Appendix A Abbreviations

This appendix lists abbreviations and abbreviated measurements used in this report.

Abbreviation	Meaning
%	percent
±	plus or minus
<	less than
>	greater than
≤	less than or equal to
≥	equal to or greater than
°	degree
3D	three-dimensional
3LPE	three-layer polyethylene
AAR	American Association of Railways
AB	Alberta
ADCP	Acoustic Doppler Current Profiler
AG	The Michigan Office of Attorney General
AIS	Automatic Identification System
AL	Alabama
API	American Petroleum Institute
AR	Arkansas
ASME	American Society of Mechanical Engineers
BEA	Bureau of Economic Analysis
BS&W	basic sediment and water
CFD	computational fluid dynamics
CFR	*Code of Federal Regulations*
CITES	*Convention on International Trade in Endangered Species*
CN	Canadian National Railway
CO	Colorado
CP	cathodic protection
CPCM	cathodic protection current mapping
CPM	computational pipeline monitoring
CS	carbon steel
CSA	Canadian Standards Association
CTE	coal tar enamel
CVN	Charpy V-Notch
CVN USE	Charpy V-Notch Upper Shelf Energy
DC	direct current
DEQ	Michigan Departments of Environmental Quality
DH	hydraulic diameter

Abbreviation	Meaning
DHI	DHI Water & Environment, Inc.
DNR	Michigan Departments of Natural Resources
DNT	dent
DNV	Det Norske Veritas
DOT	Department of Transportation
Dynamic Risk	Dynamic Risk Assessment Systems, Inc.
e.g.	for example
EIA	Energy Information Administration
Enbridge	Enbridge Energy Limited
EPA	Environmental Protection Agency
ER	electrical resistance
ERW	electric resistance welded
ES	environmental score
ESA	environmentally sensitive area
ESI	environmental sensitivity index
et al.	and others
etc.	et cetera
FBE	fusion-bonded epoxy
FBR	full-bore rupture
FERC	Federal Energy Regulatory Commission
FRA	Federal Railroad Administration
FSH	full-screen height
FW	flash welded
GDP	gross domestic product
GE	General Electric
GIS	Geographic Information System
GRT	gross register tonnage
GTA	Greater Toronto Area
GW	girth weld
GWD	girth weld
H_2S	hydrogen sulfide
HCA	high consequence area
HD	hydrodynamic
HDD	horizontal directional drilling
HF-ERW	high-frequency electric resistance welded
HPA	high population area
i.e.	that is
IBA	Important Bird Areas
ID	internal diameter

Abbreviation	Meaning
IDC	Interest During Construction
IL	Illinois
ILI	in-line inspection
IMU	inertial mapping unit
IN	Indiana
Inc.	Incorporated
ITOPF	International Tanker Owners Pollution Federation
IUCN	International Union for Conservation of Nature
KS	Kansas
L	length
lat.	latitude
LDAR	leak detection and repair
L-DSAW	longitudinally double submerged arc-welded
LFL	lower flammability limit
LOF	lack of fusion
long.	longitude
LP	Lower Peninsula
MAE	The Michigan Agency for Energy
Marysville terminal	Marysville Crude Terminal
max.	maximum
MB	Manitoba
MBES	multi-beam echo sounder
MBS	material balance system
MDNR	Michigan Department of Natural Resources
MFL	magnetic flux leakage
MI	Michigan
MMSI	Maritime Mobile Service Identity
MN	Minnesota
MOP	maximum operating pressure
N/A	Not applicable
NAIS	Nationwide Automatic Identification System
NB	New Brunswick
ND	North Dakota
NDE	non-destructive examination
NE	northeast
NEB	National Energy Board
NEPA	National Environmental Policy Act
NGL	natural gas liquid
no.	number

Abbreviation	Meaning
NOAA	National Oceanic and Atmospheric Administration
NRDA	natural resource damage assessment
NWI	National Wetlands Inventory
NY	New York
OD	outside diameter
OH	Ohio
OMB	Office of Management and Budget
ON	Ontario
OPA	other population areas
OR	Oregon
OSA	other sensitive area
PA	Pennsylvania or phased array
PADD	Petroleum Administration for Defense District
PAH	polycyclic aromatic hydrocarbon
PGA	peak ground acceleration
pH	acidity and alkalinity
PHMSA	Pipeline and Hazardous Materials Safety Administration (U.S. Department of Transportation)
prorata	proportional
Q	quarter
QC	Quebec
Re	Reynolds Number
RIAM	rapid impact assessment matrix
RIMS	Regional Input-Output Modeling System
ROW	right-of- way
RPP	refined petroleum product
RT	receipt tankage
SCADA	supervisory control and data acquisition
SCC	stress corrosion cracking
SDS	Sarnia Downstream System
SEC	Securities Exchange Commission (United States)
SI	International System of Units (Système International d'Unités)
SIA	social impact assessment
SLEAF	Scanning Laser Environmental Airborne Fluorosensor
SMYS	specified minimum yield strength
SOW	*Statement of Work*
SSC	sulfide stress cracking
Straits	Straits of Mackinac
Straits pipelines	Enbridge Inc. Line 5 pipelines, located along the Straits of Mackinac
SW	spectral wave or southwest

Abbreviation	Meaning
TBM	tunnel boring machine
TCPL	TransCanada Pipelines
the project	Analysis for Straits of Mackinac Pipelines Project
the State	the State of Michigan (collectively, the Michigan Departments of Environmental Quality and Natural Resources, The Michigan Agency for Energy, and The Michigan Office of Attorney General).
this report	*Alternatives Analysis for the Straits Pipelines*
TMCP	thermomechanical controlled processing
TOFD	time of flight diffraction
TX	Texas
U.S.	United States
UDM	Unified Dispersion Model
US	United States
US DOT Straits ILI Review	U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration
USA	United States of America
USACE	United States Army Corps of Engineers
USBEA	United States Bureau of Economic Analysis
USD	United States dollars
US DOT	United States Department of Transportation
USE	upper shelf energy
VA	Virginia
VHF	very high frequency
VIV	vortex-induced vibration
vs.	versus
W	width
WI	Wisconsin
WSD	working stress design
WV	West Virginia
y	year
ZOE	zone of exposure

Appendix B References

This appendix lists references used in this report.

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Appendix C Line 5 Monthly and Annual Volumes

Table C-1: Volumes and Associated Product Types Delivered on Line 5 (2015)

INJECTION & DELIVERIES BY LOCATION

Line 5 (m^3/d) Injections & Deliveries	2015											
	1	2	3	4	5	6	7	8	9	10	11	12
SUPERIOR	**82,276**	**82,726**	**77,452**	**82,609**	**76,356**	**63,957**	**74,922**	**83,657**	**68,063**	**71,168**	**76,377**	**81,830**
INJECTION	**82,276**	**82,726**	**77,452**	**82,609**	**76,356**	**63,957**	**74,922**	**83,657**	**68,063**	**71,168**	**76,377**	**81,830**
Light	70,738	68,557	64,791	70,018	63,135	54,691	64,185	69,866	56,031	63,087	62,660	65,797
NGL	11,538	14,169	12,660	12,591	13,221	9,265	10,737	13,791	12,032	8,082	13,717	16,033
RAPID-RIVER	**(494)**	**(570)**	**(376)**	**(257)**	**(176)**	**(156)**	**(177)**	**(194)**	**(197)**	**(272)**	**(311)**	**(495)**
RECEIPT	**176**	**191**	**137**	**102**	**79**	**76**	**98**	**91**	**90**	**132**	**173**	**196**
NGL	176	191	137	102	79	76	98	91	90	132	173	196
DELIVERY	**(669)**	**(761)**	**(513)**	**(359)**	**(255)**	**(232)**	**(275)**	**(285)**	**(286)**	**(404)**	**(484)**	**(691)**
NGL	(669)	(761)	(513)	(359)	(255)	(232)	(275)	(285)	(286)	(404)	(484)	(691)
LEWISTON	**1,483**	**1,692**	**1,944**	**1,319**	**1,715**	**1,663**	**1,646**	**1,604**	**1,642**	**1,628**	**1,189**	**1,707**
INJECTION	**1,483**	**1,692**	**1,944**	**1,319**	**1,715**	**1,663**	**1,646**	**1,604**	**1,642**	**1,628**	**1,189**	**1,707**
Light	1,483	1,692	1,944	1,319	1,715	1,663	1,646	1,604	1,642	1,628	1,189	1,707
SARNIA AREA (MV, LS, PS, SA)	**(83,205)**	**(83,831)**	**(79,009)**	**(83,753)**	**(77,869)**	**(65,495)**	**(76,452)**	**(85,081)**	**(69,428)**	**(72,486)**	**(77,089)**	**(82,925)**
DELIVERY	**(83,205)**	**(83,831)**	**(79,009)**	**(83,753)**	**(77,869)**	**(65,495)**	**(76,452)**	**(85,081)**	**(69,428)**	**(72,486)**	**(77,089)**	**(82,925)**
Light	(71,388)	(71,586)	(65,580)	(70,786)	(65,453)	(54,451)	(66,845)	(70,916)	(60,226)	(60,713)	(66,908)	(65,308)
NGL	(11,818)	(12,246)	(13,429)	(12,967)	(12,417)	(11,044)	(9,607)	(14,165)	(9,202)	(11,772)	(10,181)	(17,616)
Grand Total*	**60**	**16**	**10**	**(82)**	**26**	**(31)**	**(61)**	**(14)**	**81**	**38**	**166**	**118**

Notes:
* Monthly variances in injection and deliveries are due to timing differences.

THROUGHPUT ex LOCATION & PIPELINE UTILIZATION

Line 5 (m^3/d) Throughput ex Location	2015											
	1	2	3	4	5	6	7	8	9	10	11	12
SUPERIOR	**82,276**	**82,726**	**77,452**	**82,609**	**76,356**	**63,957**	**74,922**	**83,657**	**68,063**	**71,168**	**76,377**	**81,830**
Light	70,595	68,431	64,603	69,764	63,050	54,405	64,016	69,534	55,824	62,891	61,941	65,423
NGL	11,681	14,295	12,848	12,845	13,306	9,552	10,906	14,123	12,239	8,278	14,436	16,407
RAPID-RIVER	**81,782**	**82,156**	**77,075**	**82,351**	**76,180**	**63,800**	**74,745**	**83,463**	**67,867**	**70,896**	**76,066**	**81,335**
Light	70,566	69,523	64,741	68,395	63,850	53,599	63,994	69,499	56,729	61,151	64,287	65,416
NGL	11,216	12,632	12,334	13,956	12,330	10,201	10,751	13,964	11,137	9,745	11,779	15,919
LEWISTON	**83,265**	**83,840**	**79,019**	**83,666**	**77,895**	**65,463**	**76,391**	**85,067**	**69,508**	**72,532**	**77,255**	**83,038**
Light	70,903	71,224	66,668	69,734	65,530	55,285	66,602	71,038	59,185	61,826	64,751	67,147
NGL	12,362	12,616	12,351	13,931	12,365	10,179	9,789	14,029	10,323	10,707	12,503	15,891
Capacity Point	83,265	83,840	79,019	83,666	77,895	65,463	76,391	85,067	69,508	72,532	77,255	83,038
Capacity Point (kbpd)	524	527	497	526	490	412	480	535	437	456	486	522
Percent Utilization	**97%**	**98%**	**92%**	**97%**	**91%**	**76% ***	**89%**	**99%**	**81%**	**84%**	**90%**	**97%**

Notes:
*Significant third-party outage created pipeline shutdowns.
**Utilization is calculated based on Commercial Capacity. Capacity varies on a monthly basis due to planned maintenance and unplanned outages.
***Third-party delays created pipeline shutdowns.

Table C-2: Volumes and Associated Product Types Delivered on Line 5 (2016)

INJECTION & DELIVERIES BY LOCATION

Line 5 (m^3/d)	2016											
Injections & Deliveries	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
SUPERIOR	**87,462**	**87,194**	**84,359**	**82,874**	**80,065**	**70,084**	**70,518**	**68,175**	**65,529**	**72,572**	**80,428**	**81,690**
INJECTION	**87,462**	**87,194**	**84,359**	**82,874**	**80,065**	**70,084**	**70,518**	**68,175**	**65,529**	**72,572**	**80,428**	**81,690**
Light	73,487	74,960	71,010	68,407	65,752	58,841	57,730	55,951	52,820	59,228	66,356	70,471
NGL	13,975	12,234	13,349	14,467	14,313	11,243	12,788	12,224	12,710	13,344	14,072	11,219
RAPID-RIVER	**(551)**	**(612)**	**(316)**	**(386)**	**(244)**	**(112)**	**(83)**	**(130)**	**(166)**	**(228)**	**(326)**	**(550)**
RECEIPT	**217**	**260**	**140**	**158**	**118**	**65**	**44**	**63**	**96**	**101**	**167**	**280**
NGL	217	260	140	158	118	65	44	63	96	101	167	280
DELIVERY	**(768)**	**(871)**	**(456)**	**(544)**	**(362)**	**(177)**	**(128)**	**(193)**	**(262)**	**(329)**	**(493)**	**(830)**
NGL	(768)	(871)	(456)	(544)	(362)	(177)	(128)	(193)	(262)	(329)	(493)	(830)
LEWISTON	**1,651**	**1,219**	**1,469**	**1,133**	**1,707**	**1,520**	**1,768**	**1,486**	**1,447**	**1,461**	**1,453**	**1,468**
INJECTION	**1,651**	**1,219**	**1,469**	**1,133**	**1,707**	**1,520**	**1,768**	**1,486**	**1,447**	**1,461**	**1,453**	**1,468**
Light	1,651	1,219	1,469	1,133	1,707	1,520	1,768	1,486	1,447	1,461	1,453	1,468
SARNIA AREA (MV, LS, PS, SA)	**(88,415)**	**(87,653)**	**(85,416)**	**(83,576)**	**(81,477)**	**(71,493)**	**(72,273)**	**(69,567)**	**(66,865)**	**(73,865)**	**(81,552)**	**(82,618)**
DELIVERY	**(88,415)**	**(87,653)**	**(85,416)**	**(83,576)**	**(81,477)**	**(71,493)**	**(72,273)**	**(69,567)**	**(66,865)**	**(73,865)**	**(81,552)**	**(82,618)**
Light	(74,638)	(75,718)	(73,258)	(69,935)	(67,491)	(58,834)	(58,413)	(58,622)	(54,213)	(60,400)	(67,378)	(70,849)
NGL	(13,778)	(11,935)	(12,158)	(13,641)	(13,986)	(12,660)	(13,861)	(10,945)	(12,653)	(13,465)	(14,174)	(11,770)
Grand Total*	**146**	**148**	**97**	**46**	**51**	**(3)**	**(70)**	**(36)**	**(55)**	**(60)**	**2**	**(11)**

Notes:
* Monthly variances in injection and deliveries are due to timing differences.

THROUGHPUT ex LOCATION & PIPELINE UTILIZATION

Line 5 (m^3/d)	2016											
Throughput ex Location	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
SUPERIOR	**87,462**	**87,194**	**84,359**	**82,874**	**80,065**	**70,084**	**70,518**	**68,175**	**65,529**	**72,572**	**80,428**	**81,690**
Light	73,271	74,829	70,841	68,308	65,380	58,628	57,374	55,691	52,843	59,022	66,197	70,315
NGL	14,191	12,364	13,518	14,566	14,685	11,456	13,144	12,484	12,687	13,550	14,231	11,375
RAPID-RIVER	**86,911**	**86,582**	**84,044**	**82,490**	**79,821**	**69,971**	**70,434**	**68,045**	**65,366**	**72,344**	**80,101**	**81,140**
Light	73,137	73,669	70,825	69,986	65,569	56,670	57,351	57,009	51,668	59,071	66,099	70,355
NGL	13,773	12,913	13,218	12,504	14,252	13,301	13,084	11,035	13,698	13,273	14,002	10,784
LEWISTON	**88,561**	**87,801**	**85,512**	**83,623**	**81,528**	**71,491**	**72,203**	**69,530**	**66,812**	**73,805**	**81,554**	**82,607**
Light	74,736	74,992	74,151	69,153	67,244	59,990	58,334	57,558	54,371	60,500	67,390	71,866
NGL	13,826	12,808	11,362	14,469	14,284	11,500	13,869	11,972	12,442	13,305	14,164	10,742
Capacity Point	88,561	87,801	85,512	83,623	81,528	71,491	72,203	69,530	66,812	73,805	81,554	82,607
Capacity Point (kbpd)	557	552	538	526	513	450	454	437	420	464	513	520
Percent Utilization	**103%****	**102%****	**100%**	**97%**	**95%**	**83%**	**84%**	**81%**	**78%*****	86%	95%	96%

Notes:
* Significant third-party outage created pipeline shutdowns.
** Utilization is calculated based on Commercial Capacity. Capacity varies on a monthly basis due to planned maintenance and unplanned outages.
*** Third-party delays created pipeline shutdowns.

Appendix D General Assumptions

Assumption title:	Wall Thickness Calculation Assumptions
Applicability:	Alternative 1 Pipeline Wall Thicknesses

Large pipeline projects may have numerous wall thicknesses of pipe depending on the application and economics of purchasing additional thicknesses. Because this analysis is very preliminary, two wall thicknesses were chosen. These two wall thicknesses would cover the majority of uses on the project.

Additionally, the differences between the United States and Canadian design codes pose another level of complexity. This was removed by taking the more conservative approach from each country. Canadian Standards Association (CSA) Z662-15 criteria were used with the exception of the line pipe hoop stress, which was limited to a 72% specified minimum yield strength (SMYS) as per American Society of Mechanical Engineers (ASME) requirements:

- Line Pipe (to be used for the majority of the route) using a location factor of 1 and a maximum hoop stress of 72% SMYS
- Heavy Wall Pipe (to be used for crossings and sensitive areas such as metropolitan areas) using a location factor of 0.8 as is typical for highly populated areas.

CSA Clauses 4.3.11.2, 4.3.5.1, 4.6.5, and 4.7.1 were used to determine the two wall thicknesses of 11.1 mm (0.44 in.) and 12.7 mm (0.5 in.).

References

1. CSA Z662-15 – Oil and Gas Pipeline Systems
2. ASME B31.4 – Pipeline Transportation Systems for Liquids and Slurries

Appendix E Tunneling Methodology and Construction Techniques

Appendix E.1 Tunneling Overview/Applicability

Tunneling as a means of carrying pipelines through or below difficult obstacles is a proven technology, and is in use for this application in many places around the world.

The Trans Mountain Pipeline Expansion project in British Columbia, Canada proposes to employ an underground tunnel as a feasible alternative to surface-level pipeline construction between Burnaby Mountain Terminal and Westridge Marine Terminal. In Hawaii, petroleum products flow by gravity through 16- and 32-in. pipelines through the Red Hill tunnels to Pearl Harbor. There are also many examples of successful pipeline tunnel projects in Europe, including the large Corrib Gas pipeline tunnel in Ireland. In addition, a short tunnel section of the Camisea pipeline system in Peru was installed to avoid identified landslide geohazards.

A summary of similar tunnels to those identified within the Statement of Work for the Straits of Mackinac (the Straits) is provided in Appendix E.6. The purpose of providing these examples is to show that the tunneling alternative for the Straits is completely feasible, as many similar tunnels have been constructed and are in successful operation.

Appendix E.2 Geotechnical Considerations

Based on the geotechnical *Independent Alternatives Analysis for the Straits Pipeline Geological Model* report, dated 26 September 2017 (see Attachment 3 as listed in Appendix S of this report), a preliminary geological interpretation of the tunnel conditions has been developed. The geotechnical report describes the geologic deposits revealed from the explorations and testing conducted for the Mackinac Straits Bridge and provides supplementary information from the Bruce DGR site in Ontario in similar rock conditions of the Michigan Basin.

Based on geological mapping and drilling conducted for the Mackinac Straits Bridge crossing, conditions and properties of bedrock formations at the Straits of Mackinac are variable, with evidence of paleokarst, brecciation and local faulting in some upper formations associated with the Mackinac Breccia (Landes et al. 1945) [1]. Underlying units are generally more competent and less permeable, with no evidence of the geological processes evident in the overlying formations. The rock mass conditions in these older formations may be more conducive to tunneling (i.e., higher rock mass strength, lower fracture frequency, lower permeability) than shallower formations, but both are within the range of conditions successfully tunneled in other locations using modern tunneling technologies. Detailed investigations, sampling and testing in the same bedrock formations at the Bruce DGR site provide a comprehensive geomechanics data set that complements the earlier drilling and testing done at the Mackinac Straits Bridge crossing.

The location of the Mackinac Straits Bridge crossing is within 2 to 3 mi. (3.2 to 4.8 km) of the considered pipeline crossing. A profile at the bridge site indicates that soil overburden may be less than 50-ft. (15-m) thick. Surficial geology units include lacustrine silt and clay, glacial till, outwash deposits (sand, boulders) and sandy clay (possibly till). These surficial soils overlie varying thicknesses of limestones, dolomites, shales, with intergradations of salt and gypsum. Healed and partially healed sedimentary breccias occur in the Straits region. Potential for paleokarst features also may exist. Permeability of the formations ranges from low to high depending on location and depth. A top of bedrock profile interpreted from detailed drilling and probing of the Mackinac Straits Bridge crossing indicates a deep, ancient submerged river valley in the middle of the crossing, and a secondary rock valley located about 0.5 mi. (0.8 km) from the south shore. Both valleys were formed late in the glacial period and penetrate the Bois Blanc and the St. Ignace Formations, and the main channel cuts into the Pointe Aux Chenes Formation. Based on the information from the Mackinac Bridge investigations, bedrock depth is about 237-ft. (72-m) deep in the secondary rock valley, and possibly more than 350 ft. (107 m) in the main submerged valley. The submerged valley may be filled with sediment or could transition to rock at depth, perhaps related to the thickness of the Mackinac Breccia. A profile developed for the Mackinac Straits Bridge has been adapted to superimpose the proposed pipeline crossing in Appendix E.10.

The geologic profile is based on interpretation and experience in this region of North America. There are no drill holes in the deepest part of the submerged channel, so the depth to bedrock is unknown but estimated to be about 350 ft. (106 m) based on projecting the north and south slopes in a v-shaped trough. While the trough associated with this simple projection may extend deeper than the projected tunnel alignment, bedrock may occur at a shallower depth. The formations intersected by the submerged river valley may contain healed breccias from ancient salt formation dissolution and collapse, overlain by till and dominantly clayey silts/silty clays, the permeability of which is generally low. If the submerged valley bottom is filled with low permeability rock and/or soil, special temporary support measures such as steel rings and liner plate/lagging or shotcrete may be required during construction. If the submerged valley bottom is filled with permeable materials, special measures to grout ahead of tunneling with a high strength cementitious grout may be required to provide adequate support and prevent groundwater inflow. Other options may also exist to cross this zone if it intersects the tunnel profile.

Based on laboratory test data from dolomite and dolomitic limestone rock cores between 153 and 218 ft. (47 and 66 m) below lake level tested for the Mackinac Straits Bridge project, the unconfined compressive strengths (UCS) generally range between 5,000 and 11,000 psi for bedrock. The presented tunnel depth is approximately 100 ft. (30 m) below the tested rock samples and thus results may differ at the tunnel depth, but are expected to be in line with tested samples. For example, results from the Bruce DGR site indicate that the Salina A formation may have unconfined strength up to 30,000 psi and is below any zone of brecciation.

No active faults have been identified in the area and no significant seismic activity has been recorded by the USGS. Consideration of significant seismicity was therefore deemed unnecessary for the Mackinac Straits tunnel design.

Based on the information provided by the geotechnical report the following interpretations provide the basis for the conceptual design approach. No site-specific borings or samples were tested or used to develop the conceptual tunnel design.

Overburden at the shafts and adjacent materials handling and storage area is expected to range between 30 and 50 ft. (9 and 15 m) below existing grade, and consists of thin to thick layers of glaciofluvial and glaciolacustrine deposits of silts, clays, sand, gravelly sands, and very dense glacial till, overlying bedrock.

The bedrock at the tunnel depth being considered is expected to be slightly weathered to fresh, thin to thick sedimentary rock layers of limestone, dolomite, sandstone, shale, and healed sedimentary breccias. The bedrock joint patterns in the region generally indicate NW, E, and NNW-NNE trending orientations; the NW and E sets are generally vertical to sub vertical dipping, and the NNW and NNE sets generally dip moderately to the W and SW, respectively. These joint patterns are based on the Bruce DGR site in Ontario, in similar rock conditions of the Michigan Basin. While this location is on the eastern side of Lake Huron, the Michigan Basin is a large scale, 500- to 1,000-mi. (805- to 1,609-km) geologic structure and the geostructural trends are consistent with experience in the region.

Based on data from the Mackinac Straits Bridge project, rock characteristics indicate occasional zones of permeable, fractured rock and karstic features that may require grouting during the shaft construction and tunneling process. Generally, groundwater infiltration requires pre-excavation grouting ahead of the tunnel boring machine (TBM) for approximately 8% of the tunnel length. An estimated 2,500 LF (762 m) of grouting ahead of the TBM will be required along the alignment, and may be concentrated toward the middle of the tunnel drive at the trough area. This grouting will provide adequate support and prevent groundwater inflow in the case that a deeper trough is determined. Based on UCS data for similar rock types from the region, the rock strengths are expected to range between 5,000 and 11,000 psi. Based on the geologic interpretation, the most feasible and economical approach for the shafts and tunnel have been developed.

In the end, no target formation was selected as the specific depth and conditions of the various formations at the tunneling depths considered are not presently known. A comprehensive site-specific subsurface investigation and lab testing program would be required to determine the in-situ behavior of all materials to be encountered, especially at the submerged river valley area, before a specific tunneling horizon is confirmed.

Appendix E.3 Tunneling Methodology

The two major and fundamental design components involved in a tunnel project are the shafts and the tunnel, and the two most economical approaches to excavating the rock in the tunnel is by the conventional drill and blast method, or by using a TBM.

Appendix E.3.1 Tunnel Boring Machine Method

TBM tunnels have the advantage of a relatively smooth and constant diameter over their length, which offers options for lining installation, and more predictable concrete/grouting requirements than drill-and-blast depending on rock quality and blasting quality.

Advancing the tunnel using a TBM involves selecting the most appropriate machine to fit the underground conditions. The major TBM machine types include open face, single shield, double shield, and earth pressure balance machine (EPBM). The basic material removal process for each machine consists of the machine being thrust against the tunnel "face" with rotating cutter discs that break the rock into chips. The rock chips fall into a collection hopper located above a conveyor and are transported away from the face to the tunnel conveyor, and out to the launch shaft.

The TBM types are chosen based on the stability of the rock material, the high or low volume of water infiltration expected, and the project schedule. Detailed discussion for each type of machine relates to the site-specific ground conditions which are unknown at this time.

One approach is to drive the tunnel with temporary installed support to the retrieval shaft, and followed by a final, cast-in-place concrete liner, referred to as a two-pass method. The tunnel is advanced faster than any other method with good ground conditions, but the final liner requires mobile formwork, steel reinforcing, and poured-in-place concrete, all installed in sections.

The other approach is to advance forward with a TBM while placing pre-cast, steel fiber-reinforced concrete segments behind the back of the machine as a final support liner as the machine advances. These fiber-reinforced segments experience minimal cracking, compared to rebar or welded mesh segments. They are also equipped with grout ports to seal the annular space between the bedrock and the segments so the tunnel is sealed from water infiltration and will prevent exfiltration as well. The TBM advance rate in good rock, with a segment erector, is approximately 60 ft/day (18 m/day).

Appendix E.3.2 Drill and Blast Method

The drill and blast method involves drilling holes within the working/launch shaft boundary, loading the holes with charges which break the rock into manageable size pieces (muck), and then removing the rock in muck pans. Advancing the tunnel by the drill and blast method involves establishing a drill hole pattern, blasting the rock, removing the rock to the shaft bottom area, and the muck is hoisted up the shaft by crane, for the first 2,000 ft. (610 m) of tunnel. Circular patterns may not be the only shape used for drill and blast. Inverted U, horseshoe, or other shapes can provide more working room and options for additional equipment access to aid in muck removal.

For efficiency, temporary mini-rails are installed in the tunnel invert (floor) to provide rail access for material supplies and muck removal. The muck can be removed by flatbed/rail car muck pans, which are loaded by specialized equipment, removed to the working shaft, and lifted out of the working shaft. Depending on rock quality, initial tunnel support may consist of installing rock bolts, pattern bolts, mesh, straps, or steel ribs with liner plate (poor rock), or spraying fiber-reinforced shotcrete. A combination of these methods may be used to maintain safe working conditions. Groundwater infiltration is handled by probe drilling ahead of the tunnel face and grouting the hole to stop the flowing water. However, the blast method may weaken the grouted joints and fractures, and these may need to be re-grouted. Production along the tunnel length in good rock conditions, using the drill and blast method, is anticipated to range between 30 and 45 ft/day (9 and 14 m/day) assuming three working shifts/day. A cast-in-place concrete or fiber-reinforced shotcrete final liner is often used for final support.

Appendix E.4 Tunnel Configuration and Construction

Appendix E.4.1 Configuration

There are two main configurations of pipeline tunnels: open annulus and sealed annulus. In the open annulus configuration, the interior of the tunnel is open to the interior surface, while in the case of the sealed annulus, the opening between the pipe and tunnel wall is filled with an impermeable cement bentonite grout material.

The open annulus arrangement has the advantage of accessibility to inspect and repair the pipeline if needed; however, this accessibility leads to the need for ventilation (costly), security, lighting, and leads to the potential inflow of water, thus requiring a de-watering strategy. Also, tunnel liner maintenance is required.

The sealed annulus configuration provides redundant support around the pipe, and additional containment around the pipeline, and is easy to apply by pump. Disadvantages include the additional construction costs associated with the backfill material, lack of access for repair/inspection, and no opportunity for secondary use (e.g., fiber-optic cables, power lines, etc.).

The sealed annulus option is more in line with the objective of isolating the pipeline from the open waters of the Great Lakes, and so is the configuration of choice for this study.

Appendix E.4.2 Launch and Retrieval Shafts

The basic concept for the launch and retrieval shafts is the same, since both shafts would be used as working shafts to install the pipeline and fill the tunnel annular space with grout. A description of the conceptual basic launch shaft design follows.

The circular launch shaft would be 35 ft. (11 m) in diameter to its base, with a total depth of 340 ft. (104 m) to the bottom area floor at the tunnel invert. The overburden portion of each shaft is estimated to be about 30-ft. (9-m) deep. The shaft wall in overburden would be constructed using the secant pile method of construction, embedded 5 ft. (1.5 m) into sound bedrock, for a total secant length estimated at 35 ft. (11 m) below existing grade. Pre-excavation grouting of the bedrock outside the shaft perimeter would be required to eliminate groundwater infiltration during shaft excavation. Excavation of the shaft interior, including soil overburden and weathered rock, would be conducted by using an extended bucket backhoe, track mounted excavator and/or crane and muck pans. The bedrock would be excavated using drill and blast methods in 10-ft. (3-m) lifts; blasted rock removal would be accomplished using a crane and muck pans. All excavated material would be temporarily stored in the staging area and subsequently hauled off site. The sidewall of the shaft would be supported by applying a 6-in. (15-cm) thick layer of fiber-reinforced shotcrete in approximately 10-ft. (3-m) lifts as excavation proceeds.

The bottom area would also be excavated by drill and blast methods, and would include a 70-ft. (21-m) long tail tunnel and a 400-ft. (122-m) long starter tunnel. The starter tunnel is to provide room to assemble the TBM and trailing gear, and ample room for materials handling and temporary segment storage. The shaft wall support would consist of a 6-in. (15-cm) thick layer of fiber-reinforced shotcrete, and 10-ft. (3-m) long, number 10, friction type spot bolts as required. The bottom area has been designed to accommodate the main rail line and side spurs, vertical muck belt, conveyor belt, and sump pump area; the sump area is designed to accommodate a total tunnel groundwater infiltration rate of 4,000 gpm. A plan and profile of the launch shaft is shown in Appendix E.11 and Appendix E.12.

The conceptual design of the retrieval shaft is the same as the launch shaft, at 320 ft. (98 m) deep to the bottom area floor at the tunnel invert, except the muck belt, vertical belt, and sump area would not be installed. A plan and profile of the retrieval shaft is shown in Appendix E.13 and Appendix E.14.

The proposed slope will be at 0.1%, from the launch shaft upwards toward the retrieval shaft. The slope would provide positive drainage of groundwater inflow toward the sump area at the launch shaft during the tunnel advance. The gasket sealed, 9-in. (23-cm) thick segments, would be installed using a segment erector located at the back of the TBM trailing gear. The annular space between the excavated bedrock surface and the outside of the liner is estimated to be 3-in. (8-cm) thick around the tunnel perimeter, and would be sealed by contact grout methods during the excavation process as the TBM is advanced. A TBM power cable, fiber-optic guidance cable for line and grade, lighting, inflow discharge water pipe, water supply line, and compressed air line, would be installed concurrently as the TBM is advanced.

Locations of potential launch and retrieval shaft and staging areas, assumed for analysis purposes are shown in Appendix E.8 and Appendix E.9, respectively.

Appendix E.4.3 Tunnel Construction Sequence

A single- or double-shielded TBM with a segment erector, with grouting-ahead capabilities is the most practical approach with respect to the construction risk, and post-construction risk for the pipeline.

The major components of the contemplated tunnel include constructing the launch and retrieval shafts by drill and blast methods with surface material storage and handling areas and excavation of a 10- to 12-ft. (3- to 4-m) diameter bedrock tunnel using a TBM, lined with fiber-reinforced concrete segments that are installed at the back of the TBM during the tunnel drive.

The concrete segments would be installed with pre-sealed gaskets. During TBM excavation, a small annulus is created between the outside of the segments and the excavated bedrock. The annulus between the bedrock and the outside surface of the segment would be periodically sealed using contact grouting methods during the TBM advancement. Contact grouting fills the void space, and prevents any groundwater inflow from entering the tunnel.

After the tunnel is complete, dry, and the TBM is removed, a flat, 2-ft. (0.6-m) thick grout/concrete base would be poured at the tunnel invert to provide a flat working surface to install the mini-rail and 30-in. steel carrier pipeline (30-in. outer diameter, Grade X65, 0.69 in. wall thickness). The pipeline would be installed from both shafts, starting in the middle of the tunnel and working outward. The pipeline would be welded in segments, anchored to the grouted base, and tested for leaks. The annular space between the tunnel and the pipeline would be grouted in sections using a portable batch plant and removable bulkheads. A typical 10-ft. (3-m) diameter tunnel section is the basis for the cost analysis, and is shown in Appendix E.7. Upon successful completion of the leak tests, concrete pipe collars would be installed at each circumferential weld, which would act as a watertight barrier at each pipe joining location. The remaining tunnel annular space around the pipeline would be grouted in place using incremental bulkheads. The sequence would be repeated until the pipeline is completed. The grout chosen for this concept application is a low permeability grout with a permeability of 10^{-7} cm/sec, an ultimate compressive strength of 1,500 psi, and a pH of 12.

An area of 4 to 7 acres would be required for the material storage and handling for each shaft, and is shown in Appendix E.11 and Appendix E.13.

Appendix E.5 Tunneling Risk Factors

The risk factors for the conceptualized tunnel pipeline project appear to be consistent with similar major construction projects. Typical risks include schedule delays related to material deliveries, labor disputes, weather, and equipment breakdowns.

An additional geohazard for underground openings is tunnel instability, which can lead to rock fall, tunnel collapse etc. in certain conditions. This is a construction related risk as the installation of lining, support and backfilling the tunnel would resolve long-term stability issues.

One potentially large risk would be inadequate subsurface exploration along the tunnel route, and/or laboratory testing, leading to poorly defined geotechnical conditions for the shaft and tunnel excavation. This risk would be mitigated by conducting a thorough geotechnical program, with a large enough borehole drilling plan to effectively characterize the route. The borehole program would be supplemented with a significant seismic investigation as well.

Good rock conditions and minimal water inflow are anticipated at the Straits based on the *Geotechnical Report* (see Attachment 3 in Appendix S of this report) and the proximity to the Mackinac Bridge, where previous geotechnical investigations were undertaken.

The potential for breakout of the TBM hydraulic fluids beyond the excavation would be mitigated by the installed pressure monitoring instrumentation, and automatic low/high pressure shut-off valves that would be engaged during the drive.

No hazardous contamination or natural toxic gases are expected in the shaft or tunnel subsurface materials, and extra mitigation measures to overcome this risk are not included in the cost analysis.

The risk of discharge of the pipeline fluid from the welded steel pipe during system operation is not predicted to be a concern, given the construction methodology of surrounding the product pipe by grout, surrounded by a gasket sealed concrete segmental liner, surrounded by contact grout, surrounded by sound bedrock.

In the event that a pinhole leak was to develop in the pipe wall, there are several commercially-available technologies to identify the presence of hydrocarbons in the grout annulus surrounding the pipe, including:

1. Liquid-sensing cables embedded in the grout outside the pipe, with an outer conductive polymer that swells in the presence of hydrocarbons and trips an alarm.
2. A fiber optic system that detects temperature changes when hydrocarbons escape the pipe.

The optimal means of leak detection would need to be studied and identified during the detailed design phase of the tunnel option.

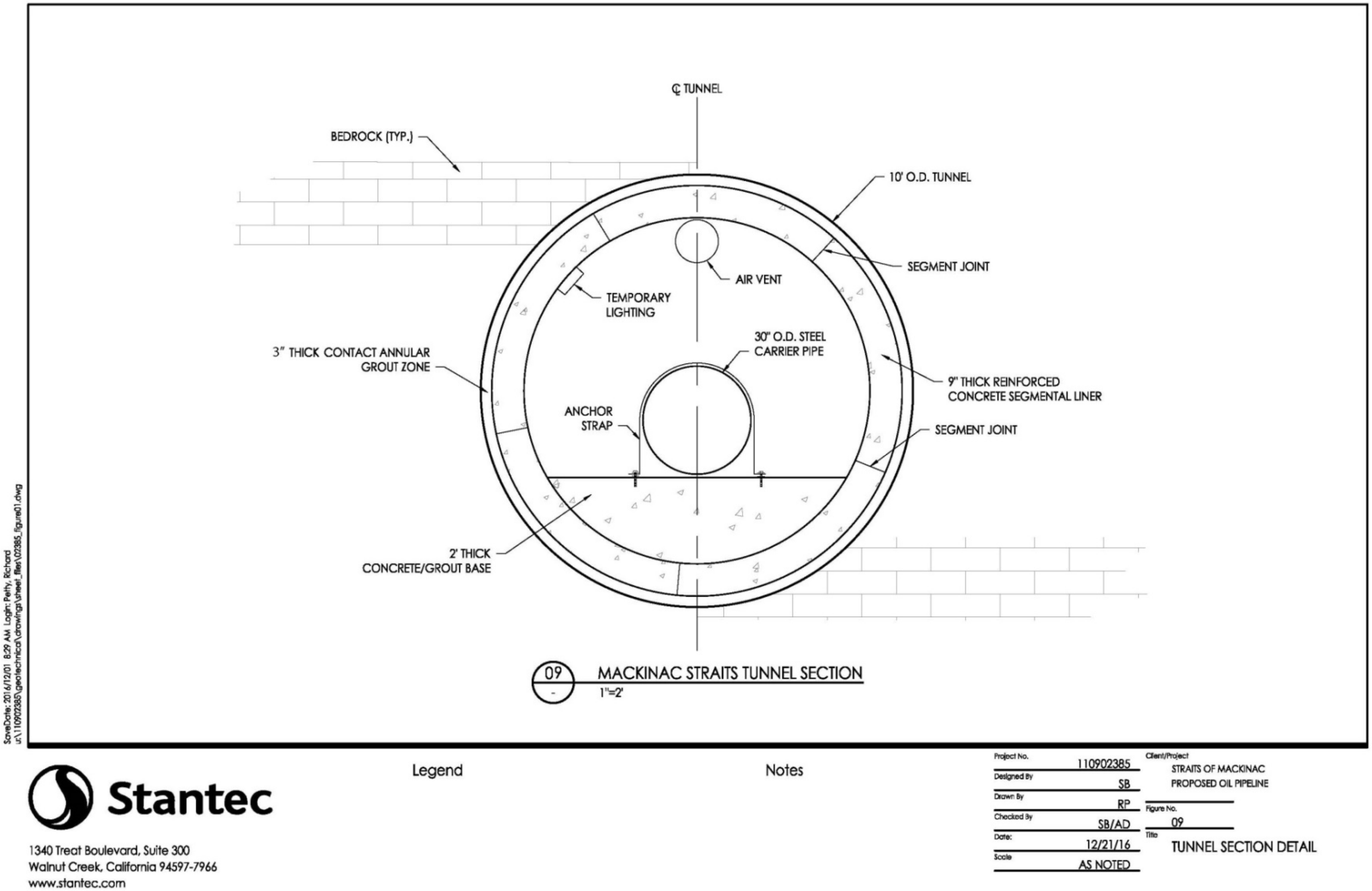
In the event of material degradation within the pipe wall, either by thinning or cracking, the presence of grout would act to restrain the pipe radially and prevent bulging by providing a continuous transfer of load/stresses, through the grout, to the surrounding concrete liner, and ultimately to the bedrock beyond. This constraint would act to prevent the type of localized plastic deformation that precedes failure in ductile pipeline material subject to internal pressure loading. In the absence of the development of large strains caused by outside forces such as fault movements or geotechnical hazards, this leaves the only hypothetical loss of containment mechanism for the pipeline to be by means of through-wall pinhole penetration without accompanying localized deformation. Given the lack of evidence of any thinning within the existing Straits Crossing pipeline segments after 64 years of service and regular monitoring for wall loss, this scenario is not considered realistic. Nevertheless, given the low release rates associated with pinhole perforations, and the secondary containment capacity of the low permeability grout and adjacent bedrock, the use of leak-sensing technologies such as those identified above would enable the pipeline to be pre-emptively shut down and evacuated before products could enter the waters of the Great Lakes should such a perforation occur.

Appendix E.6 Pipeline Tunnel Examples

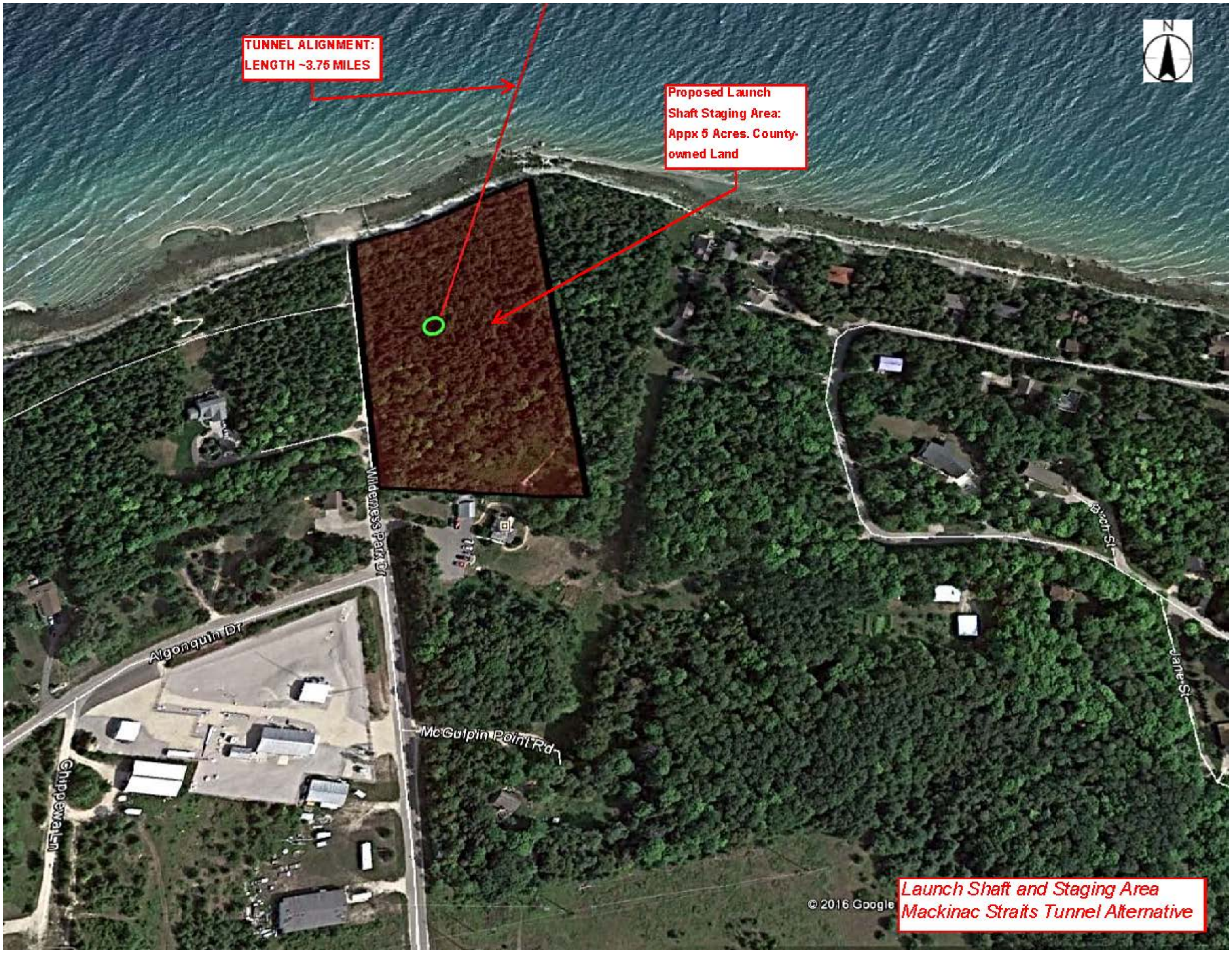
Project	Owner / Location	Year Constructed	Purpose	PL/Tunnel Diameter	Length (mi.)	Comments
Raritan River Tunnel	Middlesex County Utility Authority (New Jersey)	2010	Carry 2 x 60-in. diameter sewer mains and 2 x 16-in. HDPE gas pipelines	Excavated tunnel diameter of 15.5 ft., with pre-cast concrete liner having an internal diameter (ID) of 14 ft.	0.75	Approx. 16-ft. diameter, soft-ground tunnel in New Jersey for crossing the Raritan River, with precast concrete segmental lining.
Diesel Pipeline	Near Honolulu, Hawaii	1940 - 1943	Fuel conveyance from Red Hill storage facility to Pearl Harbor fuel depot (pumping station); includes 4 fuel pipelines ranging from 16 to 32 in. to carry diesel, fuel oil, jet fuel and aviation gasoline	Approx. 16-ft. tunnel diameter	3.5	Constructed in volcanic rock using “advanced” mining techniques. Tunnel allows for maintenance access.
Burnaby Mountain Tunnel	Trans Mountain Pipeline (BC, Canada)	Designed	Carry crude and refined oil from Westridge Marine Terminal to Burnaby Terminal	2 x 30-in. pipelines	1.67	Tunnel designed to carry 3 pipelines (600,000 bpd), from the Westridge Marine Terminal to the Burnaby Terminal, to avoid urban pipelining
TQM Pipeline Tunnel	Trans Quebec & Maritimes Pipeline Inc. (Quebec, Canada)	1998	To carry utility gas under the St. Lawrence River in Quebec	30-in. pipeline	2.36	Transports natural gas to the Montréal and Québec City corridor, and interconnects with the Portland Natural Gas Transmission System from the Northeast US.
Hoult Tunnel	Northern Gateway Pipeline (BC, Canada)	Designed	Convey diluted bitumen (dilbit) from Alberta to the British Columbia coast, and return condensate in parallel 20-in. pipeline	36-in. pipeline for dilbit and parallel 20-in. pipeline for condensate	4.1	Capacity 525,000 bpd of dilbit, and 193,000 bpd of condensate
Northwest Lateral Project	Houston, TX	1989	Convey raw water to City’s East Purification Plant with pipe crossings of the Houston Ship Channel and Greens Bayou	Excavated tunnel diameter of 11 ft., with primary 10-ft. steel liner and 9-ft. carrier pipe	0.34 for Ship Channel crossing, and 1.64 for Greens Bayou crossing	Soft ground tunnel in glacial-era clays, silts and sands.

