this technique.", the general design considerations for HDD construction method can be summarized as follows:

- The HDD method is ideally suited for soft soils such as clays and compacted sands. Subgrade soils consisting of large-grain materials, including gravel, cobbles, and boulders, are difficult to negotiate and may contribute to pipe damage and/or project failure;
- Pipeline diameter, depth, and material are the most important conditions in HDD project and are considered in operation design during preconstruction services and

during installation. Thus these factors are key parameters to developing HDD design profiles;

- A sufficient cover depth is necessary to ensure drilling mud pressure in the borehole should not exceed that which can be supported by the overburden to prevent heaving or hydraulic fracturing of the soil. This hydraulic fracturing can assist in creating communication channels between the HDD bore area 92' below the surface of the lake and the lake bed, thus allowing intermingling of fluids in the event of a leak in the pipeline;

- The drill path should be aligned to minimize the frictional resistance during pull back and maximize the length of the pipe that can be installed during a single pull. This is accomplished through geometrical testing of entry and exit angles, total crossing length, total depth, and radius of the curvature;

- The radius of curvature is determined by the bending characteristics of the drill string and product line and increases with diameter. A rule-of-thumb in the industry is 1.2 m of radius of curvature for every millimeter of product line diameter;

- The entrance angle of the drill string should be between 8° and 20° to the horizontal, with 12° considered optimal. Shallower angles may reduce the penetrating capabilities of the drilling rig, whereas steeper angles may result in steering difficulties, particularly in soft soils;

- With regards to construction, HDD installations should be planned so that back reaming and pulling for a section can be completed on the same day if at all possible. This is to reduce the chance of the borehole collapsing over time as well as reducing the chances that the pipe will become "stuck" during pullback. As the diameter of the HDD bore increases, so do the risks of collapsing over time. A smaller diameter well bore has a naturally higher mechanical integrity to prevent 'caving' compared to a larger diameter bore-hole.

The subsequent examples indicate the constructional challenges experienced in the past during HDD construction:

Walnut Grove Crossing, Walnut Grove, CA, USA

In November 2008, Gabe's completed yet another maxi-rig HDD crossing in Walnut Grove, California. This crossing included one 24" × 0.500" steel casing. The total drill length was approximately 5,900'.

Site conditions were problematic and condensed a pond located at the front of the rig combined with fluid returns contributed to soft soil conditions. Operations were ongoing to keep drill solid when pulling pipe. In addition, pullback required mid welds which slowed down pullback and resulted in stalling of the pipe during pullback.

Qin River Crossing, Zhengzhou, Henan Province

Crossing of the Qin River with two parallel pipelines installed using the HDD method. The crossing included two 40” steel pipelines to be used for irrigation to the riverbed during dry planting seasons. The total length for each of these crossings was nearly 6,038’.

The Qin River Crossing, as do many large-scale HDD crossings, had its challenges. Because of the soil conditions, liquefaction of saturated sand was an ongoing problem that contributed to the collapse during pipe 2 installation. In addition, drainage of foundation pit and seepage failure also contributed along with slope stabilization. These conditions combined contributed to fluid loss, bore hole collapse, and collapse pit.

Yangtze River Crossing, Wuhan City, Hubei Province, China

Crossing of the Yangtze River which included one 24” steel pipeline to be used for crude oil transmission. The total length for this crossing of the Yangtze River near Wuhan, Hubei was nearly 11,000’. This crossing is part of the overall Lanzhou-Zhengzhou-Changsha Pipeline Project, which is a main transmission line to the Hubei and Hunan provinces.

Stuck Pipe: The first level reaming of 20” for the 3rd time crossing of Yangtze River was started on Feb. 13, 2011 and the applied drilling rig was the rock reamer produced by America INROCK®. When placing the 3rd set of reamer (the body is imported and the cone is domestic), it was found that the torque is big which would increase as long as the drilling depth is increasing. Upon the analysis and discussion on the site, it was decided to withdraw the 3rd set of reamer and increase hole-flushing. However, when withdraw the No.45 drill pipe, the rupture occurred. It was analyzed that the rupture occurred at the side of RP-5 (north bank, the side of designed exit point) according to the situation of mud return after grouting.

The length of crossing of Yangtze River was about 2km, the drill pipe easily buckled and collapsed under pressure which would cause the drill pipe to be damaged and broken. One drilling rig was equipped for each bank, separately used for reaming and withdrawing the reamer. It was strictly prohibited to push back the drill pipe directly.

On March 19, the drill pipe were dragged from the exit point side on the north bank with RP-5 drilling rig, totally 16 pieces and the distance from the fracture to the joint of drill pipe was about 4.9’. On the north bank, RP-5 drill rig was adopted to find the hole, but after drilling about 20 pieces of drill pipe still cannot coincide with the original hole. Later tried again but still failed. After failing, HK 450 drilling rig was adopted to drill the pilot hole and kept moving backwards and forwards while drilling every drill pipe so as to carry out hole-flushing. On Apr. 1st, the mud flow varied from 14 to 18 ft^3/min, the rotate speed was about 2rpm and the penetration rate is approximately from 3.3' to 5' after the crossing of sand layer. Basically there was no pushing force and the drill pipe was driven by the drill bit. Because of the disturbance by former two times of finding hole, the incline angle was downward. For long-distance pipeline with large moment of torsion, the pushing force cannot be applied to drill pipe, otherwise, it will make the drill pipe broken under combined stress.

The moment of torsion is oversize. During the stage of finding hole, the moment of torsion for drill rig was about 40,000 Nm. Even after increasing the mud flow more than 529,720ft3, the moment of torsion was still above 28,000Nm. The result was not ideal.