Project	Owner / Location	Year Constructed	Purpose	PL/Tunnel Diameter	Length (mi.)	Comments
San Francisco Bay Tunnel	San Francisco, CA	2015	Convey raw water from the Hetch Hechy Reservoir across San Francisco Bay as part of a longer pipeline	Excavated tunnel diameter of 15 ft. with 13-ft. ID precast concrete tunnel lining for initial support and 9-ft. final steel welded liner with 5/8-in. thick mortar lining	Approx. 5	Soft ground tunnel in interbedded clays, silts and sands, with a section of hard rock at the receiving shaft end of the tunnel.
New York Harbor Siphon Tunnel	New York, NY	2015	Convey treated water under New York Harbor from Brooklyn to Staten Island; replaces two older siphons constructed at shallower depth and allows deepening of the harbor	Excavated diameter of 12 ft. with precast concrete tunnel liner for initial support and internal, 6 ft. diameter steel carrier pipe grouted in place	5	Soft ground tunnel in interbedded clay, silt and sand.
Hanlan Feedermain - South	Brampton (Ontario, Canada)	2015	Provide a redundant water transmission main from the main Lakeside Water Treatment Plant to the Hanlan Pumping Station	Excavated diameter of about 12 ft. with 8 ft. ID PCCP grouted in place within the tunnel	3.72	Rock tunnel in interbedded shale, limestone and siltstone

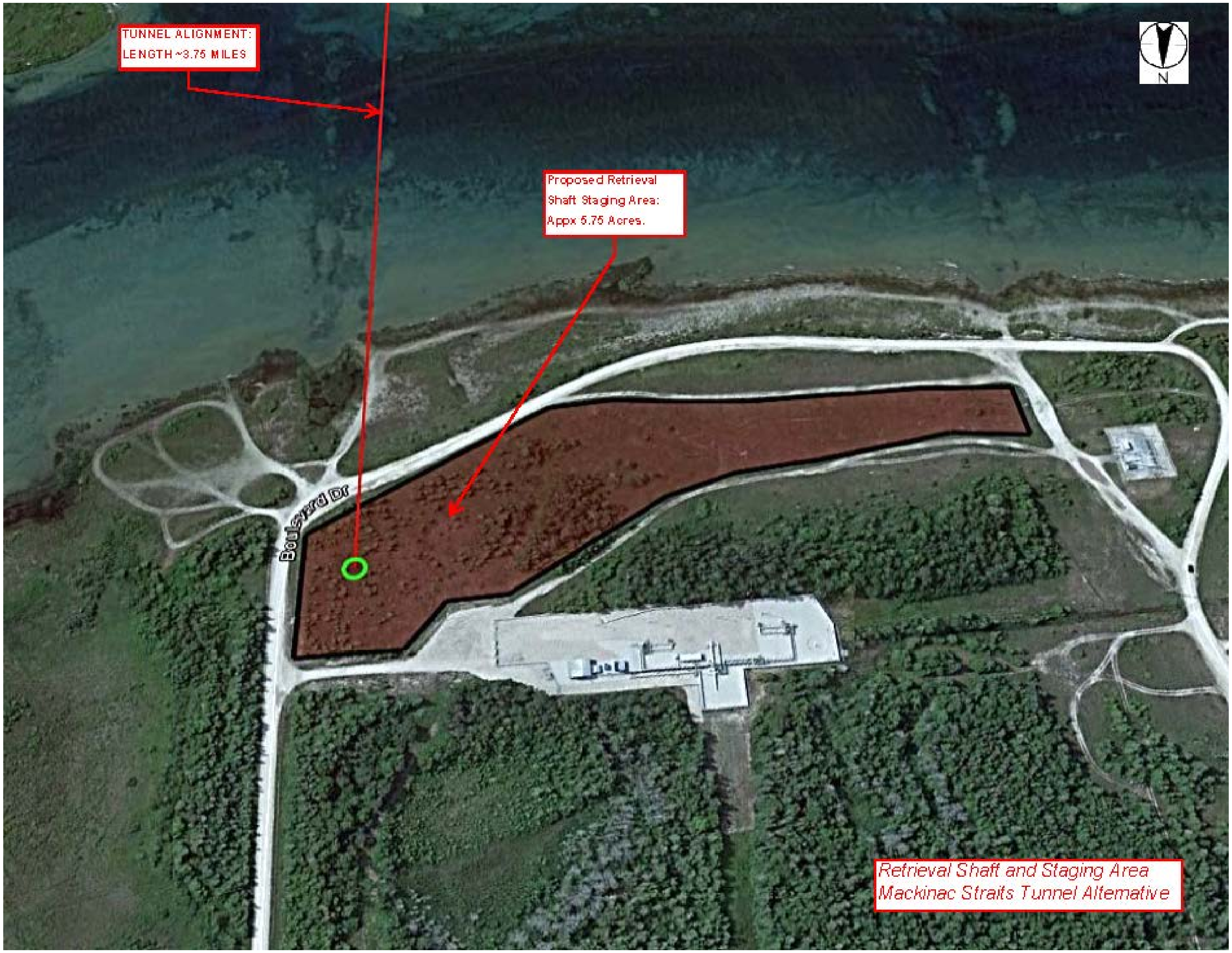
Appendix E.7 Tunnel Section Detail



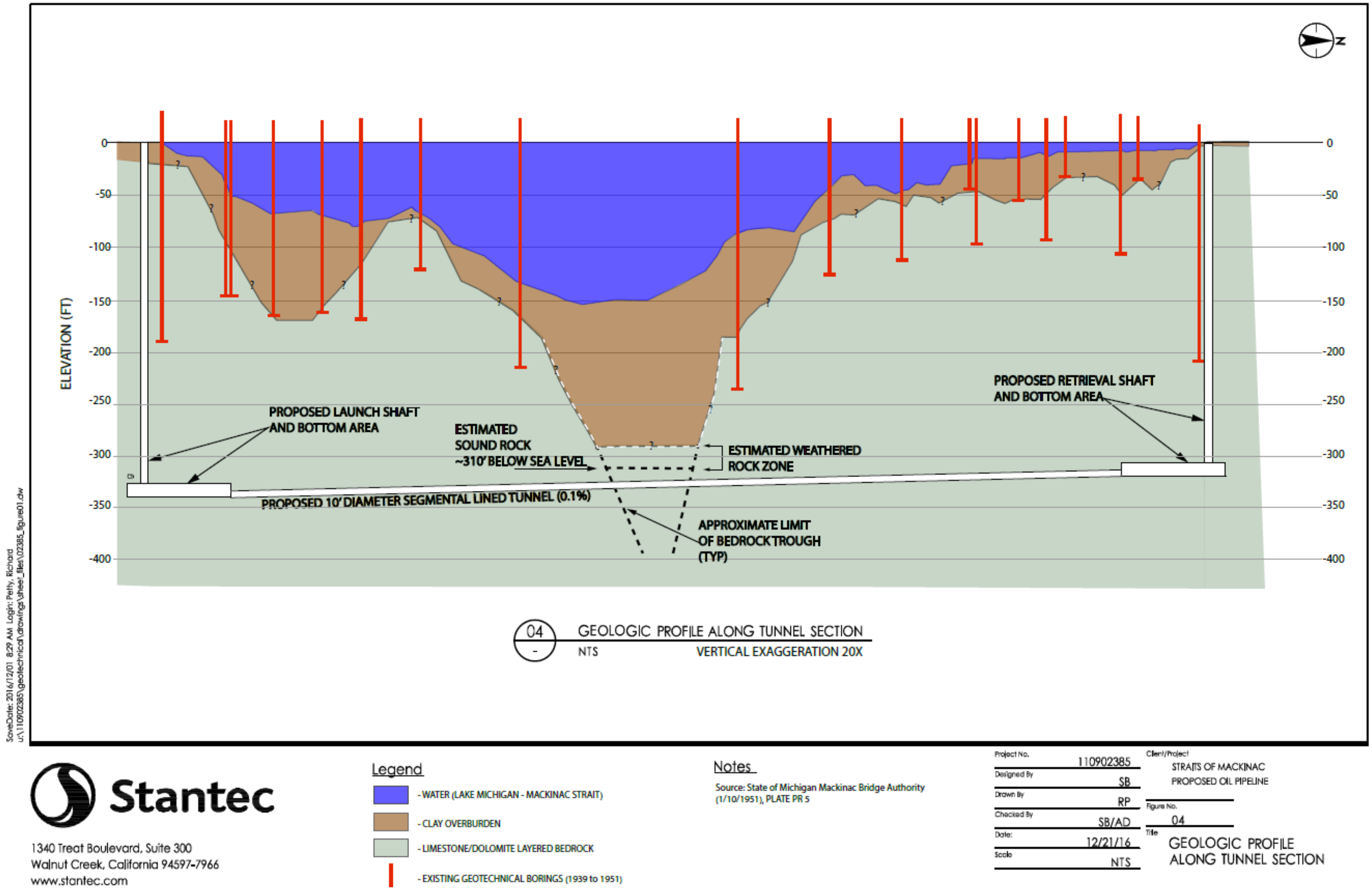
Appendix E.8 Launch Shaft and Staging Area



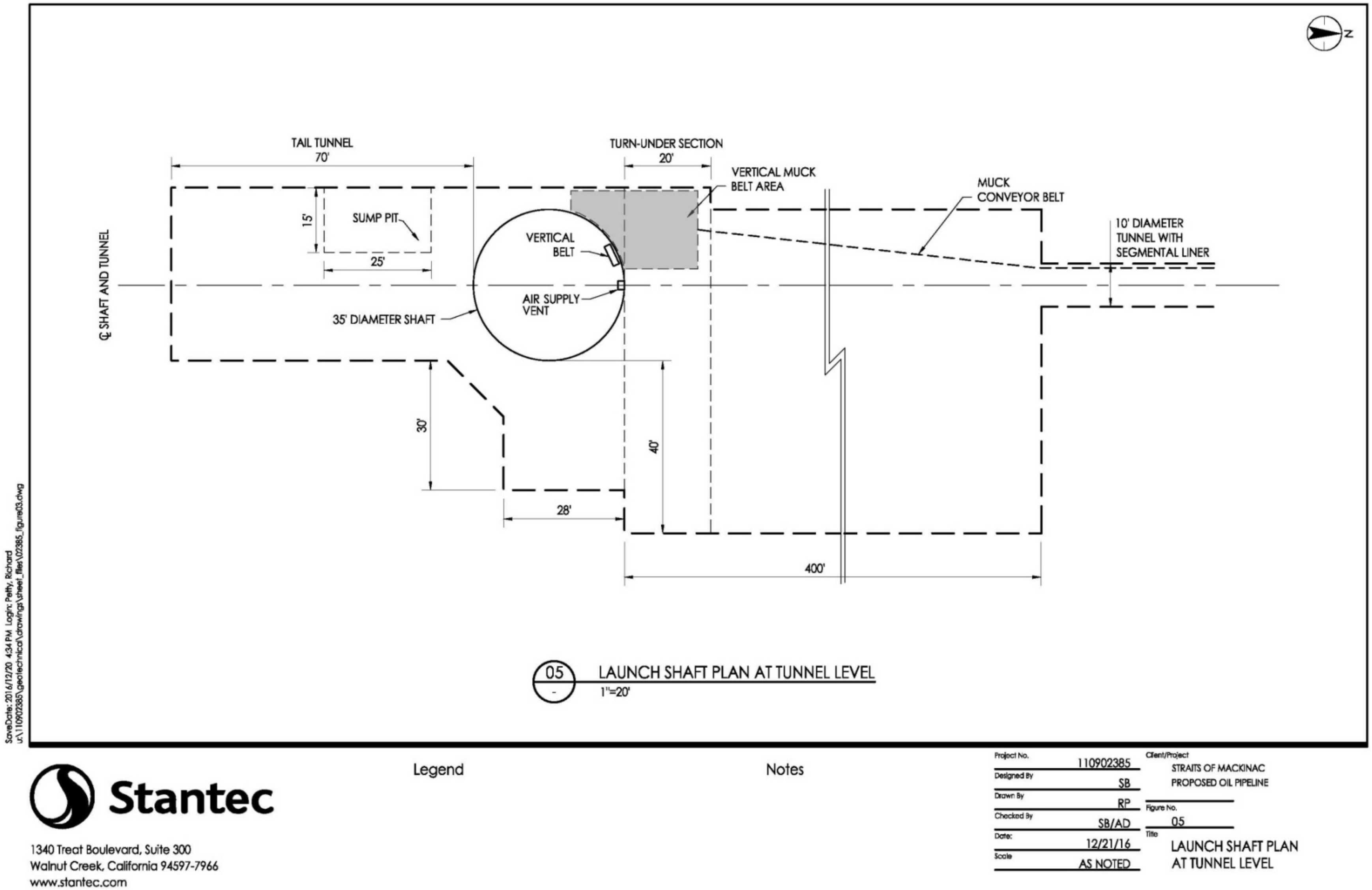
Appendix E.9 Retrieval Shaft and Staging Area



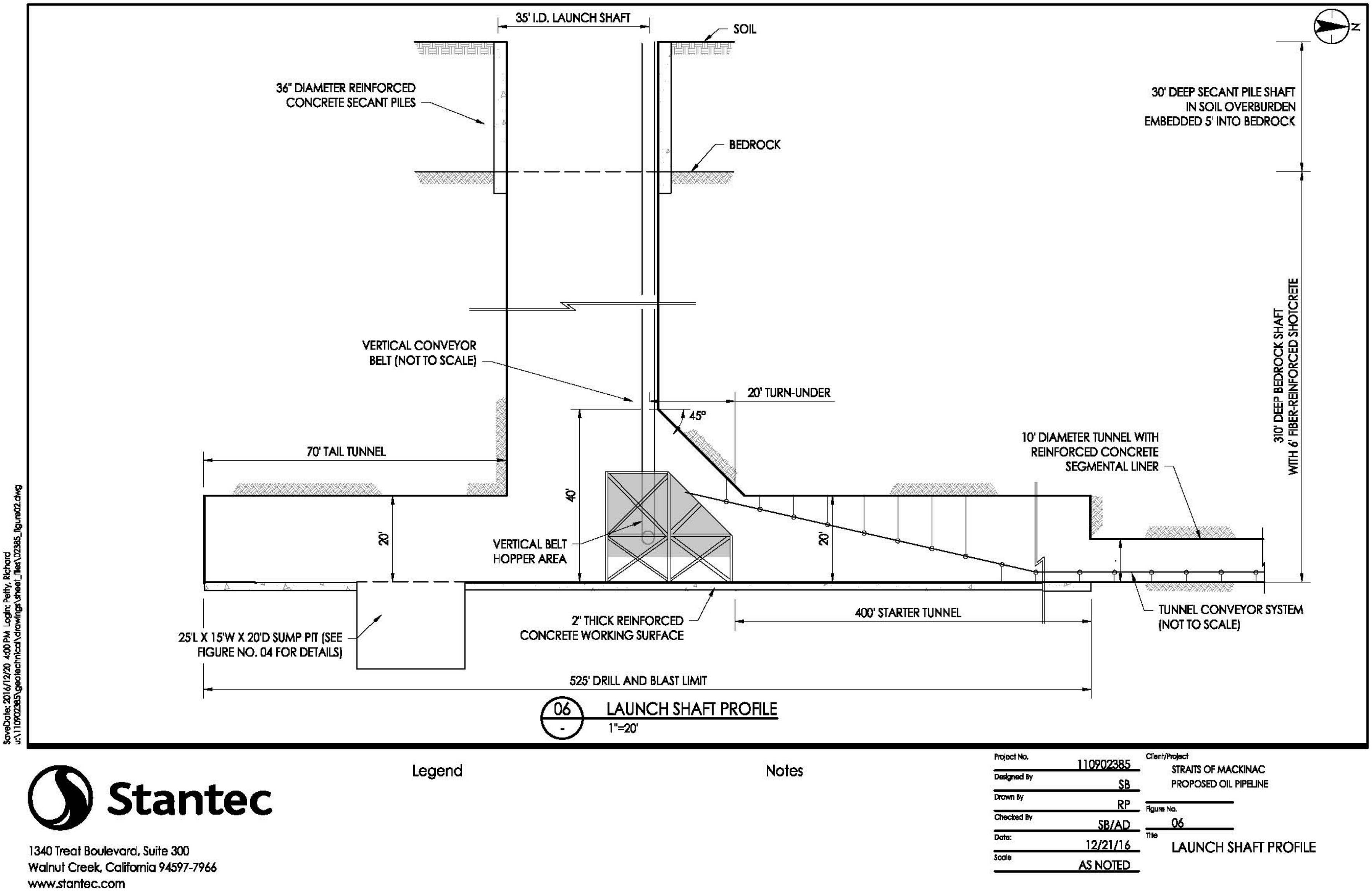
Appendix E.10 Geologic Profile Along Tunnel Section



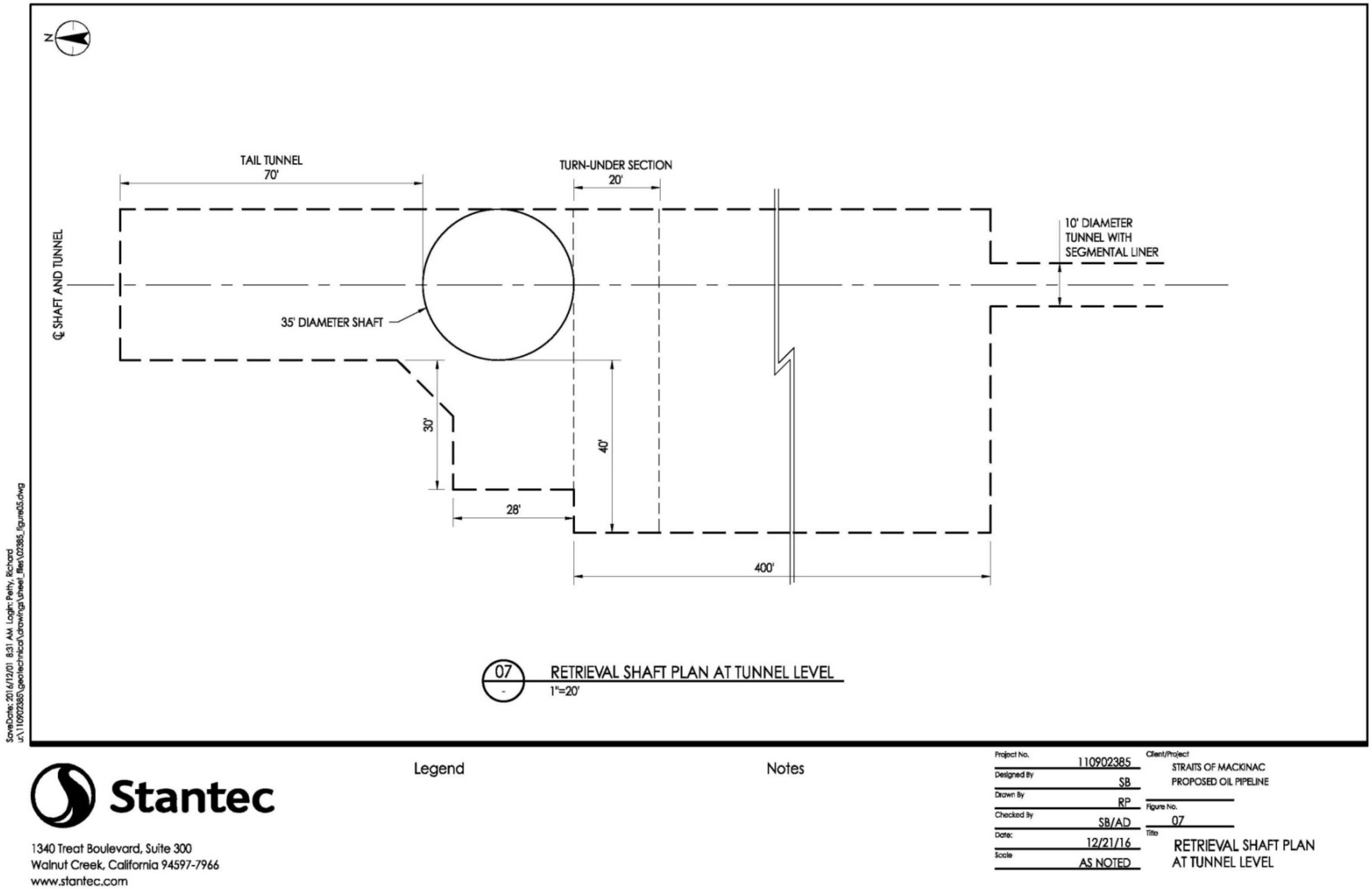
Appendix E.11 Launch Shaft Plan at Tunnel Level



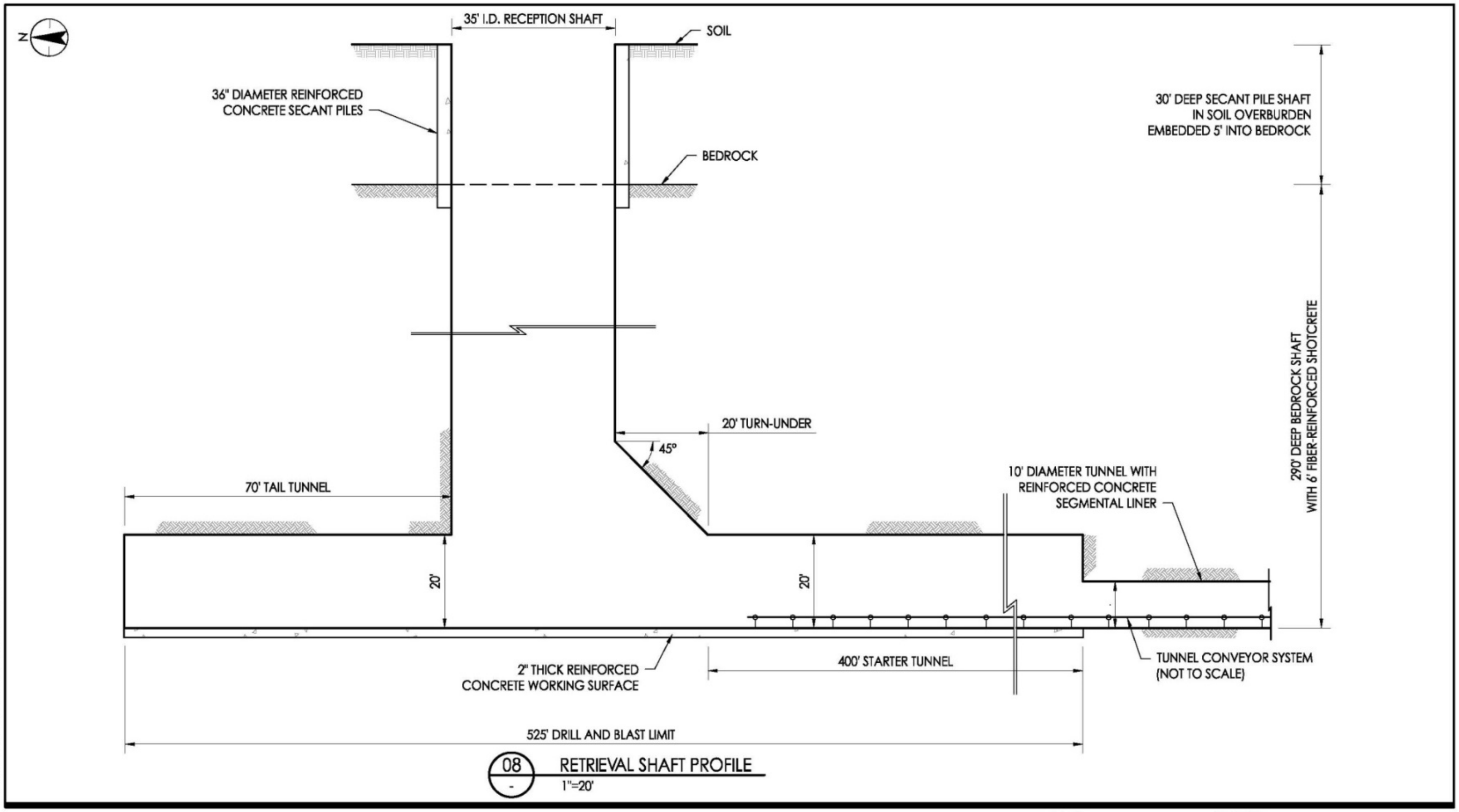
Appendix E.12 Launch Shaft Profile



Appendix E.13 Retrieval Shaft Plan at Tunnel Level



Appendix E.14 Retrieval Shaft Profile



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Legend

Notes

Project No.	110902385
Designed By	SB
Drawn By	RP
Checked By	SB/AD
Date:	12/21/16
Scale	AS NOTED
Client/Project	STRAITS OF MACKINAC PROPOSED OIL PIPELINE
Figure No.	08
Title	RETRIEVAL SHAFT PROFILE

Appendix E.15 References

[1] Kenneth K. Landes, George M. Ehlers and George M. Stanely, "Geology of the Mackinac Straits Region and Sub Surface Geology of the Northern Southern Peninsula," University of Michigan, Lansing, Michigan, 1945.

Appendix F Enbridge System Overview

Appendix F.1 Description of Pipeline Segments and Capacities

The Enbridge Mainline System extends from Edmonton, Alberta to Sarnia, Ontario with several integrated extensions and terminals to provide for delivery points in Eastern Canada, the US Midwest, and US Gulf Coast.

Figure F-1: Enbridge Mainline System Overview

Canadian and US domestic crude from both Western Canada and the Bakken in North Dakota are transported eastward on the Enbridge Mainline System using a batched system to retain commodity integrity and shipper ownership for a wide variety of grades and types of crude petroleum, as well as a mixed stream of natural gas liquids (NGLs).

Enbridge describes its system as extremely complex, transporting more than 50 distinct types of crude oil and other commodities for more than 100 separate shippers on multiple lines. Individual segments of the Mainline system transport specific commodities, and the allocation of commodities to these pipelines depends on several factors, including but not limited to petroleum quality, supply, tankage constraints, connectivity, receipt and delivery patterns, ratability, pro-rationing, and power costs.

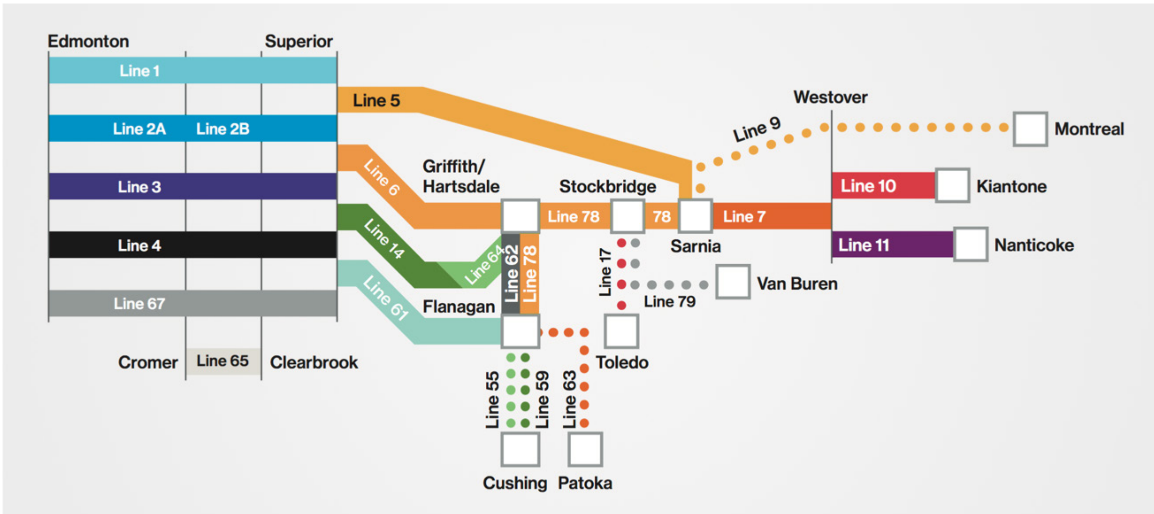


Figure F-2: Enbridge Mainline System – Segments

East of Superior, the Enbridge Lakehead System transports crude oil and other liquids on four separate lines with a total takeaway capacity of 2.5 million barrels per day (bbl/d). Throughput on the Mainline System for 2015 was in the range of 2.2 million bbl/d. The four lines are generally described as follows:

- **Line 5 (Capacity 540 kbbl/d)**
  Transports condensate, light synthetic, light sweet crude oil, and NGL volumes destined for the Sarnia area (including Marysville, MI) and east of Sarnia delivery points.
- **Line 6 (Capacity 667 kbbl/d)**
  Transports crude oil from Superior to the Chicago area (specifically Griffith, IN).
- **Lines 14/64 (Capacity 318 kbbl/d)**
  Transports volumes ranging between condensate and medium crudes for delivery at Mokena, IL, and Griffith, IN, respectively. It is also possible for volumes transported on Line 64 to access breakout tankage at Griffith/Hartsdale, IN, for subsequent movement on Line 78. In normal operations, Line 14/64 is considered a light crude line.
- **Line 61 (Capacity 931 kbbl/d)**
  This line can transport all approved mainline commodities except NGL, refined products, and cracked material from Superior to Flanagan, IL.

Other key pipeline segments of the Enbridge System which provide further connectivity to specific market delivery points receiving crude/NGL from Superior include:

- **Line 62 (Capacity 235 kbbl/d)**
  Transports heavy crude oil from Flanagan to Griffith.
- **Line 78 (Flanagan to Griffith: (Capacity 570 kbbl/d); Griffith to Stockbridge (Capacity 570 kbbl/d); Stockbridge to Sarnia (Capacity 500 kbbl/d)**
  Transports volumes of heavy, heavy high tan, and heavy low residual crude for delivery in the Chicago area and those destined for delivery at Sarnia/Toronto/Buffalo area refineries. Although Line 78 and Line 5 both terminate at Sarnia, each serves both commodity types and different receipt and delivery points. Line 78 was recently constructed and replaces Line 6B.
- **Line 17 (Capacity 100 kbbl/d) and Line 79 (Capacity 80 kbbl/d)**
  Transports volumes from Stockbridge terminal to Samaria and Romulus, MI where the pipelines interconnect with third party pipelines that provide delivery of volumes to the Toledo and Detroit refineries.
- **Line 7 (Capacity 180 kbbl/d)**
  Transports volumes from Sarnia terminal to Nanticoke and United Warren refineries via Line 11 (Capacity 117 kbbl/d) and Line 10 (Capacity 74 kbbl/d) respectively.
- **Line 9 (Capacity 300 kbbl/d)**
  Transports volumes from Sarnia terminals to Montreal refineries. Enbridge recently reversed Line 9 operations providing new access to crude transported on its system for Eastern refineries.

Shippers submit monthly nominations for service on the Enbridge Mainline System by advising Enbridge of the origin point, delivery point, volume and grade of crude oil to be shipped. Shippers do not specify which line is to be used for transporting crude to downstream delivery points. Enbridge unilaterally assigns nominations to the pipeline segments.

If shippers tender more crude oil than can be transported, Enbridge will apportion such tenders on a prorata basis among the shippers, based on the tenders and current operating conditions of the system.

Appendix F.1.1 Line 5 Overview

Enbridge's Line 5 is a 645-mi. (1,038 km), 30-in. diameter pipeline that travels through Michigan's Upper and Lower Peninsulas, originating in Superior, WI, and terminating in Sarnia, ON, Canada.

As it travels under the Straits of Mackinac, Line 5 splits into two 20-in. diameter pipelines that are buried onshore and taper off deep underwater, crossing the Straits west of the Mackinac Bridge for a distance of 4.5 mi. (7.2 km).

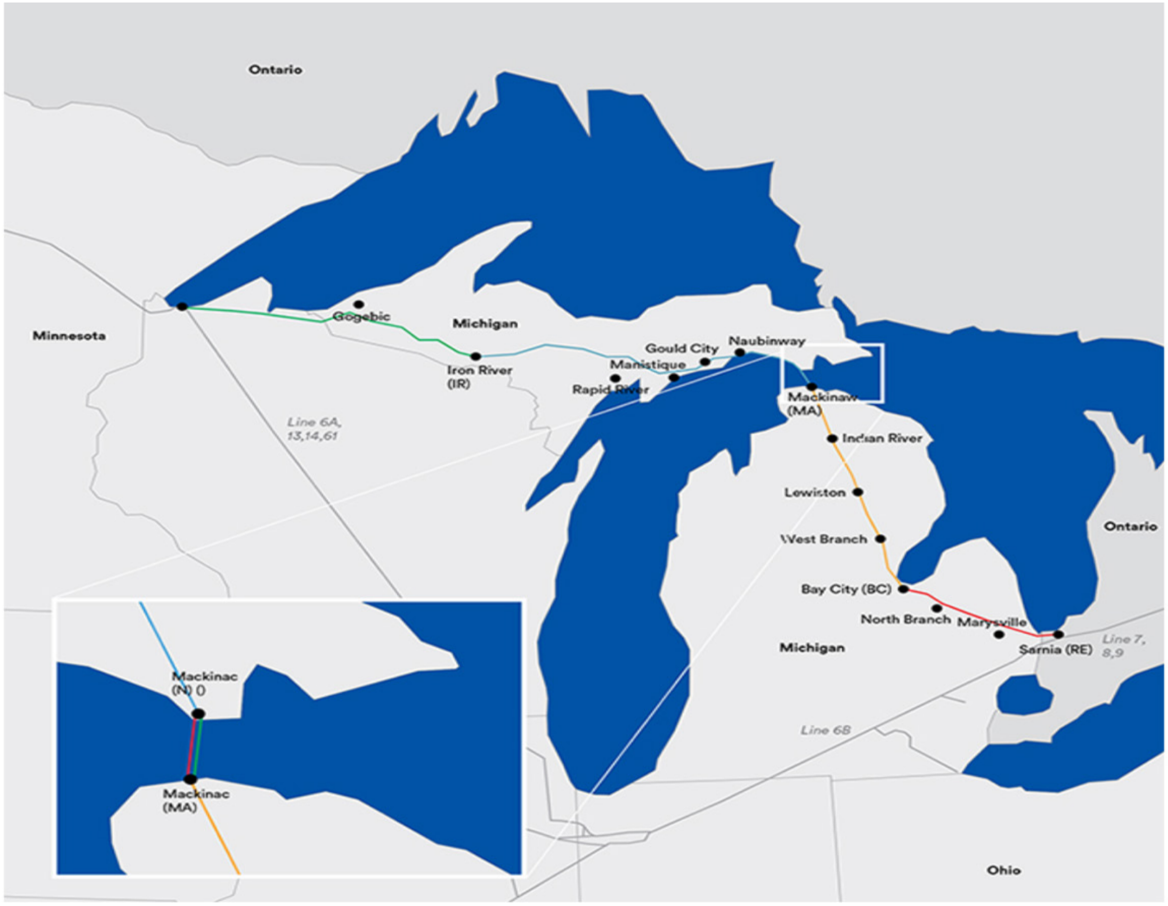


Figure F-3: Enbridge Mainline System – Line 5 Overview

Enbridge has a long-standing practice of transporting light crude on Line 5 including condensate, light synthetic, light sweet crude oil, and NGL volumes with many shippers relying on the configuration of its system in structuring their business operations.

On the Upper Peninsula, Line 5 delivers NGL to the Plains Midstream depropanization facility at Rapid River, MI. Propane is extracted from the NGL stream and the depropanized NGL stream is returned to Line 5 for transport to Sarnia.

On the Lower Peninsula, Line 5 provides receipt of Michigan light oil production at Lewiston where it interconnects with the MarkWest Michigan Crude Pipeline system. Also on the Lower Peninsula, Line 5 delivers crude to the Marysville crude terminal that interconnects to the Sunoco Eastern System pipeline that transports crude from Marysville terminal to refineries in Detroit and Toledo.

The majority of Line 5 throughput is delivered to the Sarnia terminal where it is then transported to refineries in Ontario, New York State, and Quebec. NGLs are delivered to the Plains fractionation facility in Sarnia, and a proportion of the propane produced at that facility is returned to PADD 2 markets via Michigan.

Appendix F.1.2 Enbridge Pipeline System Tariff Rates

Transportation tolls on the Enbridge system are regulated by the NEB for the pipeline segments in Canada and by FERC for pipeline segments in the US. Enbridge posted joint rates reflect the full path toll for receipt from specific receipt terminals to delivery to specific delivery terminals. Tolls are provided based on grades of crude oil being transported as well as for NGL.

FERC regulates the rates, terms, and conditions that oil pipelines charge under the *Interstate Commerce Act* (ICA). The ICA prohibits oil pipelines from charging rates that are “unjust and unreasonable” and permits shippers and the Commission to challenge both pre-existing and newly filed rates. Posted rates in 2016 for the Enbridge System are shown in Table F-1.

Table F-1: Enbridge System 2016 Rates

ENBRIDGE SYSTEM TRANSPORTATION RATES IN US DOLLARS PER BARREL					
	NGL	CND	LIGHT	Medium	Heavy
EDMONTON TO:					
Superior, Wisconsin	$2.68	$2.81	$2.94	$3.13	$3.46
Lockport, Illinois		$3.87	$4.00	$4.27	$4.74
Mokena, Illinois		$3.87	$4.00	$4.27	$4.74
Flanagan, Illinois		$3.80	$3.93	$4.20	$4.67
Griffith, Indiana		$3.87	$4.00	$4.27	$4.74
Stockbridge, Michigan		$4.23	$4.36	$4.66	$5.18
Rapid River, Michigan	$3.27				
Marysville, Michigan		$4.23	$4.36	$4.66	$5.18
Corunna/Sarnia Terminal, Ontario	$4.03	$4.28	$4.42	$4.72	$5.24
Nanticoke, Ontario		$4.63	$4.79	$5.12	$5.69
West Seneca, New York		$4.68	$4.85	$5.18	$5.77
Montreal, Quebec			$6.06	$6.48	$7.19
LEWISTON TO:					
Marysville, Michigan			0.65		
STOCKBRIDGE TO:					
Oregon, Ohio; Samaria/Van Buren Michigan			1.25	1.25	1.25

Appendix F.1.3 Interconnection with Other Pipelines

The Enbridge System connects with third party pipelines in providing receipt and delivery service to its shippers.

Receipt point interconnects include:

- At Mokena, IL – with the Chicap Pipeline.
- At Lewiston, MI – with the Michigan Crude Pipeline.

Delivery point interconnects include:

- At Marysville, MI – with the Sunoco Pipeline system; a 16-in. crude oil pipeline that runs from Marysville, MI to Toledo, OH. This pipeline has a capacity of 190 kbbl/d and receives crude oil from the Enbridge system for delivery to refineries located in Toledo, OH and to Marathon's Samaria, MI tank farm, which supplies its refinery in Detroit, MI.

  The toll for delivery of volumes from Marysville to Samaria, Van Buren, or Toledo is $0.6293/bbl.

- At Samaria and Romulus, MI – with Marathon's Detroit Crude System consisting of the following pipeline segments:
  - Samaria to Detroit – delivers crude oil from Samaria, MI, to Marathon's Detroit, MI, refinery—includes a tank farm and crude oil truck offloading facility at Samaria.
  - Romulus to Detroit – delivers crude oil received from pipeline systems operated by third parties at Romulus to Marathon's Detroit refinery.

The local rate on the Marathon Detroit System from Samaria, MI to the Detroit refinery is $0.6149/bbl.

These interconnects are shown in Figure F-4.

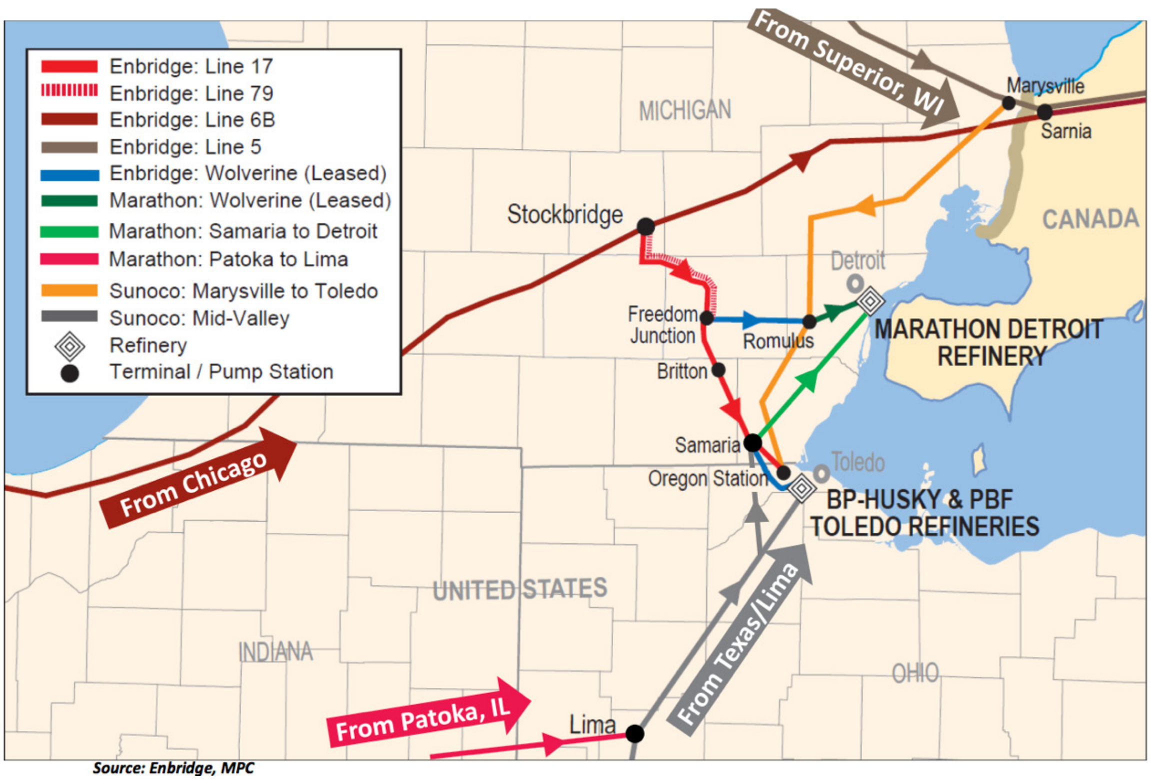


Figure F-4: Detroit/Toledo Crude Oil Supply Pipelines

Appendix G Market Overview

Appendix G.1 Crude Oil Supply and Demand

Appendix G.1.1 Crude Oil Demand

North American refinery feedstock supplies include Canada crude production, US crude production, and other foreign imports. Refinery feedstock supply is provided by a combination of pipeline, rail, and marine tanker deliveries.

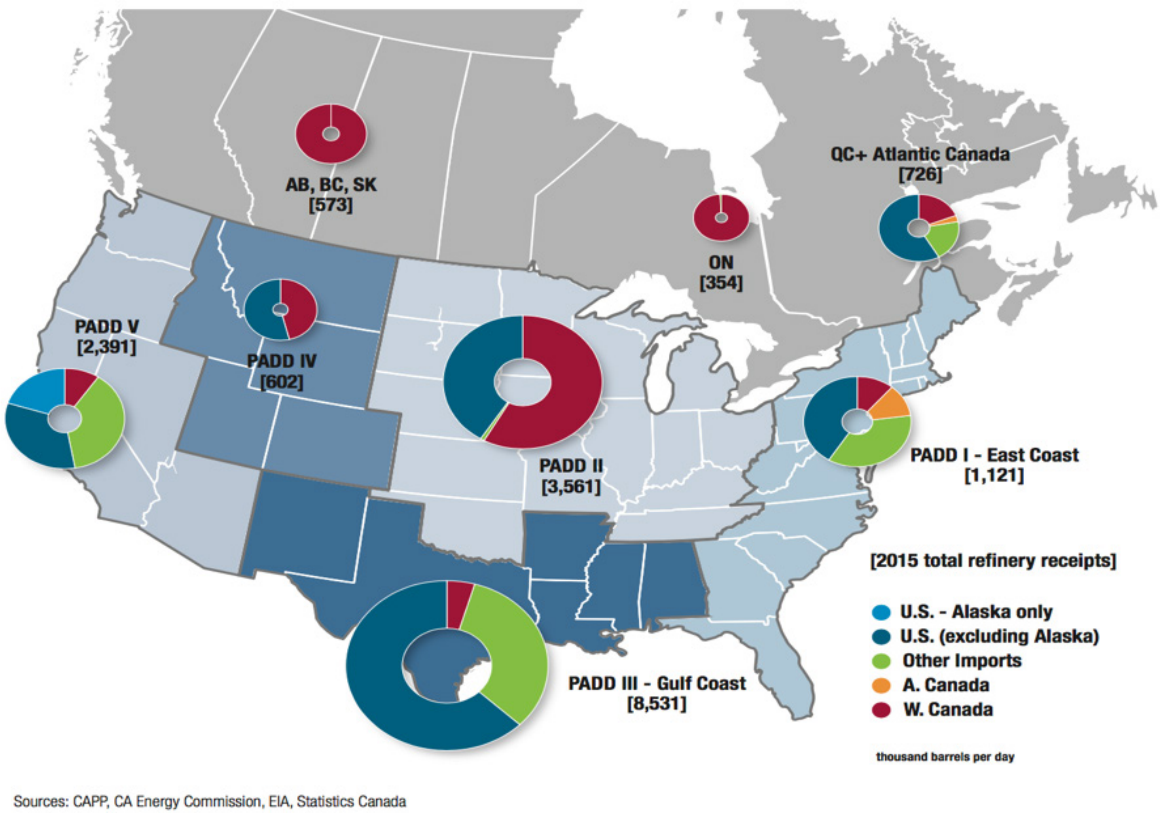


Figure G-1: 2015 Canada and US Crude Oil Demand by Market Region

East of Superior markets have been and are expected to continue to be the primary market for Western Canada and North Dakota crude oil.

Several expansions on the Enbridge System in recent years have provided for increased flow to the Midwest and Eastern Canadian refineries for Western Canadian Crude and North Dakota crude oil.

With the growth in Canadian heavy oil production, refineries in the Midwest and Eastern Canada have also reconfigured to accommodate a heavier crude slate as the heavy crude slate provides greater refinery margins.

Pipelines from the US Gulf Coast that have historically provided Midwest and Eastern Canadian refineries with foreign crude oil supply are now being reconfigured (reversed) to further expand market access to new supply growth. At the same time other pipelines are seeing a marked reduction in utilization rates: e.g. the Portland Pipeline that provided delivery of foreign crude to Quebec and Ontario refineries.

Appendix G.1.2 Crude Oil Supply

US crude oil production averaged 9.4 million barrels per day (bbl/d) in 2015. Domestic production continues to be led by Texas and North Dakota which have steadily increased their daily output since 2009.

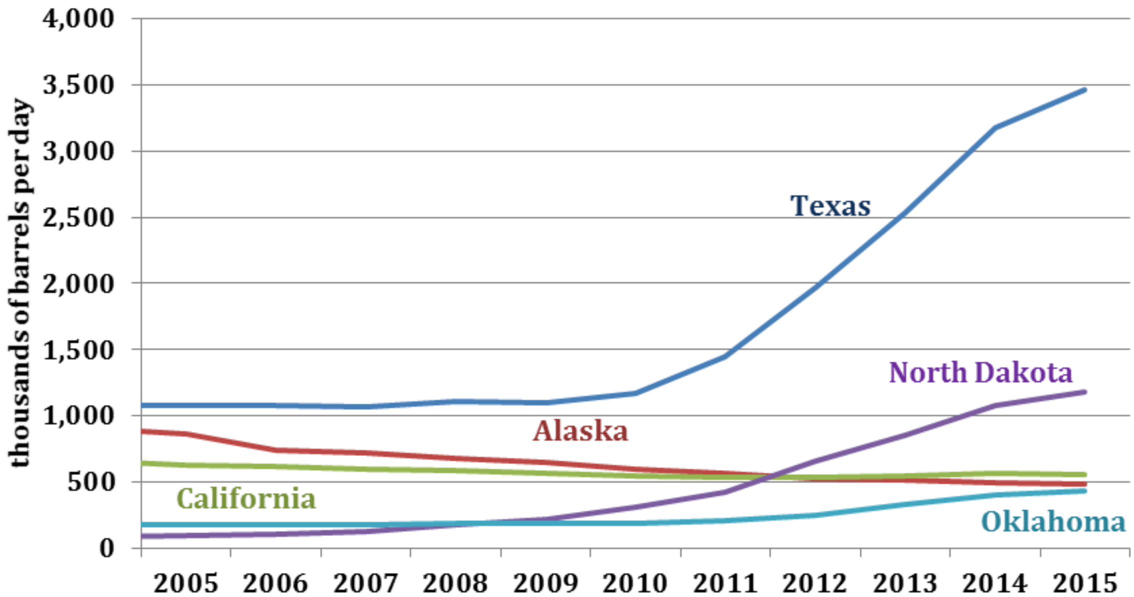


Figure G-2: Annual US Crude Oil Production

Crude oil production in the Midwest and Eastern US continue to be stable, contributing less than 150 kbbl/d. Accordingly, the Midwest (PADD 2) and Eastern US (PADD 1) refineries rely heavily on crude oil delivered from outside their respective regions.

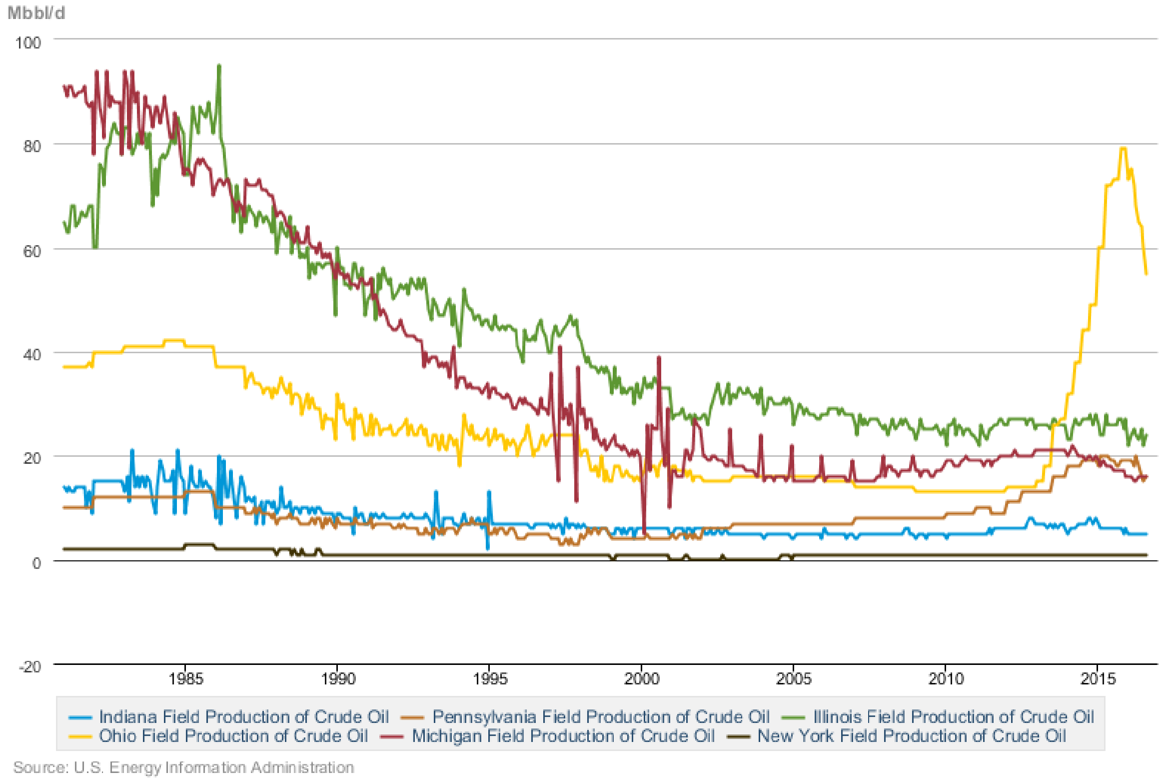


Figure G-3: Midwest/Eastern US Crude Oil Production

Canada and US liquids supply is expected to further expand with growth driven by US tight oil, Natural Gas Liquids (NGLs), and Canadian oil sands. Western Canadian light oil supply is expected to remain flat at 1.4 to 1.5 million bpd.

million b/d	2015	2020	2025	2030
Light	1.44	1.36	1.39	1.46
Heavy	2.54	3.21	3.48	3.99
Total Supply*	3.98	4.57	4.87	5.45

*Total may not add up due to rounding.

Figure G-4: Western Canada Crude Oil Supply

The market for Western Canadian light sweet crude in the United States is shrinking due to growing US domestic tight oil production. This combined with the recent conversions of light sweet crude refineries to take heavy crude is further decreasing demand for light sweet crude.

Appendix G.1.3 Midwest Refineries

Refineries in Illinois are located in two major areas; the Chicago region, and the central part of the state. ExxonMobil's Joliet, IL refinery has a capacity of 236 kbbl/d and CITGO owns a 167 kbbl/d refinery in Lemont, IL. These refineries can receive Canadian crude via the Enbridge system, and can also receive domestic or foreign barrels from the Wood River area via the Chicap pipeline from the Gulf Coast.

The central region of Illinois is also home to two large terminal areas—Wood River and Patoka. These two locations receive domestic crude from Cushing as well as Canadian crude from the north and foreign cargoes from the Gulf Coast.

Refineries in the central part of Illinois include the 306 kbbl/d Wood River refinery and the 204 kbbl/d Marathon refinery in Robinson, IL. Both refineries are near the Patoka and Wood River terminals and can be supplied by many sources.

Also in the Chicago area is the BP facility in Whiting, IN, just across the Illinois state line, at 410 kbbl/d.

Refineries in the State of Ohio include the PBF Toledo refinery that has a throughput capacity of approximately 170 kbbl/d. The PBF Refinery processes a slate of light, sweet crudes from Canada, the Mid-continent, the Bakken region and the US Gulf Coast. The Toledo petroleum refinery is located 60 miles south of Detroit.

The BP-Husky Toledo Refinery is located east of Toledo in the city of Oregon, OH. The refinery can process up to 160 kbbl/d. The Toledo, OH Refinery processes approximately 50% heavy crude oil feedstock.

The State of Michigan has one crude oil refinery - the Detroit Marathon refinery located near I-75 in southwest Detroit. In 2012, Marathon completed the Detroit Heavy Oil Upgrade Project that enabled the refinery to process up to 80 kbbl/d of heavy sour crude oils, including Canadian crude oils. This refinery currently processes sweet and heavy sour crude oil with a capacity of 132 kbbl/d.

Appendix G.1.4 Eastern Canadian Refineries

Total refinery capacity in Eastern Canada is 1.21 million bbl/d. Average crude runs for Eastern Canada refineries for 2015 were 1.036 million bbl/d. Eastern Canada crude runs for 2015 included 450 kbbl/d of US crude oil imports.

Ontario refineries rely entirely on crude delivered from the Enbridge System. Total refinery capacity in Ontario is 395 kbbl/d with crude runs averaging 325 kbbl/d in 2015 and 350 kbbl/d in 2016.

Enbridge’s Line 9 full reversal and expansion to 300 kbbl/d completed in late 2015, is expected to increase Western Canada and North Dakota supply shipped on the Enbridge System into Eastern Canada in addition to offsetting current rail deliveries.

In addition to the Canadian eastern refineries, the United Warren refinery (70 kbbl/d) located in western Pennsylvania receives its crude oil supplies via Ontario on the Enbridge Mainline (via Line 10).

Total market access for crude transported on the Enbridge System to Eastern Canada (inclusive of the United Warren Refinery) is 775 kbbl/d.

Accordingly, The Eastern Canada market (and United Warren refinery) for Western Canadian crude and Bakken crude from North Dakota offers highest netbacks for producers, given current market access and continental pricing dynamics. The outlook for receipt of Western Canadian crude is expected to remain relatively the same for the next five years. Conventional light sweet crude oil is expected to remain the primary feedstock.

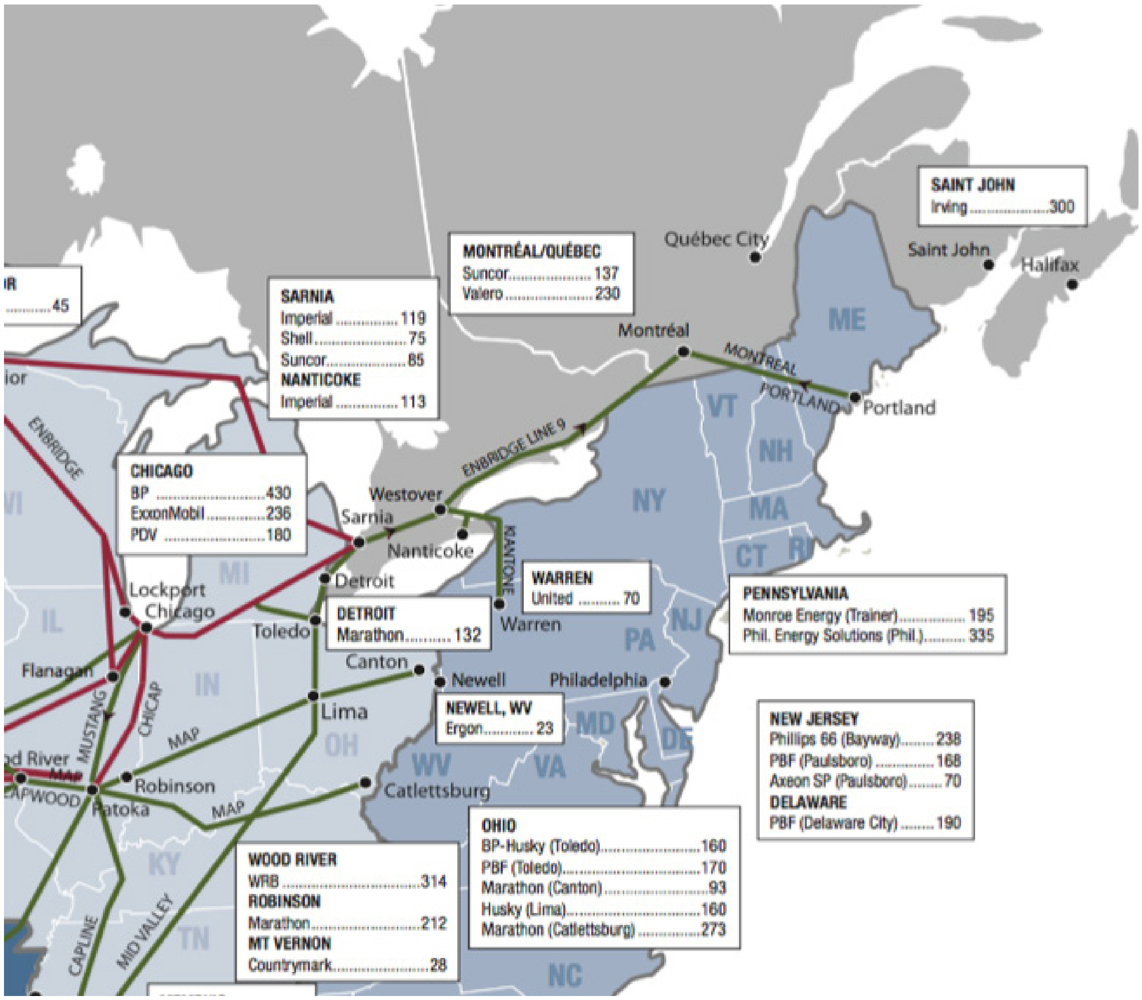


Figure G-5: Midwest, Eastern US, and Eastern Canada Refineries

Appendix G.1.5 Midwest Crude Oil Pipelines

Appendix G.1.5.1 Capline Pipeline

Capline originates in St. James, LA and terminates in Patoka, IL. It delivers to Collierville and Patoka terminals. It is a 40-in. crude oil pipeline that spans 632 mi. (1,017 km) in length with a capacity of 1.2 million bbl/d. The pipeline is operated by Marathon Petroleum.

Appendix G.1.5.2 Chicap Pipeline

The Chicap Pipeline is comprised of 203 mi. (327 km) of 26-in. mainline from Patoka to Manhattan/Mokena, IL. It has a capacity of 360 kbbl/d. The Chicap Pipeline receives low sulfur and heavy crude oil from the Capline Pipeline, Woodpat Pipeline, and ExxonMobil at Patoka. It interconnects with the Enbridge System at Mokena.

Capline Ownership	
Marathon	32.632%
Plains	33.132%
Southcap	20.998%
BP	13.328%
Total	100.00%

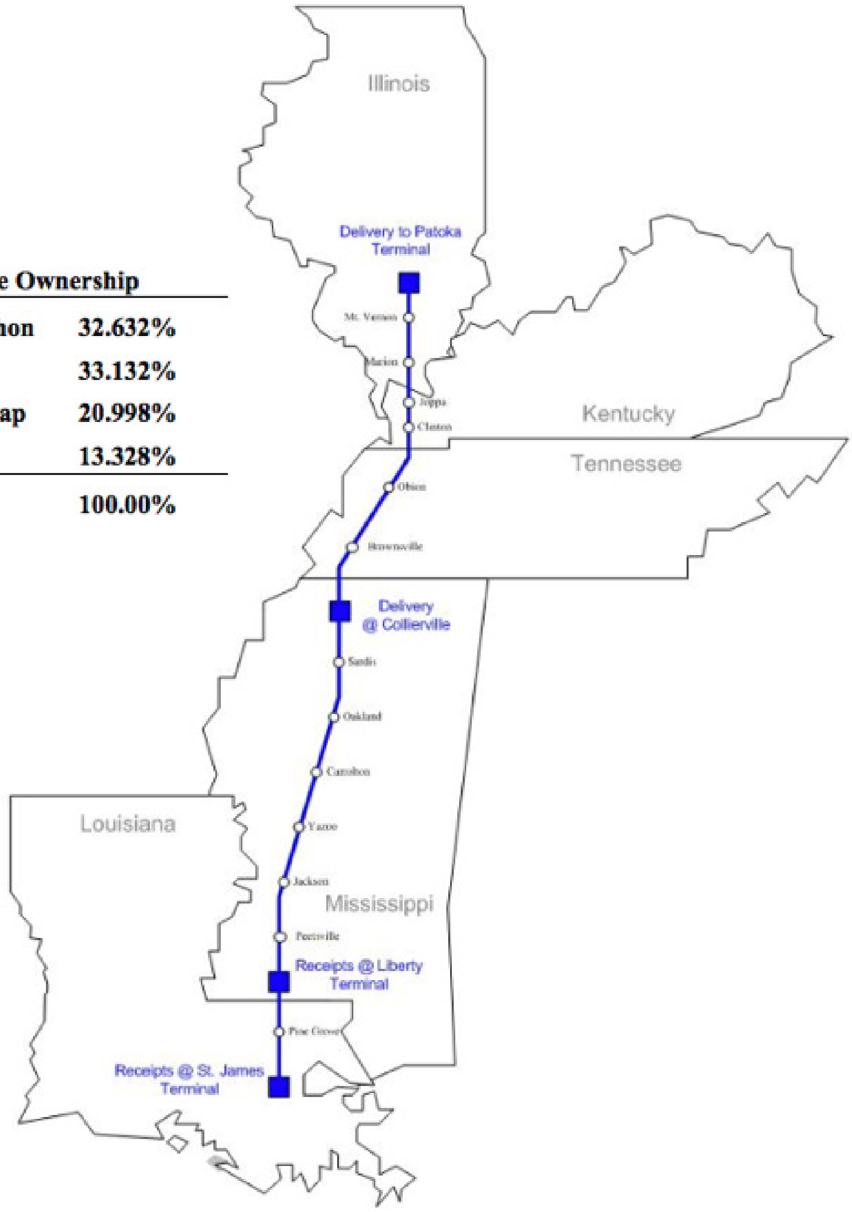


Figure G-6: Capline System Schematic

Appendix G.1.5.3 Sunoco Eastern Pipeline System

The Sunoco Pipeline system includes a 16-in. crude oil pipeline that runs from Marysville, MI to Toledo, OH. This pipeline has a capacity of 190 kbbl/d and receives crude oil from the Enbridge system for delivery to refineries located in Toledo, OH and to Marathon's Samaria, MI tank farm, which supplies its Detroit, MI refinery.

Appendix G.1.5.4 Mid-Valley Pipeline System

The Mid-Valley Pipeline system consists of approximately 1,000 mi. (~1,600 km) of crude oil pipelines. The pipeline system extends from Longview, Texas and passes through Louisiana, Arkansas, Mississippi, Tennessee, Kentucky, and Ohio. It terminates in Samaria, Michigan. The pipeline provides crude oil to a number of refineries, primarily in the Midwest United States, including the Lima Refinery and Toledo Refinery. Mid-Valley Pipeline has a nominal capacity of 240 kbbl/d. (The toll from Longview, TX to Toledo is $1.0651/bbl).

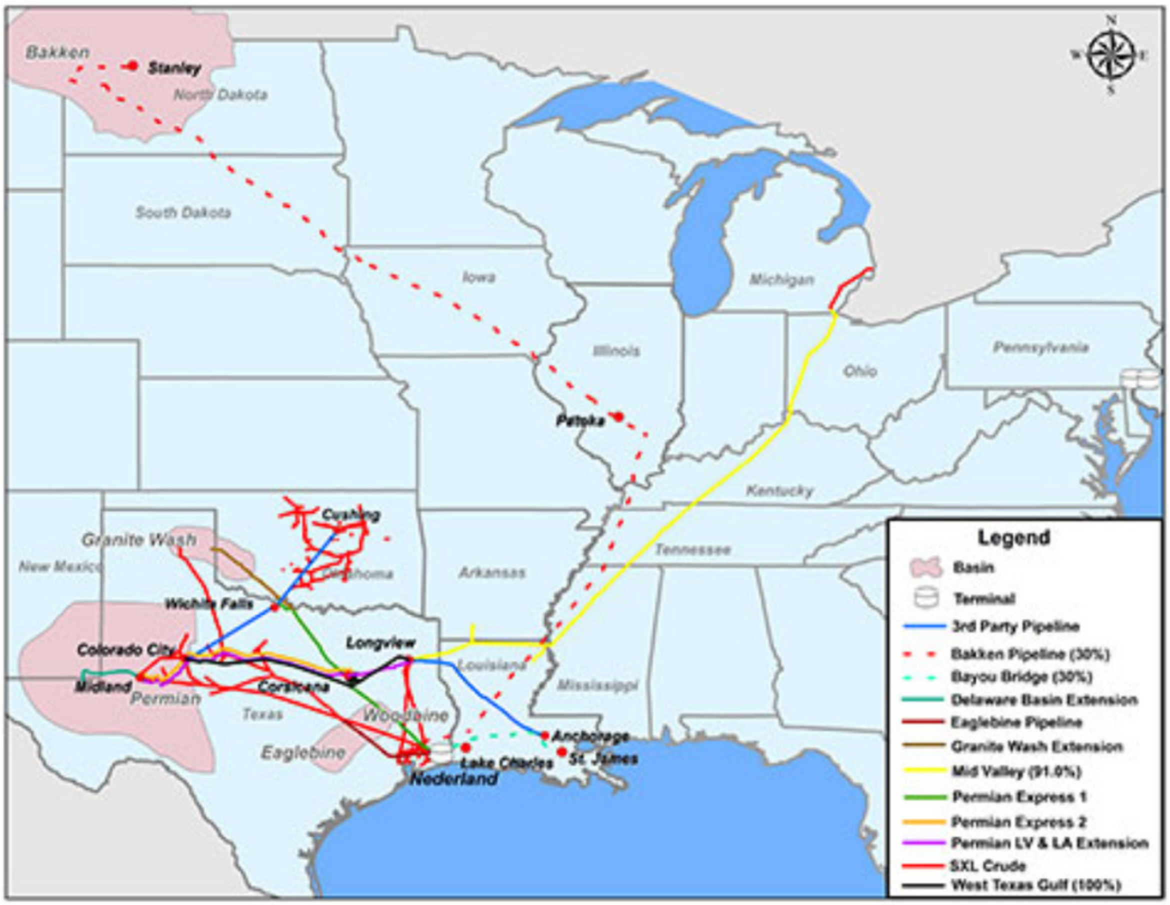


Figure G-7: Mid-Valley Pipeline System Schematic

Appendix G.1.5.5 Dakota Access Pipeline

Dakota Access Pipeline is presently under construction with an estimated 2017 in service date. It is expected to have a capacity of approximately 470 kbbl/d from the Bakken/Three Forks production area to the Midwest.

Figure G-8: Dakota Access Pipeline

Appendix G.1.6 Rail Transportation

The movement of crude by rail within the United States reached a high of 928 kbbl/d in October 2014, with most of the shipments originating in the Midwest and going to the East Coast, West Coast, and Gulf Coast regions. Since October 2015, crude-by-rail volumes have declined as production has slowed, as crude oil price spreads have narrowed, and as more pipelines have come online.

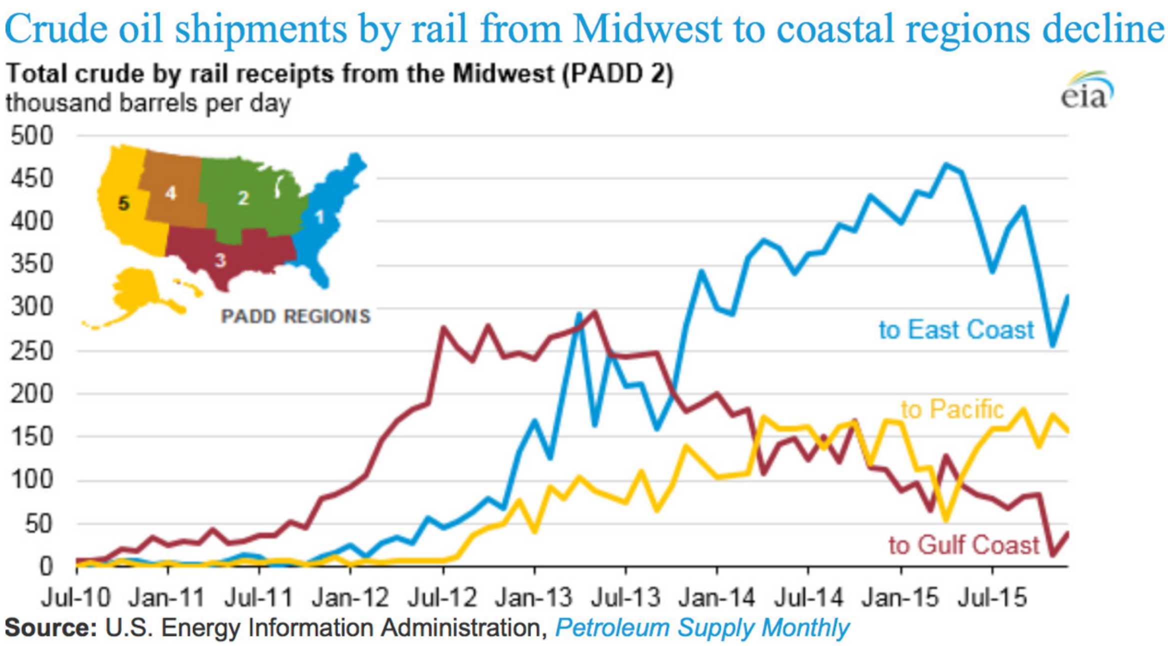


Figure G-9: Crude Shipments by Rail from Midwest

Appendix G.2 NGL[1] Overview

Appendix G.2.1 NGL Supply

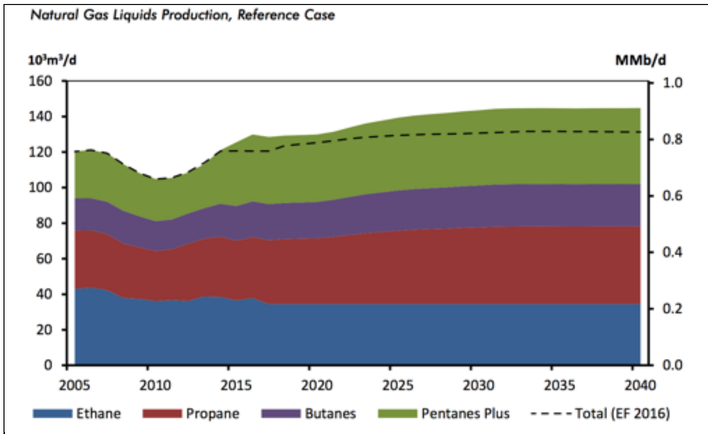
NGL supply has significantly increased over the past several years as a result of natural gas drilling across North America. NGLs are fractionated to provide supplies of ethane, propane, butane for both domestic and offshore markets.

Given the increased availability of NGLs petrochemical complexes have converted their oil based feedstock to NGL based feedstocks given the more favorable economics.

With the potential availability of low cost ethane and additional propane from Marcellus and Utica, the Sarnia area petrochemical industry is able to source alternate feedstock supplies for their respective plants given the well-developed infrastructure and logistics available in the region as well as proposed new pipelines.

Production of NGLs in western Canada and in the Eastern US is expected to remain strong and continue to increase in the future and very competitive in securing markets.

[1]NGL – "Natural gas liquid" is a term used to describe all types of hydrocarbons that can be liquefied and removed from a stream of natural gas. NGL include various proportions of ethane, propane, butane and pentanes.



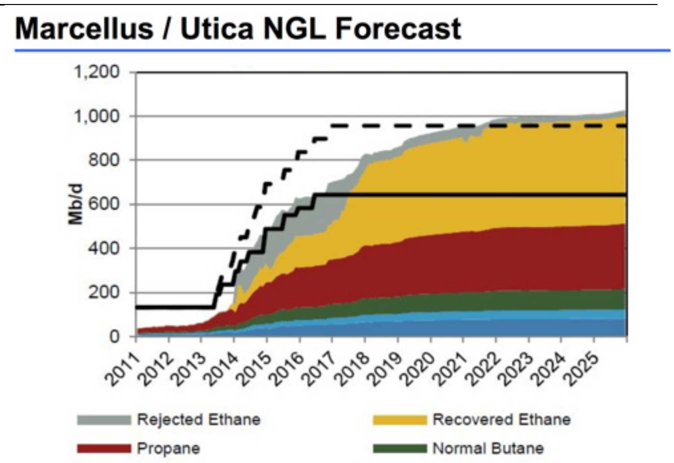


Figure G-10: Western Canada and Eastern US NGL Production Outlook

Appendix G.2.2 Sarnia Area NGL Fractionation Facilities

Major petrochemicals complexes rely on liquid feedstock from refineries and on NGL supplies that are fractionated to its various components.

Currently a mixed NGL stream is delivered via the Enbridge Mainline System (Line 5) to a 100 kbbl/d fractionator in Sarnia, which is owned by Plains Midstream Canada (61%), Pembina (19%) and Shell (20%).

Additional NGL feedstock for the petrochemical complexes is transported to Sarnia by rail from western Canada.

Additional analysis and discussion of exports of propane from these facilities to PADD 2 via Michigan is provided in Appendix J.

Appendix G.2.3 NGL Pipelines

Significant new pipeline development is underway in NE US to create additional market access for Marcellus/Utica gas/NGLs to Canadian markets.

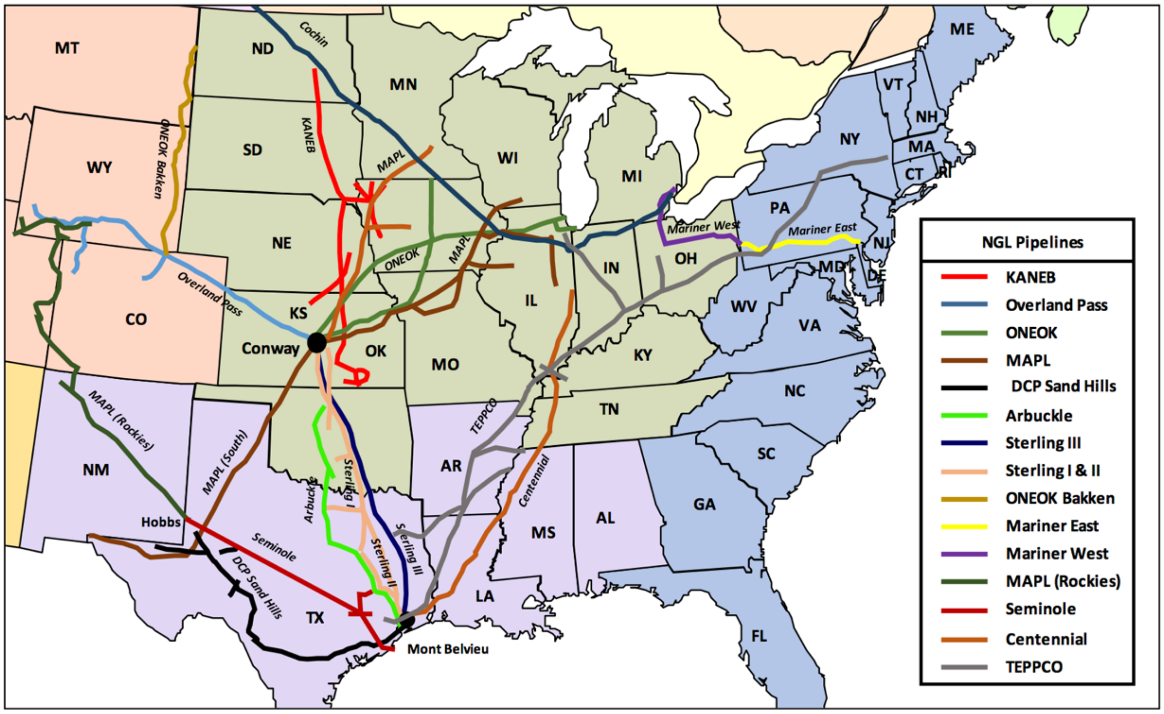


Figure G-11: NGL Pipeline System

Appendix G.2.3.1 MarkWest Pipeline

The MarkWest "Mariner West" pipeline was commissioned in the fourth quarter 2013. It is designed to deliver 50 kbbl/d of ethane to NOVA Chemicals in Sarnia for petrochemical use.

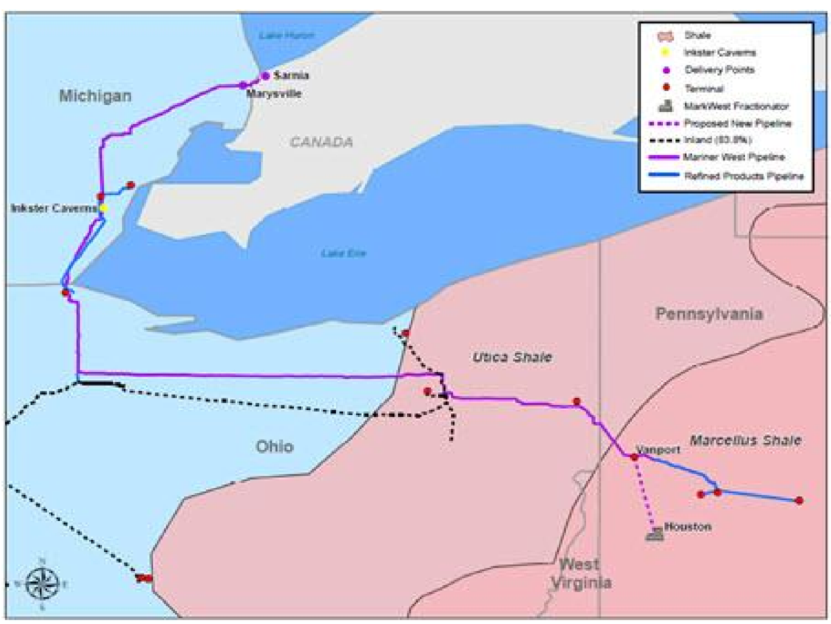


Figure G-12: MarkWest "Mariner West" Pipeline

Appendix G.2.3.2 Utopia Pipeline

Kinder Morgan and NOVA Chemicals are proposing a conversion of the 12-in. Cochin East pipeline to continue the Cochin pipeline in west to east service for the section of the line east of Riga, MI. The project is named the Utopia Pipeline and is due to start-up 2018. The current plan for capacity is to transport 50 kbbl/d of ethane and E/P mix with expandability to 75 kbbl/d. The mix of liquids would originate from shale gas processing facilities in Ohio and be delivered to Windsor, ON.

Figure G-13: Utopia Pipeline

Appendix G.3 State of Michigan Market Overview

Appendix G.3.1 Crude Production

In-state production of crude oil peaked in 1979 at 95 kbbl/d and has since declined. Current 2016 crude oil production is in the range of 500 thousand barrels per month (16 kbbl/d). Approximately 75% of Michigan crude production is transported by the MarkWest crude oil gathering system for injection into Line 5 at Lewiston, MI. The remaining 25% of crude oil production is transported by truck to crude terminals for transfer to refineries.

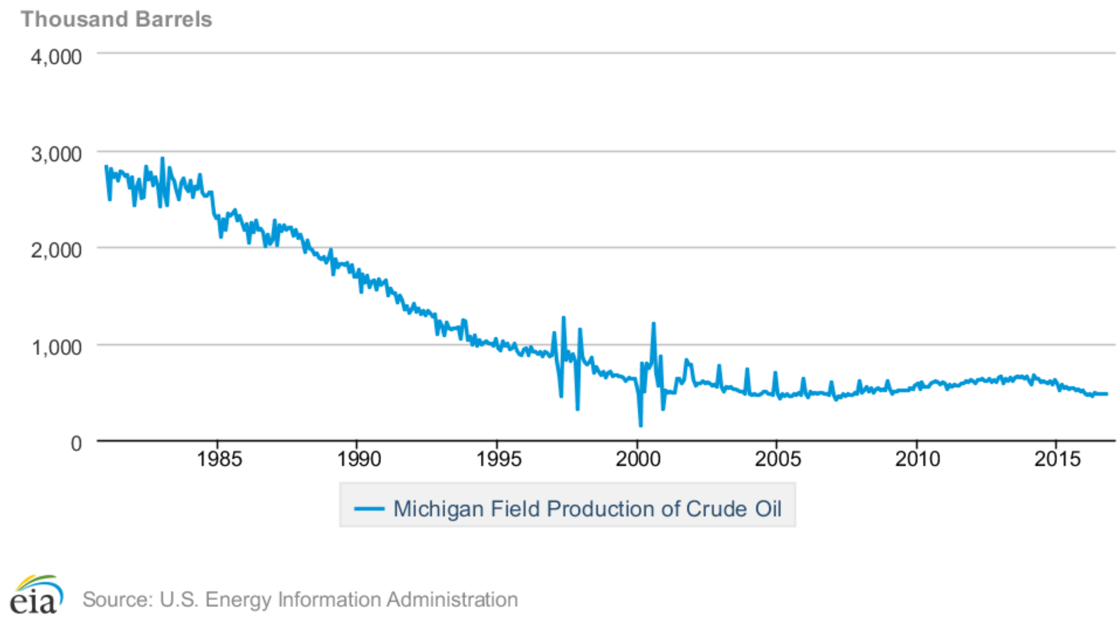


Figure G-14: Michigan Monthly Field Production of Crude Oil

Appendix G.3.2 Propane Supply/Demand

The State of Michigan propane sales vary throughout the year based on seasonal requirements with approximately 9% of Michigan residents relying on propane for heating fuel. Other uses for propane include crop drying. Propane sales rates in Michigan range between 12 to 39 kbbl/d with peak consumption in January.

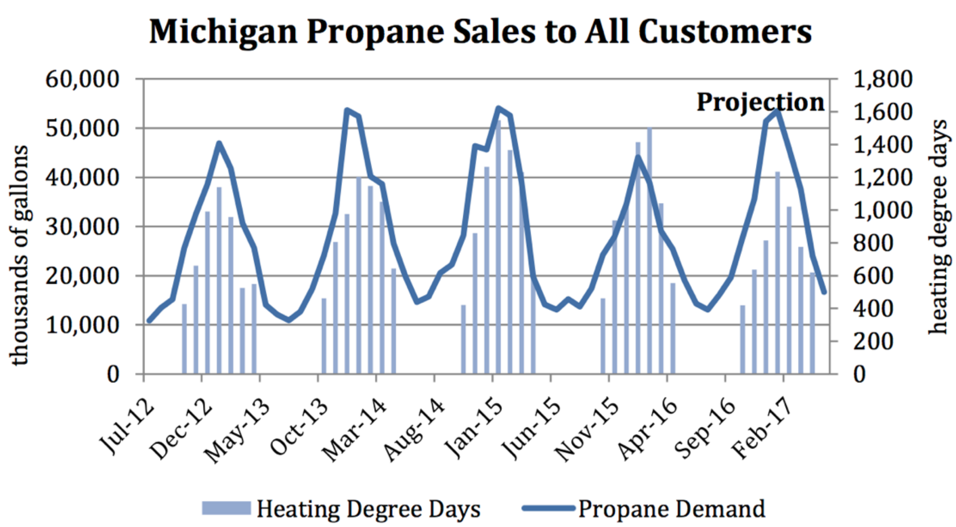


Figure G-15: Michigan Propane Sales to All Customers

Sources of propane in Michigan include local refinery production in Detroit, propane extracted from NGLs at Rapid River Depropanizer Facility, and imported supplies of propane from outside the State.

The four-week average Midwest propane production for the week ending November 11, 2016, was 417 kbbl/d, up about 16% from the same period in the previous year.

Storage facilities for propane in Michigan are located at Rapid River and Kincheloe in the Upper Peninsula and at Alto and St. Clair in the Lower Peninsula (Figure G-16).

Figure G-16: Propane Storage Facilities in Michigan

At Rapid River (located 125 mi. or ~200 km west of the Straits) an NGL stream is drawn from Line 5. The NGL extracted from Line 5 is fed to a depropanizer at Rapid River which produces a commercial grade propane (HD-5 specification). The C3+ off the bottom of the depropanizer tower is returned to Line 5. Propane from the depropanizer is stored at the Rapid River facility for distribution to local markets by means of the truck loading facility.

Residential propane prices for the State of Michigan for the past two winters are shown in Figure G-17 (with corresponding heating oil prices). Propane prices for the 2016/17 winter period are relatively higher than the prior winter. Prices in December of 2016 were in the range of $1.80/gal.

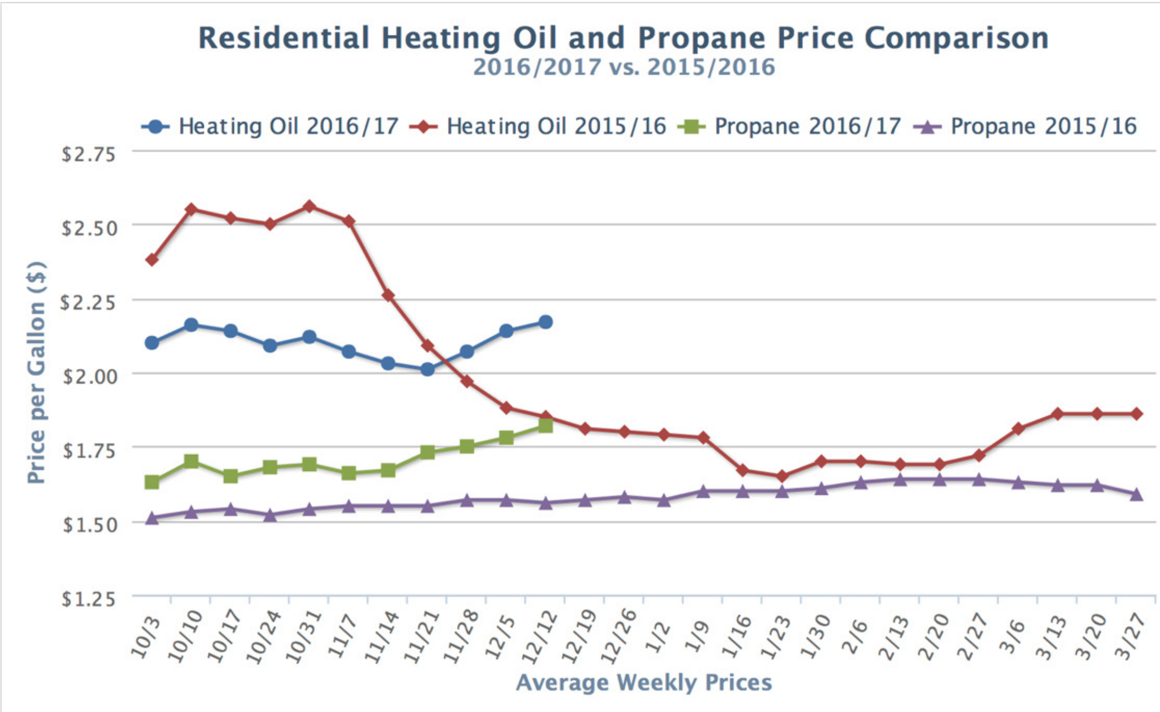


Figure G-17: Michigan State Propane Prices (SHOPP)

Appendix G.3.3 Refined Products Supply/Demand

Total distillate sales in Michigan projected for 2016 is 1.14 billion gallons and for gasoline is 4.56 billion gallons.

Michigan relies on its Detroit refinery as well as other regional refineries located in Ohio, Indiana, and Illinois for supplies of refined petroleum products. The Lower Peninsula port cities of Detroit and Port Huron have also occasionally received refined petroleum products from Canada.

Appendix G.3.4 Pipelines

Several petroleum pipelines cross Michigan. Crude oil pipelines from western Canada enter Michigan from the northwest by way of Wisconsin and from the southwest by way of Wisconsin through Illinois and Indiana. Other crude oil pipelines originating in the Gulf South enter Michigan through Ohio.

Crude oil produced in Michigan is transported by the Michigan Crude Pipeline, operated by the MarkWest Michigan Pipeline Company, L.L.C. (Figure G-18). The Michigan Crude Pipeline consists of approximately 250 mi. (~400 km) of 4 to 16-in. pipeline. It is connected to over 1,000 wells through 50 direct connects and delivers to the Enbridge Line 5 Pipeline at Lewiston, MI. The pipeline has four truck loading facilities and 15,000 barrels of storage.

Petroleum refined product pipeline systems that supply Michigan markets enter the Lower Peninsula from the Chicago, IL area to the southwest and also from the Toledo, OH, area to the southeast (Figure G-19). There are no petroleum product pipelines in the Upper Peninsula.

Figure G-18: Michigan In-State Crude Gathering Pipeline

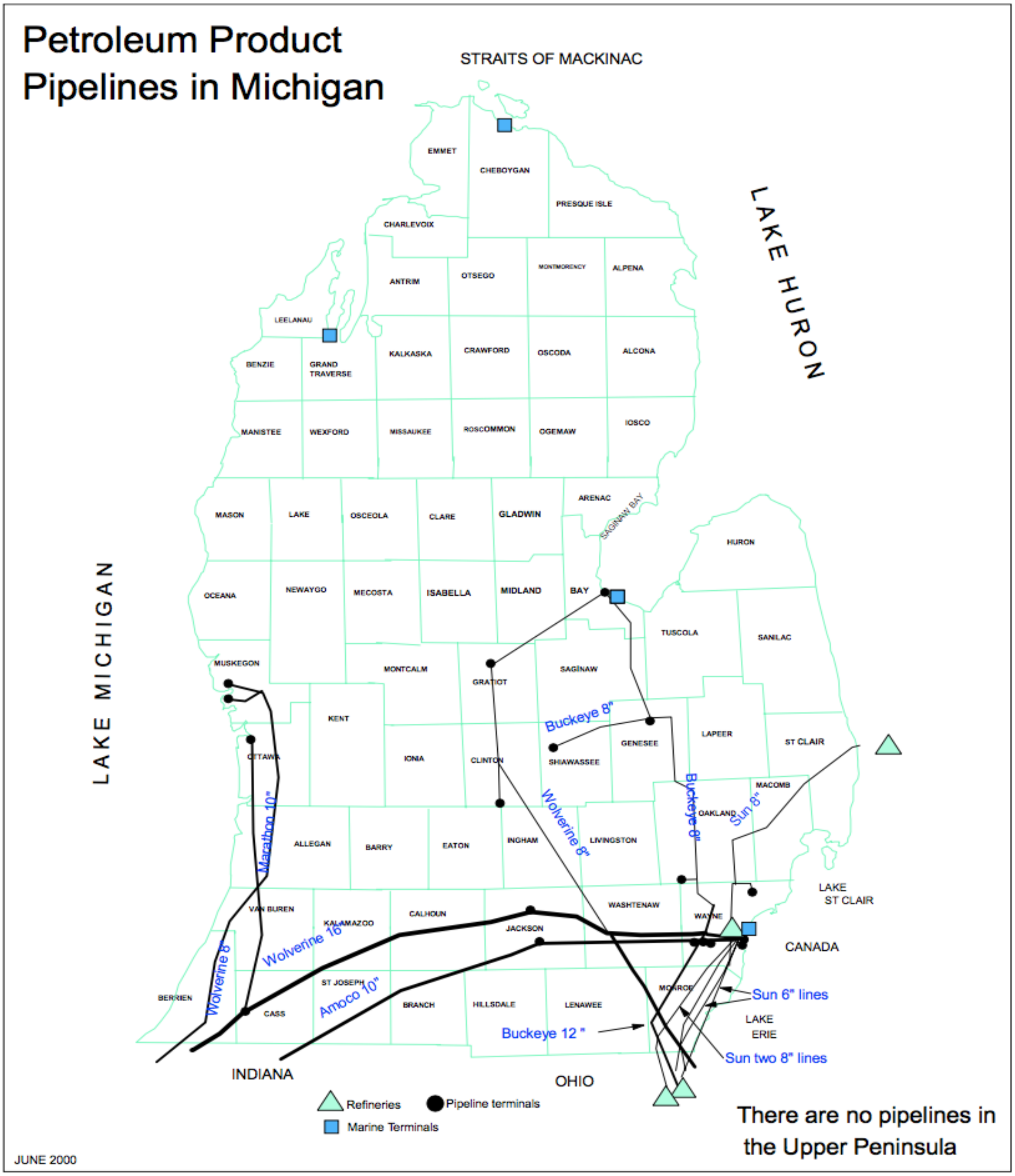


Figure G-19: Michigan In-State Product Pipelines

Appendix H Capital Cost Estimate and Costing Assumptions

Appendix H.1 Basis of Estimate Introduction

This Basis of Estimate (BOE) describes the methodology used to develop the cost estimates of various options with respect to the abandonment of the Straits of Mackinac (the Straits) Crossing. It outlines the construction assumptions and pricing sources that underlie the cost estimates to provide the appropriate -30%/+50% accuracy range.

Each alternative will require a different number and combination of materials, construction, and construction support activities for the proposed infrastructure. The methodology used for each line item across all alternatives was maintained to create a fair comparison wherever possible. Where the alternative must deviate from the assumed methodology it will be specifically outlined in the corresponding subsection.

Additional information on the rationale and logic used when creating the estimates can be found in pertinent sections of SOM-2017-01-RPT-001, *Alternatives Analysis for the Straits Pipelines*.

This document, and all support information, can be updated by the project team to reflect a more realistic execution strategy or as the project dictates. The main purpose is to support the estimate and ensure the work can be completed safely, on schedule while maintaining quality and cost objectives.

The specific assumptions, methodologies and conditions accounted for in these estimated costs are described in subsequent sections of this BOE, with supporting documentation and calculations included in various appendices.

All estimated costs are presented in Q1 2017 US dollars. Where costs are calculated in Canadian dollars, a currency conversion factor of 0.75 is used.

Appendix H.2 Scope of Cost Estimates

Included in all the cost estimates are:

- engineering and associated pre-construction support costs, such as:
    - third-party sub-contracts
    - surveys
    - environmental.
- materials and equipment costs with associated procurement support, such as:
    - procurement
    - expediting
    - materials inspection
    - logistics
    - materials delivery and receiving.

- construction and construction support costs, such as:
  - construction direct and indirect costs
  - construction management and inspection
  - surveys
  - non-destructive examination (NDE)
  - geotechnical.

Excluded from the estimate scopes are:

- weather delays (other than those normally included in a contractor's tender assumptions)
- allowance for funds used during construction (AFUDC)
- owner's costs (during all phases of the project)
- contingency
- escalation.

The excluded costs are not typically included in Class 5 estimates for a study at this high level and of this type. Collecting and interpreting all the relevant scope elements, such that the estimates cover the entire project, can be extremely challenging. Collectively, they constitute a significant portion of the overall capital cost. However, the specific costs can vary considerably across the different alternatives and respective studies. Furthermore, the complexity of these costs and their economic dependence on each other could result in significantly inaccurate cost estimates.

Appendix H.2.1 Estimate Classification

The project team Estimating Department adheres to the estimate classification guidelines published by the Association for the Advancement of Cost Engineering (AACE). The AACE guidelines suggest that the Level of Project Definition determines the Level of Accuracy possible and the Level of Effort required to develop a given project estimate. The AACE guidelines also recommend the end usage and estimating methods across the range of estimate classes, as defined in Table H-1.