The proposed HDD profile under Lake Oahe is designed to provide 92 feet of cover below the bottom of the lake. The length of the crossing is 7,500' (2,290 m), of which approximately 5,420 ft (1650 m) occurs beneath the bed of Lake Oahe, the crossing depth is 92 ft.

Both the EA and foregoing experiences show that HDD crossing activity will face many challenges and risks, and there are always risk of pipeline collapse, hydraulic fracture, loss of drilling fluids, hole collapse, etc. When considering the depth and length, it is very ambitious target even for any HDD construction. Moreover, ***the Lake Oahe is a freshwater lake and classified as Class I water as per Section 33-16-02.1 of the North Dakota Administrative Code, and HDD crossing process has many potential risks during both construction and operation phase***.

All risks can be managed by good applications, however low risk never means no risk. Consequently, the EA does not duly address all risks and mitigation measures. ***For a project that have another route alternatives, very deep crossing of a freshwater lake with long distance should have been the last option***.

6 LEAK DETECTION

The proposed leak detection system (LDS) for DAPL Project is compared with the system proposed for Baku Tbilisi Ceyhan (BTC) Crude Oil Pipeline Project.

6.1 BTC Crude Oil Pipeline [11]

The proposed BTC Project comprises a pipeline to transport crude oil from the oil fields of the Caspian Sea region via the Republics of Azerbaijan, Georgia and Turkey to a crude oil storage and export terminal to be constructed at Ceyhan on the Mediterranean coast of Turkey.

The proposed BTC Pipeline will originate at the existing Sangachal Terminal near Baku in Azerbaijan and will be approximately 1,760 km long. The Turkish section of the BTC Pipeline will be approximately 1,076 km in length. The diameter of the pipeline ranges between 46", 42" and 34".

LDS for the BTC Pipeline

The Turnkey Agreement between BTC Owners and BOTAS states that the BTC Project components are to constitute a “highly reliable and operationally efficient” system and are required to include a leak detection system capable of “identifying and shutting down the pipeline system within several minutes of a major leak occurring anywhere on the pipeline system”.

A leak detection system will be installed. It will be designed in accordance with the requirements of API 1130 Computational Pipeline Monitoring (Oct 1995) and API 1155 Evaluation Methodology for Software Based Leak Detection Systems.

The system will operate by comparing various combinations of actual profiles of flow, pressure, temperature and density with modeled profiles of the same parameters. Excessive differences between the real-time measurements and the modeled profiles indicate possible leakage. The time taken to detect a leak will therefore be dependent on the size of the leak and the accuracy of the measurement instrumentation.

Several independent leak detection algorithms will be developed to add reliability to the system. These leak detection algorithms will be designed with the aim of identifying any leaks in excess of 1.0% of BTC full pipeline flow rate in the shortest possible time. The system may also be able to identify smaller leaks over a longer period of time.

The system will be capable of identifying the approximate location of the leak and the pipeline section containing the leak will be isolated via automatic activation (closing) of the nearest block valves on either side of the leak.

The LDS will be designed to be effective over the range of flow rates for which the pipeline system is designed to operate. It will also cater for foreseeable abnormal incidents such as pump trips, pig launching, block valve partial stroke testing and any internal wax deposition removal.

The LDS will tie-in to the Supervisory Control and Data Acquisition (SCADA) communication system, facilitating remote control from the Sangachal (Azerbaijan) terminal control room with full back-up control available from the control center located at the BTC Marine Terminal at Ceyhan.

SCADA for the BTC Pipeline

The basis of the control philosophy for the entire BTC Pipeline system is the SCADA system. The pipeline will be supervised and controlled from the manned control room located at the Sangachal (Azerbaijan) terminal. Full backup facilities will be available at the manned control room located at the BTC Marine Terminal (at Ceyhan). Local monitoring and local control will also be available at the manned pump stations along the pipeline route.

Telecommunication System for the BTC Pipeline

The BTC Pipeline will have a dedicated telecommunications system based on a Fiber Optic Cable (FOC) placed within a high-density polyethylene (HDPE) conduit that will run alongside the buried pipeline in the same trench. The FOC will be fully backed up via a satellite communications links system. The FOC will also provide voice and facsimile communication between the Sangachal and Ceyhan terminals and at each of the above ground installations along the route.

Emergency Shutdown (ESD) System for the BTC Pipeline

The objective of the BTC Pipeline ESD System will be to avoid any harm resulting from hazardous situations and to reduce the consequences of such an event on the pipeline or surrounding environment. To fulfill this requirement, the extended functionality of the ESD System will incorporate the following basic attributes:

- monitoring the correct functioning of the SCADA system, Unit Control System and Station Control System in conjunction with safety relevant key parameters;
- control and monitoring function for safety relevant station equipment units which are without integrated failsafe controllers;
- emergency shutdown function.

In order to monitor the correct operation of the SCADA System, Station Control System, Unit Control System and equipment without integrated control units, the ESD System will collect safety relevant parameters independently of these systems and will come into action in case of:

- detection of illogical status of station equipment;
- process parameters have reached defined limit values; or
- a manual trip by push button has occurred.

To prevent serious damage to the pipeline facilities, the ESD System will block dangerous actions and shut down station equipment or the relevant section(s) of the station, safely. If the malfunction also affects other local stations of the entire pipeline system (including Azerbaijan and Georgia Sections) then an ESD System with an overall view to the entire pipeline and BTC Terminal will come into operation to cater for this situation.

To provide this function it has been necessary to realize an ESD system with a hierarchical structure of at least two levels:

- overall ESD System;
- station-specific ESD System.

The installation of appropriate transmission facilities with redundant and independent communication lines ensures a safe transmission of information between the individual ESD systems at the station sites and the overall ESD system at the terminal control centres.

Pipeline surveillance for the BTC Pipeline
A suite of precautionary measures will be implemented to reduce the risk of damage to the pipeline either from natural causes or from third party interference. An environmental risk assessment has been undertaken to identify potential risks to the pipeline as well as risks posed by the pipeline to the environment. The results of this assessment have directly informed the selection of mitigation measures which have then been incorporated into the design of the pipeline. Such measures have included specification of the LDS and ESD and the selection of block valve locations.

These pipeline integrity measures notwithstanding, BOTAS will implement a comprehensive surveillance program over the lifetime of the BTC Pipeline. The surveillance programwill monitor the entire BTC Pipeline length, however particular attention will be paid to the following potential sensitive features along the route:

- river, rail and road crossings;
- stretches where the pipeline crosses over sensitive aquifers;
- protected areas;
- above ground installations (comprising pump stations, pressure reducing station and block valve stations);
- stretches of the pipeline in proximity to settlements and villages.

Closed Circuit Television and intruder alarm systems will be provided at the pump stations and pressure reduction station and will tie-in to the SCADA system to facilitate remote monitoring of these locations.

The entire pipeline route will be ‘walked’ periodically and sensitive portions will be patrolled more regularly to ensure that no unauthorized activities are taking place that could damage or otherwise encroach upon the pipeline’s use or access.

Land agents will maintain regular contact with occupiers of land traversed by the pipeline right of way. Change of land ownership or land use along the pipeline corridor will be monitored.

Pipeline condition monitoring
The integrity of the pipeline will be monitored periodically using an intelligent pig. The intelligent pig is a device that is conveyed within the pipeline between pig launcher/receiver stations via the motive power of the pipeline fluid. As the intelligent pig is thrust along inside the pipeline, a strong magnetic field is applied to the pipeline wall by two poles located on the intelligent pig and a sensor also located on the pig then detects any changes in the induced magnetic field in the pipeline wall. For a uniform pipe, the sensor would detect only a uniform response, but at sites where metal loss occurs, the sensor detects a leakage in magnetic flux and this is recorded by the pig's onboard computer. In this way the location (to within 1.5 meters) and size of all material defects, wall thickness changes and corrosion can be identified along the pipeline length, thereby enabling the integrity of the entire pipeline to be mapped.

6.2 DAPL Project [12]

For DAPL Project, a continuous SCADA pipeline monitoring system is also proposed. This system remotely measures changes in pressure and volume on a continual basis at all valve and pump stations, is immediately analyzed to determine potential product releases anywhere on the pipeline system.

- Pipeline variables are the parameters pertaining to SCADA systems, instrumentation, fluid properties, physical attributes of pipelines, pressure, temperature, and flow rate;
- Includes pressure transmitters to monitor flowing pressure in real-time and alarm in the event of adverse pressure changes due to potential leaks / releases;
- Includes custody transfer quality meters to monitor pipeline Receipts / Deliveries in real time and alarm in the event of flow rate discrepancies due to potential leaks / releases.

A Computational Pipeline Monitoring System to monitor the pipeline for leaks via computational algorithms performed on a continual basis is proposed as LDS for DAPL Pipeline Project.

- Includes separate ultrasonic meters at each pump station to continuously verify and compare flow rates along the pipeline in real-time as part of a leak detection system.
- This measurement data is immediately analyzed to determine potential product releases anywhere on the pipeline system.
- The mathematical algorithms are based on physics and abide by the conservation principles of mass, momentum and energy.

- Periodic pipeline integrity inspection programs using internal inspection tools to detect pipeline diameter anomalies indicating excavation damage, and loss of wall thickness from corrosion.
- Periodic above-ground Close Interval Surveys conducted along the pipeline.
- Aerial surveillance inspections will be conducted 26 times per year (not to exceed 3 weeks apart) to detect leaks and spills as early as possible, and to identify potential third-party activities that could damage the pipeline.
- Mainline valves are installed along the pipeline route to reduce or avoid spill effects to PHMSA defined HCAs.
- Periodic landowner outreach and the implementation of a Public Awareness program
- Participation in "One-Call" and "Before You Dig" notification systems.

6.3 Comparison of the LDSs

As seen from foregoing comparison, leak detection system of BTC Pipeline and the one proposed for DAPL Pipeline is very similar. Both are SCADA controlled and computer based systems. The system checks the predefined parameters between two control points (i.e. valves, pump stations, etc.) and when unexpected changes are perceived in the parameters, the system alarms. Then the whole system is closed down by means of operator in a control room, the flow rate is stopped, via remote control valves, if it is necessary. Moreover, both of the systems are accompanied by route/pipeline surveillance inspections to be performed by personnel.

The LDSs do not have self shut-down systems, inherently. The system cannot decide to close the pipeline by itself and requires human instruction. Human errorwill always exist in the system. Kalamazoo River oil spill is a good example of human error.

On July 26, 2010, a 30-inch pipeline belonging to Enbridge Inc. ruptured near Marshall, Michigan and contaminated Talmadge Creek and the Kalamazoo River with hundreds of thousands of gallons of crude oil. EPA ordered Enbridge to dredge submerged oil and oil-contaminated sediment from the Kalamazoo River. From 2010 to 2014 over 1.2 million gallons of oil were recovered from the river.

Though alarms sounded in Enbridge's Edmonton headquarters at the time of the rupture, it was eighteen hours before a Michigan utilities employee reported oil spilling and the pipeline company learned of the spill. Meanwhile, pipeline operators had thought the alarms were possibly caused by a bubble in the pipeline and, while for some time it was shut down, they also increased pressure for periods of hours to try to clear the possible blockage, spilling more oil. [14]

The EA describes only very limited information about LDS system of the DAPL Pipeline. Although most leak detection systems are capable of identifying major leaks occurring anywhere on the pipeline system, minor leaks are still a big problem for the system and often go undetected.