Table H-1: AACE Estimate Classifications

Estimate Class	Level of Project Definition	End Usage	Estimating Methodology	Level of Accuracy (Relative to Definition)
Class 5	0% to 2%	Concept Screening	Capacity Factored, Stochastic or Judgment	0%: -50% to +100% 2%: -20% to +30%
Class 4	1% to 15%	Study or Feasibility	Primarily Stochastic	1%: -30% to +50% 15%: -15% to +20%
Class 3	10% to 40%	Budget, Authorization, or Control	Mixed, but primarily Stochastic	10%: -20% to +30% 40%: -10% to +10%
Class 2	30% to 70%	Control or Bid/Tender	Primarily Deterministic	30%: -15% to +20% 70%: -5% to +5%
Class 1	50% to 100%	Check Estimate or Bid/Tender	Deterministic	50%: -10% to +15% 100%: -3% to +3%

The Level of Accuracy values represent a typical percentage variation of actual costs from estimated costs after application of a risk-dependent contingency, to be applied at a 70% confidence level (i.e., P70 estimating) as required by Dynamic Risk Assessment Systems, Inc. (Dynamic Risk).

Availability of applicable reference cost data can have a significant impact on estimate accuracy, particularly for estimates derived by factored or stochastic methods.

Based on engineering progress at the time of estimate development, the level of project definition is assumed to be 1%, which conforms to an AACE defined Class 5 cost estimate and a proposed accuracy of -30%/+50%.

Appendix H.3 Materials and Transportation

The Class 5 capital cost estimates for the alternatives have been developed for all materials required for completion of the project. The project team used a factored approach wherein only major materials impacting cost are tabulated and quantified. Pricing has been determined for each item based on budgetary vendor pricing from previous projects or in-house pricing.

For some line items, the material and transportation costs are blended into the construction unit price. This is a result of not being able to easily extrapolate the costs from the in-house data.

Appendix H.3.1 Pipe

Pipe material and fabrication costs depend on grade of steel, pipe diameter and wall thickness. Recent budgetary quotes of $1,020 US/T have been received by the project team. This is assumed and is equated to a unit price per meter based on industry standard calculations. Table H-2 indicates unit pipe material prices in dollars-per-meter.

Table H-2: Pipe Material Costs

Pipe Size	Description	Unit Price ($/ft.)
30 in. – 11.1 mm (0.437 in.) WT	Mainline Pipe	71
30 in. – 12.7 mm (0.500 in.) WT	Mainline Heavy Wall Pipe	80
30 in. – 20.6 mm (0.811 in.) WT	Alternative 4a Conventional Crossing Pipe	129
30 in. – 17.6 mm (0.692 in.) WT	Alternative 4b Tunnel Crossing Pipe	110
Notes: WT = wall thickness		

Appendix H.3.2 Coating

After fabrication at the pipe mill, mainline pipe shall be coated with fusion-bonded epoxy (FBE) and crossing pipe shall be coated with abrasion resistant coating (dual-layer FBE/ARO) at the coating mill. Upon completion of induction bending and beveling, FBE coating will be applied to bends. Coating prices are based on recent budgetary quotes received by the project team. The unit pipe coating prices in US dollars per foot for FBE and dual-FBE are $6.40 and $18.30, respectively.

The Alternative 4a Conventional Replacement (bottom lay replacement) pipe will require a 2 in. (51 mm) concrete coating. These costs have been included at $545/T.

Appendix H.3.3 Bends

The estimates include costs for induction bends with angles greater than 24°. The unit cost of $2,500 for bending, beveling, coating and testing is included in the estimate based on recent budgetary vendor pricing.

The cost of induction bend pipe material is included in the pipe costs line item of the estimate.

Appendix H.3.4 Valve and Trap Assemblies

Valve and trap assemblies have been included in the estimate based on benchmark pricing. The unit costs of $280,000 and $360,000 have been used for the valves and traps, respectively. The cost included accounts for the materials, fabrication and testing.

Field Installation costs are included in mainline construction costs.

Appendix H.3.5 Miscellaneous Pipeline materials

A lump sum allowance equivalent to 10% of all pipeline materials is included to account for minor miscellaneous materials such as, pipe rollers, skids, field joint coating kits, imported fill materials, rock dump material, etc.

Appendix H.3.6 Facility Major Equipment

Costs of major equipment are derived from similar historical projects.

Appendix H.3.7 Rail Track

Material costs are included in the unit prices of each line item.

Appendix H.3.8 Transportation/Freight

Appendix H.3.8.1 Pipeline

The estimate includes the costs for all materials (including pipe, bends, traps, valves, etc.) to be trucked to the right-of-way (ROW). Transportation costs are based on the total number of loads required, total travel time per load and industry standard trucking rates. Trucking from the stockpile site to the ROW will be handled by the mainline contractor.

Valve and pig traps will be fabricated in a local fabrication facility and shipped to site for installation by the pipeline contractor.

Appendix H.3.8.2 Facility

A lump sum allowance of 8% for major equipment and bulk materials has been included for the freight required in the construction of proposed facilities.

Appendix H.4 Abandonment, Construction and Support Services

Appendix H.4.1 Abandonment

Abandonment costs have been included in each estimate, depending on the specific alternative and strategy. Costs were assigned to the assumed land use and chosen abandonment type outlined in Appendix I of SOM-2017-01-RPT-001, *Alternatives Analysis for the Straits Pipelines*.

The estimated costs were calculated by following the recommended unit costs for abandonment activities set out by National Energy Board (NEB) of Canada document no. MH-001-2012, Table A-3.

Those unit costs were validated by the project team construction planners as they were developed in 2010. It was assumed that while construction costs have increased on average by 12.5% since 2010, the integrity side of construction has not been as impacted by the current economic downturn. Therefore, the calculated costs were increased by 20%.

The abandonment estimates account for the following activities:

- abandonment preparation, including:
  - land access and clean up
  - pipeline purging and cleaning.
- pipeline abandonment-in-place, including:
  - basic pipeline abandonment-in-place
  - provision for post abandonment activities, including:
    - financial provisions for periodic monitoring
    - removal of some pipeline/associated facilities if problems occur.
- special treatment, including:
  - abandon-in-place and fill with concrete
  - abandon-in-place and fill with water.
- above-ground facilities, including pump stations to be abandoned.

Appendix H.4.2 Construction

Appendix H.4.2.1 Pipeline

Pipeline construction encompasses all clearing, ROW preparation, pipeline installation, testing, ROW restoration and reclamation, and support activities such as construction inspection, and third-party contractor costs incurred during the construction phase of the project.

The pipeline costs are predominantly dependent on route conditions, terrain, season of construction, industry conditions, weather, unionization, and to a lesser extent, on others. The base pipeline estimate (Base Lay Price) is produced using the known aspects of a job; costs are mainly derived from the build-up of linear crews for each activity. Unknown quantities for items that cannot be accurately defined are captured in the unit price items (UPIs). These costs are typically measured in units of dollars-per-meter.

At a high level, pipeline construction is based on base-lay, UPIs, and ancillary costs. Base-lay is broken down to ROW disposition, grading, stringing, engineering and bending, welding, joint coating, trenching, lowering-in, buoyancy control, backfill, tie-ins, valve and trap field installation, NDE, caliper pigging, testing, and cleanup and reclamation.

Labor and equipment (including miscellaneous items) for construction will be acquired to complete a construction segment of pipeline (spread) based on an assumed schedule and durations.

Appendix H.4.2.1.1 New Pipeline Construction

The project team used a contractor-type approach and estimate programs to develop the pipeline construction base-lay cost of $160/ft. ($525/m). In developing productivity rates, contractors were contacted to acquire realistic figures. Productivity rates were based on location, terrain difficulty, season, construction duration and crew mix. Using these productivity rates, a typical crew mix was developed to complete a generic spread of 47 mi. (75 km) and 62 mi. (100 km) in winter and summer construction, respectively. It is assumed each crew will have a main pipe gang and a poor boy crew using mechanized welding.

Pipeline construction costs, especially when viewed as a unit dollar-per-meter, tend to be higher for shorter pipeline segments and decrease inversely with construction length as economies of scale and efficiencies are realized.

Appendix H.4.2.1.1.1 Base-lay Costs

The Straits benchmarked construction base-lay costs have been factored to account for these option-specific conditions:

- length and assumed number of spreads
- terrain type (based on overview maps):
    - Precambrian Shield
    - agricultural

  - urban
  - forest/fishing.
- location:
  - Canada
  - United States (US).
- degree of difficulty.

Labor costs for this Class 5 estimate are based on recent Pipeline Contractors Association of Canada (PLCAC) labor rates and include wages, payroll burdens, union benefits, overtime and travel allowances as required for supervision and trades personnel.

Equipment costs are based on recent in-house equipment rental and operating rates and include fuel, lube, parts, and minor repairs for rolling stock (truck and trailers) and heavy equipment.

Construction costs for the US have been reduced by 20% to reflect the typical savings realized by current pipeline industry activity and economic climate.

Appendix H.4.2.1.1.2 Clearing

To obtain the figure for clearing costs, the project team used an overall footprint of the area to be cleared. Based on these quantities, an all-inclusive unit price of $4,860/acre was developed for clearing, under salvage, grubbing and burning/disposal of slash and un-merchantable material.

Appendix H.4.2.1.1.3 Mobilization and Demobilization

The personnel and equipment mobilization and demobilization costs assume availability within 93 mi. (150 km) of the ROW.

Appendix H.4.2.1.1.4 Horizontal Directional Drilling (HDD)

HDD unit costs were obtained from verbal discussions with specialist consultants and contractors. They represent current conditions in the trenchless crossing industry. A price of $686/ft. ($2,250/m). was applied to the complete length of the crossings for nominal pipe size (30 in.). This unit cost is for the drill and pull only. The mainline crews support the other associated activities.

Slurry/mud disposal volumes, sufficient hydrovac trucks, casing requirements, and an allowance to cover disposal fees and permits have been included as an all-inclusive lump sum cost.

Appendix H.4.2.1.1.5 Rock Blasting

The estimate includes costs for grade and ditch blasting at an additional $55/ft. ($180/m) for the Precambrian Shield terrain.

Appendix H.4.2.1.1.6 CM, Field Inspection, Survey, NDE, Geotechnical

The estimate includes these services calculated at 15% of material and construction costs. This line item also includes items such as the initial caliper and geo-pig runs. The support crews for these activities are included in the base lay costs under the contractor directs and indirects.

Appendix H.4.2.1.1.7 Unit Priced Items (UPIs)

During pipeline construction activities, the mainline contractor may be required to supply and install bedding, padding, matting, etc., and will be reimbursed for items on a unit price basis. A lump sum allowance at 10% of contractor directs and indirects have been included to reflect the anticipated items and costs for construction of the pipeline.

Appendix H.4.2.1.1.8 Contractor OH&P and Performance Bond

Contractor overhead and profit (OH&P) is included in the estimate at an industry standard rate of 10% of all construction and UPI costs.

A contractor performance bond is included in the estimate at an average assumed rate of $6.00 per $1,000 of all construction and UPI costs.

Appendix H.4.2.1.1.9 Living out allowance (LOA)

Accommodations for construction crews are assumed to be available in surrounding towns for non-local resources. An all-inclusive living out allowance (LOA) has been included in the estimate at $135 per-man-day for all contractor and HDD subcontractor crew members.

Appendix H.4.2.2 Bottom Lay Replacement

Bottom lay replacement (conventional replacement) construction costs consider the estimated duration, labor, materials, and equipment necessary to construct the new 30-in. pipeline crossing and associated pigging facilities described in SOM-2017-01-RPT-001, *Alternatives Analysis for the Straits Pipelines* (Alternative 4a).

Appendix H.4.2.2.1 Offshore Vessels Sourcing (Mobilization)

Vessels and barges for offshore work are assumed sourced from within the Great Lakes. Since the precise Great Lakes port of origin is uncertain, a nominal five days has been assigned for mobilization-demobilization of offshore vessels and barges.

All offshore vessels and barges are assumed to be US-flagged, US-registered, or both to comply with the *Jones Act*.

Offshore activities such as pipeline jetting and rock dumping would typically be supported by specialized (non-US) vessels. The use of Great Lakes' barges as support vessels may result in a less efficient operation. Total vessel spread and activity durations have been calibrated to account for this.

Appendix H.4.2.2.2 Onshore Equipment Sourcing (Mobilization)

Onshore equipment (such as side booms, cranes, etc.) are assumed to be locally sourced. Again, a nominal five days has been assigned for mobilization-demobilization. For conservatism, the higher-fueled day rate has been applied to the mobilization-demobilization duration. Also for conservatism, an equipment mobilization-demobilization charge is applied to each activity; whereas, in practice, certain equipment may transfer from one activity to another, depending upon timing. A 20-day nominal mobilization duration is included for specialized winching equipment.

Appendix H.4.2.2.3 Equipment, Vessels and Crew Day Rate Cost

Equipment, vessel and day rate costs were based upon in-house data. No vendors or contractors were contacted for day rates due to project confidentiality.

Appendix H.4.2.2.4 Pigging Facilities

The existing twin 20-in. Straits crossing pipelines have pig launching and receiving facilities located on each side of the Straits. The cost of converting these twin launchers-receivers to a single launcher-receiver each side of the Straits, within the existing facilities site, is included in the estimate.

Appendix H.4.2.2.5 Offshore Survey

The estimate for the initial survey is based on 10 survey lines. A slow 3 knot survey rate is assumed to allow for magnetometer deployment and to account for discontinuous operations resulting from the relatively short survey length. The duration for survey activities accompanying offshore work (such as pipe winching/trenching/rock dumping, etc.) are dictated by the duration of those offshore operations.

Appendix H.4.2.2.6 Bottom Current Measurement Program

The bottom current measurement program is based on 16.6 ft. (5 m) deployed for one year. Meters are assumed to require seven offshore trips for initial deployment, servicing and data retrieval.

Appendix H.4.2.2.7 Pipeline Concrete Coating

Concrete coating of the pipeline, to modern offshore pipeline standards, is assumed to be completed out at an existing established coating yard. The cost of transporting uncoated line pipe to a coating yard and then transporting the coated pipe to site has been included.

Appendix H.4.2.2.8 Pipeline Temporary Buoyancy

Temporary buoyancy (of 331 T net uplift) to reduce pipe winch force requirements is assumed fabricated onsite using thin-walled 20-in. pipe that is internally air-pressurized to prevent collapse. In practice, buoyancy uplift may be adjusted (+ or -) to suit available winch capability. Buoyancy removal-retrieval has been estimated based on the use of divers, for cost conservatism. However, a diver-less retrieval system could be configured that would reduce costs.

Appendix H.4.2.2.9 Pipeline Trenching

Offshore trenching is assumed by jetting. Ploughing may also be viable, although costs are expected to be similar to jetting.

Pre-trenching of shallower regions (less than 100 ft. or 30 m) is required to aid lateral stability during the winched installation of the pipeline: this equates to approximately 3 mi. (4.8 km) of pre-trenching. A single pass of the pre–jetting spread at 50 m/h (164 ft/h) is assumed and five days of weather downtime are included.

Post-trenching of the entire offshore route is required for protection from ship anchors. Two passes of the jetting spread is assumed at 70 m/h (230 ft/h), and five days of weather downtime has been added.

Appendix H.4.2.2.10 Rock/Gravel Dumping

In the event the specified trench depth is not achieved, rock/gravel dumping may be performed. It is assumed that 10% of the pipeline route will require rock/gravel dump to provide 3.3 ft. (1.0 m) of cover over the pipeline. The equipment and vessel spread for rock/gravel dumping is developed based in a similar project carried out in the Straits. Rock/gravel dumping duration is estimated at six days and five days of weather downtime added.

Appendix H.4.2.2.11 Pipeline String Fabrication

An available fabrication site length of 3,281 ft. (1,000 m) is estimated based upon preliminary desktop review of the north bank of the Straits. A total of seven strings are required. All seven strings will be prefabricated prior to commencing the winch operation.

Appendix H.4.2.2.12 Pipeline Winching

Estimates indicate that it will take one day to pull each string. Three days are allowed to lift the subsequent string onto the launch rollers, perform the tie-in weld, field joint coat the weld and allow for curing of fast-setting concrete at the field joint.

Appendix H.4.2.2.13 Bathymetric Survey and Pigging

After construction of the crossing, a baseline bathymetric survey will be completed. A caliper pig with an inertial measurement unit (IMU) and magnetic flux leakage (MFL) capabilities will also be run through the pipeline. These costs were based upon in-house data. No vendors or contractors were contacted for day rates due to the confidentiality of the project.

Appendix H.4.2.3 Tunneling

Tunneling construction costs consider the estimated duration, labor, materials, and equipment necessary to construct the launch and retrieval shafts, and the approximately 3.75-mi.-long (6-km-long) tunnel as described in SOM-2017-01-RPT-001, *Alternatives Analysis for the Straits Pipelines* (Alternative 4b).

Rates for materials, labor, and equipment necessary for construction of the tunnel alternative are derived from previously bid projects of similar size and scope, available industry data, and contractor quotes. As mentioned, some material costs are blended into the unit price of the construction line items because the costs are not easily extrapolated.

Costs should be adjusted to the midpoint of the construction schedule depending on the anticipated start date. The site is assumed to be free of environmental contamination.

Appendix H.4.2.3.1 Launch and Retrieval Shafts

Work productivity for construction of the launch and retrieval shafts is derived from previous experience and conservative assumptions for drilling and blasting advancement rates. Launch and retrieval shafts are expected to be constructed simultaneously. Durations of construction are based on two 10-h shifts per day and a five-day workweek. The total estimated duration for shaft construction, including drilling and blasting, excavation, and shoring, is conservatively estimated to be 152 days. This duration takes into account potential work delays and reduced production during the winter season. An additional 100 days would be added for shaft work after completion of tunneling and carrier pipe placement to facilitate connection of the carrier pipe at the surface and to backfill the shafts.

Appendix H.4.2.3.2 Tunneling, Segmental Liner Installation and Carrier Pipe Placement

Similar to the shafts, work productivity for tunneling, segmental liner installation, and carrier pipe placement is derived from experience on previous projects. It is estimated that the tunnel will be constructed during continuous work shifts of two 10-h shifts per day, five work days per week. The estimated advancement rate for the tunnel is 3 ft. (0.9 m) per hour, including assembly of the segmental liner and grouting of the contact annulus between the liner and the surrounding rock formation. Productivity was reduced by 40% for six-months-per-year to account for surface work during the winter season. Upon completion of the tunnel installation and removal of the tunnel boring machine (TBM), a grout foundation will be installed within the liner to provide a flat working surface. The he carrier pipe will then be installed from the middle of the tunnel, with two crews working simultaneously and outward toward the launch and retrieval shafts, respectively. Based on these criteria, the total estimated duration for tunneling, segmental liner installation, carrier pipe placement and backfill grouting is 575 work days.

Appendix H.4.2.4 Facilities (Alternative 1 – Northern and Southern Route)

Construction costs of pump stations along the route of these options are derived from historical projects of similar capacity. Costs are further refined considering local labor rates and productivity.

Appendix H.4.2.5 Facilities (Alternative 3 Rail)

Construction cost of additional facilities at Sarnia and Lake Superior are factored based on major equipment required for these facilities.

Appendix H.4.2.5.1 Superior

Construction costs of an additional facility at Superior are based on this major equipment:

- 5 x 350 kbbl Storage tanks
- 2 x 50 kbbl NGL spheres
- 3 x 1,072 hp Pump with VFD
- 3 x 904 hp Pump with VFD
- 2 x 904 hp NGL 100% pumps with VFD
- 1 x Custody metering with positive displacement (PD) flow meters and prover (7 x 12 in. PD meters)
- 1 x Custody metering with turbine flow meters and prover (3 x 6 in. turbine meters)
- 1 x Vapor collection system with combustor
- 150 x Rail car loading arms without compressor skids.

Appendix H.4.2.5.2 Sarnia

Construction cost of additional facility at Sarnia is based on following major equipment:

- 2 x 350 kbbl Storage tanks
- 2 x 50 kbbl NGL spheres
- 3 x 1,072 hp Pump with VFD
- 3 x 904 hp Pump with VFD
- 2 x 904 hp NGL pumps with VFD
- 1 x Custody metering with PD flow meters and prover (7 x 12 in. PD meters)
- 1 x Custody metering with turbine flow meters and prover (3 x 6 in. turbine meters)
- 1 x Vapor recovery unit
- 150 x Rail car unloading arms with compressor skids.

Appendix H.4.3 Construction Support Services

Construction support costs have been included based on a combination of crewed-up estimates, in-house data from other similar projects, and budgetary quotations where available. These services vary depending on the alternative and include items such as:

- construction management
- supervision
- field inspection
- surveys
- NDE

- geotechnical
- site reconnaissance.

Appendix H.5 Engineering and External Consultants

Engineering, procurement, and external consultant costs are included in the estimates based on typical benchmarks for similar projects. This allowance accounts for the engineering design, engineering support during construction and additional external design consultants.

Engineering and procurement costs consider the costs for conceptual engineering, front-end engineering design (FEED), detailed design and beyond. This includes engineering during detailed design, pre-construction bridging, construction support and commissioning, as-building, and project close-out. Detailed design, the largest engineering cost, includes all engineering that will be used to develop the engineering designs, drawings, reports and calculations required for the final construction package.

Appendix H.5.1 Abandonment Engineering and Project Management

Depending on the alternative and its assumed abandonment strategy, an allowance for Engineering and Project Management has been included. This allowance accounts for these abandonment categories:

- regulatory
- legal and finance support
- external relations and land support
- environment
- health and safety support
- operations support
- stakeholder consultation
- detailed cost estimates
- planning
- applications
- detailed engineering and environmental studies
- engineering and project management
- construction management
- project and cost control.

A factor was applied to the sum of the costs outlined in the abandonment construction Appendix H.4.1. The factor used for the Straits Crossing segment only was 20%, while the factor used for the full length of replacement from Superior to Sarnia was 5%.

Appendix H.5.2 Pipeline

A lump sum allowance of 5% for pipeline material and construction costs has been included for new pipeline construction based on typical benchmarks for similar projects. This allowance accounts for the aforementioned engineering design, engineering support during construction and additional external design consultants, including as-built/legal surveys, cathodic protection (CP)/alternating current (AC) mitigation design and geotechnical design costs.

Appendix H.5.3 Facilities

Similar to the pipelines' portion of the estimate, the facilities estimate includes an allowance at 5% of the facility total installed cost (TIC).

Alternative 1 estimates have had this allowance scaled back as possible savings would be realized depending on the quantity of pump stations. It has been determined, based on comparisons to a recent detailed proposal, that these costs would be included in the estimates.

- Northern Route (17 pump stations) – total of $22.5 million
- Southern Route (10 pump stations) – total of $18.75 million.

Appendix H.5.4 Bottom Lay

The bottom lay replacement estimate includes an allowance at 20% of the TIC to account for engineering and external consultants. This allowance is based on typical benchmarks for similar projects.

Appendix H.5.5 Tunneling

The tunneling estimate includes an allowance at 3% of the TIC to account for engineering and external consultants. This allowance is based on typical benchmarks for similar projects.

Appendix H.6 Owner's Costs

These costs are the owner's responsibility and may include items such as owner's construction management, environmental planning, legal and regulatory services, government relations and public affairs, insurance, commissioning and owner's project coordination and overhead. These costs are difficult to determine because publicly-available cost breakdowns are often not available. Moreover, owners are typically unwilling to share internal project costs with other entities to maintain competitive advantage.

A large portion of owner's costs pertain to land permitting and acquisition. The costs of partial takings, commercial properties, remainder damages, court costs, utility relocations, and other ROW-related items are difficult to anticipate. Accurate estimation procedures are needed to facilitate budgeting and timely completion of projects. Land acquisition for these proposed options can be very expensive and time consuming. Determining the just compensation, even at a high level, would require significant speculation.

Because of this variability and uncertainty, owner's costs have been excluded from the estimates.

Appendix H.7 Risk Management, Finance, and Contingency

Accurate estimation procedures are needed to determine the proper amount of contingency and escalation funds to be added to individual estimates.

Contingency and escalation amounts are not included in the estimate and may be applied to the estimate based on internal risk analysis subsequent to delivery of the estimate.

An example of one such risk is the extra costs inherent in dealing with landowners and stakeholders for the Alternative 1 new pipeline construction. Stakeholders may vehemently oppose the construction of another large-diameter pipeline, and also there may be insufficient construction space in existing ROWs. This would lead to either significant route deviations or possibly the purchase and demolition of existing residences – both of which would increase construction costs. However, at this very early stage of the project, there is insufficient detail to the design and route to allow quantification or even approximation of these additional costs.

For a pipeline or facilities construction estimate of this accuracy, an overall contingency of 15 to 20% is normally added. This is predominantly influenced by unknowns related to the construction activities. In the situations that the project team has considered for this study, the contingency may be variable (depending on the scope of work being undertaken). For example, if there is a major delay or several issues in the execution of work (as depicted in Appendix H.4.2.1), the result could increase costs by 25% or more. As the volume of work in any construction program increases, the impact of delays and risks will decrease – but this value is not expected to be less than 15%. These are considered unknown factors, and consist of increased scope, construction constraints, potential delays, and excessive bad weather, etc. As the program scope increases, these factors are less likely to occur for every component within the program and hence the contingency can be reduced.

Appendix H.8 Proposed Alternatives Cost Estimates

Appendix H.8.1 Estimate Executive Summary

Estimated Costs Class 5 Estimate (-30% to +50%) All estimated costs are presented in Q1, 2017 US dollars	Alternative 1 Northern Route	Alternative 1 Southern Route	Alternative 3 Rail	Alternative 4a Bottom Lay Replacement	Alternative 4b Tunnel Replacement
New Materials and Transportation Subtotal	$978,499,000	$611,001,000	$460,405,000	$10,023,000	$2,515,000
Abandonment, Construction and Support Services Subtotal	$2,887,768,000	$1,536,162,000	$601,388,000	$12,547,000	$145,221,000
Engineering & External Consultants Subtotal	$157,687,000	$90,190,000	$58,093,000	$4,716,000	$5,118,000
Owner's Costs Subtotal	$0	$0	$0	$0	$0
Operational Expenditure Subtotal	$0	$0	$0	$0	$0
CONTINGENCY	$0	$0	$0	$0	$0
ESCALATION	$0	$0	$0	$0	$0
AFUDC	$0	$0	$0	$0	$0
TOTAL PROJECT COST =	**$4,023,954,000**	**$2,237,353,000**	**$1,119,886,000**	**$27,286,000**	**$152,854,000**

Appendix H.8.2 Summarized Estimated Costs

INPUT PARAMETERS	Alternative 1 Northern Route	Alternative 1 Southern Route	Alternative 3 Rail	Alternative 4a Bottom Lay Replacement	Alternative 4b Tunnel Replacement
PIPELINE LENGTH	1262 mi	760 mi	20 mi	4.2 mi	3.7 mi
NUMBER OF SPREADS	23	14	2	1	1
ABANDONMENT LENGTH (DUAL NPS 20 ACROSS STRAIT OF MACKINAC)	633 mi	633 mi	633 mi	7.3 mi	7.3 mi
PUMP STATIONS TO BE ABANDON	15	15	15	0	0
PIPELINE DIAMETER	30	30	30	30	30
PIPE WALL THICKNESS	0.44 in	0.44 in	0.44 in	0.81 in	0.69 in
PIPE MATERIAL	STEEL	STEEL	STEEL	STEEL	STEEL
STEEL PRICE	$1,020 / ton	$1,020 / ton	$1,020 / ton	$1,020 / ton	$1,020 / ton
LOCATION	ONT	USA	ONT	USA	USA
GEOLOGY/TERRAIN TYPE #1	PRECAMBRIAN SHIELD	PRECAMBRIAN SHIELD	PRECAMBRIAN SHIELD	PRECAMBRIAN SHIELD	PRECAMBRIAN SHIELD
GEOLOGY/TERRAIN TYPE #2	AGRICULTURAL	AGRICULTURAL	AGRICULTURAL	AGRICULTURAL	AGRICULTURAL
GEOLOGY/TERRAIN TYPE #3	URBAN	URBAN	URBAN	URBAN	URBAN
GEOLOGY/TERRAIN TYPE #4	FOREST/FISHING	FOREST/FISHING	FOREST/FISHING	FOREST/FISHING	FOREST/FISHING
ROW WIDTH	115 ft	115 ft	115 ft	N/A	N/A
NEW MATERIALS & TRANSPORTATION	**$978,499,000**	**$611,001,000**	**$460,405,000**	**$10,023,000**	**$2,515,000**
Pipe	$470,704,338	$283,393,842	$6,690,546	$0	$1,950,362
Heavy Wall Pipe	$28,363,877	$35,454,846	$2,176,046	$3,194,138	$0
Induction Bends	$777,150	$1,004,850	$127,800	$119,700	$0
Coating	$43,077,615	$25,935,455	$609,414	$450,738	$0
Concrete Coating	$0	$0	$0	$1,311,647	$0
Valves, Actuators, Assemblies, Fittings	$20,400,000	$12,300,000	$2,250,000	$0	$0
Pigging Traps, Gate Valves, Assemblies, Fittings	$3,780,000	$2,100,000	$1,673,625	$3,862,520	$0
Facility Materials	$321,062,855	$193,885,556	$412,262,810	$0	$0
Material Transportation - Facilities	$18,534,267	$11,190,880	$32,980,965	$0	$0
Material Transportation - Pipelines	$15,088,619	$9,716,188	$251,365	$424,820	$565,011
Pipeline Miscellaneous Materials	$56,710,298	$36,018,899	$1,352,743	$659,577	$0
Rail Crossings (16' Wide Timber Planks)	$0	$0	$29,925	$0	$0
ABANDONMENT, CONSTRUCTION AND SUPPORT SERVICES	**$2,887,768,000**	**$1,536,162,000**	**$601,388,000**	**$12,547,000**	**$145,221,000**
Pipeline Abandonment	$200,637,750	$200,637,750	$200,637,750	$967,395	$967,395
Above-ground Abandonment	$5,625,000	$5,625,000	$5,625,000	$0	$0
Clearing & Timber Salvage	$44,310,000	$9,143,400	$2,520,000	$34,125	$34,125
Equipment Mob / Demob	$12,937,500	$7,875,000	$2,979,701	$2,469,162	$4,466,007
Contractor Directs & Indirects	$1,069,675,070	$515,210,228	$21,441,909	$8,004,219	$0
HDD Subcontract	$54,000,000	$67,500,000	$4,743,750	$0	$0
Valve Fabrication (Incl. Materials & Testing)	$17,850,000	$10,762,500	$2,010,000	$0	$0
Trap Fabrication (Incl. Materials & Testing)	$2,700,000	$1,500,000	$1,155,750	$0	$0
Pipeline Rock Blasting	$278,456,400	$58,676,940	$0	$0	$0
Pipeline UPIs	$106,967,607	$51,521,023	$2,144,191	$0	$0
Pipeline Contractor OH&P	$231,388,137	$106,956,854	$5,171,295	$0	$0
Pipeline Contractor Performance Bond	$9,255,525	$4,278,274	$206,852	$0	$1,941,642
Pipeline Contractor Accommodations (LOA)	$120,221,719	$72,381,094	$1,743,328	$521,456	$0
Pipeline - CM, Field Inspection, Survey, NDE, Geotech	$387,999,728	$196,759,409	$8,887,247	$437,903	$9,825,375
Facility Pump Station Direct Field Costs	$198,438,355	$129,735,936	$0	$0	$0
Facility at Superior	$0	$0	$98,968,007	$0	$0
Facility at Sarnia	$0	$0	$77,715,733	$0	$0
Facility Accommodations (LOA)	$30,416,513	$20,742,564	$44,527,665	$0	$0
Facility Indirect Field Costs - CM, Supervision, Survey, etc.	$116,888,429	$76,856,234	$93,716,000	$0	$0
Rail Grade Construction (Trackwork Only)	$0	$0	$9,053,033	$0	$0
Rail Ballasted Track Construction	$0	$0	$16,415,990	$0	$0
Rail Yard Track Turnouts	$0	$0	$1,350,000	$0	$0
Rail Mainline Connections	$0	$0	$375,000	$0	$0
Tunnel Launch and Reception Shaft Excavation	$0	$0	$0	$0	$11,750,550
Tunnel Launch and Retrieval Shaft Shoring	$0	$0	$0	$0	$6,393,975
Tunnel Tunneling Operation and Liner Install	$0	$0	$0	$0	$88,388,475
Tunnel Carrier Pipe Placement and Backfill Grouting	$0	$0	$0	$0	$12,039,874
Tunnel Backfill Launch and Retrieval Shafts, Break Down Site	$0	$0	$0	$0	$9,413,408
Bathymetric Survey and Caliper Pig (including IMU and MFL)	$0	$0	$0	$112,500	$0
ENGINEERING & EXTERNAL CONSULTANTS	**$157,687,000**	**$90,190,000**	**$58,093,000**	**$4,716,000**	**$5,118,000**
Abandonment Engineering and Project Management	$5,853,657	$5,853,657	$5,853,657	$130,159	$130,159
Pipeline Engineering and External Consultants Design and Support	$129,333,243	$65,586,470	$2,962,416	$0	$0
Facility Engineering and External Consultants Design and Support	$22,500,000	$18,750,000	$47,848,858	$0	$0
Rail Engineering, Design and Coordination	$0	$0	$1,427,686	$0	$0
Crossing Replacement (Conventional) Engineering and Project Management	$0	$0	$0	$4,585,954	$0
Crossing Replacement (Tunnel)	$0	$0	$0	$0	$4,987,500
OWNER'S COSTS	**$0**	**$0**	**$0**	**$0**	**$0**
OPERATIONAL EXPENDITURE SUBTOTAL	**$0**	**$0**	**$0**	**$0**	**$0**
CONTINGENCY	**$0**	**$0**	**$0**	**$0**	**$0**
ESCALATION	**$0**	**$0**	**$0**	**$0**	**$0**
AFUDC	**$0**	**$0**	**$0**	**$0**	**$0**
TOTAL INSTALLED COST	$4,023,954,000	$2,237,353,000	$1,119,886,000	$27,286,000	$152,854,000

Appendix I Abandonment Assumptions

Appendix I.1 General Assumptions

The abandonment strategy developed for Line 5 is intended to be compliant with applicable regulations and avoid potential damage to the environment or infrastructure. In general, abandonment in place imposes less risk and disruption to the environment than excavating and physically removing the pipeline.

The licensing and notification requirements associated with decommissioning the line were not considered.

The abandonment strategy chosen for any segment may be altered at the abandonment stage depending on individual legal agreements with landowners.

Abandonment costs were estimated using the National Energy Board's *Abandonment Cost Estimates* document (MH-001-2012) as guidance.

Post abandonment activities were assumed to be consistent with the activities described in MH-001-2012.

The abandonment strategy would follow industry-accepted practices, such as:

- Purge the pipeline with nitrogen.
- Flush the pipeline with an environmentally-friendly solvent or detergent, using a foam pig.
- Monitor the hydrocarbon content of the discharge, and repeating the solvent flush until the hydrocarbon content is below the target threshold.

Appendix I.1.1 Regulations, Codes and Industry Documents Consulted

- Code of Federal Regulations
  - Title 49 Subchapter D Part 195 Transportation of Hazardous Liquids by Pipeline
  - Title 49 Subtitle VIII Chapters 601 and 603
- ASME B31.4 - 2016
- CEPA - Pipeline Abandonment Assumptions - Technical and environmental considerations for development of pipeline abandonment strategies
- National Energy Board - *Reasons for Decision Abandonment Cost Estimates MH-001-2012*.

Appendix I.2 Abandonment Strategies – Entire Line

The line will be abandoned using different methods per the land use types outlined in Table I-1.

Table I-1: Land Use Type and Required Abandonment Activity

Land Use Type	Abandonment Type
Agricultural/Grassland	
Cultivated	A
Non-Cultivated	A
Non-Agricultural	
Forest	A
Urban	A
Other	
Wetland	A
Other (shrubland, exposed rock, barren)	A
Road Crossings	A+
Rail Crossings	A+
River crossings	A
Airport Crossings	A+
Water Crossings	A++
Notes: Abandonment type A = abandon in place Abandonment type A+ = abandon in place and fill with concrete or similar material Abandonment type A++ = abandon in place and fill with water	

Table I-1 is consistent with the abandonment strategies outlined in the *CEPA - Pipeline Abandonment Assumptions* document with the following noted differences:

- Airport crossings which are not discussed in the document and were assumed to require filling abandoned segments with concrete or another similar material to mitigate future soil subsidence issues.
- Water crossings which will be filled with water to mitigate potential future buoyancy issues.
- The land cover data sets available for each state did not identify any deep tillage cultivation or proposed future development urban lands and therefore no removal abandonment type was included.
- Regardless of which abandonment activities take place, the line will first be cleaned and purged of any hydrocarbons. Each pump station will serve as a segmentation location for cleaning and purging.
- Wherever the line comes above ground it will be cut at pipeline burial depth and sealed.
- All surface equipment will be removed at each pump station and the sites will be reclaimed.

Appendix I.2.1 Abandonment Type Length Determination Methodology

GIS data sets from Wisconsin and Michigan were used to measure the length of each land cover category in each state combined with the centerline data for Line 5:

- Wisconsin - Wiscland 2.0, http://dnr.wi.gov/maps/gis/datalandcover.html
- Michigan - Upper and Lower Peninsula Land Cover 2001, http://www.mcgi.state.mi.us/mgdl/?rel=thext&action=thmname&cid=5&cat=Land+Cover+2001

The total pipeline length of each land cover type determined through GIS measurement is listed in Table I-2.

Table I-2: Lengths of Abandonment Activity Determined Through GIS Measurements

Land Use Type	Length (m)	Length (mi.)	Length in Michigan (mi.)	Abandonment Type
Agricultural/Grassland				
Cultivated	176,577	110	108	A
Non-Cultivated	38,323	24	0	A
Non-Agricultural				
Forest	612,038	380	331	A
Urban	11,972	7	5	A
Other				
Wetland	104,224	65	51	A
Other (shrubland, exposed rock, barren)	52,810	33	33	A
Road Crossings - Michigan	17,994	11	11	A+
Water Crossings*	12,969	8	8	A++
Notes: *Includes the Mackinac Straits Crossing.				

The total number of road, river, rail, and airport crossings is outlined in Table I-3

Table I-3: Type and Total Number of Crossings

Crossing Type	Number of Crossings	Number of Crossings - Michigan
Roads	121	101
River	49	38
Rail	16	15
Airport	2	2

As roads are not a defined land cover type in the Wisconsin data set, the total length of road crossings was calculated. The number of major road crossings were determined by conducting an intersect of publicly available road data and the pipeline centerline. Table I-4 outlines the pipeline lengths requiring A+ abandonment that were assumed for each road type

Table I-4: Length of Pipeline to be Abandoned According to Different Road Types

Road Type	Width for Abandonment m (ft.)
Local Road	30 (100)
County Highway	50 (165)
State and US Highway	100 (330)

Roads are a land cover type included in the Michigan land cover data set and therefore the length of A+ abandonment type was determined through the GIS measurements.

The intersect method was used to determine the number of rail crossings in both states. Each rail crossing was assumed to require 30 m (100 ft.) of A+ abandonment type.

The intersect method was used to determine the number of river crossings in both states. Each river crossing was assumed to require 30 m (100 ft.) of A abandonment type.

Water is a land cover type included in the Michigan land cover data set and therefore the length of A++ abandonment type was determined through GIS measurements.

Airport crossings were measured using Google earth based on the fence line surrounding each airport.

The total length for each calculated A+ abandonment type is listed in Table I-5.

Table I-5: Calculated Pipeline Lengths

Land Cover Type	Length (m)	Length (mi.)	Length in Michigan (mi.)	Abandonment Type
Road Crossings - Wisconsin	1,480	1	0	A+
Rail Crossings	480	0	0.3	A+
River crossings	1,470	1	1	A
Airports	1,800	1	1	A+

In order to determine the final length of each abandonment type, the total length of the type A+ abandonment in Table I-5 was subtracted from the total length of the type A abandonment in Table I-2.

The final total length of each abandonment type is shown in Table I-6.

Table I-6: Total Length of Each Abandonment Activity

Abandonment Type	Length (m)	Length (mi.)	Length in Michigan (mi.)
Abandon in place	992,184	617	527
Abandon in place filled with concrete	21,754	14	13
Abandon in place filled with water	12,969	8	8

Appendix I.2.1.1 Pump Station Abandonment

The total area of each pump station was determined by measuring the fence line of each station using Google Earth. Table I-7 lists the area of each station.

Table I-7: Pump Station Footprints

Pump Station	Footprint (ft^2)
Ino, WI	34,821
Saxon, WI	97,962
Gogebic, MI	59,200
Iron River, MI	119,385
Rapid River, MI	81,030
Manistique, MI	87,118
Gould City, MI	91,773

Pump Station	Footprint (ft^2)
Naubinway, MI	606,468
Mackinaw North Sender, MI	63,311
Mackinaw South Receiver, MI	90,749
Indian River, MI	37,309
Lewiston, MI	845,629
West Branch, MI	74,693
Bay City, MI	351,541
North Branch, MI	60,164

Appendix I.2.1.2 Straits of Mackinac Abandonment

For the scenario where only the line crossing the Straits of Mackinac (the Straits) is to be abandoned, the total length of line (12,969 m [8 mi.]) was determined through GIS measurement as described previously. This includes both 20 in. pipelines.

The abandonment strategy for this section of line is to abandon it in place with a water fill. The line will be cut and sealed at either end of the Straits.

Appendix I.2.1.2.1 Pipe Removal from the Straits

While abandonment in place is the preferred and recommended strategy for the pipeline in the Straits, the following rough estimate is provided to approximate the cost of the complete removal of the pipeline from the Straits:

- Removal cost estimate: $950,000/mi. of pipeline (for each of the two pipelines)

The pipe removal estimate is based upon the following activities:

1. Internal cleaning of the crossing pipelines using scraper/brush pig trains with slugs of detergent and solvent. The precise cleaning program is not determined within this work scope. The pigs/liquid slugs are propelled by compressed air rather than water to minimize the volume of contaminated water to be disposed of. The pipeline is then flooded with lake water in a controlled manner prior to commencing removal operations.
2. Excavation of a short nominal length (100 m [330 ft.]) of each onshore pipeline, including both banks, using backhoes.
3. Excavation of the pipelines in shallow water (less than approximately 30 m [100 ft.]) adjacent to each bank, using a barge mounted long reach excavator.

4. Removal of lakebed material along the length of the subsea pipelines where partial burial has naturally occurred (based on video/photograph observations), and to facilitate access for pipeline cutting. It has been assumed that the pipeline is half buried along 50% of its length. Lakebed material is assumed removed by jetting. Jetting around pipe supports is also allowed for.
5. Cutting of the pipeline into segments using subsea cutting tools (such as diamond wire or a Wachs type machine). This operation to be carried out by divers. Allowing for potential added weight of attached mud, marine growth, dynamic effects and “stiction”, a reasonable pipeline segment length of 50 m (165 ft.) for retrieval has been allowed for.
6. Attachment of lift cables and lifting from the lakebed to a barge and hauling of pipe segments by barge to shore.
7. Hauling by truck to disposal destination.
8. Project Management.