There is no information for the accuracy of the LDS proposed for DAPL Pipeline, but BTC mentions that the leak detection algorithms is designed with the aim of identifying any leaks in excess of 1.0% of BTC full pipeline flow rate in the shortest possible time. If it is assumed that the LDS system used on this project adheres to a similar standard, it means that the ***LDS will never alert for the leakage up to 5,700 barrels/day (1.0% of the capacity of DAPL).***

If that amount of leakage occurs beneath the freshwater Lake Oahe which provides drinking water to the individuals, it is inevitable that it will cause catastrophic effects for the users, and the leak may not be visibly detected. All surveillance inspections depends on the scenario that the leakage would be visible in the environment, which is not possible in the HDD tunnel section.

Although the DAPL EA mentions that A continuous SCADA pipeline monitoring that remotely measures changes in pressure and volume on a continual basis at all valve and pump stations, is immediately analyzed to determine potential product releases anywhere on the pipeline system, the system will be able to notice the leakage only between check points (i.e. valves and pump stations), and the amount of crude oil between those points in the pipe will be of concern in combating with oil spill. That means more than 9,000 barrel of crude oil (volume of pipeline section of 7,500') at a 92 ft depth, If it is case beneath the freshwater Lake Oahe with an assumption that block valves are placed at the entry and exit points of the horizontal directional drills, that they work correctly.

The time taken to detect a leak will therefore be dependent on the size of the leak and the accuracy of the measurement instrumentation. On the other hand, it should be noted that the ways of detection of a discharge from a pipeline system is blacked out in Appendix L (Facility Response Plan) of the DAPL EA. Thus, more detailed information is needed so as to assess the 10,000 barrel/day oil spill as per worst case discharge given in the EA to determine whether it is acceptable or not.

6.4 Combating with Oil Spill

The actions to be taken by the company personnel when an oil spill is detected are given in Appendix L of the DA Project as follows:

- Shut down affected line segment if there is an indication of a leak,
- Isolate line segment,
- Depressurize line,
- Start internal and external notifications,
- Mobilize additional personnel as required (for combating with oil spill).

In addition, a general description of various response techniques that may be utilized during a response are discussed again in Appendix L for:

- Spill on Land (Soil Surfaces),
- Spill on Lake or Pond (Calm or Slow-Moving Water),
- Spill on Small to Medium Size Streams (Fast-Flowing Creeks),
- Spill on Large Streams and Rivers,
- Spill on a Stream Which Flows into a Lake or Pond,
- Spill in Urban Areas,
- Spill in Urban Areas,
- Spill Under Ice,
- Spill on Ice,
- Spill in Wetland Areas.

First, as seen from the Appendix L, all response techniques involves general descriptions, and there is no specific response technique explained for freshwater Lake Oahe. It is important because, Lake Oahe crossing is the crucial part of DAPL Project. The freshwater Lake Oahe is the fourth largest dammed reservoir in the US so as to provide drinking water to thousands of individuals.

All response techniques in Appendix L explains mitigating techniques after an oil spill becomes visible, but no remediation is given for contaminated water table underneath Lake Oahe.

Moreover, dealing with the contaminated soil surrounding the pipeline underneath Lake Oahe will be another challenge. No explanation exists in the EA describing how that part of the soil will be cleaned or removed at a depth of 92 ft underneath the lake.

On the other hand, bioremediation can be one of the methods to be applied for cleaning up oil spills where excavation is impractical. The bioremediation process utilizes beneficial microbes, surfactants, micronutrients and bio-stimulants to decompose contaminants transforming them into harmless by-products, i.e. water and carbon dioxide. Still, application of this method may not be effective 92 ft underneath the lake. [15]

In-site injection techniques can be used to feed the degrader mixture to the required depth. Boreholes are constructed in the hydrocarbon contaminated site as well as down gradient from it. The newly constructed boreholes are utilized to administer the proposed remediation process. The remedial liquid is gravity fed into the impacted area beginning in the source area followed by the down gradient portions of the plume. Environmental monitoring occurs throughout the process in order to chart the degree of remediation occurring and to compare the results with the appropriate criteria. Soil samples for plume delineation and subsequent monitoring are taken from appropriate borehole locations and submitted to a recognized laboratory for analysis. Following the receipt of the initial soil analytical results, the remedial liquid is prepared and gravity fed into the boreholes at the site. In most cases, 21 – 35 days after the start of the remediation process, soil samples are collected from the treatment area. These interim samples confirm the rate of hydrocarbon degeneration and establish a remediation time line. [16]

In the foregoing process, it is assumed that the oil spill is stable in contaminated soil and is not conveyed to water table.

Indeed, there is also very limited action to be taken for deep contamination, and is obvious that these kind of actions will take much more time than excavation, and it is a case study whether the pipeline change/repair would be possible in the same location or not.

Consequently, site specific clean-up remediation techniques should be developed for contaminated soil and water table beneath the Lake Oahe.