Appendix J Alternative 6 Inputs and Assumptions

Appendix J.1 Supply of Propane to Alternate Terminals

Incremental Cost Model for Alternate Supply of Propane to the Rapid River Facility

Base Cost

Rapid River: Edmonton NGL Price + Pipe Cost$_{EDM-RR}$ + De-Propanizing Cost$_{RR}$

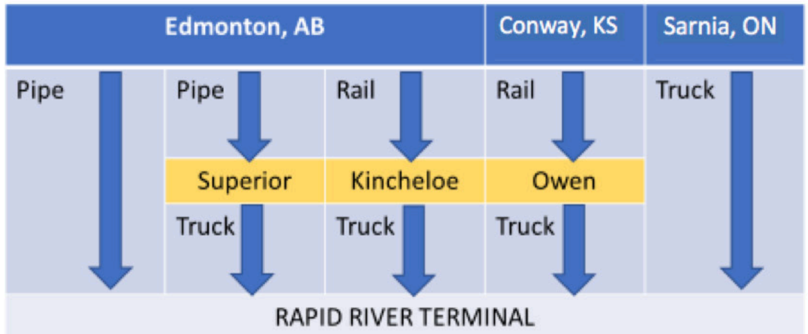
Alternate Supply Cost:

A. Superior: Edmonton NGL Price + Pipe Cost$_{Edm-Sup}$ + De-Propanizing Cost$_{Sup}$ + Truck Cost

B. Kincheloe: Edmonton Propane Price + Rail Cost + Truck Cost

C. Owen: Conway Propane Price + Rail Cost + Truck Cost

D. Sarnia: Sarnia Propane Price + Truck Cost



Net Incremental Cost = Alternate Supply Cost - Base Cost

A. Superior: Truck Cost - Pipe Cost $_{SUP\ to\ RR}$.

B. Kincheloe: Rail Cost + Truck Cost – Pipe Cost$_{EDM-RR}$.

C. Owen: (Conway – Edmonton) Propane Price + Rail Cost + Truck Cost - Pipe Cost$_{EDM-RR}$

D. Sarnia: (Sarnia- Edmonton) Propane Price + Truck Cost - Pipe Cost$_{EDM-RR}$

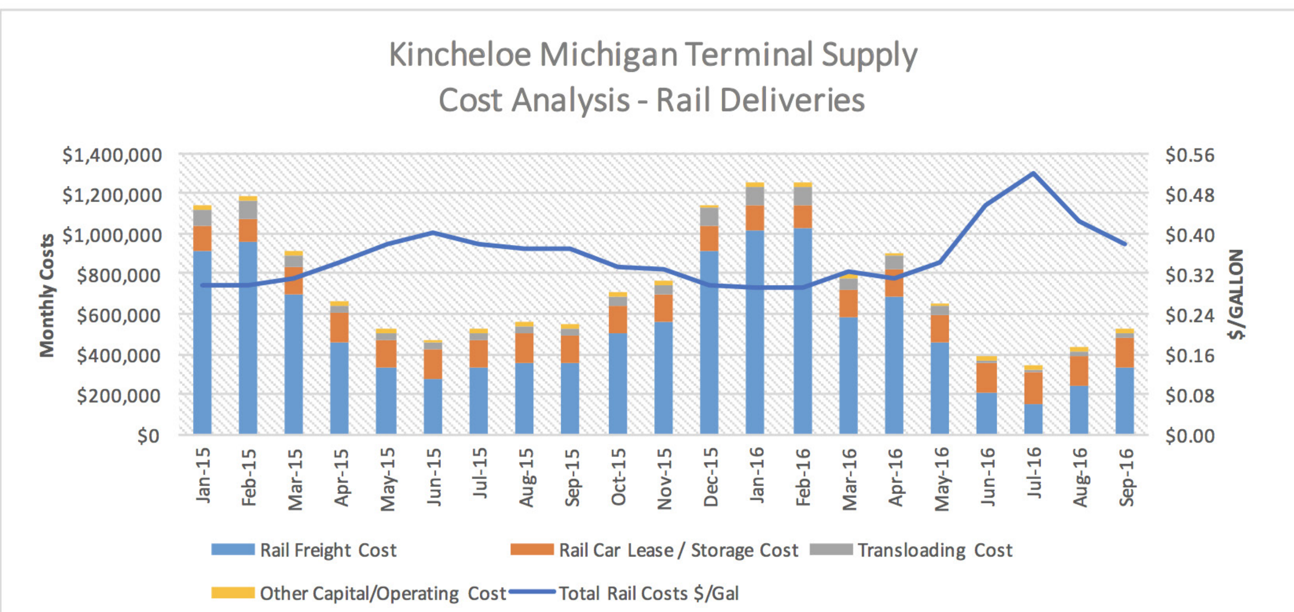
Notes:

1. De-Propanizing Cost$_{SUP}$ = De-Propanizing Cost$_{RR}$ = De-Propanizing Cost$_{EDM}$
2. Edmonton NGL Price = Edmonton Propane Price - De-Propanizing Cost $_{EDM}$
3. (Sarnia – Edmonton) Propane Price : Winter $0.29/Gal; Summer $0.45/Gal
4. (Conway – Edmonton) Propane Price : Winter $0.11/Gal; Summer $0.30/Gal
5. Pipe Cost $_{RR}$ US$3.44 / barrel (US$0.082 / Gal)
6. Pipe Cost $_{SUP\ to\ RR.}$ US$0.63 / barrel (US$0.015 / Gal)

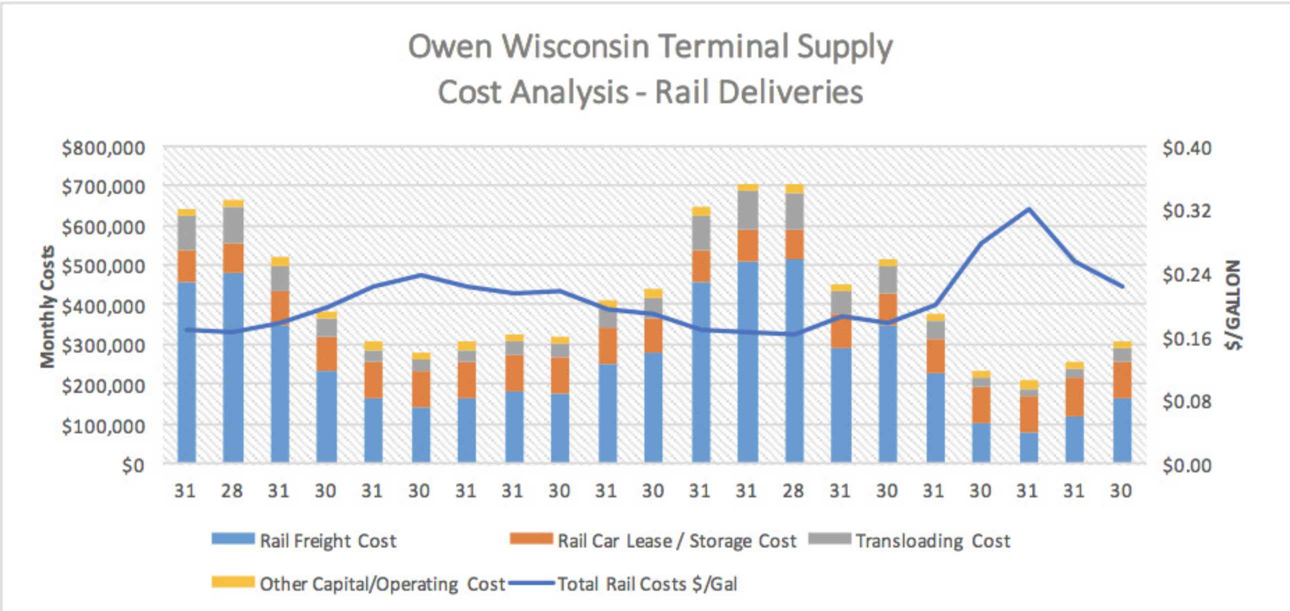
Appendix J.2 Supply of Propane to Alternate Terminals – Rail Cost Analysis

General			
Volume of Propane per Railcar	31,500		gal
Terminal Load/Unload Time	24		h
Operating Hours Per Day	24		h/d
Railcar Lease Cost	$3,000		Monthly
Railcar Storage Cost	$1,000		Monthly
Freight Charge	$10.00		$/bbl
Transload Cost	$700		$/Railcar
Incremental Overhead	0.30		Man Years
Incremental Storage	270,000		gal
Capital Cost Storage Tanks (90,000 gal)	$350,000		$/Unit
Capital Cost Transload Equipment	$100,000		$/Unit
Useful Life (Storage Tank/Transloader)	20		Years
Amortization Rate	15%		Per Annum
Cost of Overhead	$80,000		$/Annum
Terminal Specific	**Transit Time (h)**	**Cycle Time (h)**	**Fleet (#)**
Kincheloe, MI	72	192	39
Owen, WI	36	120	25

Appendix J.2.1 Kincheloe Michigan Rail Cost Analysis



Appendix J.2.2 Owen WI Terminal Rail Cost Analysis

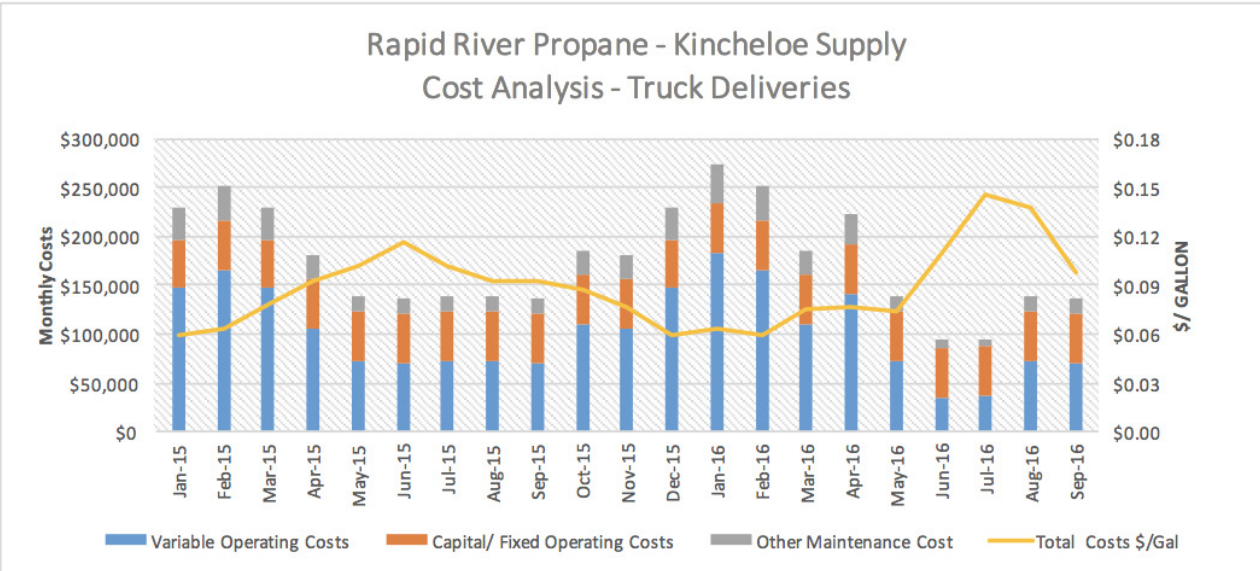


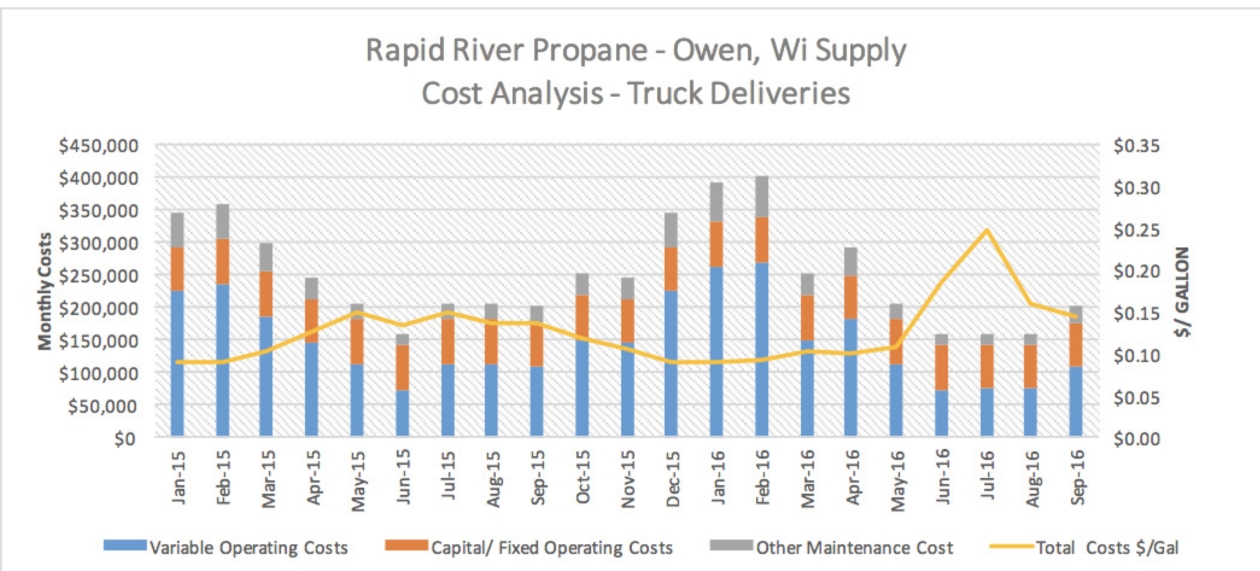
Appendix J.3 Supply of Propane to Alternate Terminals – Trucking Cost Analysis

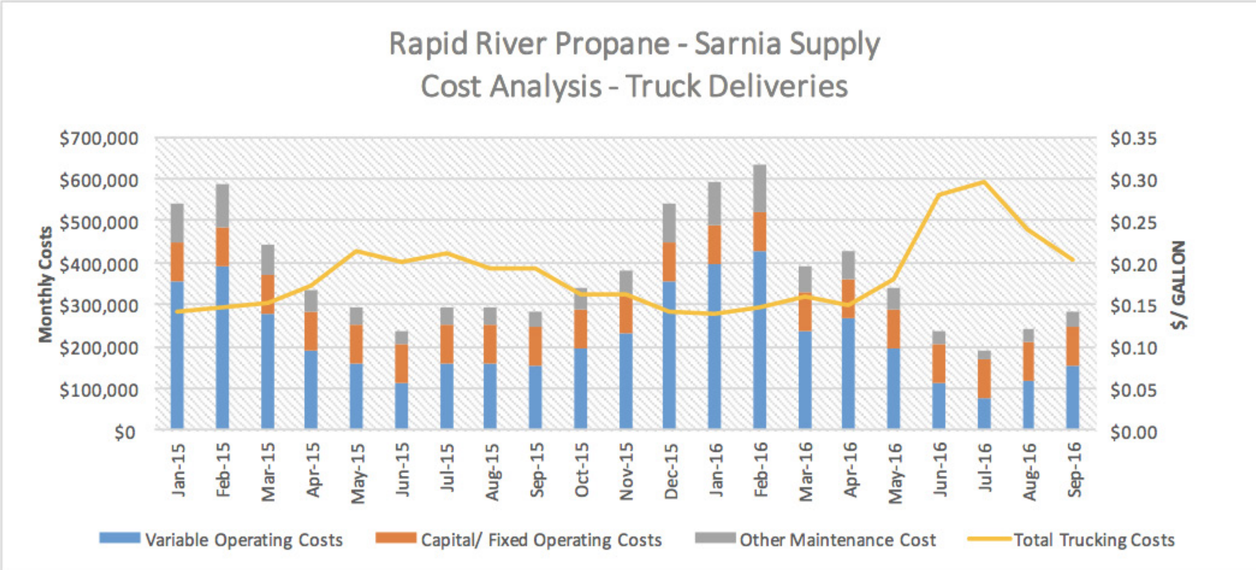
Appendix J.3.1 Operating Parameters and Cost Assumptions

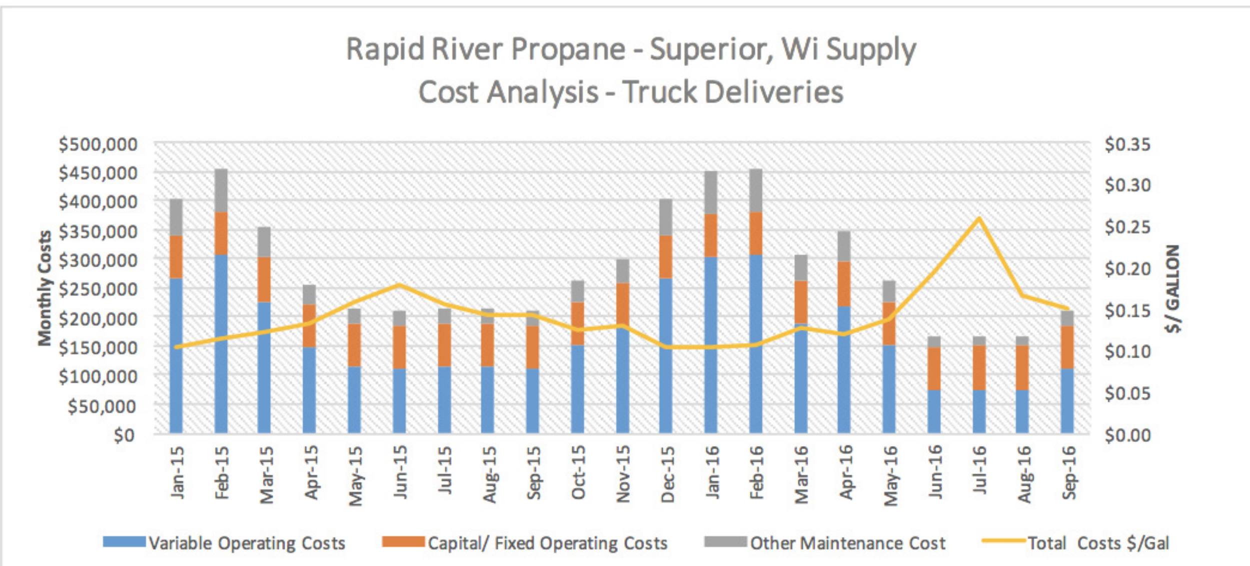
General				
Volume of Propane per Tractor Trailer	10,400		gal	
Terminal Load/Unload Time	1		h	
Operating Hours Per Day	24		h/d	
Truck Fuel Mileage	7.9		mpg	
Driver Wage	$35		$/h	
Diesel Fuel Costs	$3.00		$/gal	
Capital Costs of Tractor Truck	$120,000		$/Unit	
Capital Cost of Propane Trailer	$145,000		$/Unit	
Insurance/License Fees/Permits	$0.09		$/Mile	
Truck/Trailer Repairs	$0.16		$/Mile	
Truck/Trailer Tires	$0.04		$/Mile	
Truck Tractor Life	7		Years	
Propane Trailer Life	15		Years	
Incremental Overhead	0.45		Man Years	
Incremental Storage	270,000		gal	
Incremental Transload Equipment	2		Units	
Capital Cost Storage Tanks (90,000 gal)	$350,000		$/Unit	
Capital Cost Transload Equipment	$100,000		$/Unit	
Useful Life (Storage Tank/Transloader)	20		Years	
Amortization Rate	15%		Per Annum	
Cost of Overhead	$80,000		$/Annum	
Terminal Specific	**Distance mi. (km)**	**Transit Time (h)**	**Cycle Time (h)**	**Fleet (#)**
Kincheloe, MI	150 (241)	3	8	5
Owen, WI	240 (386)	5	12	8
Superior, WI	290 (467)	6	14	9
Sarnia, ON	427 (688)	8	18	12
Lewiston, MI	221 (356)	4	10	21

Appendix J.3.2 Trucking Cost Analysis – Summary Charts






Rapid River Propane - Sarnia Supply
Cost Analysis - Truck Deliveries
Monthly Costs
$/ GALLON
$700,000
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$0
$0.35
$0.30
$0.25
$0.20
$0.15
$0.10
$0.05
$0.00
Jan-15 Feb-15 Mar-15 Apr-15 May-15 Jun-15 Jul-15 Aug-15 Sep-15 Oct-15 Nov-15 Dec-15 Jan-16 Feb-16 Mar-16 Apr-16 May-16 Jun-16 Jul-16 Aug-16 Sep-16
Variable Operating Costs
Capital/ Fixed Operating Costs
Other Maintenance Cost
Total Trucking Costs


Rapid River Propane - Superior, Wi Supply
Cost Analysis - Truck Deliveries
Monthly Costs
$/ GALLON
$500,000
$450,000
$400,000
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
$0.35
$0.30
$0.25
$0.20
$0.15
$0.10
$0.05
$0.00
Jan-15 Feb-15 Mar-15 Apr-15 May-15 Jun-15 Jul-15 Aug-15 Sep-15 Oct-15 Nov-15 Dec-15 Jan-16 Feb-16 Mar-16 Apr-16 May-16 Jun-16 Jul-16 Aug-16 Sep-16
Variable Operating Costs
Capital/ Fixed Operating Costs
Other Maintenance Cost
Total Costs $/Gal

Appendix J.4 Estimated Apportionment of Enbridge System Capacity

Delivery Point	Maximum Take Away Capacity/Nomination (kbbl/d)	% Allocation of Capacity	Apportionment with Line 5 (kbbl/d)	Apportionment w/o Line 5 (kbbl/d)	Apportionment Change (kbbl/d)
Stockbridge (Line 17 & 79)	180	15%	162	83	–79
Marysville	190	15%	171	88	–83
-	**-**	**Subtotal**	**333**	**171**	**–162**
Sarnia – Line 7	180	15%	162	83	–79
Sarnia Refineries	283	23%	255	131	–124
Sarnia – Line 9	300	24%	270	139	–131
Sarnia NGL Facility	100	8%	90	46	–44
-	**1,233**	**-**	**1,110**	**570**	**–540**
US Refinery Capacities					
Detroit Refinery	132	-	95	49	–46
Toledo PBF Refinery	170	-	123	63	–60
Toledo BP Refinery	160	-	115	59	–56
-	**462**	**Subtotal**	**333**	**171**	**–162**

Notes:
1. All figures presented after rounding.
2. Available capacity with Line 5: 1,110 kbbl/d (Line 5 + Line 78)
3. Available capacity without Line 5: 570 kbbl/d (Line 78)
4. Sarnia refineries include Shell Corunna (77 kbbl/d), Imperial (121 kbbl/d) and Suncor (85 kbbl/d) based on:
   NEB. 2016. "Understanding the Production, Transport and Refining of Crude in Canada", April 29. [Online]. Available: https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/ftrrtcl/2016-04-29ndrstndngcrl-eng.html. [Accessed May 2017].
5. Line 7 supplies refineries in Nanticoke ON (Imperial) and Warren NY (United).

Appendix J.5 PADD 2 Propane Imports from Sarnia

Appendix J.5.1 Introduction

This section provides additional background information relating to propane imports from Sarnia into PADD 2 through Michigan. The Ontario/Michigan subsystem of natural gas storage and distribution represents an important storage hub that directly benefits United States (US) and Canadian consumers of energy products and, indirectly, manufactured products in the petrochemical supply chain. The scope of work for this analysis does not include analyses of international trade in manufactured goods, under which petrochemicals and their products fall. Energy products (principally propane and refined products) derived from the Sarnia refinery and fractionation facilities are, however, important and any crude or natural gas liquid (NGL) supply disruptions could have an impact on energy markets in Michigan. Flows of refined products to Michigan from Ontario facilities are negligible: regulators in both Canada and the US document declines in refinery exports to PADD 2 to nil over recent years.[1]

[1]US EIA. 2017. Petroleum and Other Liquids. "Weekly Midwest (PADD 2) Imports of Finished Motor Gasoline". For example, records indicate nil values since May 8, 2015 (accessed September 2017).

This section provides additional background information and assumptions that contribute to an analysis of the potential impacts on Lower Peninsula propane consumers arising from a hypothetical abandonment of Line 5. Previous sections in this appendix described impacts associated with Upper Peninsula propane markets, which face a different supply and pricing dynamic than markets in the Lower Peninsula.

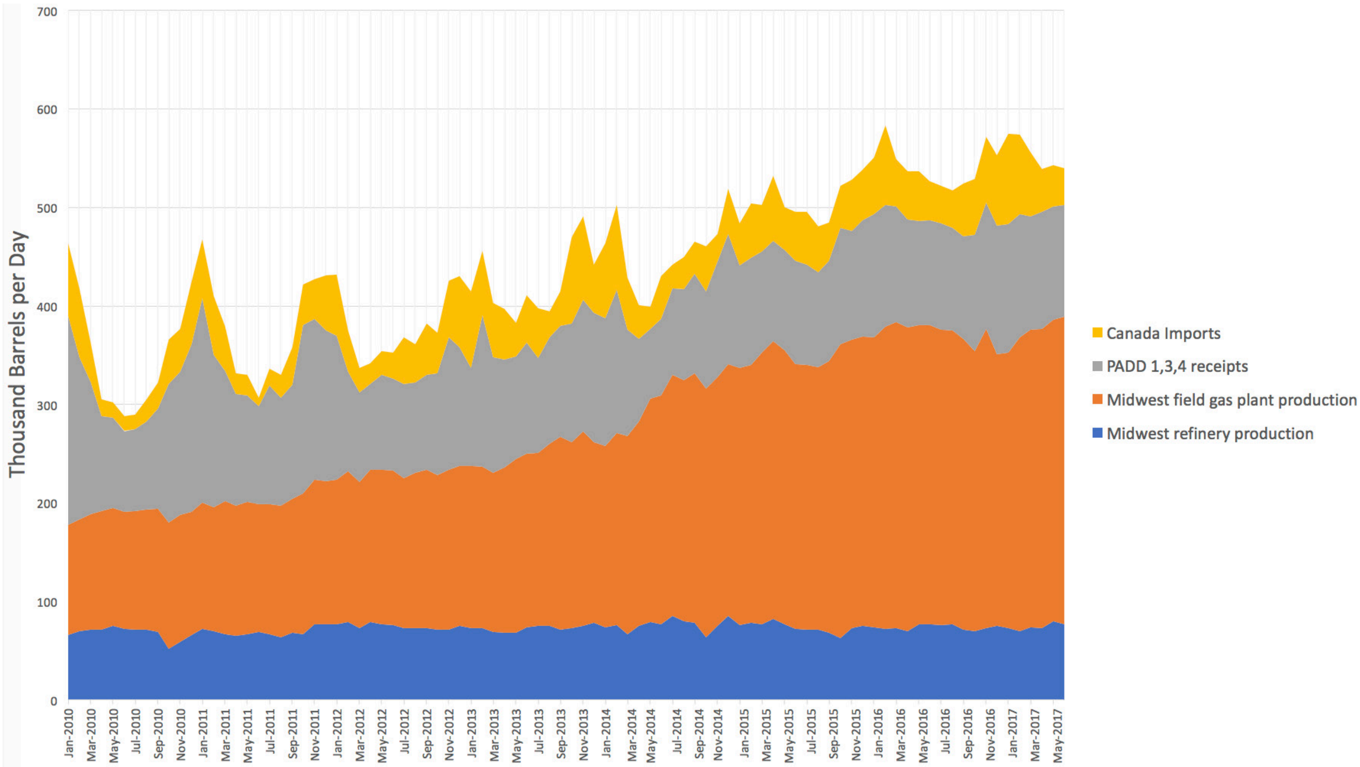
Appendix J.5.2 PADD 2 Propane Supply

Propane imports from Sarnia in PADD 2 are best seen in the context of overall propane supplies to PADD 2 from all sources. Figure J-1 shows current propane supplies to be in excess of 500,000 bbl/d in PADD 2, derived from local supplies (gas plants and refineries) as well as imports from other districts.[2] Also, ongoing monitoring by the US Energy Information Administration suggests that future supplies from PADD 1 are expected to increase considerably as natural gas processing capacity in the Appalachian region continues to grow as producers try to keep pace with natural gas production in the region.[3] Canadian supplies from Sarnia (estimated at 25,000 bbl/d) represent under 5% of the total supply of propane in PADD 2. Storage infrastructure in Michigan plays an important role in ensuring availability of supply through all seasons to all markets in neighboring states and Michigan's own Lower Peninsula. Indeed, storage levels in the US and Canada have generally been at record historical highs given higher production, leveling demand, and a more cautious industry since 2014 shortfalls. Storage and its related logistical infrastructure will moderate reliance on propane production facilities to meet peak day demands. The system has also become more robust as rail facilities and transportation of NGL and propane can quickly backfill any disruptions in the supply chain. Canada's National Energy Board shows that rail exports of propane doubled from 43 kbbl/d to 87 kbbl/d over the period 2011-2015.[4] High production levels, coupled with more extensive infrastructure, mitigate any potential loss in supply. These conditions also act as a price stabilizing mechanism within large hubs because propane is not a price-regulated commodity and it is used in diverse applications.

[2]The supply volumes described here include specification propane and exclude volumes that the US Energy Information Administration describes as a refinery produced propane/propylene blend.

[3]US EIA. 2017 (August 29). "Appalachian Natural Gas Processing Capacity Key to Increasing Natural Gas", NGPL Production. Today in Energy.

[4]NEB, Energy Infrastructure, Statistics & Analysis, Export Volumes by Mode of Transport. (https://www.neb-one.gc.ca Accessed June 2017).



Source: Based on following US EIA Petroleum and Other Liquids series: “Natural Gas Plant Field Production/Propane”; “Refinery Net Production/Propane”; “Movements by Pipeline between PAD Districts/Propane”; “Midwest (PADD 2) Imports from Canada of Propane”. EIA also reports exports of propane/propylene from PADD 1 and PADD 2 to be in the range of 82 kbbl/d in March 2017, but propylene is excluded from this graphic.

Figure J-1: Propane Supply in Midwest (PADD 2) 2010-2017

Given the higher production levels, the entire US (and Canada) has abundant supplies of propane with producers and mid-stream companies aggressively pursuing new markets as evidenced from dramatically increasing exports in recent years. These dynamic market conditions within a competitive environment contribute both to price stability and to security of supply for strategically important markets (e.g., home heating fuel, agriculture crop drying, domestic manufacturing). Given also that propane is generally a production byproduct (from NGLs in the natural gas stream or from refinery distillate production), propane producers are frequently price-takers unless they are selling into captured or isolated markets: end-use consumers are typically protected to some degree from price volatility where integrated storage and distribution facilities are available.

Generally, balancing market demand and supply is more about having adequate storage in place than focusing on specific sources of supply given the seasonal volatility of Michigan’s propane demand profile. Propane production is generally consistent throughout the year because it results from crude oil refining and natural gas processing. Propane consumption, on the other hand, is highly seasonal. Propane stocks, or inventories, are generally built up during the spring and summer when consumption is lowest. The stocks are then used to meet propane demand in the autumn and winter when consumption is highest. Production and stocks are supplemented by imports. Wholesale and retail propane prices can increase quickly and significantly when supply sources are insufficient or when they lack the capacity to respond quickly to large and/or rapid increases in demand. EIA statistics indicate that Michigan’s average 5 year storage level heading into the winter of 2017/2018 is in the range of 5 million barrels (128 days at Michigan's historical peak demand of 39 kbbl/d). Average 5 year storage in the Midwest (PADD 2) is 26 million barrels.[5] The storage facility inventories in Michigan (and PADD 2) can be efficiently maintained for purposes of distribution to meet specific market needs from a combination of propane supplies delivered by pipeline, rail, or road transport. The availability of state and regional storage supplies to mitigate peaking load, together with the abundant supplies of propane available in PADD 1 and 2 suggest that Michigan's market needs for propane would not suffer a major setback in the event of supply disruptions from a single source.

Appendix J.5.3 Propane Imports from Sarnia

In 2015, Michigan consumed 460 million gallons of propane[6] with propane being distributed from several in-state storage and distribution terminals. These terminals receive propane supplies from several sources that primarily include:

1. Produced propane from regional refineries including the Detroit and Toledo refineries.
2. Produced propane from the depropanizer facility at Rapid River.
3. Supplies of propane from Ontario refineries as well as from the NGL fractionation facility located in Sarnia.

In addition to rail and truck deliveries of propane to in-state terminals, propane is also delivered by pipeline. Plains Midstream owns and operates several pipelines that move NGLs between Michigan and Ontario. The pipelines include the:

- Kalkaska Pipeline, which transports NGLs from gas processing facilities in Kalkaska to the Sarnia fractionation facility.
- SDS Pipeline, which transports propane product to the St. Clair/Marysville terminals.
- SIP/EDS North and South Pipelines that have bidirectional transport capacity for moving NGL fractioned products between Sarnia and Windsor terminals, and to and from Michigan and Ohio terminals.

Figure J-2 is a simplified schematic of these pipeline operations.

Of particular importance to the supply of propane to the State of Michigan (the State) is the SDS Pipeline – an 8-in. pipeline system originating at Plains' Sarnia Fractionation Facility and extending to the St. Clair and Marysville Terminals in St. Clair County, Michigan (see Figure J-3).

Recent and projected transport volumes for the SDS Pipeline are shown in Table J-1. The annual transported volume for 2015 of 414 million gallons suggests that the propane transported from the Sarnia fractionation facility represents a major component of Michigan's annual propane supply, in particular for the Lower Peninsula[7].

[5] EIA, Propane Situation Update for Midwest States, July 26, 2017.

[6] Michigan Propane Gas Association. Submission to Michigan Pipeline Safety Advisory Board, August 4, 2017.

[7] This compares to the Lower Peninsula 2015 consumption of 430 million gallons.

Table J-1: Plains Eastern Pipeline System – Sarnia Downstream System (SDS) – Projected Volumes

Plains Eastern Pipeline System – Sarnia Downstream System (SDS): Projected Volumes	Annual (million gal)	Annual Average (kbbl/d)
2015	414	27.0
2016	374	24.4
2017	394	25.7
Source: Canada National Energy Board (NEB). 2017. Filing of Plains Midstream Canada ULC – Sarnia Downstream System (SDS), Tariff Filing NEB No. 112 – International Joint Rate Tariff: Land Matters Consultation Initiative ("LMCI") Collection Mechanism, May 15.		

Line 5 provides NGL volumes for the depropanizer facility at Rapid River and the NGL fractionation facility in Sarnia. Line 5 also provides the Ontario refineries with crude oil supplies from which LPGs including propane are also produced. Accordingly, Line 5 is viewed as a vital piece of the propane supply infrastructure serving consumers in Michigan and Ontario.

Abandonment of the Line 5 pipeline would create substantial ripple effects across the existing supply chain. Pipeline-supplied NGLs would no longer be available to the Rapid River depropanizer facility and, as a result, its operation would likely cease. The terminal would, however, likely remain a storage and distribution terminal to meet the propane demand requirements of the Upper Peninsula. The market dynamics in the Upper Peninsula are detached from those of the Lower Peninsula because of its lower demand and more limited supply options. These supply options have been addressed elsewhere in this appendix.

With respect to the NGL supply disruption to the Sarnia fractionation facility, given the current scale, invested capital, and integral scope of its of operations with respect to NGL product supply to both consumers and other industrial complexes, the Sarnia fractionation plant will likely continue to operate accessing alternate supplies of NGL through increased rail deliveries from Superior, Western Canada, or regional refineries and/or gas processing plants, including supplies of NGL from the northeastern US liquid rich Marcellus/Utica production. In addition to rail transport, the Sarnia fractionation plant may also be able to source NGL supplies (C3+) for fractionation from new pipelines and associated facilities moving C2+ NGL stream into the Sarnia area[8]. NGL (and propane) supplies are expected to increase substantially with continuing growth in continental shale gas production, in particular, with the Utica/Marcellus regional gas production and development of new regional fractionation facilities to provide feedstock to new petrochemicals facilities as well as to capture export market opportunities for product.

In accordance with the above, the Alternative 6 analysis for propane impacts in Michigan was premised on these assumptions:

- The Rapid River complex will remain a distribution center, accessing propane by truck deliveries from other terminals.
- The Sarnia fractionation facility will continue to operate through increased deliveries of NGLs by rail to the facility.
- Marysville/St. Clair storage and distribution volumes are not impacted.

[8]For example, the Utopia Pipeline, which commences operation in 2018, will have an initial capacity of 50 kbbl/d and will be expandable to 75 kbbl/d.

- Michigan State supply of propane is not impacted; however, increases in upstream cost structures relating to trucking/rail transport logistics may impact propane prices[9].
- Existing Michigan storage terminals/caverns are well positioned to attract alternate propane supply available in the regional markets, moderating any potential supply cost impacts from the abandonment of Line 5.
- The Lower Peninsula price impact of supply disruptions to the supply chain is likely to be low given increasing competitive supply availability of propane in the Midwest in which NGL/propane producers are price-takers.
- Propane and NGL producers are most likely to absorb any increased cost of bringing incremental supplies of propane to end-users in the Lower Peninsula, but analyses are undertaken to show a maximum unit cost ($/gal) that might accrue in Lower Michigan propane markets if the entire amount were to be borne by consumers in Michigan or PADD 2.

In summary, the analyses assume that, in the event of the abandonment of Line 5, Sarnia will access alternate supplies as necessary to maintain current throughput at existing facilities and maintain its market/storage alignments with respect to supplying the Lower Peninsula with propane supply. Propane supply in the Upper Peninsula will also be maintained through logistical arrangements to transport propane directly to Rapid River. The cost impact to do the foregoing is not expected to substantially impact local/regional pricing dynamics, although upstream and distributor profit margins may be somewhat impacted.

[9]Alternative 3 analysis estimates the cost of rail transport of NGL from Superior to Sarnia at a stand-alone rate of $6.49/bbl, compared to Line 5's current NGL toll of $1.32/bbl. The net increase in the propane supply chain cost structure would be $5.07/bbl (~ $0.12/gal); this increase would only apply throughout the supply chain if all NGL supply through the Lakehead System to Sarnia were to be interrupted. For modeling purposes it is assumed, however, that the apportionment protocols shown in Table J.4 would also apply to NGL volumes and the resultant impact on Sarnia fractionator propane supply costs would equate to under $0.06/gal. This compares to the Sarnia 2016 average wholesale price for propane of $0.60/gal.

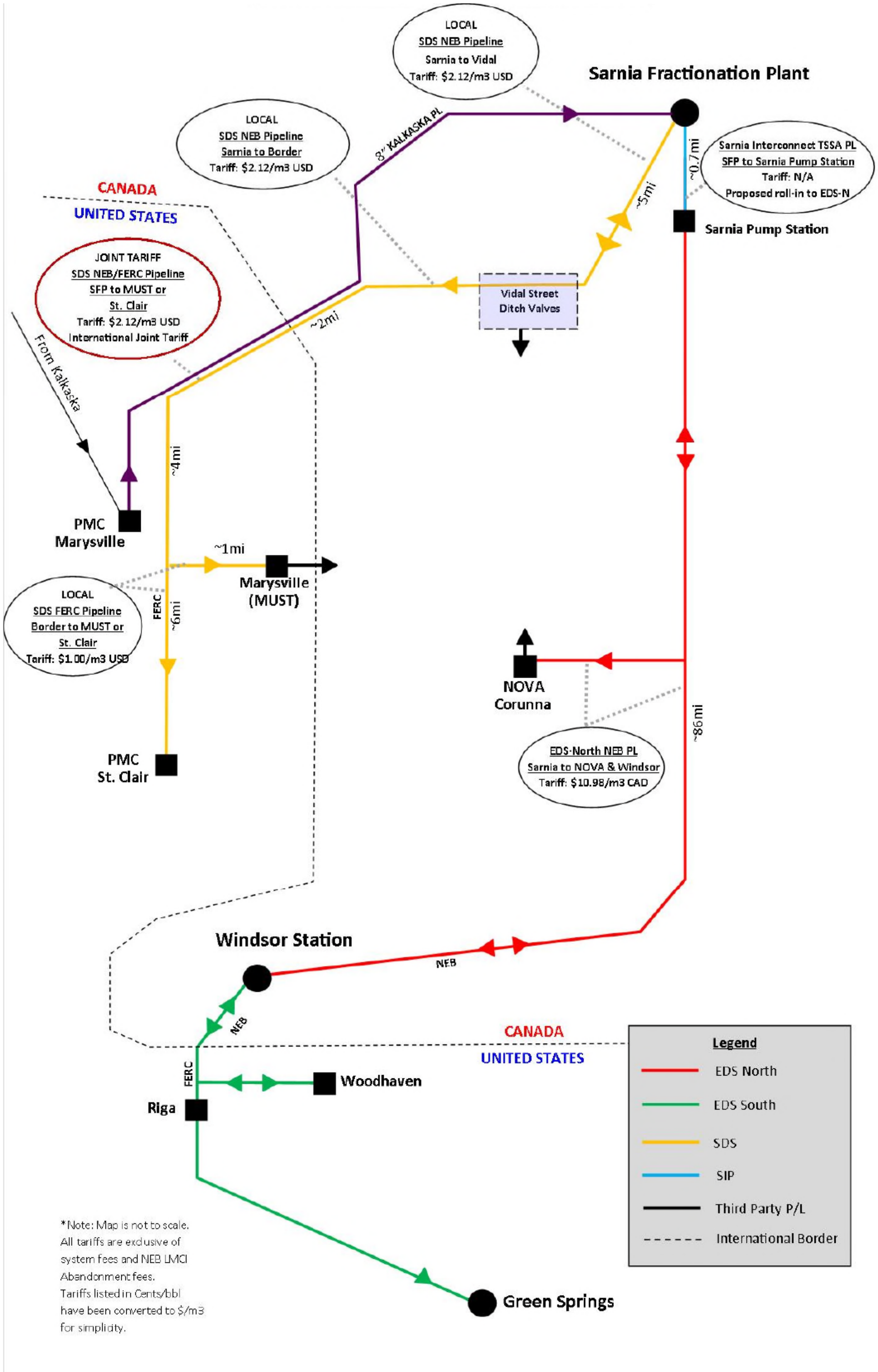


Figure J-2: Eastern Pipelines Overview

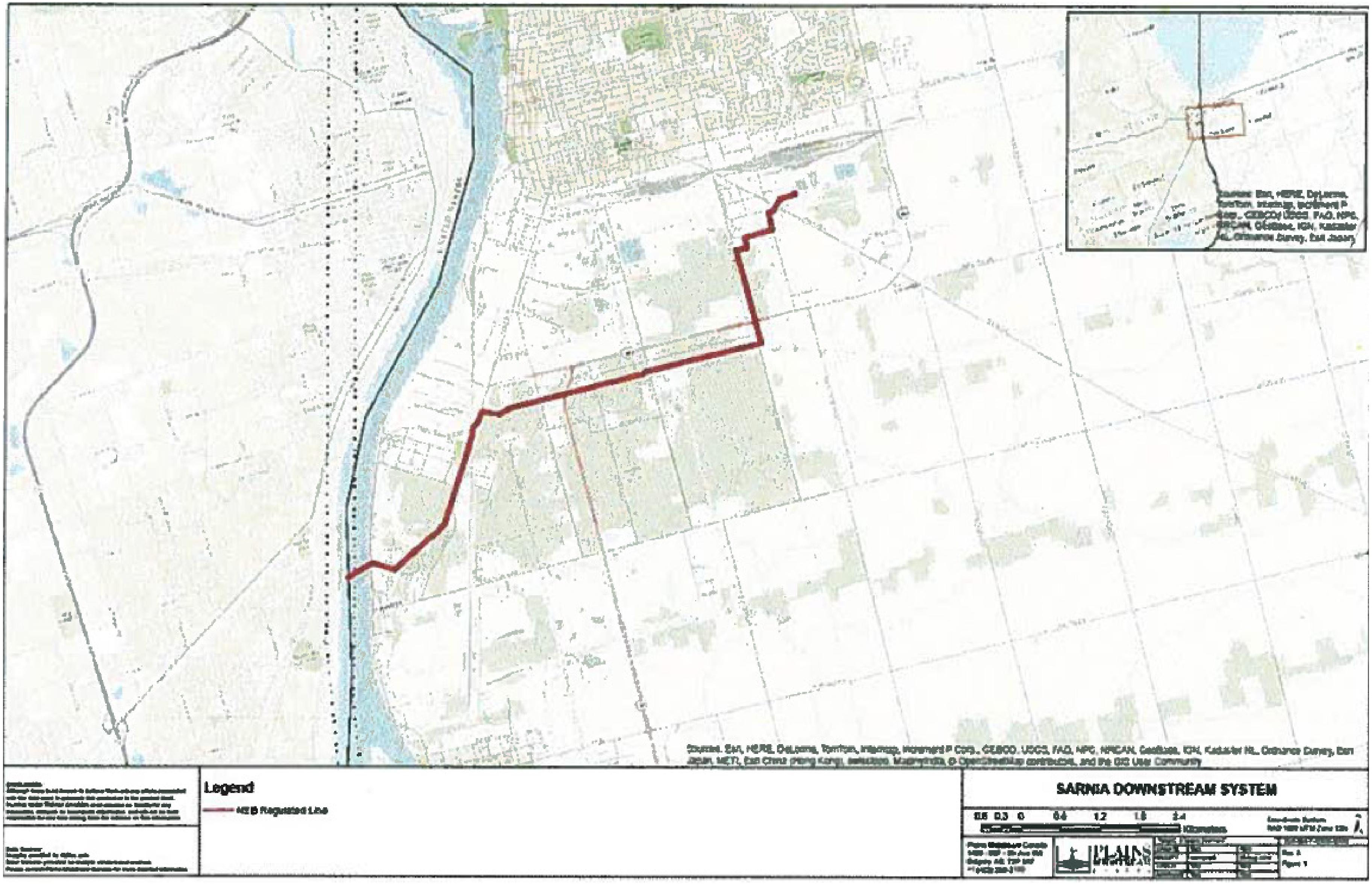


Figure J-3: Plains Eastern Pipeline System – Sarnia Downstream System (SDS)

Appendix K Local Propane and Crude Transport

Appendix K.1 Background

Options are being considered to eliminate the Line 5 Straits of Mackinac (the Straits) Crossing segment. This obviously has many implications; however, the supply of propane from Superior to Rapid River – in the Upper Peninsula (UP) – and the delivery of crude production from Lewiston to the Marysville area – in the Lower Peninsula (LP) – are the subjects of this appendix.

There are two options for transporting propane and crude:

- Continue to use the existing segments of the 30-in. Line 5 pipeline.
- Construct new pipelines specifically for these applications.

Appendix K.2 Flow Rates of Propane and Crude

The daily flow rates of propane supply to the UP and crude deliveries from the LP are summarized in Table K-1.

Table K-1: Daily Flow Rates of Propane Supply

Parameter	Propane	Michigan Crude
Volumetric Flow Rate	3,585 bbl/d (570 m^3/d)	12,000 bbl/d (1,907 m^3/d)
Fluid Velocity in 30-in. Pipeline	54 m/h (0.015 m/s)	180 m/h (0.050 m/s)
Location	Superior to Rapid River	Lewiston to Marysville

Appendix K.3 Continued Use of 30-in. Pipeline

Line 5 was sized as a 30-in. pipeline to carry 540 kbbl/d of product. The flow rates indicated in Table K-1 would lead to a dramatically lower fluid velocity in the large existing pipe. There are two challenges related to operations – fluid separation and inspection tool speed.

A low fluid velocity is a potential threat to pipeline operations in that any contaminants – particularly water – that may exist in the product will rapidly drop to the bottom of the pipe. This flow is in the laminar range and there is little turbulence to keep water suspended. This means that water will gather at the low point in the line and create corrosion cells that will be difficult to manage. These low points often occur at watercourse crossings.

Inspection tools are designed to work most effectively in a range of 4.6 ft/s with a battery pack sized for about three days of operation. At this reduced flow rate, these inspection tools would be in the pipeline for excessively long periods of time to traverse the pipeline.

Appendix K.4 New Propane and Crude Pipelines

Building a new pipeline to carry product is a potential solution to this challenge. Two pipe segments were sized to determine these possible arrangements for the new lines:

1. A new line in a new trench.
2. A new line inserted into the abandoned 30-in. pipeline.

Each option has advantages and drawbacks.

Appendix K.4.1 Propane Supply

Based on the required flow of propane from Superior to Rapid River, hydraulics modeling has indicated that a 4-in. pipeline would be needed, with a power requirement of approximately 381 hp (284 kW) split between at least two intermediate stations. This produces a fluid velocity of 2.2 ft/s.

To size the pipeline required to carry propane in liquid form from Superior to Rapid River, the pipeline design conditions in Table K-2 were assumed.

Table K-2: Assumed Pipeline Design Conditions

Parameter	Value
Flow Rate – Design (bbl/d)	3,585
Pipe WT (in.)	0.219
Pipeline Inlet Pressure (psig)	1,440
Design Pressure (psig)	1,440
Fluid Density kg/m^3 (lb/ft^3)	530 (33.1)
Fluid Viscosity (cP)	0.0047

The hydraulic modeling for these conditions indicates that a pipe size of 4 in. will be adequate to deliver the design flow rate of 3,585 bbl/d (570 m^3/day), with two intermediate pump stations in this case. Delivery pressure will be around 65 psig (450 kPa). This produces a fluid velocity of 0.8 m/s (2.6 ft/s).

The pressure profile is shown in Figure K-1.

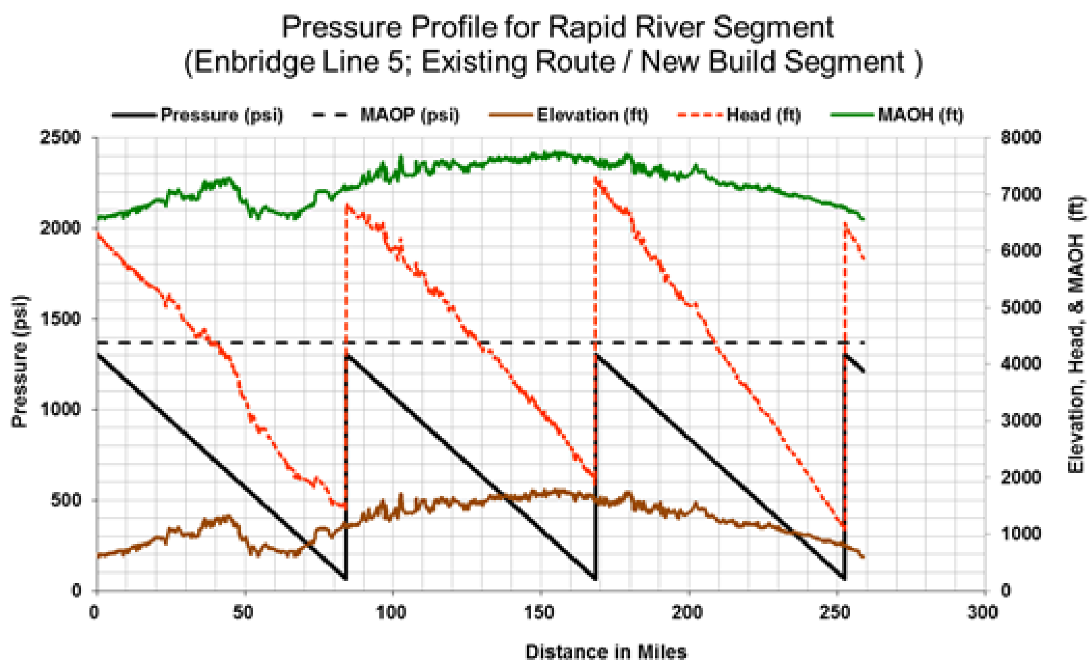


Figure K-1: Pressure Profile: Rapid River Segment Route

Appendix K.4.2 Crude Deliveries

To size the pipeline required to carry crude oil production in the LP from Lewiston to the Marysville area, the pipeline design conditions in Table K-3 were used.

Table K-3: Assumed Pipeline Design Conditions

Parameter	Value
Flow Rate – Design (bbl/d)	12,000
Pipe WT (in.)	0.322
Pipeline Inlet Pressure (psig)	1,440
Design Pressure (psig)	1,440
Fluid Density kg/m^3 (lb/ft^3)	830 (51.8)
Fluid Viscosity (cP)	3.35 @ 20°C (68°F)

The hydraulic modeling for this situation indicates that a pipe size of 8 in. will be adequate to deliver the design flow rate of 12,000 bbl/d. There is no need for an intermediate pump station in this case. Delivery pressure will be around 252 psig. This produces a fluid velocity of 2.45 kph (2.2 ft/s).

A 6-in. pipeline size was investigated, but it was determined that this size would not be sufficient without an intermediate pump station.

An 8-in. pipeline is recommended as the optimal size for this application. This pipeline size would provide additional capacity to carry increased volumes in the future, if required.

The pressure profile for this analysis is shown in Figure K-2.