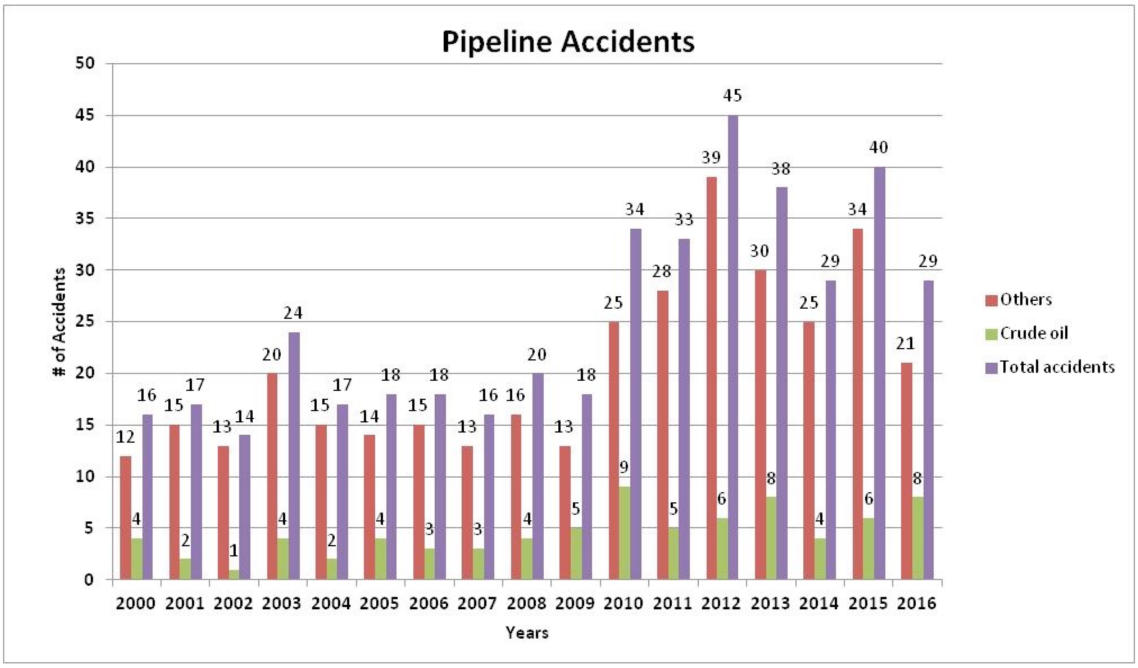
6.5 Oil Spills Experienced in the Past

The EA anticipates that all of the risks associated with oil spill are low. However, a risk does exist, although low, there is always possibility to experience a spill. The subsequent examples are evidences of risks that have happened.

They following items indicate that barrels of crude oil are being spilled into the environment as depending on different excuses such as weakness in detection, material defects, wrong repair and maintenance, human error/factor, etc. If the Lake Oahe is the case, it is obvious that the beneficiaries, the related authorities and the locals will faced with bigger problems than a case with common oil spill.

In addition, it should be noted that over the last 20 years (1995-2014) there were 10,884 pipeline incidents in the U.S., 1.5 per day. This included 5,599 ‘significant’ pipeline incidents or leaks, or 2 serious events every 3 days. [10]

The graphical demonstration of pipeline accidents including crude oil pipeline accidents in the 21st century in US is given in Figure 6.1.



Reference: [27]

Figure 6.1: Pipeline Accidents in the 21 Century in US

The brief summary of information below relates to the selected examples of crude oil accidents listed[19]. As seen from the list below, accidents occurs as a result of human error, wrong repair of pipeline, material defects, etc.:

<u>2016</u>:

1. On July 26, 2010, a 30-inch pipeline belonging to Enbridge Inc. ruptured near Marshall, Michigan and contaminated Talmadge Creek and the Kalamazoo River with hundreds of thousands of gallons of crude oil. EPA ordered Enbridge to dredge submerged oil and oil-contaminated sediment from the Kalamazoo River. From 2010 to 2014 over 1.2 million gallons of oil were recovered from the river. [20]
2. On February 14, a 6-inch crude oil pipeline broke near Rozet, Wyoming, spilling about 1,500 gallons of crude oil into a creek bed.
3. On March 22, about 4,000 gallons of gasoline spilled from a 6-inch petroleum products pipeline in Harwood, North Dakota
4. On April 17, a 10 petroleum products pipeline failed in Wabash County, Illinois, resulting in a sheen on the Wabash River. About 48,000 gallons of diesel fuel was spilled.
5. On June 23, 2016 a Crimson Pipeline crude oil line leaked in Ventura County, California. Initial reports said the spill size was from 25,200 gallons to 29,000 gallons, but, later reports estimate 45,000 gallons of crude were spilled.
6. On September 10, a Sunoco pipeline ruptured near Sweetwater, Texas. About 33,000 gallons of crude oil were spilled. The pipeline was just over a year old.
7. On October 21, an 8-inch Sunoco pipeline ruptured in Lycoming County, Pennsylvania, spilling about 55,000 gallons of gasoline into the Susquehanna River. The river was running high at the time.

8. On October 24, a pipeline ruptured on the Seaway Pipeline, in Cushing, Oklahoma, spraying the area with crude oil.
9. On December 5, a 6-inch Belle Fourche pipeline spilled 176,000 gallons of crude oil into Ash Coulee Creek in Billings County, North Dakota

<u>2015</u>:

10. On January 17, oil from a broken pipeline seeped into the Yellowstone River, and contaminated the water supply 10 miles south of Glendive, Montana. The release was from Bridger Pipeline LLC's 12-inch Poplar line, which can carry 42,000 barrels a day of crude from the Bakken formation and runs from Canada south to Baker, Montana. Bridger Pipeline is a subsidiary of True Cos., a privately held Wyoming-based company. The company said in a statement that the pipeline was shut down within an hour of the leak. About 30,000 gallons of crude was spilled, with about 28,000 gallons of crude being lost. This spill adds to a history of pipeline malfunctions—in 2011, the Exxon Silvertip Pipeline spilled 63,000 gallons of oil into the Yellowstone River two and a half hours outside of Yellowstone National Park
11. On January 21, a petroleum products pipeline in Honolulu, Hawaii ruptured, due to external corrosion, spilling about 42,000 gallons of petroleum product, of which about 22,000 gallons was lost
12. On February 25, a 26-inch crude oil pipeline in Navarro County near the Town of Dawson, Texas, failed, spill about 50 barrels of crude oil. Near the failure, investigation showed that the pipe had lost about 80% of its thickness, due to external corrosion. This anomaly was not seen in a 2011 test of this pipeline
13. On March 13 a pipeline Patrol pilot identified an oil sheen on a pond near Tehuacana Creek, Texas which was then linked to a leaking 10 inch petroleum products pipeline. About 50 barrels of diesel fuel were spilled
14. On May 19, a Plains All American Pipeline oil pipeline ruptured near Refugio State Beach, also near Goleta, California, spilling about 124,000 gallons of crude oil. It is referred to as the Refugio Oil Spill
15. On November 15, work was being performed on a flow control valve, on a Sunoco 10 inch crude oil pipeline, in Wortham, Texas, when the valve failed, injuring 5 workers, and spilling some crude oil. It was later determined that the valve was under 400 psi of nitrogen pressure when it was being worked on

<u>2014</u>

16. On March 6, contractors working for Shell Oil Company hit Shell's Houston-to-Houma (Ho-Ho) crude oil pipeline near Port Neches, Texas, spilling 364 barrels of crude oil
17. On March 18, a 20-inch Mid-Valley Pipeline Company pipeline failed in Hamilton County, Ohio, spilling at least 364 barrels of crude oil into the adjacent Oak Glen Nature Preserve. Animals in the area were affected
18. On May 6, Sinclair Oil Corporation pipeline operators detected a pressure drop on a pipeline, with the problem being traced two days later to a leak in Knox County, Missouri. A mixture of gasoline and Diesel fuel contaminated soil on a farm

On October 13, a Sunoco/Mid-Valley crude oil pipeline ruptured, and spilled about 168,000 gallons of crude oil in Caddo Parish, Louisiana. Wildlife was killed

<u>2013</u>

19. The 2013 Mayflower oil spill occurred when ExxonMobil's 20-inch Pegasus crude oil pipeline spilled near Mayflower, Arkansas on March 29, causing crude to flow through yards and gutters, and towards Lake Conway. Wildlife was coated in some places. Twenty-two houses were evacuated, due to the fumes and fire hazard. Some estimates say the total amount spilled could reach upwards of 300,000 gallons of diluted bitumen were spilled. Hook cracks and extremely low impact toughness in the LF-ERW seam of the pipe were identified as causes of the failure
20. On April 30, the Pegasus oil pipeline spilled a small amount of crude into a residential yard in Ripley County, Missouri, a month after the same pipe spewed thousands of barrels of crude in Arkansas. The Pegasus pipeline was out of service from the Mayflower, Arkansas spill, accounting for the minimal amount of oil spilled in Missouri
21. On July 26, a leaking BP 20-inch crude oil pipeline spilled 50 to 100 barrels of crude oil in Washington County, Oklahoma. Some of the crude spilled into a drainage ditch leading to a water reservoir
22. On October 7, authorities were notified of a Lion Oil Trading and Transportation crude oil pipeline leak in Columbia County, Arkansas. It was estimated that the leak started on September 21. Oil spread into a Horsehead Creek tributary

On October 29, a Koch Industries 8-inch pipeline spill about 400 barrels of crude oil near Smithville, Texas. The oil polluted a private stock pond and two overflow reservoirs

<u>2012</u>

23. On February 15, 2012, in Arenac County, Michigan, oil was discovered in the soil around a 30-inch Enbridge crude oil pipeline. About 800 gallons of crude oil was spilled
24. On April 28, an ExxonMobil 20/22-inch-diameter pipeline ruptured near Torbert in Pointe Coupee Parish, Louisiana, about 20 miles west of Baton Rouge, and crude oil spilled into the surrounding area, and flowed into an unnamed tributary connected to Bayou Cholpe. About 117,000 gallons of crude were spilled, with about 37,000 gallons being lost. The pipeline failed due to a manufacturing defect
25. A West Shore Pipe Line petroleum products pipeline burst near Jackson, Wisconsin on July 17, releasing about 54,000 gallons of gasoline. At least one family self evacuated due to the leak. At least 44 water wells nearby were contaminated from benzine in the gasoline, including a municipal well. A LF-ERW seam failure was suspected as the cause. Further testing revealed that at least 26 other areas on this pipeline needed repairs, with 22 within the Jackson Marsh Wildlife Area
26. An Enbridge crude oil pipeline ruptured in Grand Marsh, Wisconsin, releasing an estimated 1,200 barrels of crude oil. The pipeline had been installed in 1998. Flaws in the longitudinal welds had been seen during X-ray checks of girth welds

2011

27. On May 7, a threaded connection failed on a Keystone Pipeline pump at a station in Sargent County, North Dakota, spilling about 400 barrels of crude oil. Due to a number of other leaks on this pipeline system, Keystone's owner, TransCanada Corporation, was given a Corrective Action Order by PHMSA
28. Late on July 1, a 12-inch Exxon Mobil crude oil pipeline. also known as the Silvertip Pipeline, ruptured, and spilled about 63,000 gallons of oil into the Yellowstone River in south-central Montana. There was confusion in the pipeline control room, causing a delayed pipeline shutdown. Some residents of Laurel, Montana had to be evacuated. The break near Billings fouled the riverbank and forced municipalities and irrigation districts to close intakes. Exxon later increased the spill size estimate to 1500 barrels in January 2012 after seeing the damage to the pipeline.[312] About 140 people were evacuated starting about 12:15 a.m. Saturday due to concerns about possible explosions and the overpowering fumes. All were allowed to return after instruments showed petroleum odors had decreased, although no information was available regarding the concentrations of benzene in air. Speculation involves high water flow in the Yellowstone River may have scoured the river bed and exposed the pipe. Consequently, with three oil refineries are located in the Billings area, the fire chief for the city of Laurel said he asked all three to turn off the flow of oil in their pipelines under the river after the leak was reported. Exxon Mobil and Cenex Harvest Refinery did so, and that Conoco Phillips said its pipe was already shutdown. Cenex had a release into the Yellowstone River in September 2002. Exxon Mobil later announced the cleanup would cost $135 million. In 2015, Exxon Mobil was fined $1 million by PHMSA for this incident.