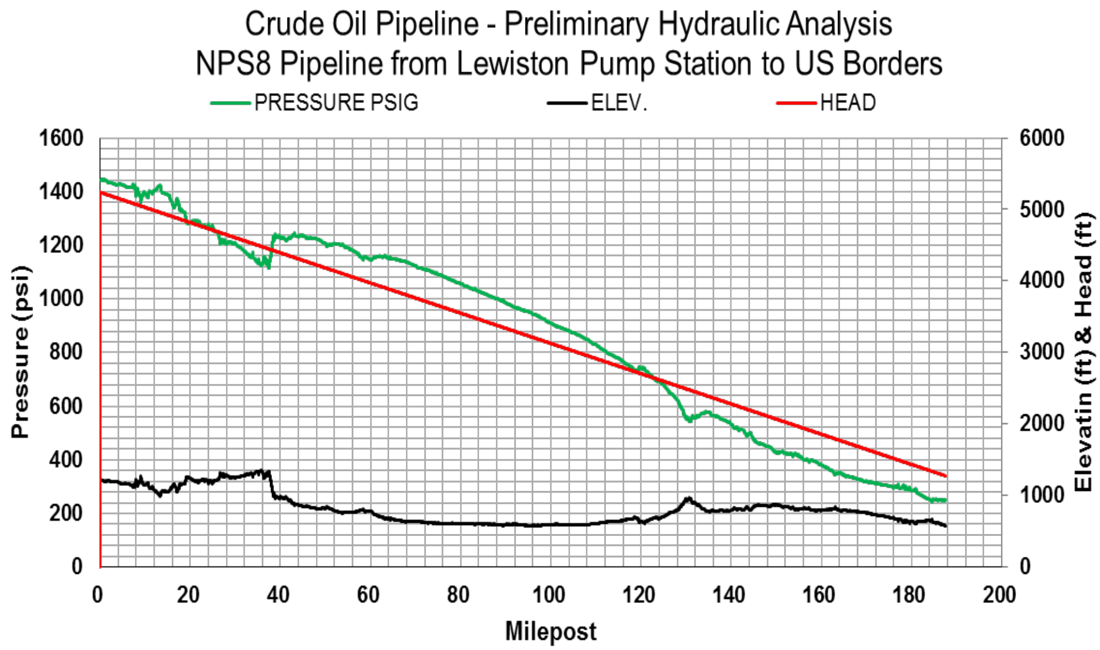


Figure K-2: Pressure Profile: 8-in. Pipeline

Appendix K.5 Construction Considerations

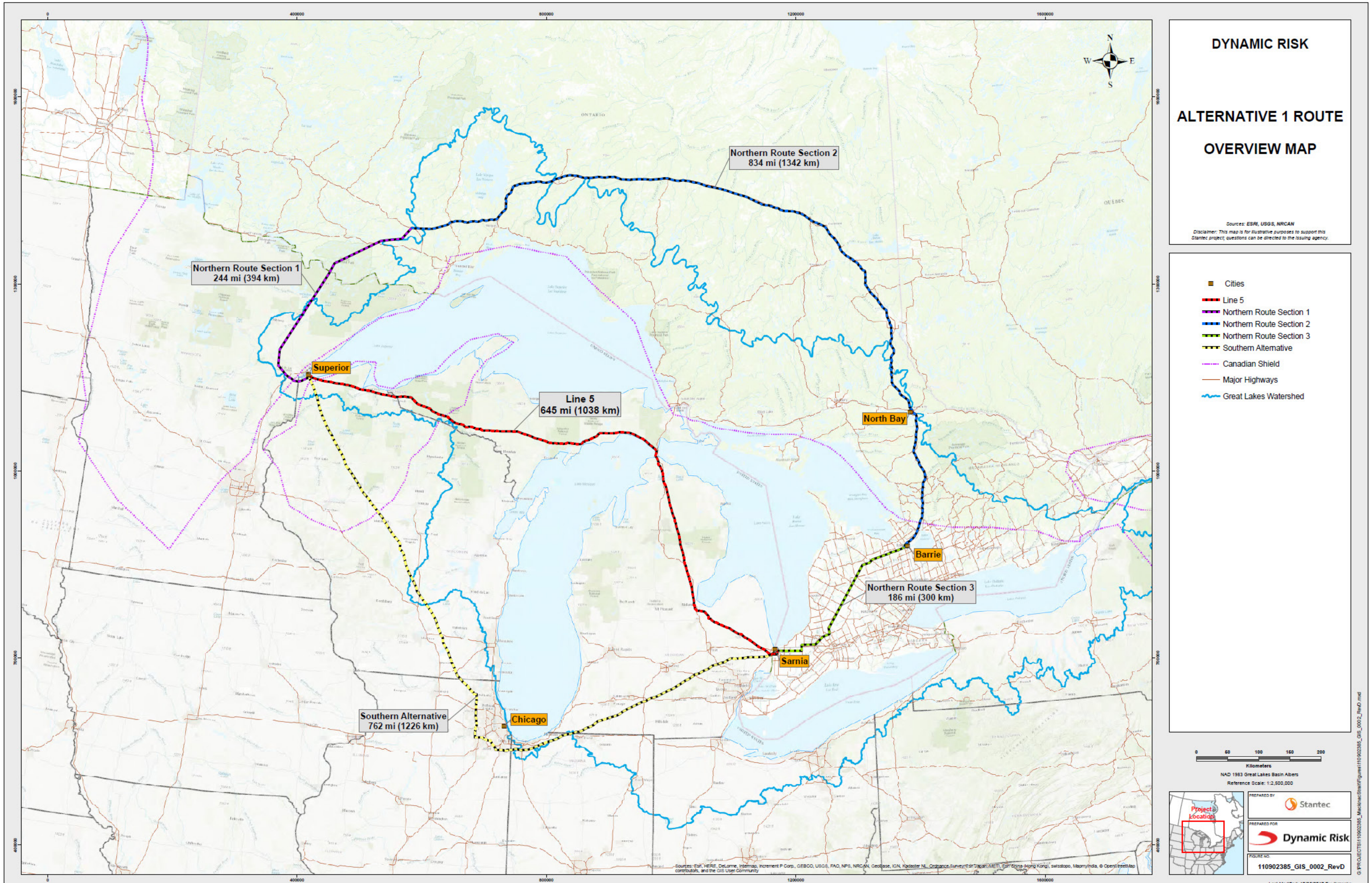
Appendix K.5.1 New Trench

Laying the pipe into a new trench alongside the existing 30-in. pipeline is the most conventional method. In this arrangement, the pipeline would be completely new and segregated from the existing pipeline in all ways. This method would involve all new construction and crossings of all obstacles, including new permitting.

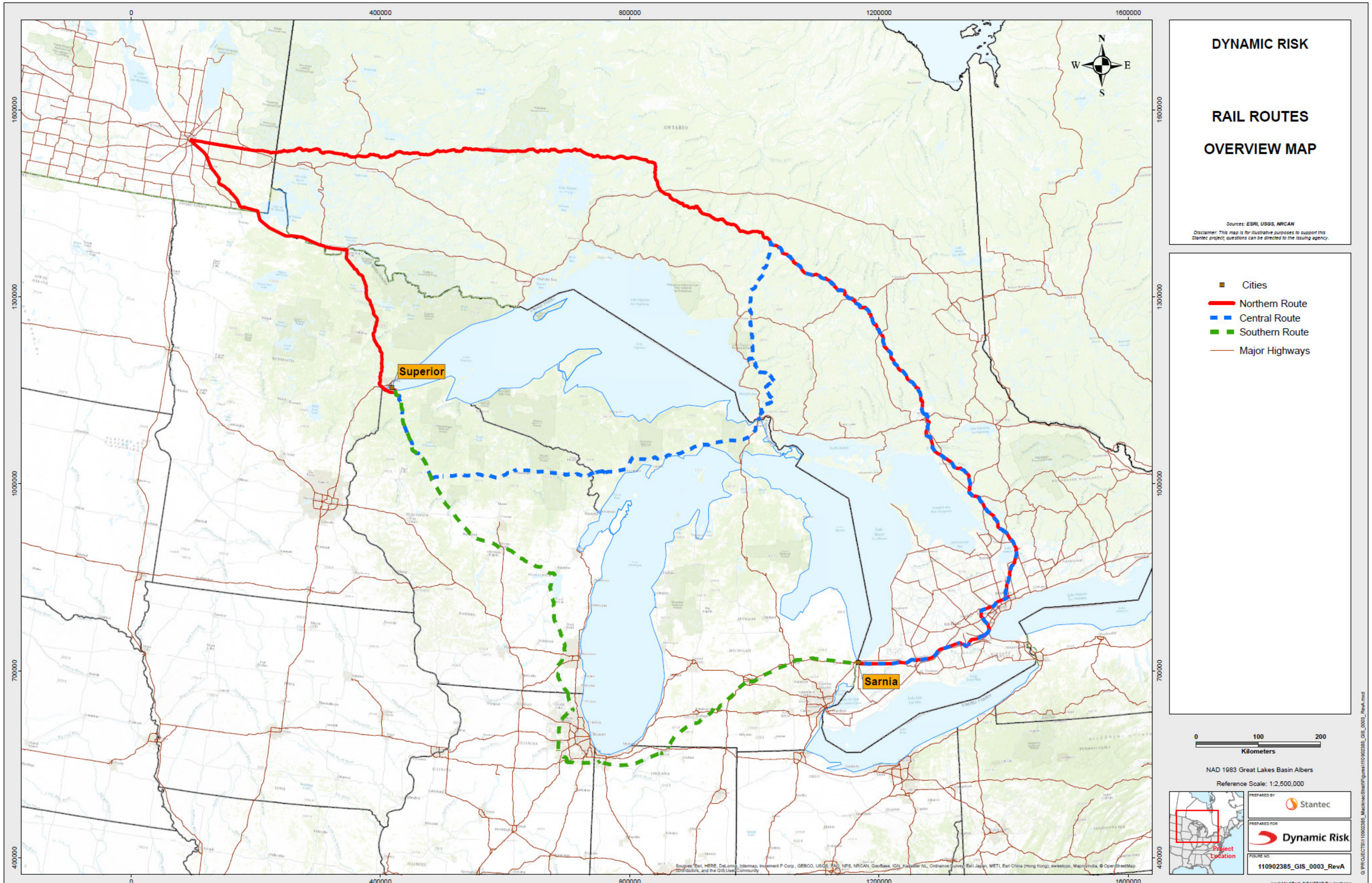
The size of pipe required to fulfill these needs is fairly small. This may present an opportunity to use a non-metallic option such as plastic or composite pipe. These technologies alleviate a number of the integrity challenges posed by steel pipe, but they also eliminate some of the integrity management tools available to a pipeline operator.

Appendix L Route Maps

Appendix L.1 110902385_GIS_0002_RevD – Alternative 1 Pipeline Routes Overview Map


DYNAMIC RISK
ALTERNATIVE 1 ROUTE
OVERVIEW MAP
Northern Route Section 2
834 mi (1342 km)
Northern Route Section 1
244 mi (394 km)
Superior
Line 5
645 mi (1038 km)
North Bay
Barrie
Northern Route Section 3
186 mi (300 km)
Sarnia
Southern Alternative
762 mi (1226 km)
Chicago
Cities
Line 5
Northern Route Section 1
Northern Route Section 2
Northern Route Section 3
Southern Alternative
Canadian Shield
Major Highways
Great Lakes Watershed
Stantec
Dynamic Risk
110902385_GIS_0002_RevD

Appendix L.2 110902385_GIS_0003_RevA – Alternative 3 Rail Routes Overview Map


DYNAMIC RISK
RAIL ROUTES
OVERVIEW MAP
Sources: ESRI, USGS, NRCAN
Cities
Northern Route
Central Route
Southern Route
Major Highways
Superior
Sarnia
Kilometers
NAD 1983 Great Lakes Basin Albers
Reference Scale: 1:2,500,000
Stantec
Dynamic Risk
110902385_GIS_0003_RevA

Appendix M Hydraulic Analysis Results

Appendix M.1 Analysis Objectives

The primary objective of the hydraulic analysis is to determine the best combination of operating pressures and compression configuration to meet system requirements at Enbridge facility in Sarnia.

The approach was to perform pipeline hydraulic simulations as follows:

- Determine the required discharge and suction pressures for pump stations along the pipeline route for the given design flow rate.
- Determine the compression power required for each pump station based on the identified station inlet pressure considering the discharge pressure for normal capacities.

Appendix M.1.1 Key Assumptions and Design Data

The hydraulic analysis of the pipeline was performed considering the following assumptions:

1. The pipeline will follow the proposed route provided in above sections known as South and North routes.
2. Fluid properties were assumed and are considered to be a stabilized stream.
3. Similar pipe size to the existing Enbridge Line 5 was used; 30 in.
4. Pipeline wall thicknesses and pipe grade were assumed as 0.500 in. and X52, respectively. No allowances for heavy wall or extra heavy wall pipe were considered.
5. Thermal transfer between the flowing fluid and the surrounding soil was not considered at this stage of the analysis.
6. The maximum operating pressure (MOP) of the mainline pipeline is assumed to be uniform. No point specific pressure design will be considered.
7. This analysis did not consider any valves.
8. Only the design flow as provided by the Client is considered in the hydraulic analysis. No seasonal variations of flows are accounted for.
9. No details of pump station(s) (at the start point, intermediate, and end-point), or Sarnia terminal facilities at the end of the line were considered for the current exercise.
10. Pressure drop through facilities was not determined in this analysis.
11. The analysis of pumping stations was limited to an estimate of the required power.

Appendix M.1.2 Hydraulic Design data

The following subsections outline the data used in the hydraulic analysis.

Appendix M.1.2.1 Line Pipe Specifications

For the purpose of this hydraulic analysis and to be consistent with the existing system, similar pipe size was considered; 30-in. pipe wall thickness was assumed to be 12.7 mm (0.5 in.) and considered uniform along the route. No allowances for heavy wall or extra heavy wall pipe were considered. Pipe grade of X52 as per API 5L was used to match the existing line pipe with a design pressure of 9,930 kPa (1440 psi).

Appendix M.1.2.2 Elevation Profile

The elevation profile used in the hydraulic analysis was based on the route selection study for the North-route and from following the existing routes for Enbridge pipelines for South-route. North-Route Elevation Profile is illustrated in Figure M-1, while Figure M-2 shows the elevation profile for the South-Route. The rationale behind route selection is to follow the existing ROWs as practical as possible and to reduce numbers of major crossings and acquisition of new land. These elevation profiles may change at an advanced stage of the analysis.

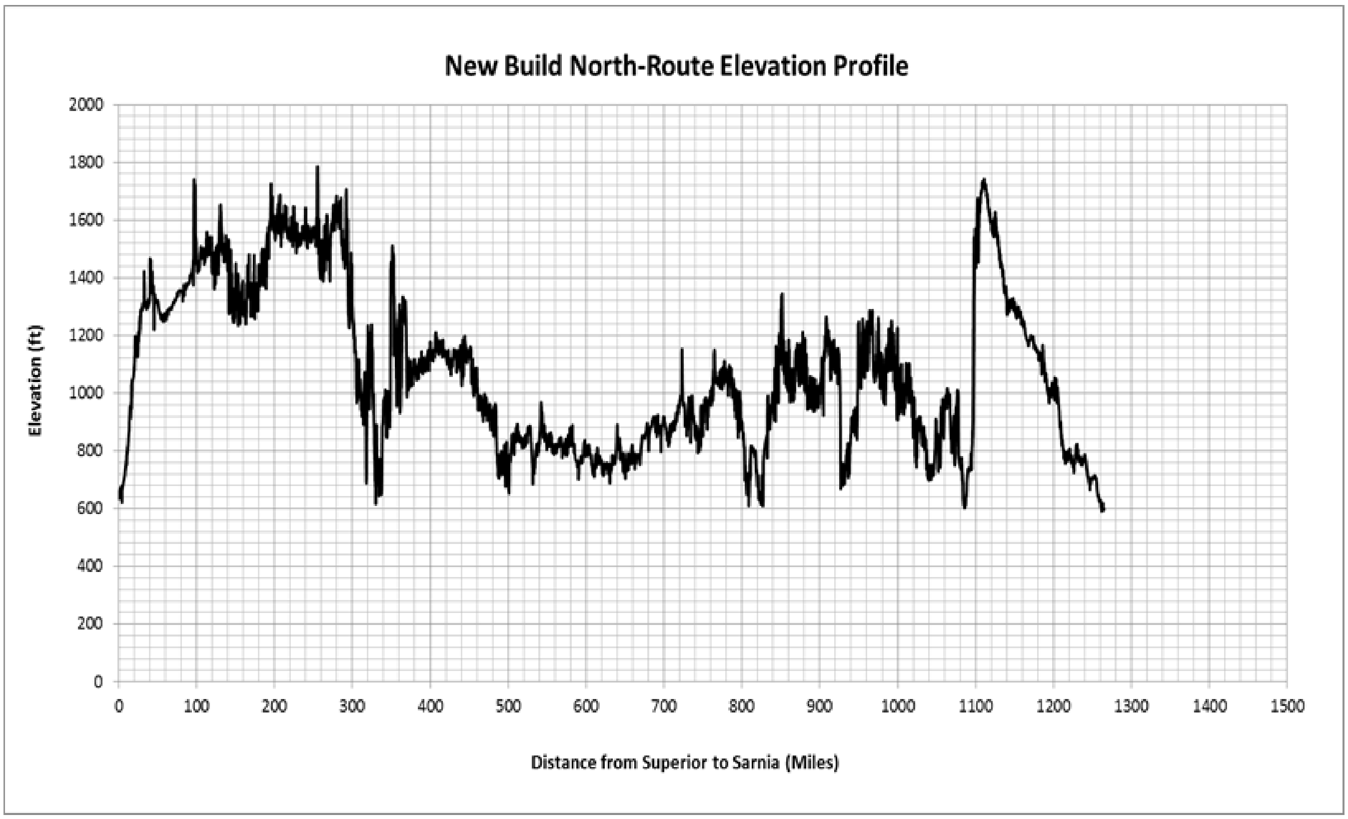


Figure M-1: New Build North-Route (Canada Route) Elevation Profile

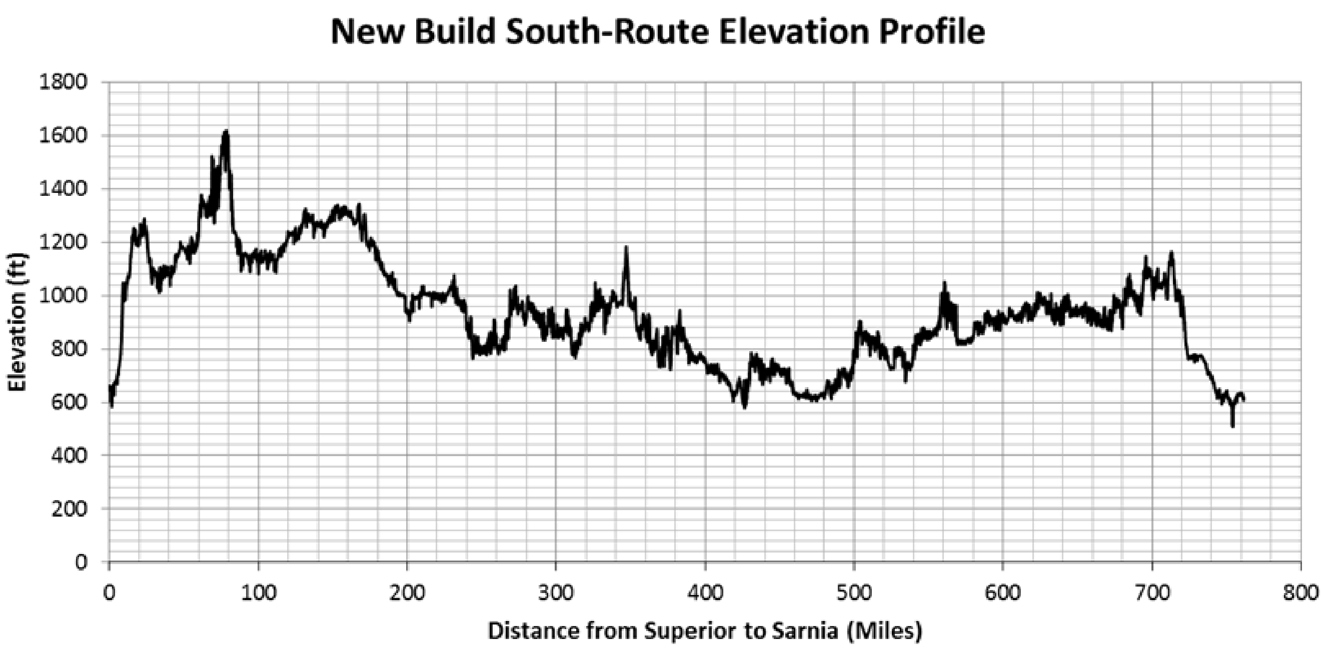


Figure M-2: New Build South-Route (US Route) Elevation Profile

Appendix M.1.2.3 Fluid Properties

The existing Enbridge Line 5 is operated in batching form transporting Light Crude or NGL. This current hydraulic analysis used Light crude as service fluid.

Appendix M.1.2.4 Thermal Analysis

At this stage of conceptual hydraulic analysis, no temperature effects were considered.

Appendix M.1.2.5 Flow Rate and Pressure Conditions

This hydraulic analysis was conducted based on an assumption of operating the pipeline below its design pressure of 1,440 psi (9,930 kPa). Discharge pressures for all pump stations were assumed to be 9,000 kPa (1,305 psi), and the suction pressure was limited to a minimum of 65 psi (450 kPa). Table M- 1 shows a summary of the pressure and flow rate values.

Table M- 1: North-Route Analysis Summary for 540,000 bbl/d

Property	Values
Flow Rate (bbl/d)	540,000
Pump Suction Pressure (psi)	65
Pump Discharge Pressure (psi)	1,305
Pump Efficiency (%)	0.80

Appendix M.1.2.6 System Configurations

System configuration was assumed based on head station in Superior, WI with intermediate stations along the route as per pressure calculations. Locations of the intermediate stations were identified based on pressure loss along the line at which minimum value of 65 psi is obtained. This low pressure value is used as the suction pressure for the following pump station.

Appendix M.1.3 Hydraulic Analysis Results

Appendix M.1.3.1 Northern Route (Canadian Route)

One of the alternatives to the existing line is to build a new pipeline that travels north of the Great Lakes through Canadian soil following an existing ROW of other pipelines. This route is called the Canadian route. The hydraulic analysis considered a design flow of 85,900 m^3/d (540 kbbl/d) and assuming inlet pressure of 1,305 psi.

Table M-2 depicts summary of the hydraulic analysis results for this route. Detailed results are presented in Table M-5 and Table M-6.

Table M-2: North-Route Analysis Summary 540,000 bbl/d

Results	Values
Total Number of Stations	17
Average Distance between Stations (mi.)	76
Total Power Required kW (hp)	180,232 (241,695)
Number of Stations per Country	2 in US, 15 in Canada

Appendix M.1.3.2 South-Route (US Route)

Another alternative to the existing line is to build a new pipeline that travels south of the Great Lakes to avoid water crossing through the US soil following an existing ROW of other pipelines. This route is called the US route. Similar data applies to the hydraulic analysis of this line including design flow of 85,900 m^3/d (540 kbbl/d) and system inlet pressure of 9,000 kPa (1,305 psi).

Find detailed results for the south-route analysis in Table M-5 and Table M-6.

Table M-3: South-Route Analysis Summary 540,000 bbl/d

Results	Values
Total Number of Stations	10
Average Distance between Stations (mi.)	76
Total Power Required kW (hp)	106,199 (142,415)
Number of Stations per Country	All in US

Appendix M.1.3.3 Pressure Profiles

Pressure profile for the hydraulic analysis for North-Route and South-Route new build options are shown in Figure M-3 and Figure M-4, respectively. Results are for flow rates of 85,900 m^3/d.

As can be observed, discharge pressures for all pump stations are at 9,000 kPa (1,305 psi), and minimum suction pressures are 450 kPa (65 psi). Changing the setup value of stations' suction or discharge pressures will result in different pressure profiles and pump locations.

Another factor may change the pressure profile is the fluid type. Based on the elevation change particularly, operating pressure at high elevation locations must be maintained higher than the vapor pressure of the service fluid especially for NGL.

Flow velocities in this 30-in. pipeline system exceed 2 m/s (6.6 ft/s) for the given flow rate. This value is within the range of typical flow rate velocities in liquid pipelines.

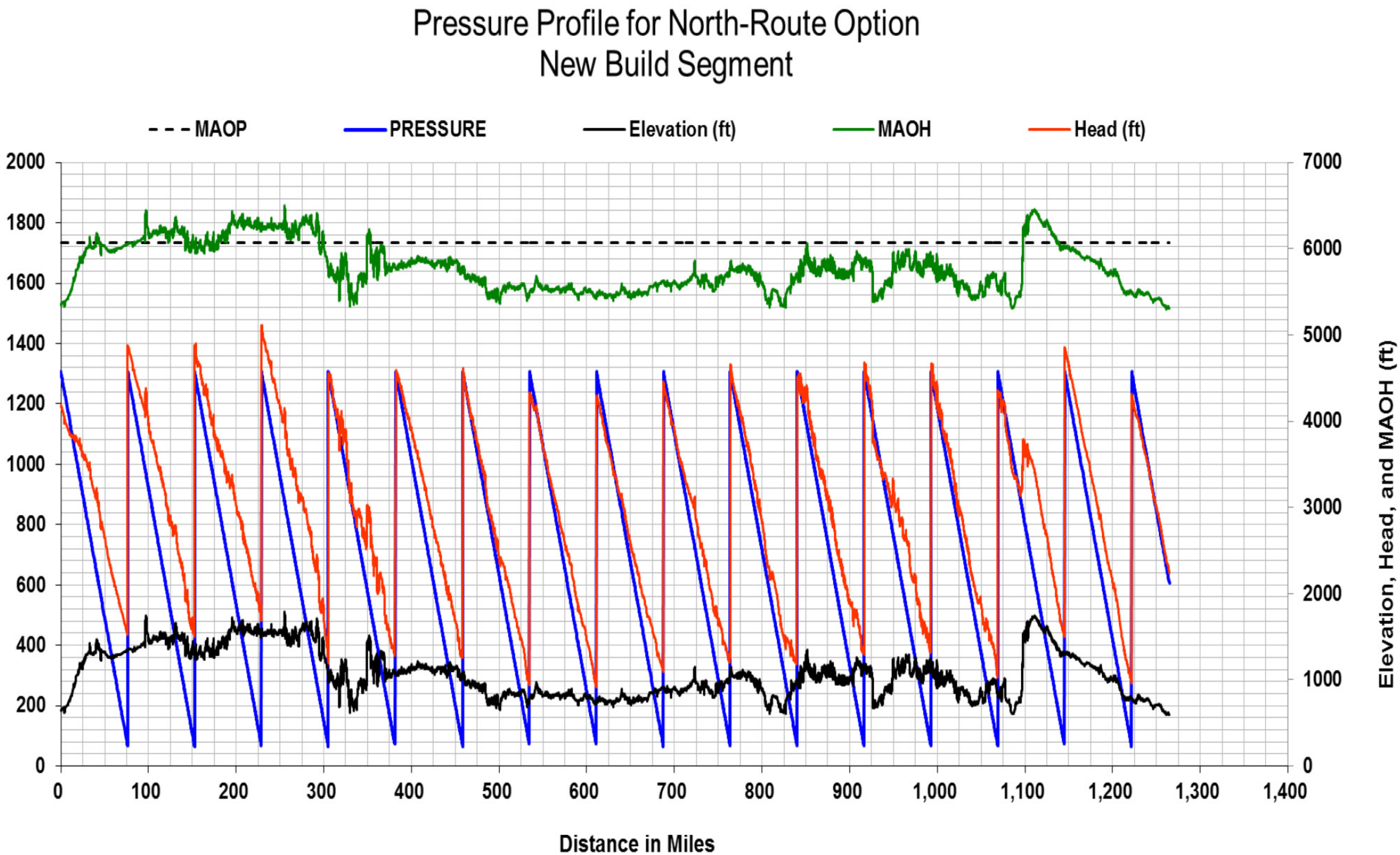


Figure M-3: Pressure Profile – North-Route New Build Option

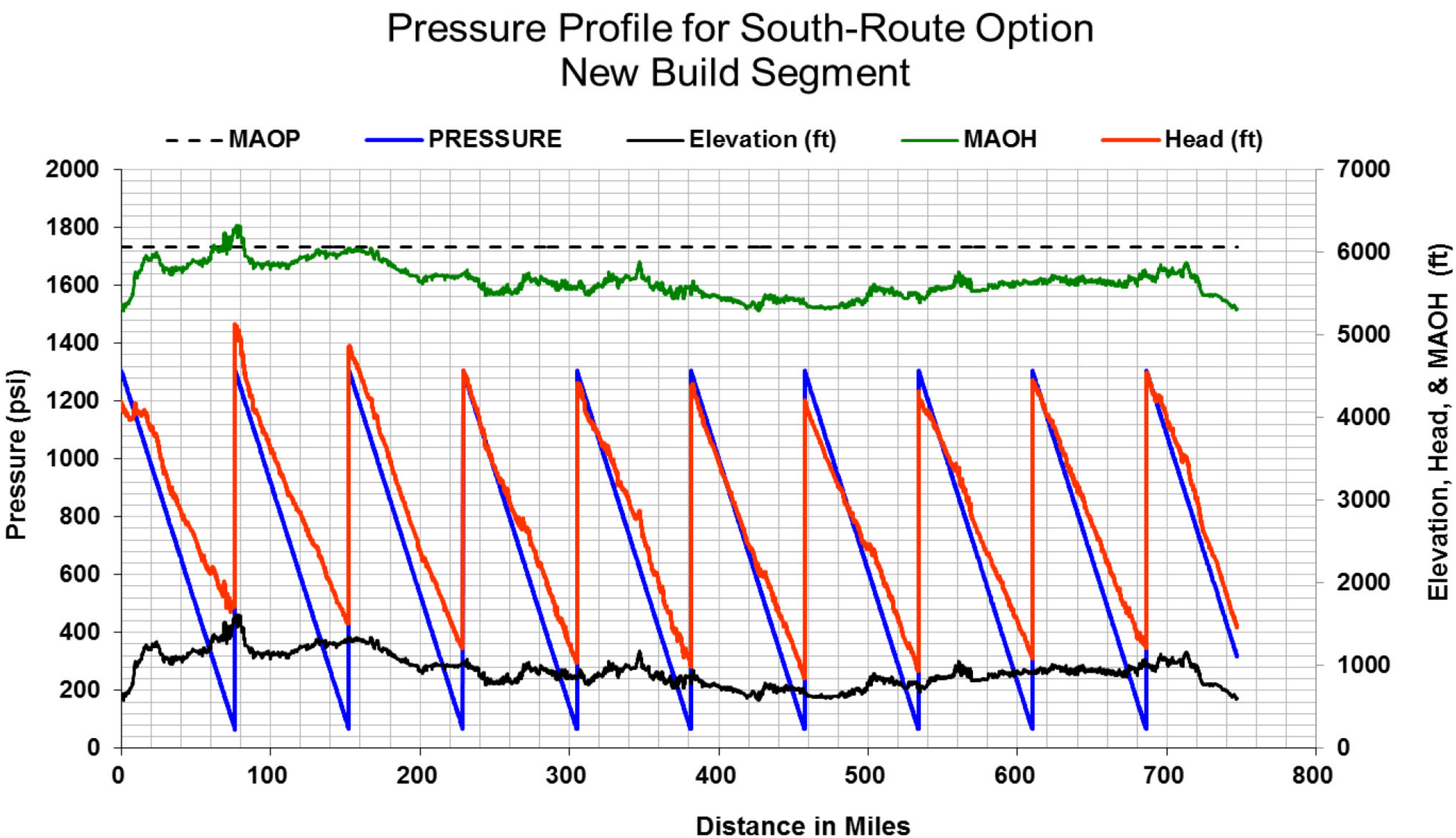


Figure M-4: Pressure Profile – South-Route New Build Option

Appendix M.1.3.4 System Capacity

Pipeline maximum operating pressure (MOP) affects system capabilities. Ultimate system capacity for the 30-in. pipeline will affect total number of intermediate pump stations required per route for discharge pressure of pipe MAOP; 1,440 psi (9,930 kPa).

Appendix M.1.3.5 Compression Requirements

Compression requirements are a function of suction and discharge pressures for each pumping station, system configuration, and operating flow rate.

For the pipeline under consideration, an inlet pressure of 450 kPa (65 psi) was used for head station's station. Whereas for intermediate stations, minimum suction pressures of 450 kPa (65 psi) depend upon pressure losses from the upstream sections, from which some values are slightly higher than 450 kPa (65 psi).

Results of the required compression calculations obtained from the current hydraulic analysis, considering a flow rate of 85,900 m^3/d (540 kbpd) and stations' discharge pressure of 9,000 kPa (1,305 psi) are summarized in Table M-4. Table M-4 depicts summary of the compression requirements for both new build routes (the North-Route and South-Route). Find detailed results in Table M-5 and Table M-6.

As presented in Table M-4 for the given operating pressure, the North-Route will require more compression units than the South-Routh due to the high travel distance for the North-Route. Thus, higher installed compression power will be required.

Table M-4: Total Compression Power Requirements

Route	Number of Stations	Power Required (hp)	Station Locations
North-Route	17	241,695	In US, 15 in Canada
South-Route	10	142,415	All in US

Table M-5: Northern Route Results: Power Calculations

Route Option	Units	Total Power (kW)	Station	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #
Station	#		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Location KP	Km		0	123	246	368	491	615	738	861	984	1106	1229	1352	1475	1598	1721	1843	1966				
Elevation	m		195	408	408	458	309	320	327	240	230	279	328	296	340	343	250	400	236				
Discharge Pressure	kPa		9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000				
Suction Pressure	kPa		450	456	455	471	451	510	452	508	506	451	459	468	465	463	457	505	454				
Power Required	kW	180,232	10626	10618	10620	10600	10624	10552	10623	10554	10557	10625	10615	10604	10608	10610	10617	10558	10621				
Country			USA	USA	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada				

Table M-6: Southern Route Results: Power Calculations

Route Option	Units	Total Power (kW)	Station	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #	Station #
Station	#		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Location KP	Km		0	123	245	368	491	614	736	859	982	1104											
Elevation	m		202	487	403	313	265	242	205	236	278	306											
Discharge Pressure	kPa		9000	9000	9000	9000	9000	9000	9000	9000	9000	9000											
Suction Pressure	kPa		450	451	463	455	454	453	452	452	455	464											
Power Required	kW	106,199	10626	10625	10609	10620	10621	10623	10624	10623	10620	10608											
Country			USA	USA	USA	USA	USA	USA	USA	USA	USA	USA											

Appendix N Dynamic Risk Outflow Methodology

Appendix N.1 Worst-Case Spill Volume

Contract documents associated with the Independent Alternatives Analysis required that the risk and economic impact analysis for spills be based on consideration of "worst-case spills", with the following guidance provided in respect of that term[1]:

> *This would include identifying the "worst case discharge" consistent, at a minimum, with the definition of that term in 40 CFR 194.5 as "the largest foreseeable discharge of oil, including a discharge from fire or explosion, in adverse weather conditions."*
>
> *The identification of the "worst case" should also consider, consistent with best practices in high-hazard industries, the maximum potential release, before applying engineering and procedural controls intended to minimize releases.*
>
> *The identification of the "worst case" should also consider the most adverse foreseeable weather conditions including, but not limited to, storms and/or ice cover.*

The analysis would include, but not be limited to, consideration of the following:

1. The design and placement of the existing pipelines, control systems, leak detection methods, and shut-off valves to determine the various types of physical or operational failures or other potential hazards that could result in releases of oil or other products, including both sudden releases and longer-term releases that could be undetected using the existing systems.
2. The types of products being transported and the maximum design flow rate.
3. The potential failure of release detection methods, control systems, or shut-off valves to operate as intended.
4. The quantity of the oil or other products that could be released at the maximum design flow rate before the flow was cut off.
5. The quantity and fate of oil or other products remaining in the affected pipeline(s) at the maximum design flow rate after the flow is cut off.

Direction provided in 49 CFR 194.5 (referenced above) is as follows:

> §194.5 Definitions
>
> *Worst case discharge means the largest foreseeable discharge of oil, including a discharge from fire or explosion, in adverse weather conditions. This volume will be determined by each pipeline operator for each response zone and is calculated according to §194.105.*

[1]Note that in this contract document, *Title 40 of the Code of Federal Regulations* was referenced in error; Title 49 should have been referenced instead.

Section 194.105 reads as follows:

§194.105 Worst case discharge

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

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

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

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

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

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

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

Appendix N.1.1 Summary of Requirements

From the above, and using the approach option outlined in (b) (1) of 194.105, the following elements are essential in the determination of worst-case spill volume (note that whereas some of the above requirements are stated more than once, and in different ways, requirements in the summary provided below do not include statement of any those requirements more than once):

1. Requirements of 49 CFR 194.5 and 194.105:
   a. Inclusion of hazards associated with fire or explosion.
   b. Consideration of volume released during the maximum time period required for detection and isolation at maximum design flow rate.
   c. Consideration of drain-out volumes contained within the isolated pipe segment following the closure of isolation valves.
2. Consideration of maximum release without applying controls to minimize releases.
3. Consideration of most adverse foreseeable weather conditions.
4. Consideration of design and placement of existing pipelines, control systems, leak detection systems and shut-off valves placement of valves, to determine the various types of physical or operational failures or other potential hazards that could result in releases, including both sudden releases and longer-term releases that could be undetected using the existing systems.
5. The types of product.
6. The potential failure of release detection methods, control systems, or shut-off valves to operate as intended.

Appendix N.1.2 How the Requirements were Met

The means by which each of the above-listed essential requirements for establishing the worst-case spills as it pertains to the spill analysis that was performed is summarized below.

Appendix N.1.2.1 Requirements 1a and 5

The Straits pipelines carry two classes of product; crude oil, which has a low vapor pressure, and natural gas liquids (NGLs), which have a high vapor pressure. In regards to the hazards of fire and explosion, it is the high vapor pressure NGLs that have the greatest potential for ignition to occur, and which have the greatest magnitude (hazard distance). Therefore, two separate spill analyses were conducted:

- one for each of crude oil
- one for NGLs (used as the basis of quantifying fire and explosion hazards).

The NGL spill analysis required the use of an advanced computational fluid dynamics software model to account for the phase change behavior of high-vapor pressure products at the elevated pressures associated with underwater releases.

Appendix N.1.2.2 Requirements 1b, 4 and 6

The time required for pipeline monitoring and leak detection equipment to identify that a leak has occurred is governed by release rate (a function of hole size), and the type of monitoring and leak detection systems employed.

The selection of hole sizes was guided by a Threat Assessment, in which various potential causes of failure were investigated to establish their viability and the release mechanism(s) (hole sizes) associated with each viable threat.

This approach is consistent with the *Statement of Work for the Alternatives Analysis*, which states:

> *Pipeline failures occur over a range of release magnitudes, ranging from small pinhole leaks to full-bore ruptures. Consequently, risk, being a compound measure of both the likelihood of incurring an adverse event and the consequences of that event, must incorporate an assessment of failure probability over a range of potential release magnitudes. A review of the US Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) Hazardous Liquids Incident Data illustrates that within a range of possible release magnitudes, the probability of incurring a failure of a given magnitude varies as a function of the underlying cause of failure. These causes of failure are termed 'threats', which are classified into categories, such as corrosion and outside force damage, as well as subcategories (internal corrosion vs. external corrosion, maritime equipment, etc.).*
>
> *In light of the above, in order to support evaluations of the potential health and safety, environmental and socio-economic consequences associated with a pipeline release, threat-specific estimates of failure probability per year of operation will be provided as a function of release magnitude. In this way, probabilities of incurring representative release magnitudes will be estimated for each threat. Release magnitudes, in turn, may be estimated from industry incident data, or outflow models, as appropriate. Threat-specific probabilities will then be combined to arrive at all-threat probabilities for each of several representative release magnitudes. Each release magnitude may then be incorporated into a separate assessment of Health & Safety, Environment, and Socioeconomic consequence by considering one or more scenarios that are associated with that release magnitude.*

Guided by the Threat Assessment, two separate release mechanisms (hole sizes) were identified: 3-in. (75-mm) holes and full-bore ruptures (FBRs), with each release mechanism being linked to specific causes of failure, and each having specific probabilities of occurrence. Consistent with the failure mechanisms associated with spanning-related threats and anchor hooking, FBRs were connected to those threats. 3–in. (75 mm) holes were connected with failures attributed to the threat of Incorrect Operations, which is a category of failure that is associated with the incorrect application of operating procedures and practices, including repair and maintenance activities. Because of the broad range of potential failure scenarios associated with this threat, the 3-in. (75-mm) hole size was derived by probability-weighting the distribution of hole sizes for offshore pipelines.[2]

Pinhole leaks, which may result in long-term releases having low release rates, are normally associated with specific threats such as pitting corrosion, seam defects, and mechanical connection failures, and are not typical of the release mechanisms associated with the Principal Threats identified for the Existing Straits Crossing segments or a replacement crossing. For this reason, this release mechanism was not considered.

For the Straits Crossing segments, three separate systems, dedicated to the Straits crossing segments are employed:

- Pipeline controller monitoring of abnormal conditions, including pressure drop via SCADA.
- Computational Pipeline Monitoring (CPM) systems that include a real-time transient model and line balance calculations.
- Local low pressure shutdown logic system in Straits isolation valves.

For large leaks and ruptures, the local low pressure logic system in the Straits isolation valves is designed to initiate an immediate cascade shutdown of Line 5 and isolate the Straits segments upon detection of a low pressure condition. The system is designed to achieve full closure of the isolation valves located at each end of the Straits crossing within three minutes of the initiation of the shutdown and isolation command. Therefore, the system is designed to achieve full isolation within three minutes of a FBR occurring anywhere in the Straits crossing segments.

For the smaller leak scenario identified by the Threat Assessment, the system is designed to achieve full isolation within eight minutes.

For the purposes of the release volume analysis, safety factors were applied to the times to achieve full isolation for both FBRs and leaks. In arriving at those safety factors, consideration was given to the ways that the monitoring, leak detection and isolation systems could fail to respond in accordance with the design standards of that equipment.

Based on past incidents involving failures in hazardous liquids pipelines, the greatest single cause of monitoring and leak detection systems failing to respond in accordance with the design standards of that equipment is a phenomenon called *column separation*.

Column separation is the creation of a vacuum within a segment of a pipeline (see Figure N-1).

Column separation can create problems for leak detection and isolation equipment, because it can trigger alarms in the leak detection equipment each time it occurs, resulting in the normalization of false alarms. In other words, where column separation is known to be feasible in a pipeline segment, lengthy delays in interpreting the cause of alarms on the leak detection equipment can result. The most well-known example of such a delay contributing to lengthy diagnosis of a pipeline failure was in the Marshall Incident, which occurred on Enbridge's Line 6B in 2010. In this incident, which was the most costly onshore liquids pipeline spill in US history, it took 17 hours for Enbridge's Operations staff to realize that the cause of the alarms was in fact a pipeline failure, and not a column separation event.

[2]Det Norske Veritas, "Recommended Failure Rates for Pipelines", DNV Report No. 2009-1115, Rev. 1, Page 40. November 16, 2011.

Column separation played such a significant role in the magnitude of the release in the Marshall Incident that the phrase *column separation* was mentioned 88 times in the *Incident Report* published by the National Transportation Safety Board.

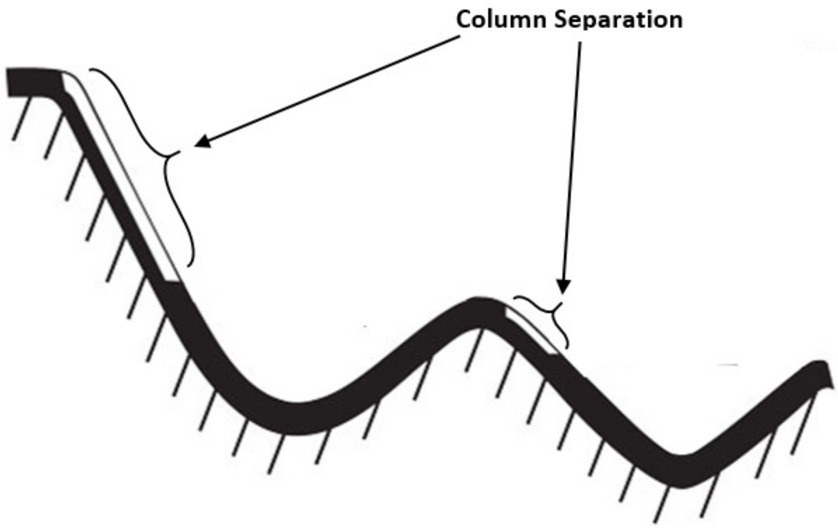


Figure N-1: Column Separation

While column separation is associated with high-elevation segments of a pipeline, the Straits Crossing segments represent the lowest elevation point along Line 5, and these segments are not prone to column separation. Therefore, the potential for monitoring and leak detection equipment to not perform in accordance with design standards due to column separation is not a factor for the Straits pipelines segments.

Apart from column separation, other factors that can cause the monitoring and detection equipment to not perform in accordance with design standards are lack of redundancy in communications equipment and lack of power redundancy at valve sites.

For the existing Straits Crossing segments, isolating valves are located at the north and south sides of the Straits crossing. The North valve site is equipped with redundant systems that ensure that valve power and communication are available in the event of a main power interruption. The South valve site is equipped with redundant communication systems and backflow check valves that provide automatic isolation in the event of power loss.

In consideration of the above, for the maximum design throughput scenario, safety factors of approximately 4 were applied to the equipment design standards for isolation times for FBRs and leaks, resulting in the isolation times summarized in Table N-1.

Table N-1: Response Time Assumptions

Release Size	Equipment Design Standards				Values Assumed For Calculations			
	Detection & Response	Pump Shutdown	Valve Closure	Total Isolation Time	Detection & Response	Pump Shutdown	Valve Closure	Total Isolation Time
FBR	Immediate	Immediate	3 min.	3 min.	10 min.	0.5 min.	3 min.	13.5 min.
3-in. (75-mm) diameter hole	5 min.	Immediate	3 min.	8 min.	30 min.	0.5 min.	3 min.	33.5 min.

Appendix N.1.2.3 Requirements 1c and 2

Following closure of the isolation valves, drain-out of product is determined by the elevation profile and the position of the leak within that elevation profile. Detailed bathymetric data showing the elevation profile of both the East and West Straits pipelines segments was employed in the analysis, and multiple release locations were considered. The most conservative combination of elevation profile and position within that profile was used for the purposes of the spill analysis. For that most conservative combination of conditions, full drain-down to the fullest extent possible was modeled, giving consideration to the elevation profile, release location within that profile, and valve configuration. The spill volumes determined do not take account of any response, intervention or any attenuation of spill volumes.

The mid-channel rupture scenario is located near the deepest point of the bathymetric profile, where, because oil is less dense than water, relatively little drain-out will occur. For this scenario, a conservative assumption was made that 10% of the isolated volume would be released due to drainage before the oil column inside the pipe and water reach an equilibrium. The remaining oil is assumed to get trapped by the water once sufficient water travels into the pipeline and blocks the pipe's opening.

For release scenarios at the shallow ends of the crossing segment it was assumed that any product trapped between the release location and the location with the lowest elevation along the pipeline crossing is drained, as the water replaces the product in the line. Any remaining product will be trapped in the line, where it can be recovered by pumping at the North and South valve sites.

Appendix N.1.2.4 Requirement 3

In the spill volume analysis for the release mechanisms indicated by the Threat Assessment, weather does not play a factor in the performance of the monitoring, detection and isolation equipment. Nevertheless, a full range of weather patterns, with consideration of periods of time with significant ice coverage was incorporated in the analysis of the spreading, fates and effects of spilled oil on the environment.

Appendix N.1.2.5 Summary

Recognizing that there is no clear and consistent approach that is universally required or accepted, 49 CFR 194.105 requires that the methodology and calculations used in establishing worst-case spill volumes be provided. Nevertheless, given that some subjectivity is involved in the definition of "worst-case spill", the worst-case spill volumes used within the Independent Alternatives Analysis met or exceeded the requirements for establishing a worst-case spill.

Consistent with the scope of work for the Independent Alternatives Analysis, the spill analysis was guided by a Threat Assessment, in which various potential causes of failure were investigated to establish their viability and the release mechanism(s) (hole sizes) associated with each viable threat. As a result, two separate release mechanisms were employed: a 3-in. (75-mm) hole and FBR, with each release mechanism being linked to specific causes of failure, and each having specific probabilities of occurrence.

Pinhole leaks, which may result in long-term releases having low release rates were not associated with the Principal Threats identified for the existing Straits Crossing or for the Trenched Crossing Alternative, and therefore this release mechanism was not considered.

The worst-case spill volumes used within the Independent Alternatives Analysis required consideration for the consequences in conjunction with the probability of that event occurring in performing the risk assessment at the Straits Crossing, and similarly with the other alternatives evaluated.