2010

29. On January 2, Enbridge's Line 2 ruptured near Neche, North Dakota, releasing about 3,784 barrels of crude oil, of which 2,237 barrels of were recovered. The cause was a material defect
30. On March 1, at about 8:10 am, Mid-Valley Pipeline identified a release of crude oil in the manifold area of the Mid-Valley tank farm in Longview, Texas. Crude oil was observed "gushing" from the soil in the manifold area. About 198 barrels of crude oil were estimated to have been released and 196 barrels were recovered from the secondary containment area within Mid-Valley's site
31. On April 5, a crude oil pipeline ruptured near Green River, Wyoming. At least 84,000 US gallons (320,000 L) of crude were spilled. Corrosion in the pipeline was the cause
32. The Red Butte Creek oil spill. On June 12, a Chevron crude oil pipeline, damage by lightning, ruptured, causing 800 barrels (130 m^3) of crude to spill into Red Butte Creek in Salt Lake City, Utah. Crude then flowed into a pond in Liberty Park
33. On July 26, the Kalamazoo River oil spill: Enbridge Energy Partners LLP (Enbridge), reported that a 30-inch (760 mm) pipeline belonging to Enbridge burst in Marshall, Michigan. Enbridge had numerous alarms from the affected Line 6B, but controllers thought the alarms were from phase separation, and the leak was not reported to Enbridge for 17 hours. Enbridge estimates over 800,000 US gallons (3,000,000 L) of crude oil leaked into Talmadge Creek, a waterway that feeds the Kalamazoo River,[252][253]

whereas EPA reports over 1,139,569 gallons of oil have been recovered as of November 2011.[254] On July 27, 2010, an Administrative Order was issued by U.S. EPA requiring the performance of removal actions in connection with the facility. The Order requires Enbridge to immediately conduct removal of a discharge or to mitigate or prevent a substantial threat of a discharge of oil and to submit a Work Plan for the cleanup activities that was to include a Health and Safety Plan,[255] as required by 29 CFR 1910.120 (HAZWOPER). In 2012, the NTSB later cited known but unrepaired cracks and external corrosion as the cause

34. On August 10, the U.S. Environmental Protection Agency (EPA) and the Justice Department announced that Plains All American Pipeline and several of its operating subsidiaries have agreed to spend approximately $41 million to upgrade 10,420 miles (16,770 km) of crude oil pipeline operated in the United States. The settlement resolves Plains' Clean Water Act violations for ten crude oil spills in Texas, Louisiana, Oklahoma, and Kansas, and requires the company to pay a $3.25 million civil penalty
35. On September 9, a pipeline leaked crude oil near Lockport, Illinois. EPA officials said the spill was near wetlands that house several endangered species. Federal officials said about 270,000 US gallons (1,000,000 L) of oil were released in Lockport and Romeoville, about 35 miles (56 km) southwest of Chicago
36. On December 21, a crude oil pipeline was discovered leaking into the Dominguez Channel in the Port of Los Angeles. Over 1,000 gallons of crude oil was recovered, but the pipeline company was alleged to have failed to report the spill to State or Federal pipeline authorities. A 61 count criminal complaint was later filed in this accident

<u>2009</u>

37. From December 3 to 4, a Minnesota Pipeline carrying crude oil leaked in Todd County, Minnesota, spilling about 5,000 barrels of crude. Pipeline workers on December 3 had been repairing sections of the 16-inch pipe in a rural area, left on the afternoon of December 3, and the spill occurred during the evening hours of December 3–4

<u>2008</u>

38. On January 11, a Belle Fourche maintenance crew damaged its own pipeline, spill about 11,100 gallons of crude in Alexander, North Dakota
39. On August 10, a 20-inch crude oil pipeline ruptured near Golden Gate, Illinois. About 243,000 gallons of crude were spilled, with about 33,000 gallons being lost. The cause was listed as a pipe seam failure

7 GEOLOGICAL ASSESSMENT

7.1 Regional Geologic Setting

North Dakota lies within the Interior Plains, a vast region stretching from the Rocky Mountains to the Appalachians. In North Dakota, the Interior Plains are divided into two major physiographic provinces by the Missouri Escarpment. To the north and east of the escarpment lies the Central Lowlands Province, characterized by its glacially smoothed landscape. To the south and west, the Great Plains Province rises gradually westward toward the Rocky Mountains.

The proposed alignment at the west of the Missouri River (Lake Oahe) crosses the Missouri Plateau, which has been so thoroughly dissected by the Missouri River and its tributaries. On the other hand, the east of the Missouri River (Lake Oahe) crosses the Coteau Slope, which is a rolling to hilly region that contains both glacial and erosional landforms.

7.2 Site Geology

The geological formations encountered at the proposed pipeline crossing at the Lake Oahe Site in Morton and Emmons Counties at approximate milepost (MP) 166 are as follows:

1. Fox Hill Formations - Late Cretaceous Age (99.6 million to 65.5 million years ago): Fox Hill Formation consists of olive brown sand, shale and sandstone derived from marine shoreline and offshore sediments and can be up to 400 feet thick (USGS Mineral Resources). The Formation includes aquifers that are one of the most economically important aquifers in Morton and Emmons counties.

2. Coleharbor Formation - Holocene Age (11,700 years to present): Coleharbor Formation overlies the Fox Hill Formation on the east side of the Lake Oahe. The formation consists of sand and gravel river sediments.

The Pierre Formation may be encountered below the Fox Hills Formation, particularly on the east side of Lake Oahe. The Pierre Formation primarily consists of dark grey shale derived from marine offshore sediment (Bluemle, 1979), (Bluemle, 1984), (USGS Mineral Resources). It is considered the base of the active near-surface aquifers, because it is thick and relatively impervious.

The near surface soil types likely to be encountered at the Lake Oahe Crossing Site are:

- Silt loam and clay loam derived from loess and clayey alluvium on the west side of Lake Oahe,
- Silt loam and loam derived from alluvium and sedimentary bedrock on the east side of the lake.

Surficial materials and bedrock as described above is likely to be encountered below these surficial soils (NRCS Soil Survey).

7.3 Surface Description

The entry point of the crossing is located approximately 950 feet east of Lake Oahe, in a gradually sloping cultivated field. The entry point is at an elevation of roughly 1638 feet (North American Vertical Datum [NAVD] 88). Westward from entry, the ground surface along the proposed HDD alignment slopes gradually downward toward Lake Oahe where the ground surface remains relatively flat at an elevation of approximately 1605 feet NAVD 88. The ground surface slopes steeply upward approximately 600 feet from the west bank where it begins to slope more gently up to the conceptual exit point at roughly 1705 feet NAVD 88.

7.4 Subsurface Description

Subsurface conditions were explored at the site by drilling seven geotechnical borings (LO-B-1 through LO-B-7), which were drilled to depths of up to 235 feet below ground surface near the alignment of the proposed crossing. Soil samples were generally obtained from the borings at 5-foot depth intervals. Soil samples were visually classified and collected. Laboratory tests, including moisture content determinations, sieve analyses and Atterberg limits were completed on selected samples from the borings.

In general, the subsurface conditions encountered in the borings consist predominantly of medium stiff to hard clay with varying amount of sand, overlaid by medium dense to very dense sand with varying amounts of silt, clay and gravel. A thin layer of gravel was encountered at boring LO-B-7.

The HDD profile was designed to a depth to help provide adequate cover beneath the Lake Oahe and to avoid the gravelly sand units observed in borings LO-B-3 and LO-B-4.

As for the groundwater conditions, groundwater was not observed in the borings at the time of drilling.

7.5 Overall Assessment

In consideration of the subsurface conditions observed in geotechnical explorations, detailed HDD constructability review and review of Michels' drill plan for this installation, it is stated in EA Report that the proposed Lake Oahe HDD is feasible. On the other hand, as it is mentioned in Appendix D, variations in subsurface conditions are possible between the explorations. Furthermore, although not encountered in the borings, Pierre Formation can be problematic during the drilling due to sloughing that could occur when the freshwater contacts with shale.

The risk for earthquakes is very low throughout North Dakota.

Considering the landslide risk, the Lake Oahe crossing is not on lands that are listed as prone to landslides by North Dakota Geological Survey (see Official Letter of North Dakota Geological Survey dated April 16, 2015 [page 1014 in DAPL EA Report]). Conversely, the DAPL EA, Section 3.1.3.1 states that some parts of the HDD work area could be susceptible to landslides.

8 CONCLUSION

Our assessments on The Lake Oahe HDD crossing are summarized as follows:

1. Many documents are withhold from public, and some sections of the DAPL EA are blacked out. This situation causes lack of knowledge during assessment process.
2. From the technical point of view, it seems possible to place 30" pipe at 92 ft depth, 7,500' (2,290 m) long underneath Oahe via HDD construction method, although it is not an industry standard work for crude oil as the product fluid.
3. Subsurface conditions may also vary with time, and variations in subsurface conditions are possible between the explorations. Permeable and unstable geological levels may cause problems during construction period of the HDD line. As per the information owned, no geological constrain is identified.
4. The experiences reveals that the contractor and operator of DAPL will face with many challenges and risks during construction and operation period beneath the Lake Oahe.
5. The amount of 10,000 barrels/day spill oil as per worst case discharge could not be verified due to lack of information in the DAPL EA.
6. There is no mechanism to prevent the release of crude oil into freshwater Lake Oahe and water table via some connected aquifers.
7. The DAPL EA offers no methodology to combat oil spill and cleaning of contaminated soil underneath the Lake Oahe at 92 ft.
8. The Lake Oahe is not just a lake:
    - It is classified as Class I water as per Section 33-16-02.1 of the North Dakota Administrative Code,
    - It is a freshwater lake supplying drinking water to thousands of individuals in the local area and millions more downstream
    - It is the fourth largest dammed manmade reservoir in the US,
    - It has a freshwater treatment plant, but the plant has no ability to treat benzene to be originated from oil spill,
    - All of the member tribes to the Great Sioux Nation have both treaty-based and statutory rights to the waters of Lake Oahe, which are considered sacred by the Tribe and the Oceti Sakowin.
9. The route alternative assessment methodology of DAPL is lacking and inadequate. Other routes could be selected instead of passing through the Lake Oahe. Because placing of 30" pipe at 92 ft depth in 7,500' long underneath Lake Oahe via HDD construction method has more potential to cause devastating effects on the environment and on the individuals than the other alternatives.
10. The LDS is blind to detect minor leakages, and it may take too much time to detect meanwhile water sources can be polluted.
11. The LDS and SCADA systems are never designed to shut-down themselves when every alarm sounds, as usual. The shut-down is decided by SCADA personnel and/or managers of the pipeline. The human factor/errors always exist in the system.

Consequently, we believe that the alternative route assessment study should be re-performed in an acceptable methodology with detailed information and the results should be re-discussed. As per the indicative assessment of route alternatives performed with limited information in this report reveals that the route proposing the crossing of freshwater Lake Oahe is not the best alternative.

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