From an industry perspective, a spill volume of 4,527 bbl is greater than more than 99% of the releases reported between 2010-2016 inclusive (US DOT's Pipeline Hazardous Liquids Incident Database).

Relative to the maximum design throughput scenario, safety factors of approximately 4 were applied to detection and isolation times, after consideration of the Supervisory Control and Data Acquisition (SCADA), Computational Pipeline Monitoring (CPM), and automatic low pressure shutdown of the isolation valves that would result in full closure of the isolation valves within three or eight minutes for a FBR or leak, respectively.

While phenomena such as column separation has the potential to adversely affect the detection of a release, as was the case in the Marshall incident, column separation cannot occur at the Straits Crossing due to the elevation profile and it being a low point along the segment.

Appendix N.2 Credible Consequences Associated with a Worst-Case Spill Volume

The purpose of the economic consequence assessment is to provide an estimate of the economic consequences of a worst-case spill. The worst-case spills are based on the outflows derived as described above, and fate of the *oil* is modeled through procedures described in Attachment 2 (see Appendix S). The Statement of Work (SOW) also calls for the potential identification of a *credible* worst-case consequence. For the purposes of this analysis, the report adopts standard actuarial understandings of the word *credible*. These definitions and understandings are associated with statistical predictions used in establishing insurable monetized losses, and also reflect possible risk premiums with different credibility measures. Extensive literature exists on the topic of credibility, and most jurisdictions have established procedures to deal with its treatment in the context of insurable losses.[3]

Assessment of credibility generally depends on a number of factors, including what is described in actuarial terms as a broad class of *relevant experience* based on information about a given risk event and a smaller class of *subject experience* associated with specific available information associated with a single event (ASOP 25 [US Actuarial Standards Board, Actuarial Standard of Practice 25: Credibility Procedures, revised 2013]). ASOP 25 notes in §3.3 that, in circumstances where limited historical information is available, an analyst "should use professional judgment, considering available *subject experience*, in setting an estimate of the parameter under study." For assessment of consequences, the *subject experience* on which this report relies for general spill incidence is the fate modeling described in Attachment 2 (see Appendix S). The statistical means of the individual spill sets are regarded as appropriate for assessing credible consequences of the spill. The use of

[3]Foundations of the use of mathematics and statistics in insurable losses for property, life, health, liability and other potential damages have been supported through actuarial organizations world-wide, represented globally through the International Actuarial Association, headquartered in Ottawa, Canada. European insurance under-writing and re-insurance protocols typically follow national norms, such as those of the UK Institute and Faculty of Actuaries or of the Swiss SAV (Schweizerische Aktuarvereinigung). In North America, such norms are established by the Canadian and US Actuarial Standards Boards within their respective jurisdictions. Also, Pitselis (2016) provides a brief survey of literature regarding the topic and shows how the 95th percentile has often been used as a practical measure for determining limits where additional risk premiums associated with unknown factors may be regarded as appropriate. [Georgios Pitselis, Credible risk measures with applications in actuarial sciences and finance, Insurance: Mathematics and Economics, Volume 70, 2016, Pages 373-386, ISSN 0167-6687, http://dx.doi.org/10.1016/j.insmatheco.2016.06.018.]

averages or means is a typical basis for assessing risks in these circumstances, and is appropriate for providing a benchmark measure for which insurance premiums and expected liabilities can be measured.

It is also acknowledged within actuarial underwriting, however, that some level of financial risk premium (or reduction) may be warranted if the probability distribution is biased. If such biases exist, a credibility assessment would consider the potential degree of bias and make appropriate adjustments. In the case of the spill sets considered here, for example, there is an inherent bias to over-estimate the damages because of the aforementioned factors that establish worst-case outflows as potentially higher than the expected outflows. This treatment within some insurance contexts (associated with rare events) is not uncommon, and would not necessarily earn a premium reduction. It is more likely that an additional premium increase might arise from either:

- lack of ability to pool risks
- information asymmetries associated with the insured party.

In the context of the Straits pipelines, it would normally be expected that the risks of the segment are pooled with a larger system (such as the entire Lakehead System). Risk pooling is common within this industry and is thus not expected to be an issue. Information asymmetry, however, requires an assessment of whether the Insured may have information available in-hand that is not available to an Insurer. If such asymmetries exist, the Insured may be regarded as a higher risk, with either the probabilities or the consequences under-estimated. This higher level of risk (or consequence) would be regarded as credible, to the extent that it should be incorporated within any eventual assessment of potential damages or likelihood. Such an assessment is typically done at the time of underwriting and would be reviewed on a routine basis.

As discussed in Section 2.4.1.1.1.4.1.3, an assessment of Enbridge spill events shows that failures associated with Enbridge's operations are not significantly different than those of the industry. Analyses of PHMSA data showed that the Enbridge Incorrect Operations failure rate was approximately 5.9% lower than the Incorrect Operations failure rate associated with all companies. Use of mean values would thus normally be regarded as a reasonable actuarial assumption, and is used within this analysis.

However, it is also acknowledged that future underwriting may face different circumstances, and the report also therefore establishes a sensitivity analysis for a credible spill at the 95th percentile level for one of the consequence parameters: shoreline oiling within the worst-case highest outflow spill set. The 95th percentile is judgmentally regarded as consistent within actuarial practice (Pitselis, 2016) for considering increased risk premiums.[4]

To summarize, this report treats a credible spill consequence and cost as that corresponding to the mean impacts of the worst-case outflows and the associated fate of those outflows within typical environmental conditions encountered within the Straits over a one year period. A sensitivity analysis is also provided for a 95th percentile spill within the highest outflow spill set (south shore leak); this may also be a credible spill consequence at

[4]Pitselis (2016) in fact considers a range of five quantiles for assessing such premiums: 0.80, 0.90, 0.95, 0.975, and 0.99. The discussion contained in Appendix R focuses on the highest outflow spill set: the south shore leak in Alternative 4 and Alternative 5. Each of these spill sets provides information on 120 spills. It should be noted that the south shore spill set is not the highest probability event: a mid-channel rupture with lower volume outflows has a higher likelihood than a south shore spill. The 95th percentile for the south shore outflow thus corresponds to an unweighted quantile measure of 0.9833 for the entire information base of 360 spills. This places it within the highest levels of *credibility* normally considered in the literature. Note, also, that statistically it is not meaningful to speak of a 100th percentile spill: the information set is always finite and it is impossible to reject the possibility that an outlier will arise outside of the bounds of the data set.

some future date for the purposes of actuarial assessment if the Straits segment risks cannot be pooled with those of other assets or if the Insured party at the time is a higher risk operator.

Appendix O Caveats

Appendix O.1 Regional Input-Output Modeling System (RIMS) II

RIMS II multipliers provided by the US Bureau of Economic Analysis (BEA) were used to estimate the potential impacts on regional economies of construction and operation expenditures associated with the alternatives investigated in this report.

To note, the BEA does not endorse any of the results or any of the conclusions about the economic impacts of the regional expenditures analyzed. Economic impact estimation results are presented in the following parts of the report:

- Executive Summary
- Section 2 – Alternative 5
- Section 3 – Alternative 4
- Section 4 – Alternative 6
- Section 6 – Alternative 1
- Section 7 – Alternative 3
- Appendix Q – Socioeconomic Analysis

Appendix P Cost-Effectiveness Analysis

Appendix P.1 Introduction

Economic feasibility analysis results are a common method for comparing alternatives. Economic feasibility is an *efficiency* measure in economic terms. In standard economic analyses, it assesses the economic viability of a facility in terms of cost and benefit streams from normal operations: this is traditionally called a social cost benefit analysis. For this study, the alternatives described are designed to provide equivalent capacity and deliveries to that of the existing Line 5. In practical terms, this corresponds to total delivery capacity of 540,000 bbl/d, of which $1/6^{th}$ is assumed to be natural gas liquids (NGLs). The project employs a cost-effectiveness analysis to permit a simpler comparison that does not rely on explicitly estimating the benefit streams or revenues from the alternatives. Such a cost-effectiveness analysis is consistent with *OMB Circular No. A-4* (2003), which focuses on regulatory analysis of alternatives [1]. It also serves as an appropriate starting point for performing subsequent market impact analyses.

Cost-effectiveness analysis is undertaken for each alternative passing the preliminary screening. It is based on the present value of a cash-flow profile of capital and operating costs needed to deliver a volume equivalent to that of the current pipeline infrastructure. This volume is selected as a benchmark to permit comparisons of alternatives independent of selected upstream and downstream impacts (which will be addressed elsewhere). The key reported metric is a levelized cost in $/bbl terms. The levelized costs are subsequently used in market analyses to determine the degree to which producers, refiners, and consumers of energy products may be impacted. A levelized cost can be thought of as the real (excluding inflation) price that must be received for every barrel of throughput over the life of a project for a transportation service to break even. The current Lakehead System toll to transport products from Superior to the Sarnia area is a useful benchmark for comparison: approximately $1.50/bbl[1].

The report also at times calculates stand-alone operating costs (e.g., for leased equipment), which already have capital returns embedded within them. Such costs can be translated directly into $/bbl amounts without going through a levelization procedure because the operating costs are already expressed in $/bbl terms. Such calculations are provided in the report text (e.g., for small scale propane deliveries) without need for levelization. Such calculations are also independent of discount rates as expenses are incurred exactly at the time that product is delivered.

Appendix P.2 Discount Rates

For a stand-alone comparison of alternatives, the levelized costs are calculated based on the design-based cost estimates for each alternative, the throughput of the reference case for Line 5 (540,000 bbl/d), and a real discount rate of 6%/y. A discount rate is a common metric for weighting future economic returns generated by a given initial investment. In addition to the base rate of 6%/y, specific sensitivity results for this study are shown at 4%/y and 8%/y.

[1]The component of the toll from Superior to the Sarnia area can be inferred from either the local tariff or the joint international tariff. Those in effect in May 2017 provide the following results: Local 2017 FERC Tariff 43.22.0 implies US$1.505/bbl to Marysville [6]; International 2016 FERC Tariff 45.12.0 implies US$1.48/bbl [7].

Reviewed literature and guidelines in the US and Michigan placed potential positive real discount rates within a range of 2.875%/y to 10%/y.

The US Army Corps of Engineers uses discount rates on projects related to water planning that are largely linked to market interest rates because they are limited by statute using a formula that refers to market rates. This rate is fixed at 2.875%/y for Fiscal year 2017.[2] (USACE [2]) This has created a debate about the proper discount rate to use for such projects, because Congress requires analyses to be done using a discount rate of 7%/y. The US Executive Branch Congressional Research Service issues routine circulars on the topic, the most recent (2016 [3]) states:

> *The executive branch has used a 7% discount rate for its evaluation of most federal programs since 1992, pursuant to Office of Management and Budget (OMB) Circular A-94. According to the circular, the 7% rate is intended to reflect the pretax rate of return on capital in the private sector. Since the late 1990s, the water planning discount rate has been below 7%. [p ii]*

> *There are no current proposals to alter the water planning discount rate. However, since the mid-2000s, the executive branch has used a 7% discount rate to calculate construction project BCR [Benefit Cost Ratio] for use as metric for budgeting. For many Corps projects, the BCR at the 7% discount rate is used to set a minimum threshold for inclusion in the executive branch's annual budget request for Corps construction. [p 22]*

Sensitivity ranges are routinely described; most commonly suggesting the use of lower rates under circumstances where regulators are addressing safety or heath issues and higher rates: *OMB Circular No. A-4* prescribes sensitivity tests at 3%/y under such circumstances (pp 33-34 [1]). Higher rates are usually considered where corporate capital may be at stake under conditions of uncertainty: 10%/y is a common sensitivity test in corporate submissions to regulators.

Use of the Michigan discount rate of 5%/y, used for damages, was considered in this study but its discounting methodology makes it less appropriate for facility analyses involving interstate systems. The Michigan discount rate refers to Michigan law that results in a damage award based on a methodology of using a simple discount rate of 5%/y.[3] This is in contrast with conventional practice that uses compounded discounting. This report uses compounded discounting. However, the results for this Michigan methodology fall within the sensitivity range reported in this report.

Finally, Watson (2016 [4]) surveys discount rates used for water use planning internationally and documents values as low as 1.4%/y used by the UK Treasury; and notes that the UK standard commences with variably-prescribed discount rates, which decline in time such that costs 100 years out are discounted at a rate of 2.5%/y

[2] *Water Resources Development Act* of 1974 (WRDA 1974; P.L. 93-251) requires the executive to use an annually adjusted water planning discount rate for project planning. The discount rate is calculated annually based on a formula established in S.Doc. 97 from 1962; the rate was 3.125%/y in FY2016. The calculation uses the average yield on Treasury securities with 15 years or more remaining to maturity, rounded to the nearest one-eighth of 1%/y and capped at an annual change of 0.25%/y.

[3] The original provision for this is in the *REVISED JUDICATURE ACT OF 1961* Act 236 of 1961 / Michigan Compiled Laws (MCL)§ 600.6306(1) Entering order of judgment; order; judgment amounts; "gross present cash value" defined; reduced judgment amount. It is applied to the "total amount of future damages reduced to present value at a rate of 5% per year, compounded annually, for each year in which those damages will accrue." Michigan Supreme Court further ruled that the statutory 5% rate is simple, not compounded. According to (MCL)§ 600.6306(2), *"…the court shall determine the ratio of total past damages to total future damages and shall allocate the amounts to be deducted proportionately between past and future damages"*.

thereafter. The US analyses undertaken by Watson, however, rely on values in the range of 3.375%/y to 7%/y.

The reader is cautioned that – in comparing alternatives – it is best practice to use the same discount rate methodology and rate in any such comparisons. The 6%/y real discount rate in the mid-range provides an appropriate basis for such comparisons.

Appendix P.3 Levelized Costs

Levelized cost *L* is solved through Equation P-1a and Equation P-1b. Levelized cost *L* is a *constant amount*, which solves an equation for a break-even price, such that if *L* is received for every unit of throughput, then the present value of the resultant revenue stream is equal to the present value of the total cost stream associated with producing, processing or delivering the throughput. Equivalently, if this were a benefit cost analysis of a project, then the net present value of the project would be zero at that discount rate: it would break even.

For an analysis of this type, all costs are expressed in *real* terms, with inflation removed (see Equation P-1a and Equation P-1b).

$$\sum_{t=0}^{T}(L_{i,r}Q_{i,t})(1+r)^{-t}=\sum_{t=0}^{T}(K_{i,t}+OC_{i,t})(1+r)^{-t}$$

Equation P-1a: Levelized Cost

Thus:

$$L_{i,r}=\frac{\sum_{t=0}^{T}(K_{i,t}+OC_{i,t})(1+r)^{-t}}{\sum_{t=0}^{T}Q_{i,t}(1+r)^{-t}}$$

Equation P-1b: Levelized Cost

Where:

$L_{i,r}$ = Levelized cost ($/bbl) for Alternative *i* at discount rate *r*
i = Alternative index [1N, 1S, 3S, 4A, 4B, 5, 6B]
r = real discount rate (/y)
t = year [0,1,…, T]
T = duration of cash flow (y)
$K_{i,t}$ = Capital expenditures in year t ($)
$OC_{i,t}$ = Operation expenditures in year t ($)
$Q_{i,t}$ = quantity of throughput in year t (bbl)

Default assumptions for these calculations are as follows:

r = 6%/y [also sensitivity results at 4%/y and 8%/y]
T = 54 y

The value for T corresponds to a maximum 55 year project evaluation permitting up to 5 years of construction expenditures and minimum 50 years of operation thereafter.

Construction expenditures are assumed to commence in year t = 0 and occur over a period of P_{iK} years such that operations start in year $t = P_{iK}$.

Appendix P.4 Levelized Costs, Tariffs, and Market Impacts

Tariffs are also expressed in unit terms, for example the current tariff between Superior and Sarnia for oil is approximately $1.50/bbl. Levelized costs from different alternatives can be compared to each other, and can also be related to system tariffs under certain circumstances. The circumstances essentially require that:

- The system is operated on a cost of service revenue recovery basis, or is in a highly competitive market where normal profits can be realized but excessive profit margins are temporary.
- The discount rate is representative of regulated rates of return, if the system is regulated on a cost of service basis.

Both of these conditions are substantially met for most of the comparisons conducted in this report. A June 2017 Enbridge report to investors characterizes the Lakehead System as follows [5]:

> *100% Cost of service or equivalent agreements**
> **Contract terms for our Lakehead system expansion projects mitigate volume risk for all expansions subsequent to Alberta Clipper. In the event volumes were to decline significantly the pipeline could potentially file cost of service rates. Similarly, the Bakken Classic system can also file cost of service rates if there is a substantial divergence between costs and revenues on the pipeline. [slide 4]*

Also, the Federal Energy Regulatory Commission (FERC) regulates returns based on a weighted average of *real return* on equity (ROE) for companies and *nominal* borrowing rates for debt. As described previously, the US Executive Branch regards a 7%/y pretax rate of return on capital to be an appropriate benchmark. ROE in many utilities is routinely higher than 7%/y when calculated in hindsight after the annual accounts are closed.[4] But if higher ROEs persist, it is not uncommon for shippers or customers to object, or for the regulator itself to change its assumptions in the rate-setting context: rates are regulated with a view to being just and reasonable.

In current debt markets (for bonds) or in a yield seeking financial environment for high quality preferred shares as a substitute for debt, the base case discount rate assumption of 6%/y is regarded as a reasonable basis for comparison to regulated cost of service tariffs in the pipeline sector. It is acknowledged that some of the alternatives considered in this report (including trucking and railways) are not regulated, but they are participating in a competitive environment alongside pipeline infrastructure. The use of the levelized costs at a 6% discount rate to inform market impact analysis is thus regarded as sound.

[4]Inspection of FERC annual filings for the Lakehead System for 2015 imply a real ROE of approximately 9.5%/y and nominal debt of about 5%/y (equivalent to real debt of about 3%/y). Equity:debt ratio is slightly higher than 1:1 for 2015 and the real weighted average is approximately 6.8%/y for that reporting year.

Appendix P.5 Results

Appendix P.5.1 Levelized Costs

Table P-1 provides results for the reference case of Q = 197.1 million bbl/y for all years t = P_{iK} to T. This quantity corresponds to a volume of 540 kbbl/d.

Note that the results for the abandonment scenario i = 6B are similarly shown for this scenario although, obviously, there will be no throughput if the pipeline is abandoned. The calculation effectively assumes that as soon as abandonment commences, throughput stops ($P_{6B,K}$ = 0 years). This calculation is conducted to provide the incremental contribution of full abandonment costs for any alternative (rail, pipeline, or other), which is intended to replace the 540 kbbl/d capacity of Line 5. No levelized cost is shown for current Line 5 operations as the figures in the table reflect *incremental costs* to current operations.

Table P-1: Levelized Cost based on 540 kbbl/d Throughput

Alternative	Specific Assumptions *Ki* : Total Capital Costs	Levelized Cost r=4%/y ($/bbl)	Levelized Cost r=6%/y ($/bbl)	Levelized Cost r=8%/y ($/bbl)
4A Trench Crossing	K_{4A}: $27.3 million $P_{4A,K}$: 2 years	0.006	0.009	0.011
4B Tunnel Crossing	K_{4B}: $152.9 million $P_{4B,K}$: 2 years	0.034	0.046	0.059
1N North Pipeline	K_{1N}: $3,811.8 million $P_{1N,K}$: 5 years $OC_{1N,t}$: $407 million/y (t=5) $OC_{1N,t}$: ~ linear (t=6 … 14) $OC_{1N,t}$: $293 million/y (t=15,…$T$)	2.568	2.977	3.432
1S South Pipeline	K_{1S}: $2,025.2 million $P_{1S,K}$: 5 years $OC_{1S,t}$: $225 million/y (t=5) $OC_{1S,t}$: ~ linear (t=6 … 14) $OC_{1S,t}$: $165 million/y (t=15,…$T$)	1.411	1.628	1.870
3S South Rail	K_{3S}: $907.8 million $P_{3S,K}$: 3 years $OC_{3S,t}$: $1,220.0 million/y (t=13,…T)	6.407	6.492	6.585
6B Full Abandonment	K_{6B}: $212.1 million Includes terrestrial and Straits Crossing sections	0.049	0.067	0.087

Appendix P.5.2 Market Impact

As described previously, the levelized costs can also be used to inform the market impact analysis. This requires a simple arithmetic conversion of the levelized costs in Table P-1. As described in the report, the low levelized costs associated with the trench and tunnel crossings imply that market impacts are negligible. Also, Alternative 1N (North Pipeline) is filtered out because it is not competitive compared to Alternative 1S (South Pipeline). The results of interest to the market impact analyses are therefore the

South Pipeline and the South Rail configurations. Both of these, if implemented, would involve abandonment of Line 5 *after* Alternative 1S or Alternative 3S come into service.

Table P-2 provides an estimate of the incremental impacts of these alternatives, including Line 5 abandonment costs, on system volumes. Results are shown for Q = 949.1 million bbl/y. This quantity corresponds to a volume of 2,600 kbbl/d.

Table P-2: Levelized Cost based on System Volumes (r=6%/y)

Alternative	Levelized Cost [540 kbbl/d]			Levelized Cost 2,600 kbbl/d
	Reference ($/bbl)	Abandonment ($/bbl)	Total ($/bbl)	Total ($/bbl))
1S South Pipeline	1.628	0.067	1.695	0.352
3S South Rail	6.492	0.067	6.559	1.362

Levelized cost values in the last column of Table P-2 relating to 2,600 kbbl/d can be interpreted as an expected incremental impact to the average cost in the system for all throughput in the system. For example, against a current Superior–Sarnia tariff of $1.50/bbl, Alternative 1S (South Pipeline) would generate an expected *increase* in shipping costs of $0.35/bbl. This increased cost would potentially be seen by refiners, and eventually consumers. If it were all borne by refiners, then a first approximation of impact can be derived by considering refinery yields for gasoline and distillates, which are the main products that would impact consumers directly. Yields vary with refinery configuration, season, and regional demand patterns. A summary of US and PADD 2 refinery yields is provided in Table P-3. For analyses in this study, an average yield of 85% is assumed.

Table P-3: US Refinery Yields

Area	2015	2016
All US Refineries	85.3%	85.4%
All PADD 2 Refineries	87.2%	87.2%
Source: US Energy Information Administration. Petroleum and Other Liquids. Refinery yields. Includes finished motor and aviation gasoline products, kerosene products, distillate fuel oil. https://www.eia.gov/dnav/pet/pet_pnp_pct_dc_r20_pct_a.htm		

Translation of increased shipping costs into product prices can be approximated by dividing the system levelized costs by 85% (to obtain cost per barrel output instead of barrel input); this assumes revenue recovery by the refinery on the higher value consumer products. The result can then be converted to prices consumers see based on conversions using 42 gal barrels. The $0.352/bbl increase in shipping costs for Alternative 1S becomes a $0.00986/gal increase (1.0¢/gal). The $1.362/bbl increase in shipping costs for Alternative 3S equates to a $0.0382/gal increase (3.8¢/gal).

Similarly, an increase in shipping costs could potentially be passed on to propane consumers in PADD 2 and Michigan, causing these consumers to experience higher prices (see Appendix J). The mechanisms associated with this relate to the volumes of NGLs (90 kbbl/d) currently delivered through Line 5 to a Sarnia fractionation facility with a capacity of ~100 kbbl/d. An estimated 25 kbbl/d of propane is subsequently exported from this facility into PADD 2 via Michigan. The initial increase in shipping costs, if passed on to final consumers in PADD 2, would be distributed over a very large market: PADD 2 propane supplies exceed 500 kbbl/d (see Appendix J). If impacts were distributed over this market, they would be negligible or non-existent as the relative volumes would be inadequate to move the expected market price: any adjustment is more likely to be reflected in reduced producer or fractionator net income. For this analysis, however, it is assumed that all the costs are borne by Michigan consumers in the Lower Peninsula (LP). The initial $0.352/bbl increase in shipping costs for Alternative 1S becomes a $0.3168/bbl increase in propane value at the outlet of the fractionator. This change in propane value reflects an assumption that 10 kbbl/d into the fractionator would still come from existing NGL sources with no change in delivered price to the fractionator. At the propane export point to PADD 2 the $0.3168/bbl increase equates to $7,920/d or $2.89 million/y over the 25 kbbl/d of propane. The LP market for propane is approximately 430 million gal/y; therefore, the maximum propane price impact in that market is 0.67¢/gal under Alternative 1S. A similar calculation for Alternative 3S shows that the $1.362/bbl incremental shipping costs would translate into an impact on LP propane consumers of approximately 2.60¢/gal.

Appendix P.6 References

[1] Office of Management and Budget, "Office of Management and Budget Circular A-4," 17 September 2003. [Online]. Available: https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/. [Accessed November 2016].

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[3] Congressional Research Service, "Discount Rates in the Economic Evaluation of U.S. Army Corps of Engineers Projects," 2016.

[4] K. Watson, "Quantifying flood mitigation services: the economic value of Otter Creek wetlands and floodplains to Middlebury VT," *Ecological Economics,* no. 130, pp. 16-24, 2016.

[5] Jarvis, Guy, Enbridge: Liquids Pipelines Report (Enbridge Mid-Year Investor Update Meeting 2017), June 2017. [Online]. Available: https://www.enbridge.com/~/media/Enb/Documents/Investor%20Relations/2017/2017_ENBDays_05-LP.pdf.

[6] ENBRIDGE ENERGY, LIMITED PARTNERSHIP, "FERC Tariff No. 43.22.0 Effective April 1, 2017; LOCAL TARIFF APPLYING ON CRUDE PETROLEUM AND NATURAL GAS LIQUIDS".

[7] ENBRIDGE PIPELINES INC. IN CONNECTION WITH ENBRIDGE ENERGY, LIMITED PARTNERSHIP, "FERC Tariff No. 45.12.0 Effective September 1, 2016; INTERNATIONAL JOINT RATE TARIFF APPLYING ON CRUDE PETROLEUM, CONDENSATES AND NATURAL GAS LIQUIDS," 2016.

Appendix Q Socioeconomic Analysis

Direction from *National Energy Policy Act* (NEPA) and Council on Environmental Quality (CEQ) Regulations indicates that it is necessary to identify potentially undesirable social and economic effects of projects to the human environment before they occur in order to make recommendations for mitigation.[1] The socioeconomic impact assessment (SIA) screening tool presented here provides a preliminary identification of potential social and economic concerns/impacts associated with the alternatives presented in this report. The tool is meant to provide a basis for comparison of socioeconomic impacts within each alternative and across alternatives. The screening tool would also provide a starting point for more detailed information gathering and public consultation on any of the alternatives.

The appendix is structured as follows:

- Appendix Q.1 provides basic socioeconomic data used throughout this appendix.
- Appendix Q.2 presents the SIA screening tool and its results: a preliminary identification and ranking of SIA impacts associated with the alternatives considered in the report. The analyses behind the screening results are summarized in subsequent appendix sections.
- Appendix Q.3 presents economic analyses of construction and operation expenses. The reader is also directed to Appendix O to review caveats associated with the use of USBEA RIMS II multipliers. Capital cost estimates are further elaborated in Appendix H, which describes assumptions for each alternative including categories of excluded costs. Abandonment assumptions are detailed in Appendix I, including the conditions under which costs reflect abandonment in place *vs* pipeline removal. Abandonment of the existing twin 20-in. pipelines is assumed to be via in place procedures for the purposes of assessing costs and impacts; Appendix I details assumptions and costs in the event that regulatory authorities require pipeline removal in this segment.
- Appendix Q.4 presents associated government revenue impacts.
- Appendix Q.5 to Appendix Q.7 discuss impacts related to community resources, populations, and community structures.
- Appendix Q.8 and Appendix Q.9 discuss Tourism and Fisheries Resources, respectively.
- Appendix Q.10 discusses Hunting and Trapping Resources.
- Appendix Q.11 provides a selected bibliography showing thematic sources contained in the appendix text.

Appendix Q.1 Baseline Socioeconomic Characteristics in Areas of Interest

This section assembles baseline socioeconomic data for the *areas of interest* to the report. These areas are the counties and Prosperity Regions implicated in the alternatives analyzed in sections 2 to 7 in the report. They are the counties over which

[1]CEQ Regulations for implementing the Procedural Provisions of the NEPA. C40 CFR 1508.14: Human environment shall be interpreted comprehensively to include the natural and physical environment and the relationship of people with that environment. 40 CFR 1508.8: Effects includes ecological, aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative.

Line 5 currently passes, or a new southern pipeline or railway route would pass; and the larger Prosperity Regions containing these counties.

For the SIA screening, the socioeconomic area of analysis is first identified by the characteristics of its population and general socioeconomic environment.

Table Q-1 provides population data; Table Q-2 provides income and employment statistics. These tables also indicate which counties currently intersect with Line 5, and those that would intersect with new projects: a new southern pipeline route (Alternative 1) or a southern rail route for Line 5 product (Alternative 3).

Table Q-3 provides information on housing in those same counties, similarly indicating which counties are – or would be – in the right-of-way (ROW) of different alternatives.

Table Q-4 provides information on the labor force employment in each county that would be impacted by new construction or new operations associated with Alternative 1, Alternative 3, and Alternative 4 – a new trench or tunnel to replace the current Line 5 Straits of Mackinac (Straits) crossing.

Table Q-5 provides land use/land cover data for the corridor counties that would be affected by Alternative 1 (southern pipeline) and Alternative 3 (southern rail). These data provide information about the extent of developed area and environmentally sensitive land in counties where construction and operation associated with the alternatives would occur.

Population and housing data were sourced from the U.S. Census Bureau and the American Community Survey (ACS). Information on Tribal trust land was obtained from the Bureau of Indian Affairs. Employment and labor force data were sourced from the US Bureau of Labor Statistics (BLS) and the US Bureau of Economic Analysis (USBEA). County-level land use/land cover data were derived using the National Land Cover Database (2011) classification scheme (Homer et al., 2015).

Table Q-1: Population Information in Areas of Interest

Counties in Areas of Interest	Intersect Counties			Population 2015	Population Change 2010-2015	Population Density (persons/ sq mile)	Tribal Trust Land in County	American Indians & Alaska Native 2015
	Alt 5: Line 5 Status Quo	Alt 1: South Route Pipeline	Alt 3: South Route Rail					
Region 1								
Chippewa				38,033	-1.5%	24	◆	15.7%
Delta	◆			36,377	-1.9%	31	◆	2.5%
Dickinson	◆			25,788	-1.4%	34		0.7%
Gogebic	◆			15,431	-5.9%	14	◆	2.8%
Iron	◆			11,348	-3.8%	10		1.3%
Mackinac	◆			10,890	-1.8%	11	◆	17.1%
Marquette	◆			67,215	0.2%	37	◆	1.9%
Schoolcraft	◆			8,173	-3.6%	7	◆	9.2%
Region 2								
Antrim				23,154	-1.5%	49	◆	1.1%
Charlevoix				26,238	1.3%	63	◆	1.6%
Emmet	◆			33,161	1.6%	71	◆	3.7%
Grand Traverse				91,636	5.4%	197	◆	1.2%
Region 3								
Alpena				28,803	-2.5%	50		0.6%
Cheboygan	◆			25,427	-2.5%	36		3.0%
Crawford	◆			13,801	-1.8%	25		0.7%
Ogemaw	◆			20,937	-3.2%	15		0.9%
Oscoda	◆			8,251	-4.1%	15		0.9%
Otsego	◆			24,253	0.4%	47		0.8%
Presque Isle				12,841	-3.5%	19		0.9%
Region 5								
Arenac	◆			15,261	-3.7%	42	◆	1.3%
Bay	◆			105,659	-1.9%	239		0.6%
Saginaw	◆			193,307	-3.3%	242		0.6%
Region 6								
Genesee			◆	410,849	-3.3%	645		0.6%
Lapeer	◆		◆	88,373	0.2%	137		0.5%
Shiawassee			◆	68,619	-2.8%	129	◆	0.6%
St. Clair	◆	◆	◆	159,875	-1.7%	222		0.5%
Tuscola	◆			53,777	-3.4%	67		0.6%
Region 7								
Eaton			◆	108,801	1.0%	189		0.5%
Ingham		◆	◆	286,085	1.8%	514		0.6%
Region 8								
Berrien		◆		154,636	-1.4%	272	◆	0.6%
Calhoun		◆	◆	134,314	-1.3%	190	◆	0.8%
Cass		◆	◆	51,657	-1.0%	105	◆	1.2%
Kalamazoo		◆	◆	260,263	3.8%	463		0.5%
St. Joseph		◆	◆	61,018	-0.4%	122		0.6%
Van Buren			◆	75,077	-1.4%	124	◆	1.2%
Region 9								
Jackson		◆		159,494	-0.4%	227		0.4%
Livingston		◆		187,316	3.5%	331		0.4%
Region 10								
Macomb		◆		864,840	2.8%	1805		0.3%
Oakland		◆		1,242,304	3.3%	1432		0.3%

Source: US Census Bureau. Population Estimates Program. QuickFacts for States and Counties.

Table Q-2: Personal Income and Employment Statistics for Areas of Interest

Counties in Areas of Interest	Intersect Counties			Per capita income ($)	Employment			Jobless Rate (% of labor force)
	Alt 5: Line 5 Status Quo	Alt 1: South Route Pipeline	Alt 3: South Route Rail		Proprietor (%)	Wage and salary (%)	Total (persons)	
Region 1								
Chippewa				31,358	21	79	17,376	7.7
Delta	◆			36,319	22	78	18,836	6.7
Dickinson	◆			42,709	14	86	17,158	5.6
Gogebic	◆			35,495	21	79	7,215	7.3
Iron	◆			38,557	26	74	5,449	7.0
Mackinac	◆			38,607	25	75	6,182	9.6
Marquette	◆			36,788	18	82	35,419	6.0
Schoolcraft	◆			35,475	21	79	3,647	10.8
Region 2								
Antrim				39,731	39	61	9,036	7.4
Charlevoix				46,000	30	70	15,671	6.0
Emmet	◆			48,882	26	74	25,769	7.2
Grand Traverse				43,876	27	73	70,167	4.6
Region 3								
Alpena				36,467	23	77	15,986	6.2
Cheboygan	◆			34,608	31	69	9,977	9.0
Crawford	◆			29,960	23	77	5,169	7.8
Ogemaw	◆			30,925	27	73	8,660	7.8
Oscoda	◆			32,631	36	64	3,007	8.6
Otsego	◆			35,102	29	71	14,588	6.1
Presque Isle				34,262	35	65	4,962	10.1
Region 5								
Arenac	◆			34,226	26	74	6,687	8.9
Bay	◆			37,884	21	79	47,916	5.7
Saginaw	◆			35,429	18	82	108,893	5.7
Region 6								
Genesee			◆	36,612	24	76	188,803	6.1
Lapeer	◆		◆	38,417	31	69	32,872	7.2
Shiawassee			◆	35,078	31	69	26,381	5.6
St. Clair	◆	◆	◆	39,268	27	73	65,437	6.8
Tuscola	◆			34,771	36	64	19,304	6.7
Region 7								
Eaton			◆	37,921	22	78	55,502	4.4
Ingham		◆	◆	37,142	18	82	187,889	4.7
Region 8								
Berrien		◆		41,939	22	78	84,061	5.2
Calhoun		◆	◆	36,958	16	84	71,794	5.1
Cass		◆	◆	38,838	33	67	14,589	5.0
Kalamazoo		◆	◆	43,062	18	82	150,809	4.3
St. Joseph		◆	◆	34,215	23	77	29,338	4.5
Van Buren			◆	37,247	29	71	31,709	6.2
Region 9								
Jackson		◆		36,413	20	80	75,286	5.3
Livingston		◆		49,608	27	73	82,533	4.6
Region 10								
Macomb		◆		41,847	22	78	429,804	5.8
Oakland		◆		63,454	21	79	963,331	4.8

Source: U.S. Bureau of Economic Analysis. Table CA4. Personal Income and Employment by Major Component; U.S. Bureau of Labor Statistics. Labor Force Data by County.

Table Q-3: Housing Data for Areas of Interest

Counties in Areas of Interest	Intersect Counties			Housing Units	Home owner Vacancy (%)	Rental Vacancy (%)
	Alt 5: Line 5 Status Quo	Alt 1: Southern Route Pipeline	Alt 3: Southern Route Rail			
Region 1						
Chippewa				21,231	3	7.1
Delta	◆			20,200	3.3	2.5
Dickinson	◆			14,008	1.7	6.5
Gogebic	◆			10,749	3.2	8.3
Iron	◆			9,256	3.4	6.3
Mackinac	◆			11,021	4.9	9.9
Marquette	◆			34,480	1.7	7.3
Schoolcraft	◆			6,325	3.7	7.7
Region 2						
Antrim				17,811	4.5	6.5
Charlevoix				17,336	2.8	4.3
Emmet	◆			21,319	2.9	9.3
Grand Traverse				42,126	1.8	8.2
Region 3						
Alpena				15,983	2.9	4.7
Cheboygan	◆			18,284	3.8	13.1
Crawford	◆			11,107	2.2	14.9
Ogemaw	◆			16,023	2.5	3.6
Oscoda	◆			9,106	5.7	6.3
Otsego	◆			14,758	2.4	2.4
Presque Isle				10,414	2.7	11.4
Region 5						
Arenac	◆			9,767	2.2	3.5
Bay	◆			48,057	2.1	5
Saginaw	◆			86,823	1.9	5.6
Region 6						
Genesee			◆	191,178	2.3	7.4
Lapeer	◆		◆	36,238	2	8.4
Shiawassee			◆	30,129	1.8	6.4
St. Clair	◆	◆	◆	71,889	2.1	5.4
Tuscola	◆			24,303	3.1	6.2
Region 7						
Eaton			◆	47,092	2.2	5.6
Ingham		◆	◆	121,722	2.2	6.1
Region 8						
Berrien		◆		76,772	2.9	9.5
Calhoun		◆	◆	60,716	2.7	9.7
Cass		◆	◆	25,909	3.3	4.4
Kalamazoo		◆	◆	110,196	1.7	4.8
St. Joseph		◆	◆	27,682	2.1	7.8
Van Buren			◆	36,690	2.4	8.1
Region 9						
Jackson		◆		69,121	2	7.6
Livingston		◆		74,169	1	4.2
Region 10						
Macomb		◆		359,902	1.5	4.3
Oakland		◆		531,609	1.3	5.6

US Census Bureau. 2011-2015 American Community Survey 5-Year Estimates. DP04 Selected Housing Characteristics.

Table Q-4: 2015 Labor Force in the Areas of Interest by Industrial Sector (% of Total)

Counties in Areas of Interest	Farming	Forestry, fishing, and related activities	Mining, quarrying, and oil and gas extraction	Construction	Manufacturing	Wholesale trade	Retail trade	Transportation, Warehousing; Utilities	Information	Finance, insurance; Real estate, rental, leasing	Professional, scientific & tech services; Mgmt of companies; Admin & support & waste mgmt	Education services; Health care & social assistance	Arts, entertainment & recreation; Accommodation & food services	Other services excl public admin	Government & government enterprises incl military
Alpena	3.1	0.6	1.0	5.2	9.9	3.1	14.7	2.5	1.1	7.4	3.0	11.5	8.0	6.9	18.7
Antrim	6.3	[a]	[a]	8.2	11.4	1.5	10.1	[a]	1.2	9.2	8.8	[a]	14.6	7.4	13.0
Berrien	2.3	0.5	0.3	4.2	16.1	2.8	10.0	[a]	0.9	7.4	11.7	13.6	10.1	5.6	11.4
Calhoun	1.7	[a]	[a]	3.8	17.0	2.8	9.7	[a]	0.9	4.7	4.7	16.2	7.6	5.8	15.4
Cass	6.6	0.9	0.3	5.4	16.8	2.2	8.2	[a]	0.4	8.1	8.4	[a]	8.7	9.3	14.9
Charlevoix	2.1	[a]	[a]	[a]	16.8	1.0	8.2	2.0	0.3	9.5	4.1	[a]	15.0	5.4	11.4
Cheboygan	3.4	[a]	[a]	9.7	2.7	1.8	16.8	2.6	0.7	8.9	8.6	8.5	17.0	7.4	10.6
Chippewa	2.4	0.8	0.6	4.1	3.3	1.9	12.2	[a]	1.1	4.9	4.6	7.2	9.9	5.4	39.1
Eaton	2.1	0.3	0.3	4.9	12.4	[a]	11.3	8.6	1.6	12.6	10.2	8.4	7.6	6.2	10.4
Emmet	1.3	[a]	[a]	8.1	5.6	1.5	12.6	1.6	1.1	8.4	9.2	14.5	15.3	6.0	10.1
Genesee	0.6	0.1	0.2	4.7	6.8	3.2	13.0	0.0	2.4	7.6	12.2	18.3	9.5	7.5	11.2
Grand Traverse	0.9	0.6	2.9	6.0	7.7	2.6	12.8	1.7	1.7	10.3	9.5	17.3	11.4	5.1	9.6
Ingham	0.7	0.2	0.4	3.2	5.9	2.2	8.6	2.4	1.5	10.0	12.4	15.5	8.8	5.8	22.5
Jackson	1.6	0.2	0.3	4.4	13.6	3.7	10.9	[a]	0.7	6.8	12.2	15.6	8.0	6.2	10.5
Kalamazoo	1.1	0.2	0.2	4.6	12.7	4.5	10.4	[a]	0.8	10.0	11.6	16.0	10.4	5.5	9.8
Lapeer	4.1	0.7	0.6	7.1	16.8	1.6	12.2	[a]	0.5	7.5	10.4	7.4	9.0	6.9	13.2
Livingston	1.1	0.2	0.2	6.9	10.8	3.3	12.3	2.8	0.9	11.4	14.9	9.8	10.8	6.6	8.0
Mackinac	1.9	[a]	[a]	6.6	2.4	[a]	10.5	3.7	[a]	6.1	4.7	[a]	28.6	5.6	17.2
Macomb	0.2	0.1	0.2	5.8	15.3	3.4	11.6	2.8	0.8	7.6	16.6	12.1	8.7	6.0	8.9
Oakland	0.1	0.04	0.2	3.8	6.9	4.6	9.7	1.8	2.0	13.3	24.8	14.1	8.4	4.9	5.3
Presque Isle	7.2	[a]	[a]	6.2	4.3	[a]	10.9	5.6	0.8	7.1	6.5	[a]	7.9	6.9	13.3
Shiawassee	4.4	[a]	[a]	6.5	8.2	7.5	12.1	[a]	1.0	6.2	4.9	12.6	7.8	7.3	12.7
St. Clair	1.7	[a]	0.2	6.5	13.0	2.6	12.9	4.4	0.9	7.6	4.3	15.1	9.0	6.7	10.7
St. Joseph	4.1	[a]	[a]	4.3	31.6	[a]	10.2	3.4	0.4	5.0	3.1	9.2	6.3	5.6	10.0
Van Buren	5.7	[a]	[a]	6.2	7.9	2.5	11.1	[a]	0.6	6.6	13.9	8.1	8.6	6.1	16.6

Note: [a] Not shown to avoid disclosure of confidential information, but the estimates for this item are included in the totals.
Source: US Bureau of Economic Analysis. Table CA25N Total Full-Time Employment by NAICS Industry.

Table Q-5: Land Use/Land Cover in Corridor Counties

Counties that Intersect with Alternative 1: Southern Route Pipeline

Counties in Area of Interest	Barren Land (Rock/Sand /Clay)	Cultivated Crops	Deciduous Forest	Developed High Intensity	Developed Medium Intensity	Developed Low Intensity	Developed Open Space	Emergent Herbaceous Wetlands	Evergreen Forest	Grassland/ Herbaceous	Mixed Forest	Open Water	Pasture/ Clay	Shrub/ Scrub	Woody Wetlands	Total Area (sq miles)
Berrien	0.8%	44.1%	15.8%	0.6%	2.0%	7.2%	9.0%	0.5%	0.3%	3.7%	0.5%	1.4%	5.4%	0.1%	8.5%	580
Calhoun	0.3%	38.7%	16.1%	0.6%	1.3%	4.4%	7.2%	0.4%	0.4%	0.8%	0.3%	1.4%	11.7%	0.2%	16.1%	718
Cass	0.2%	44.0%	16.5%	0.2%	0.4%	3.9%	5.3%	0.6%	0.3%	1.5%	0.4%	2.7%	11.3%	0.1%	12.7%	508
Ingham	0.3%	35.3%	10.3%	1.4%	3.5%	8.2%	6.9%	0.1%	0.3%	0.3%	0.3%	0.6%	20.4%	0.1%	12.0%	561
Jackson	0.2%	24.2%	17.5%	0.6%	1.3%	4.3%	7.0%	1.3%	0.5%	0.6%	0.5%	2.3%	20.0%	0.2%	19.6%	723
Kalamazoo	0.5%	31.7%	19.9%	1.2%	2.6%	7.6%	8.7%	0.3%	0.8%	1.3%	0.8%	3.2%	9.8%	0.2%	11.5%	580
Livingston	0.5%	15.3%	20.7%	0.7%	1.9%	6.3%	13.3%	1.4%	0.9%	0.9%	0.8%	2.8%	18.0%	0.2%	16.3%	585
Macomb	0.5%	18.5%	10.2%	6.0%	19.4%	16.1%	12.2%	0.5%	0.2%	1.4%	0.2%	0.7%	8.3%	0.3%	5.6%	484
Oakland	1.0%	3.3%	18.0%	4.4%	9.7%	18.7%	20.3%	1.2%	0.6%	1.1%	0.7%	4.5%	6.6%	0.1%	9.7%	907
St. Clair	0.4%	35.6%	23.2%	0.7%	2.1%	5.0%	6.1%	2.0%	0.6%	2.0%	0.6%	0.6%	12.1%	0.4%	8.8%	724
St. Joseph	0.2%	53.0%	12.0%	0.3%	0.6%	4.5%	4.3%	0.9%	0.3%	0.6%	0.3%	3.3%	9.0%	0.1%	10.4%	521
Total	**0.5%**	**29.9%**	**16.8%**	**1.6%**	**4.0%**	**8.1%**	**9.6%**	**0.9%**	**0.5%**	**1.3%**	**0.5%**	**2.2%**	**12.0%**	**0.2%**	**12.1%**	**6,893**

Counties that Intersect with Alternative 3: Southern Route Rail

Counties in Area of Interest	Barren Land (Rock/Sand /Clay)	Cultivated Crops	Deciduous Forest	Developed High Intensity	Developed Medium Intensity	Developed Low Intensity	Developed Open Space	Emergent Herbaceous Wetlands	Evergreen Forest	Grassland/ Herbaceous	Mixed Forest	Open Water	Pasture/ Clay	Shrub/ Scrub	Woody Wetlands	Total Area (sq miles)
Calhoun	0.3%	38.7%	16.1%	0.6%	1.3%	4.4%	7.2%	0.4%	0.4%	0.8%	0.3%	1.4%	11.7%	0.2%	16.1%	718
Cass	0.2%	44.0%	16.5%	0.2%	0.4%	3.9%	5.3%	0.6%	0.3%	1.5%	0.4%	2.7%	11.3%	0.1%	12.7%	508
Eaton	0.2%	44.6%	12.8%	0.6%	1.3%	4.1%	5.9%	0.1%	0.2%	0.4%	0.2%	0.7%	18.2%	0.1%	10.4%	579
Genesee	0.5%	21.8%	18.3%	2.1%	4.8%	12.1%	13.8%	0.6%	0.6%	1.5%	0.4%	1.8%	15.3%	0.3%	6.2%	650
Ingham	0.3%	35.3%	10.3%	1.4%	3.5%	8.2%	6.9%	0.1%	0.3%	0.3%	0.3%	0.6%	20.4%	0.1%	12.0%	561
Kalamazoo	0.5%	31.7%	19.9%	1.2%	2.6%	7.6%	8.7%	0.3%	0.8%	1.3%	0.8%	3.2%	9.8%	0.2%	11.5%	580
Lapeer	0.3%	30.2%	20.3%	0.2%	0.5%	2.5%	5.9%	1.3%	1.2%	1.3%	0.9%	1.4%	23.1%	0.2%	10.7%	663
Shiawassee	0.3%	48.4%	8.1%	0.2%	0.7%	4.1%	4.5%	0.2%	0.4%	0.3%	0.2%	0.9%	21.6%	0.1%	9.9%	541
St. Clair	0.4%	35.6%	23.2%	0.7%	2.1%	5.0%	6.1%	2.0%	0.6%	2.0%	0.6%	0.6%	12.1%	0.4%	8.8%	724
St. Joseph	0.2%	53.0%	12.0%	0.3%	0.6%	4.5%	4.3%	0.9%	0.3%	0.6%	0.3%	3.3%	9.0%	0.1%	10.4%	521
Van Buren	0.4%	40.0%	20.2%	0.2%	0.8%	3.3%	5.9%	0.3%	0.7%	2.8%	0.6%	1.6%	7.4%	0.3%	15.5%	623
Total	**0.3%**	**37.9%**	**16.5%**	**0.7%**	**1.7%**	**5.4%**	**6.9%**	**0.7%**	**0.5%**	**1.2%**	**0.5%**	**1.6%**	**14.5%**	**0.2%**	**11.3%**	**6,669**

Appendix Q.2 Social Impact Assessment (SIA) Screening Matrix

A matrix of potential socioeconomic concerns and impacts is presented in Table Q-6. A project evolves in different stages – planning, construction, operation, and abandonment – and each stage has a different set of socioeconomic concerns and potential impacts. Table Q-6 separates the first three project stages for alternatives 1, 3, 4a, and 4b; it includes only the final stage – abandonment – for Alternative 6 – which assumes the complete shutdown of Line 5.

To be emphasized, the SIA screening matrix provides a *preliminary* list of potential social and economic concerns/impacts to communities living within the areas of interest of the different alternatives. For any project, public consultation is required to elicit all concerns/impacts of affected populations and to gather community-level input on the relative significance of those concerns/impacts.

The concerns/impacts are known as *assessment variables*, for which an assessor would undertake further analysis and, importantly, public consultation. The list assembled here is from an examination of SIA assessment variables required by different regulatory bodies, and from SIA research and reports on socioeconomic concerns typically expressed about construction projects in general, and linear infrastructure projects in particular.

The matrix cells of Table Q-6 provide a preliminary ranked checklist of potential concerns for different stages of each alternative. One bar indicates that a concern or impact may exist, and should be investigated to determine: a) if it does exist; and b) if it exists, what, if any, mitigation measures should be undertaken. A double bar indicates that the concern or impact will certainly be present, and further investigation is required to determine: a) its level of significance; and b) appropriate mitigation options. All impacts that are checked (barred) will be discussed during the course of public consultation. The ranking in Table Q-6 is based on the analyses summarized in the sections of this appendix.

Appendix Q.3 Economic Impacts of Alternatives

Appendix Q.3.1 Alternative 5: A Status Quo – Line 5 Unchanged

Under Alternative 5, the economic contribution of the status quo is examined. The current operation of Line 5 (original 1953 construction) moves oil and NGLs from Superior, WI, through Michigan's Upper Peninsula, across the Straits to the Lower Peninsula, across Emmet and Cheboygan counties, through Prosperity Regions 2, 3, 5, and 6, on a southeast route around Saginaw Bay to St. Clair County, and across the St. Clair River to Sarnia, Ontario. The counties that intersect Line 5 are indicated in Table Q-1.

Economic multipliers (BEA RIMS II) were used to estimate the economic contribution of Line 5 operation expenses to Michigan, and the Prosperity Regions and counties over which the pipeline passes. Table Q-7 presents the direct, indirect, and induced economic contributions associated with $83 million in Line 5 annual operating expenses. This amount includes routine annual capital expenditures for pipeline integrity, and excludes Line 5 operation expenses occurring outside of Michigan.

Table Q-6: SIA Screening Matrix

Social Assessment Variables	Alt 1: South Pipeline Route – Superior, WI to Sarnia, ON via IL, IN, MI			Alt 3: South Rail Route – Superior, WI to Sarnia, ON via IL, IN, MI			Alt 4a: Straits Crossing Pipelines Replaced with Trenched Pipeline			Alt 4b: Straits Crossing Pipelines Replaced with New Tunnel Pipeline			Alt 6: Abandon Line 5
	Planning	Construction	Operation	Planning	Construction	Operation	Planning	Construction	Operation	Planning	Construction	Operation	Construction
Economic Impacts													
Economy: impacts from project expenditures		■	■			■		■			■		■
Community Resources													
Land: cultivation disruption		■				■							■■
Land: disruption on Tribal trust or treaty land		■				■		■			■		■■
Land: disruption to hunting/trapping access		■											■
Water: disruption of commercial traffic in Straits of								■■					■
Water: disruption of recreational boating in Straits of								■■					■
Water: disruption on Treaty water & fisheries								■■					■
Infrastructure disruption: road traffic congestion		■■				■■		■■			■■		■■
Infrastructure disruptions: access to local business		■						■			■		■
Infrastructure disruption: access to lakefront								■			■		■
Compromised visual aesthetics								■			■		■
Population Impacts													
Housing issues influx of temporary construction		■				■		■■			■■		■■
Housing issues: disproportionally-affected seasonal								■			■		■
Housing issues: influx of special interest groups –	■			■			■	■		■	■		
Seasonal population: reduced presence of seasonal								■			■		■
Seasonal population: reduced tourist influx								■			■		■
Community Structural Impacts													
Changes to labor force composition		■						■			■		■
Inequity: increased accommodation costs for								■			■		■
Business: increased cost of seasonal workers								■			■		■
Business: reduced tourism revenue								■			■		■
Property speculation	■						■			■			■
Community and Family Impacts													
Stresses: increased costs – community services		■						■			■		■
Anxiety: perception of increased risk to public health						■■		■	■		■	■	
Anxiety: conflict between project opponents and	■						■			■			
Health: noise impact		■				■■		■			■		■
Health: air pollution impact – dust						■					■■		

The analysis indicates that the operation of Line 5 currently contributes to the Michigan economy by generating about 900 (full and part-time) jobs a year. About 250 people are employed directly by Line 5 operations, and another 660 jobs result from the indirect spending on materials and services by supply contractors to Line 5 operations, and induced spending by employees of both Line 5 and its suppliers. The results show that the corridor counties could account for as many as 600 of these jobs.

Employment earnings associated with operations are in the order of $45 million/y for all of Michigan, with as much as $31 million/y accruing to the corridor counties. The larger area – the Prosperity Regions – could account for as much as $37 million/y of Line 5-related earnings. Total output generated by Line 5 operations is estimated at $137/y million, for a value added value of $81 million/y for Michigan as a whole.

Table Q-7: Alternative 5: Status Quo Line 5 Operation Expenses

Alternative 5: Operation Expenses of Line 5			
Operation expenses (includes routine annual capital expenditures)			$95 million/y
Operation expenses for Michigan portion of Line 5			$83 million/y
Impact Area	**Employment (jobs)**	**Labor Earnings (million $/y)**	**Output (million $/y)**
Corridor Counties			
Direct	225	20.3	77.0
Indirect	198	4.7	15.3
Induced	181	6.0	16.6
Total Contribution	603	31.1	108.9
Prosperity Regions 1, 2, 3, 5, 6			
Direct	246	22.1	77.0
Indirect	237	6.5	16.3
Induced	238	7.9	21.5
Total Contribution	722	36.6	114.8
Michigan			
Direct	252	22.5	77.0
Indirect	302	10.0	22.4
Induced	359	12.7	37.1
Total Contribution	913	45.2	136.5
Value Added currently contributed to Michigan: $81 million			
Notes: Economic contribution results derived using BEA RIMS II Multipliers.			

Appendix Q.3.2 Alternative 4a: Conventional (Trench) Replacement

In Alternative 4a, the Straits Crossing segment of Line 5 – the existing twin 20-in. pipelines – is replaced by a *trenched* pipeline that incorporates modern marine, best available pipeline design technology. The counties directly affected by the replacement of the Straits portion of Line 5 are Emmet, Cheboygan, and Mackinac.

Appendix Q.3.2.1 Construction

Economic multipliers (BEA RIMS II) were used to estimate the economic impacts of construction expenditures for a trenched pipeline crossing replacement (see Table Q-8). Although construction is centered in the counties of Mackinac, Emmet, and Cheboygan, for comparison with the Line 5 status quo (Alternative 5), impact estimation is done for Line 5 Prosperity Regions 1, 2, 3, 5, and 6, as well as for the State of Michigan.

The cost of this alternative is estimated at $27 million, which includes abandonment costs related to the existing pipeline crossing. Most of the materials and services for the trench construction are expected to produced and provided by Michigan firms, which translates into construction spending in Michigan of some $22 million. For Michigan, this capital expenditure would result in about 400 (full and part-time) jobs and $21 million in earnings from combined total direct, indirect and induced economic impacts. Most of the jobs and earnings could occur in Prosperity Regions 1, 2, 3, 5 and 6. The total output associated with construction would be about $71 million to Michigan as whole. The total value added to the Michigan economy would be about $23 million.

Table Q-8: Alternative 4a: Trenched Pipeline Crossing Construction

Alternative 4a: Trenched Pipeline for Line 5 Straits of Mackinac Crossing			
Construction Expenditures			$27 million
Michigan-sourced Construction Purchases			$22 million
Impact Area	**Employment (jobs)**	**Labor Earnings (million $)**	**Output (million $)**
Prosperity Regions 1, 2, 3, 5, 6			
Direct	137	7.5	27.3
Indirect	146	8.2	29.7
Induced	60	2.0	6.4
Total Impact	343	17.7	63.3
Michigan			
Direct	145	7.9	27.3
Indirect	172	9.7	32.8
Induced	95	3.4	10.9
Total Impact	413	21.0	71.0
Value Added for Michigan: $23 million			
Notes: Economic contribution results derived using BEA RIMS II Multipliers.			

Appendix Q.3.2.2 Operation

The operation expenses of Line 5 with a replaced (trenched) pipeline segment to cross the Straits (Alternative 4a) are expected to remain essentially unchanged from their current level. Therefore the economic contribution of the operation expenses of Line 5 in Michigan will remain as they are now. The economic contribution of the status quo – wherein Line 5 is unaltered – is estimated under Alternative 5 (see Appendix Q.4.1).

Appendix Q.3.3 Alternative 4b: Tunnel Replacement for Straits Crossing

In Alternative 4b, the Straits Crossing segment of Line 5 is replaced by a deep rock tunnel that houses a 30-in. pipeline. The tunnel is designed to carry only the pipeline. The pipeline within the tunnel is encased in cement. The counties directly affected by the replacement of the Straits portion of Line 5 are Emmet, Cheboygan, and Mackinac.

Appendix Q.3.3.1 Construction

Economic multipliers (BEA RIMS II) were used to estimate the economic impacts of construction expenditures for a tunnel pipeline crossing replacement (see Table Q-9). Although construction is centered in the counties of Mackinac, Emmet, and Cheboygan, for comparison with the Line 5 status quo (Alternative 5), impact estimation is done for Line 5 Prosperity Regions 1, 2, 3, 5, and 6, as well as for the State of Michigan.

Construction spending for the tunnel alternative is estimated at $153 million, which includes the abandonment cost of the current (twinned) pipeline crossing. More than half of that spending – $92 million – would be spent on materials and services produced and provided by Michigan firms. The total employment impacts of that spending could result in around 1,700 (full and part-time) jobs in Michigan: 800 jobs directly, and another 900 from indirect spending on materials and services by supply contractors, and induced spending by employees linked directly or indirectly to the construction project. These jobs would represent a total of $91 million in earnings. Most of the employment and earnings impacts could fall in Prosperity Regions 1, 2, 3, 5, and 6. The total output associated with building the tunnel would amount to some $329 million for Michigan. The value added to the Michigan economy for the tunnel construction could be $93 million.

Appendix Q.3.3.2 Operation

The operation expenses of Line 5 with a tunnel pipeline segment that crosses the Straits (Alternative 4b) are expected to remain essentially unchanged from their current level. Therefore the economic contribution of the operation expenses of Line 5 in Michigan will remain as they are now. The economic contribution of the status quo – wherein Line 5 is unaltered – is estimated under Alternative 5 (see Appendix Q.4.1).

Table Q-9: Alternative 4b: Tunnel Pipeline Crossing Construction

Alternative 4b: Tunnel Pipeline for Line 5 Straits of Mackinac Crossing			
Construction Expenditures			$153 million
Michigan-sourced Construction Purchases			$92 million
Impact Area	**Employment (jobs)**	**Labor Earnings (million $)**	**Output (million $)**
Prosperity Regions 1, 2, 3, 5, 6			
Direct	769	41.9	152.9
Indirect	519	29.7	125.2
Induced	210	7.2	27.9
Total Impact	1,498	78.8	306.0
Michigan			
Direct	814	44.3	152.9
Indirect	635	35.8	139.8
Induced	314	11.1	35.8
Total Impact	1,763	91.3	328.5
Value Added for Michigan: $93 million			
Notes: Economic contribution results derived using BEA RIMS II Multipliers.			

Appendix Q.3.4 Alternative 6: Abandonment of Line 5

Under Alternative 6, the abandonment of the Straits Crossing segment of Line 5 is considered. Just removing the Straits Crossing segment would be a *partial abandonment* of Line 5. Various analyses of partial abandonment found that segmenting Line 5 by abandoning the Straits Crossing would render the entire line operationally unviable. Hence, segmenting Line 5 with a partial abandonment would lead to a total abandonment of Line 5.

Full abandonment requires a construction project. For this alternative, the cost estimate of Line 5 abandonment is based on best practices for pipeline decommissioning, as developed by the National Energy Board of Canada. (Appendix I) Also, the cost estimate assumes that the terrestrial and Straits Crossing segments of Line 5 are abandoned as part of the same project.

The counties and Prosperity Regions directly affected by the abandonment are those that intersect with Line 5. These are listed in Table Q-1.

Appendix Q.3.4.1 Construction

Economic multipliers (BEA RIMS II) were used to estimate the economic impacts of abandoning the whole of Line 5. The construction cost is estimated to be $212 million: this includes abandonment of both the terrestrial and the Straits Crossing segments. As the 91 mi. (147 km) of Line 5 are located in Wisconsin, some of the terrestrial expenses would be incurred in that state. Accounting for only those expenses related to Line 5 in Michigan means that abandonment of Line 5 terrestrial and Straits Crossing segments amounts to some $184 million in construction spending.

Table Q-10 shows the economic impact results of construction spending associated with Line 5 abandonment. The project would generate about 2,200 (full and part-time) jobs in Michigan, with as many as 1,700 generated in the Prosperity Regions 1, 2, 3, 5, and 6. For Michigan as a whole, total labor earnings could be around $100 million. Total output resulting from the construction expense could be $362 million, for a value added of some $190 million.

Table Q-10: Alternative 6: Abandonment of Line 5

Alternative 6: Abandonment Expenditures Related to Line 5			
Abandonment Expenditures for all of Line 5 –terrestrial plus Straits Crossing			$212 million
Abandonment Expenditures for all of Line 5 – terrestrial in MI plus Straits Crossing			$184 million
Impact Area	**Employment (jobs)**	**Labor Earnings (million $)**	**Output (million $)**
Corridor Counties			
Direct	790	43.1	183.5
Indirect	247	11.9	58.4
Induced	389	14.0	47.1
Total Impact	1,426	68.9	289.0
Prosperity Regions 1, 2, 3, 5, 6			
Direct	923	50.3	183.5
Indirect	324	16.6	69.6
Induced	487	16.1	52.2
Total Impact	1,734	83.0	305.2
Michigan			
Direct	977	53.2	183.5
Indirect	450	24.1	91.6
Induced	761	26.9	87.0
Total Impact	2,188	104.3	362.1
Value Added for Michigan: $190 million			
Notes: Economic contribution results derived using BEA RIMS II Multipliers.			

Appendix Q.3.5 Alternative 1: Southern Pipeline Route

Under this alternative, Line 5 is abandoned, and a new pipeline is built to move current Line 5 product volumes from Superior, WI, to Sarnia, Ontario – without crossing water. The Southern Pipeline Route Alternative essentially twins the existing Enbridge System around the south end of Lake Michigan. It follows Enbridge Line 6 and Line 14/4 routes from Superior, WI, southeast to Chicago. Line 78 is followed northeast from Chicago, across the northwest corner of Indiana, entering Michigan in Berrien County.

From Berrien County, the new South Pipeline traverses Prosperity Regions 6, 7, 8, 9, and 10, to Marysville in St. Clair County. From Marysville it crosses the St. Clair River to Sarnia, Ontario. Counties that intersect the new pipeline are indicated in Table Q-1.

Appendix Q.3.5.1 Construction

Economic multipliers (BEA RIMS II) were used to estimate the economic impacts of a new southern pipeline. As designed, the southern pipeline is approximately 761-mi. (1,226-km) long, but only 227 mi. (365 km) of the line would traverse Michigan. Consequently, out of the estimated $2,025 million in construction expenditures for the southern pipeline alternative, only $586 million is attributable to the Michigan portion of the new line. Of that amount, construction expenditure on materials and services produced or provided by Michigan contractors is estimated to be $435 million.

The construction expenditure on the Michigan portion of the southern pipeline would directly support approximately 3,000 (full and part-time) jobs within the state, with most being located in Prosperity Regions 6, 7, 8, 9, and 10, which contain the 11 pipeline corridor counties. Another 5,000 jobs would result from indirect spending on materials and services by construction contractors, and induced spending by employees working for any supplier implicated in the construction process.

Employment supported by the construction of the southern pipeline in Michigan would translate to approximately $369 million in total earnings. Total economic output from construction expenditure could be $1,308 million. Value added for Michigan is estimated to be $396 million. The results of the economic impact analysis are summarized in Table Q-11.

Appendix Q.3.5.2 Operations

Economic multipliers (BEA RIMS II) were used to estimate the economic impacts of the new pipeline's operation. When the southern pipeline goes into service, its total operation cost would be about $165 million/y. (This represents the long-term operating cost estimate for this alternative.) The Michigan portion of the new pipeline's operation cost is estimated to be about $49.5 million/y. The direct employment impact to the State of the operation expense could be 126 (full and part-time) jobs, with as many as 100 of those direct jobs located in the corridor counties. The indirect and induced economic impacts of a new southern pipeline could result in another 270 (full- and part-time) jobs for Michigan as a whole.

Total statewide employment earnings from operations could be approximately $24 million/y. The total output generated would be about $80 million/y with value added to the Michigan economy of $43 million/y (see Table Q-12).

Table Q-11: Alternative 1: South Pipeline Route Construction

Alternative 1: South Pipeline through WI, IL, IN, and MI			
Construction Expenditures			$2,025 million
Construction Expenditures Specific to the Michigan Portion of the Pipeline			$586 million
Michigan-sourced Construction Purchases			$435 million
Impact Area	**Employment (jobs)**	**Labor Earnings (million $)**	**Output (million $)**
Corridor Counties			
Direct	2,403	154.4	585.8
Indirect	1,818	93.7	398.0
Induced	2,072	71.8	285.7
Total Impact	6,293	319.8	1,269.5
Prosperity Regions 6, 7, 8, 9, 10			
Direct	3,033	154.4	585.8
Indirect	2,226	115.9	407.6
Induced	2,606	91.8	299.0
Total Impact	7,864	362.2	1,292.4
Michigan			
Direct	3,118	154.4	585.8
Indirect	2,297	119.5	413.8
Induced	2,695	95.3	308.0
Total Impact	8,110	369.2	1,307.5
Value Added for Michigan GDP: $396 million			
Notes: Economic contribution results derived using BEA RIMS II Multipliers.			

Appendix Q.3.6 Alternative 3: Southern Rail Route

In Alternative 3, products currently carried by Line 5 are instead transferred into railcars at Superior, WI, and moved on existing railways around the southern end of Lake Michigan, through Chicago, IL, northern Indiana, and up into Michigan. It enters the state through Cass County, then heads northeast through Kalamazoo and Calhoun counties towards St. Clair County, where it goes through the train tunnel under the St. Clair River near Sarnia, Ontario.

Appendix Q.3.6.1 Construction

Because the existing railway network in Wisconsin, Illinois, Indiana, and Michigan is used to move the product of Line 5, only minor railway construction is foreseen in this alternative, and it does not occur in Michigan: short rail connection lines, and transfer and storage facilities are anticipated for product loading and unloading at the rail terminals in Wisconsin and Ontario. Therefore, there are no construction impacts for Michigan associated with Alternative 3.

Table Q-12: Economic Impact of Alternative 1: South Pipeline Route Operations

Alternative 1: South Pipeline Route			
Operation Expenses – total for WI, IL, IN, & MI			$165 million/y
Operation Expenses for portion of the line in Michigan			$49.5 million/y
Impact Area	**Employment (jobs)**	**Labor Earnings (million $)**	**Output (million $)**
Corridor Counties			
Direct	100	10.2	44.2
Indirect	80	3.8	15.1
Induced	118	4.1	16.2
Total Impact	298	18.2	75.5
Prosperity Regions 6, 7, 8, 9, 10			
Direct	122	12.5	44.2
Indirect	94	4.6	14.9
Induced	165	5.8	18.9
Total Impact	380	22.9	77.9
Michigan			
Direct	126	12.9	44.2
Indirect	98	4.8	15.6
Induced	175	6.2	19.9
Total Impact	399	23.9	79.7
Value Added for Michigan: $42.5 million			
Notes: Economic contribution results derived using BEA RIMS II Multipliers.			

Appendix Q.3.6.2 Operation

Economic multipliers (BEA RIMS II) were used to estimate the economic impacts of the southern rail alternative. Once the railway system to move the current volume of Line 5 product is operational (necessary infrastructure and facilities on both ends of the rail route are built), the annual operation expenses to carry by rail Line 5 product from Superior to Sarnia would be about $1,220 million: this includes leasing and amortized capital expenses associated with the railcars. Removing the leasing and terminal expenses associated with facilities outside of Michigan, the operation expenses to move the product from Superior to Sarnia is reduced to $672 million/y. Of that amount, $184 million/y would occur Michigan, given that the rail crosses 223 mi. (359 km) of that state.

Table Q-13 shows the estimated economic impacts to Michigan of rail operation expenses. The rail service would employ approximately 500 (full and part-time) employees directly, with as many as 475 located in the corridor Prosperity Regions 6, 7, 8, 9, and 10. Indirect and induced economic impacts could generate as many as 1,000 (full and part-time) jobs. Total labor earnings for these 1,500 jobs could be around $84 million/y. Total output generated by increased Michigan railway operations could be about $324 million/y. Total value added for Michigan is estimated to be $173 million/y.

Table Q-13: Economic Impact Alternative 3: South Rail Route Operations

Alternative 3: Use of Southern Railways			
Operation Expenses of Rail including WI & ON railcar leasing expenses Operation Expenses of Rail excluding WI & ON leasing & terminal charges Operation Expenses of Rail for MI portion of the route only			$1,220 million/y $672 million/y $184 million/y
Impact Area	**Employment (jobs)**	**Labor Earnings (million $)**	**Output (million $)**
Corridor Counties			
Direct	417	35.6	184.1
Indirect	192	9.4	38.5
Induced	310	10.4	40.1
Total Impact	919	55.5	262.7
Prosperity Regions 6, 7, 8, 9, 10			
Direct	475	40.5	184.1
Indirect	363	19.9	67.3
Induced	582	20.5	66.8
Total Impact	1,420	80.9	318.2
Michigan			
Direct	491	41.9	184.1
Indirect	385	20.5	69.3
Induced	615	21.8	70.3
Total Impact	1,491	84.3	323.6
Value Added for Michigan: $173 million/y			
Notes: Economic contribution results derived using BEA RIMS II Multipliers.			

Appendix Q.4 Government Revenue Impacts

Appendix Q.4.1 Introduction

This report provides estimates of government revenues associated with each of the alternatives evaluated. These revenues are not generated by the RIMS II multipliers, but are based on earnings estimates from the economic impact model. These earnings estimates are then coupled to assumptions that capture the contribution to or impact on major revenue sources currently accruing to the State. The assumptions used are consistent with current tax regimes and rates, and are summarized in Table Q-14.

The assumptions are also based on:

- Information relating to average personal property taxes for the current fiscal year on some utilities. [1]
- Revised FY 2016-17 forecasts in the Michigan Consensus Revenue Estimating Conference (CREC) adopted in January 2017. [2]

CREC estimates show that the major sources of revenue to the State for FY 2016-17 are from individual income taxes (40.9%) and sales taxes (31.4%).[2] These taxes are thus explicitly treated in this study's estimates, and will normally constitute the major part of government revenues. In addition, the study considered other taxes and sources as noted in Table Q-14. Corporate income tax (CIT) and other business taxes such as the Michigan Business Tax (MBT) are not estimated because net contribution in some periods has been negative; the economic impact models available estimate total earnings but there is no basis for projecting or estimating the extent or profile of businesses that will be subject to the various credit schemes. The Senate Fiscal Agency notes, for example, that in February 2017 "Net CIT collections totaled $19.5 million while net MBT revenue totaled a negative $293.4 million." [2, p. 1] Subsequent months showed some net inflows and at end April the total from CIT and MBT created a net deficit to treasury of –$73.5 million on $10,706.8 million of net receipts on year-to-date for FY 2016-17. [3]

Also, both personal and corporate taxation is sensitive to business cycles. Single observations therefore do not necessarily reflect long-term trends, and some trends show little change in future conditions. Recent forecasts in the Michigan Consensus Economic Forecast, for example, anticipate little change in Michigan's civilian unemployment rate, although this is less optimistic than that for the US as a whole. For 2016, the Michigan rates matched exactly those of the US; in 2016, US and Michigan unemployment rates were identical at 4.9%. The Michigan Consensus Economic Forecast (May 2017 [4]) is that U.S. unemployment rates will decline to 4.4% by 2019 while Michigan unemployment rates will be 5.1% in 2017 and fluctuate slightly to end 2019 at 5.0%. In such an environment, any changes to government revenue are of interest.

Discussions in the following sections additional details on selected assumptions regarding the government revenue impacts shown here.

[2] Of total revenue of $23,840 million, net individual income taxes represent $9,757 million and sales taxes represent $7,485.2 million.

Table Q-14: Basis for Government Revenue Estimate

Revenue Source	Description	Estimating Basis	Assumption
Personal Income Tax (State)	Effective average personal income tax rate	2016 Michigan tax revenues (MI Senate Fiscal Agency); 2016 personal income (US BEA)[3]	2.5% of income
Sales and Use Tax (State)	Sales and Use taxes on consumption of goods and services expressed as the effective sales tax rate in proportion to income.	2016 Michigan tax revenues (MI Treasury); 2016 personal income (USBEA)	2.0% of income Note: Not to be confused with the sales tax rate of 6%. The above implies that on average about one-third (32.93%) of earnings are spent on taxable goods and services.
Pipeline Taxes (State)	Taxes paid by pipeline	FERC Form 6 (2015; 2016) apportioned to Line 5 based on length and age of line.	Consultant estimates for existing Line 5 and new pipeline alternatives. Estimates assume long-term revenues after 10 years of operation and reflect capital replacement to maintain pipeline integrity.
Personal Property Tax (State)	PTT applied to capital expenditures	Phased out for persons and most commercial and industrial enterprises with 100% exemptions commencing in 2017.	$0
Personal Property Tax (State)	PTT applied railway operations	Maximum value on through-state carriage of cargo.	Consultant estimate for Alternative 3 southern corridor. See text.
Transportation Fuel Tax (State)	Taxes from gasoline and diesel paid by households	US BEA Consumer Expenditure Survey 2015 adjusted for increase in gasoline and diesel taxes effective January 2017.	0.3% of income
Severance Tax (State)	Payments to State or associated with oil or gas extraction; these apply only to estimated production from volumes produced in Lower Peninsula and injected into Line 5.	Severance is 4% of value on marginal wells. 10 kbbl/d production potentially impacted but transportation alternatives considered in this study indicate that incremental transportation costs will not force well shut-in.	$0
Corporate Income Tax (CIT) Michigan Business Tax (MBT) Single Business Tax (State)	CIT is payment to state based on corporate profits; others potentially provide credits.	CIT 6% but many businesses exempt or receiving credits.	Not estimated

[3] USBEA. SA1 Personal Income Summary. Michigan 2016. Released 28 March 2017.
[https://www.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=6#reqid=70&step=30&isuri=1&7022=21&7023=0&7024=non-industry&7033=-1&7025=0&7026=26000&7027=2016,2015,2014,2013,2012&7001=421&7028=1&7031=0&7›040=-1&7083=levels&7029=21&7090=70

Appendix Q.4.2 Treatment of Market Price Dynamics

The revenue impacts are based on impacts associated with final demand changes from construction and operations of the alternatives. They exclude higher round impacts that might be associated with changes in market dynamics arising from impacts on product prices. For example, the study illustrates that in some instances there might be changes to consumer prices for refined products such as gasoline. Such changes may change net tax revenues directly because fixed tax rates would potentially generate higher revenues. This study has not estimated such impacts.

Also, change in consumer prices (from increased gasoline prices) can change consumer behavior and result in higher round impacts such as decreased consumption in an inflationary environment, or increased wage expectations. This study also has not estimated such impacts.

These market price dynamics do exist, but they will be similar in direction for all of the alternatives considered. The impacts estimated here are regarded as an appropriate and consistent basis for considering the relative impacts on government revenues.

Appendix Q.4.3 Recurrent Taxes

The personal earnings estimated through the RIMS II multipliers are used as a basis for estimating a number of the taxes. As discussed previously, these earnings estimates are most robust for operational impacts and at the largest geographic level (the State). Government revenue impacts are therefore not ascribed to Prosperity Regions, count corridors, or individual counties: they are reported only at the State level. For the capital component of projects, the estimated government revenue applies only to the total earnings associated with the direct, indirect and induced impacts. As with the impacts themselves, the timing of these receipts is not possible to estimate and in any event is not a permanent addition to revenue. The reader is reminded that earnings and revenue impacts associated with construction impacts are represented as a fixed amount (million $), whereas recurrent impacts are expressed in annual amounts (million $/y).

Appendix Q.4.4 Railway Taxes

The primary source of revenue for Michigan from the railroad system operated within the State is through the property tax. Railyards and their operation under this alternative are located outside of the State. The relevant property potentially subject to taxation does include, however, the rail cars moving through Michigan. State provisions provide for a valuation based on the *car-miles* of the property operating in Michigan when such operations are less than 100% of the total car-miles. As a dedicated fleet of train-sets is assumed, the associated car-mile allocation can be considered for the purposes of this estimate to be the proportion of the route in Michigan: in this case approximately 240 of 800 mi. (386 of 1,287 km), or 30%. Although the study used cost estimates for leased cars, the total fleet cost is estimated to be of the order of $540 million and depends on the lease contractual arrangements. This translates to an apportioned capital value of $162 million. For the average tax, the study uses the average tax rate for Michigan on Commercial, Industrial and Utility (CIU) classifications as a proxy to reflect that railcar vintage and cost may change over the years [1]. This rate is $52.38 per $1,000 of taxable value. Partial exemptions are available for certain types of industrial property and credits may be available to rail operators because of other elements of their operation. At the current level of project design and cost estimating, it is not possible to determine how the rail operation would impact upon other aspects of a rail operator's investment decisions within Michigan. For illustrative purposes, a rate of $50/$1,000 is assumed, resulting in potential rail taxes of $8.1 million/y.

Appendix Q.4.5 Results

The net effect of the various income and sales taxes is that for every $100 of earned labor income, there will be a corresponding change in government revenues of $4.80. These taxes – personal income tax, sales tax, and transportation tax – represent the most significant contribution to state coffers from personal earnings. The reader is reminded that the timing of these impacts is not necessarily immediate, and that those associated with construction expenditures are not recurrent.

Facility charges through pipeline or rail taxes will be in addition to these earning impacts. Table Q-15 presents total estimated impacts.

Table Q-15: Summary of Estimated Government Revenue Impacts

Alternative	Earnings Impact [a]		Government Revenue Impact			
	Construction (million $)	Recurrent Operation (million $/y)	Construction (million $)	Recurrent Operations (million $/y)	Recurrent Other [b] (million $/y)	Recurrent Total (million $/y)
Alt 5 Status Quo	$ -	$ 45.2	$ -	$ 2.17	$ 5.00 - 7.00	$ 7.17 - 9.17
Alt 4a Trench Crossing	$ 21.0	$ 45.2	$ 1.0	$ 2.17	$ 5.00 - 7.00	$ 7.17 - 9.17
Alt 4b Tunnel Crossing	$ 91.3	$ 45.2	$ 4.4	$ 2.17	$ 5.00 - 7.00	$ 7.17 - 9.17
Alt 6Z Abandonment	$ 104.3	$ -	$ 5.0	$ 0	$ 0	$ 0
Alt 1 Pipeline South	$ 369.2	$ 23.9	$ 17.7	$ 1.15	$ 5.00 - 10.00	$ 6.15 - 11.15
Alt 3 Rail South	$ -	$ 84.3	$ -	$ 4.05	$ 8.1	$ 12.15

[a] Includes direct, indirect and induced earnings within Michigan.
[b] Estimated long-term Pipeline or Facility Taxes.

Appendix Q.5 Community Resource Impacts

Appendix Q.5.1 Land Disturbances

Appendix Q.5.1.1 Alternative 1

The southern pipeline route in Michigan assumes a ROW width of 38 yd (35 m). It needs three pumping stations along its Michigan stretch. It would have four work-spreads of about 70 mi. (113 km) each.

The construction of the southern pipeline follows the ROW of existing pipelines, which in addition to reducing construction cost also reduces land use impacts because existing linear infrastructure is already in place along the entirety of the route.

The pipeline enters Michigan in Berrien County, and runs northeast to St. Clair County where it exits Michigan into Ontario. Most of the pipeline passes through sparsely populated counties with low levels of urban development. Of the 11 Michigan counties in the corridor of the southern pipeline, only Macomb and Oakland counties have large developed areas: 41 and 33%, respectively, of combined low, medium and high intensity urban development (see Table Q-5). The other 9 counties together have only 8.1% urban development, and most of their combined area (67%) is in crops, pasture and forests. However, since 23% of the total pipeline length passes through the more densely populated urban areas of Macomb and Oakland, urban infrastructure is likely affected by pipeline construction. The SIA screen therefore flags the need to examine the pipeline route to fully assess the impacts of construction in these urban areas, and plan appropriate mitigation strategies. In the less populated regions of the southern route, rural traffic may be disrupted by construction spreads, but there would be fewer people and less traffic circulation, and mitigation strategies are thus likely to be simpler than those in the larger urban centers.

Appendix Q.5.1.2 Alternative 3

The southern rail route would transport Line 5 product volumes using existing track, with 9 trains of about 100 railcars each, for between 800 and 900 railcars per day traversing 223 mi. (359 km) of Michigan. The shipment of Line 5 products by rail (Alternative 3) is on existing track that follows a northeast route to St. Clair County that is slightly different from the southern pipeline route. Whereas the latter enters Michigan at Berrien County, the railway enters Michigan further to the east in Cass County. It then passes to the north of the southern pipeline route where it stays, never entering Macomb or Oakland counties.

Land cover data show that as in the case of the southern pipeline, the railway route passes through areas of low urbanization. Moreover, as there is no new construction required for the railway alternative, disruption due to construction is not an issue. However, with the increase in railcar traffic all road/street crossings will be subject to more delays due to increased train traffic. Train-related noise along the length of the rail line will increase. Concerns for human and animal safety will be increased with the increased frequency and volume of rail traffic.

Appendix Q.5.1.3 Alternative 6

The abandonment of Line 5 in Michigan involves 545 mi. (877 km) of pipeline and 13 pump stations that in total cover 59 acres (24 ha). Most of the land cover affected by Line 5 pipeline abandonment is forest – 331 mi. (533 km), and cultivated land – 108 mi. (174 km); only 5 mi. (8 km) falls in urban areas; and there are 156 crossings (road, river, rail, and airport). The abandonment strategy has the pipeline abandoned *in place*, with 13 mi. (21 km) filled with concrete or similar material to mitigate soil subsidence issues. The Straits Crossing would be filled with water to mitigate potential buoyancy issues.

Over the length of the pipeline work crews would be purging the line of hydrocarbons. Where the line comes aboveground, it would be cut and sealed. Pump stations would be cleaned and purged, all surface equipment removed and the land reclaimed. Under this alternative, because the approach is in place abandonment, land disturbance will be minimal. Where pipeline fill is required at road and water crossings, there will be temporary traffic disruption and increased congestion.

Appendix Q.5.2 Water and Shoreline Disturbances

Appendix Q.5.2.1 Alternatives 4a and 4b

These alternatives entail the replacement of the Line 5 Straits Crossing. The trenched pipeline (Alternative 4a) requires pre-trenching the straits, shoreline winch pulling the pipeline into place, and final burial of the pipeline. Tunnel construction requires the excavation of a 3.75-mi. (6.04-km) tunnel with a diameter of 10 ft. (3 m), plus two access shafts. Drill and blast activities will create launch and retrieval shafts; a tunnel boring machine (TBM) will create the tunnel.

The Line 5 Straits Crossing directly impacts the counties of Emmet, Cheboygan, and Mackinac. Trench construction will disrupt boat traffic in the Straits, as work crews trench and winch the pipeline into place. Adjacent shoreline areas will be temporarily transformed into worksites for materials delivery and machinery installation. Tunnel construction will involve minor water disturbance, but considerable disturbance on the shoreline at both ends of the tunnel. Tunnel excavation will require 4 to 7 acres (1.6 to 2.8 ha) for material storage and handling at each shaft. The material will need to be trucked elsewhere, increasing both traffic congestion and dust in all three counties. The estimated duration of the tunnel alternative is 27 months.

Passenger ferry service operates between St. Ignace, Mackinaw City, and Mackinac Island during the warmer months. Ferry service also operates between the Port of Cheboygan and Bois Blanc Island. As the trench or tunnel replacement alternatives are to the west of the Mackinac Bridge, neither project would disrupt ferry services.

Three commercial ports are located in Mackinac County: one in the southeast of Clark Township (Port Dolomite), and two at the southwest corner of Garfield Township (Naubinway commercial fishing port and Port Inland). The Port of Cheboygan is important for both domestic and international commercial vessels, and for the US Coast Guard. Commercial shipments of materials not allowed across the Mackinac Bridge are shipped across the lakes to and from the Port of Cheboygan. Alternative 4a (trenched pipeline) could cause temporary disruptions to regional commercial shipping.

Recreational boating and fishing activities could also be temporarily disrupted by trenched pipeline construction in the Straits. Both activities are fundamental to the tourism attraction of the region. The Straits are also tribal treaty waters, and important for tribal commercial and subsistence fisheries. Tourism and fisheries resources in the Straits of Mackinac area are discussed in more detail in Appendix Q.8 and Appendix Q.9, respectively.

The impacts of any disruption to water traffic needs careful assessment with area tribes, the Michigan Department of Natural Resources (MDNR) Fisheries Division, and others affected by lake traffic in the Straits of Mackinac.

Appendix Q.5.3 Tribal Land and Water Resources Disturbances

Appendix Q.5.3.1 Alternatives 1 and 3

Table Q-1 shows that there is Indian trust land in three counties of Alternative 1: Berrien, Calhoun, and Cass; and three counties of Alternative 3: Calhoun, Cass, and Van Buren. There is also Indian trust land in counties affected by alternatives 4a and 4b: Emmet and Mackinac. The routes of the southern pipeline and the southern railway do not appear to cross on tribal trust land, or the 1836 Treaty-ceded land. However, minimally, it is known that tribes in areas of Calhoun and Cass counties practice subsistence activities, particularly inland fishing and, consequently, they may have concerns about the construction/operations of new linear infrastructure and its potential impact on their frequented watersheds, or areas/sites of cultural importance. Regarding Alternative 4, construction activities near Mackinaw City may disrupt urban infrastructure, and in so doing, may impact business at the casino, which is owned and operated by the Little Traverse Bay Band of Odawa Indians.

Appendix Q.5.3.2 Alternative 6

Table Q-1 indicates that in most of the counties of the Upper Peninsula where Line 5 currently passes there exists tribal land. Therefore, construction activities associated with the abandonment of Line 5 would need to be checked for associated potential concerns of tribes in the area.

Appendix Q.5.3.3 Alternative 4

In Emmet and Mackinac counties, disturbances to adjacent water resources are potentially more important to the local tribes than disturbances to their trust lands. The replacement of the Straits Crossing – particularly the trench – impacts the waterways, which are 1836 Treaty-ceded waters. The Chippewa Ottawa Resource Authority (CORA) manages the commercial and subsistence fisheries in these waters. Project impacts under Alternative 4a involve potential disruptions to boat traffic, which could, in turn, disrupt fishing activities.

Tribal commercial fisheries in northern Lake Michigan and Lake Huron, joined by the Straits, are important natural resources to the fishers and economies of the area. The tribal commercial harvest in 2016 in these areas was 2.8 million lb. (1.3 million kg); subsistence fish harvest was 141,262 lb. (64,075 kg). Potential disruption caused by Alternative 4 would need further investigation and consultation with tribal authorities in the area. Fisheries are discussed in more detail in Appendix Q.9.

Appendix Q.6 Population Impacts

Temporary construction crews are required for alternatives 1, 4, and 6. Permanent employment for operations would result from the realization of alternatives 1 or 3. Since Alternative 4 involves replacement of an existing pipeline segment, no change in employment related to Line 5 operation is expected.

Both the southern pipeline and southern rail routes traverse the southeast portion of Michigan. The southern pipeline route (Alternative 1) involves construction of a pipeline along existing pipeline ROWs. The southern rail (Alternative 3) does not involve construction because Line 5 product is carried on existing rail lines. Abandonment of Line 5 (Alternative 6) involves deconstruction activities in Line 5 corridor counties in the Upper Peninsula and Lower Peninsula, southeast from Emmet towards Saginaw Bay and St. Clair County. In alternatives 1 and 6, construction crews will advance their worksites along the pipeline as construction proceeds.

Alternative 4 considers the replacement of the Line 5 pipeline segment that crosses the Straits. In this alternative, construction crews will be centered at the northernmost reaches of Emmet and Cheboygan counties, and the southern tip of Mackinac County. The Alternative 6 abandonment of the Straits Crossing segment of Line 5 will also have work crews stationed in these same areas.

Appendix Q.6.1.1 Existing Conditions

Along the southern pipeline route, average population density is 516 persons/mi^2, varying from a low of 105 persons/mi^2 in Cass County, to a high of 1,805 persons/mi^2 in

Macomb County. Along the southern rail route (Alternative 3), the average population density along the route is 241 persons/mi^2, and the most densely populated county along that route is Genesee with 645 persons/mi^2. See Table Q-1 for population data.

In the corridor counties where Line 5 currently passes, population density averages 55 persons/mi^2. The most densely populated areas are Bay and Saginaw counties, each with about 240 persons/mi^2.

Population density in the three counties affected by Alternative 4 – Mackinac, Emmet, and Cheboygan – averages 40 persons/mi^2. But the construction of a replacement (trench or tunnel) pipeline occurs to the west of the Mackinac Bridge, near the urban centers of the Village of Mackinaw City (in both Emmet and Cheboygan counties), and the City of St. Ignace (Mackinac County). Population density in these areas is of course much greater than the county averages: 900 persons/mi^2 in St. Ignace; and 239/mi^2 in Mackinaw City.

Appendix Q.6.1.2 Influx of Temporary Workers

All alternatives involving construction – Alternatives 1, 4a and 4b, and Alternative 6 – will create an influx of temporary workers to the affected counties. But the duration of the influx differs across alternatives.

In the case of Alternative 1 (south pipeline), workers will seek temporary lodging in urban centers in proximity to the pipeline worksites, but since the construction is linear, the location of lodging requirements will change as the work-spread moves along. Similarly with Alternative 6 (abandonment of Line 5), the linearity of the overall construction task will have worksites moving along the pipeline route as the pipeline is treated for abandonment (purged, sealed, or filled), and pump stations are disassembled for land reclamation.

In contrast, in Alternative 4, construction is stationary. Construction crews will be concentrated near the City of St. Ignace and the Village of Mackinaw City for the duration of the project. Hence under Alternative 4, relatively more people are affected by construction activities for a longer period of time. The abandonment of the Straits Crossing segment of Line 5 (Alternative 6) will also involve work crews stationed in these urban centers.

Appendix Q.6.1.3 Housing

Along the southern pipeline route, rental vacancies are relatively high in the lower southwest corner of the state – around 8% – falling to around 5% heading along the route northeast to St Clair County. Temporary lodging for southern pipeline construction workers should be sufficient in counties in or neighboring the pipeline corridor.

Along the Line 5 route in the Upper Peninsula, rental vacancy rates vary from 6% in Iron County to 10% in Mackinac County. (Delta County is an exception, with a low rate of 2.5%.) In the Lower Peninsula, rental vacancies can be quite low: Otsego County at 2.4%; Ogemaw at 3.6%. But Crawford County, which is on Line 5 between these two counties, has a rental vacancy rate of near 15%. That high rate would ease housing requirements for work crews decommissioning the large Line 5 pump station in the small community of Lewiston.

In counties adjacent to the Straits: Mackinac, Emmet, and Cheboygan, rental vacancies are high: 10 to 13%. But these are annual average vacancies. These three counties experience high seasonal population influxes. In Alternative 1, temporary housing for work crews moving on linear construction spreads are not expected to significantly impact the local housing markets of adjacent urban centers. However, in Alternative 4, temporary lodging for construction crews could be more problematic given the seasonal influx of tourists and seasonal workers and residents.

Appendix Q.6.1.4 Seasonal Residents and Tourists

Mackinac, Emmet, and Cheboygan counties are accustomed to large influxes of tourists and seasonal service sector workers in the warmer months. Tourism data for this area show that a large percentage of local housing is dedicated to seasonal and rental housing. Tourism is discussed in more detail in Appendix Q.8.

Given the large supply of rental housing, in the off-tourism season, the influx of temporary construction workers is unlikely to significantly impact the supply of available housing. However, during the tourism season, seasonal tourism workers and tourists may face rental shortages, increased rental costs, or both.

In Alternatives 4 and 6, construction crews will be stationed in the Straits area. Abandonment of the Straits Crossing involves cleaning and filling the lines with water, and reclaiming 3.5 acres of land currently used for pump stations. These activities may not take as long as those associated Alternative 4. Alternative 4a requires on- and off-shore equipment mobilization and activities for at least a half year. In the case of tunnel construction (Alternative 4b), the construction period estimate is 27 months. For these alternatives, it would be important for an SIA to determine the expected duration of the work, the timing during the year, and the level of housing required for construction crews. Mitigation plans to reduce seasonality impacts would need to be developed with the affected communities.

Appendix Q.7 Community Structural Impacts

Appendix Q.7.1.1 Existing Conditions: Employment

Along the southern pipeline route (Alternative 1), in 2015, annual unemployment as a percent of the labor force (see Table Q-2) varies from a low of 4.8% in Oakland County to a high of 6.8% in St. Clair County. For the abandonment of Line 5 (Alternative 6), unemployment in the Upper Peninsula averages around 8%; and in the affected counties of the Lower Peninsula, unemployment averages around 6%.

In the three counties affected by Alternative 4 – Mackinac, Emmet, and Cheboygan – unemployment is generally higher than elsewhere, ranging from 7.2% in Emmet to 9.6% in Mackinac. But, these latter three counties are particularly affected by seasonal employment. For example, in February 2017 unemployment reached 24% in Mackinac County, 10% in Emmet, and 20% in Cheboygan.[4] Employment seasonality in these counties is further discussed in Appendix Q.8.

In the counties along the southern pipeline route, the manufacturing sector employs the greatest number of people: typically between 11 and 17% of the labor force. By contrast, the largest sector in Mackinac, Emmet, and Cheboygan counties is the entertainment

[4]US Bureau of Labor Statistics. Local Area Unemployment Statistics (LAUS). Labor Force Data by County, not seasonally adjusted. February 2016-March 2017. https://www.bls.gov/lau/#tables

and service sector, which reflects this region's dependency on tourism. In Mackinac County, 29% of the labor force is in entertainment/service; in Cheyboygan,17%.

The construction sector in the counties of Mackinac, Emmet, and Cheboygan is relatively large; employing, respectively, 7%, 8%, and 10% of the workforce. In counties along the southern route, the range is lower, from 4% to 7%.

Appendix Q.7.1.2 Labor Impacts

As shown in the economic analyses above, construction expenses for Alternatives 1, 4, and 6 will have positive employment impacts for the affected regions. In the counties along the southern pipeline route, there is both a construction sector and unemployment, hence the area can probably support the human resource needs linked to a pipeline construction project, and without overheating the local labor markets. Moreover, labor resources will also be drawn from the larger Prosperity Regions.

Similarly in the three counties adjacent to the Straits Crossing pipeline replacement, there is both a considerable construction sector and a potentially large unemployed labor pool – depending on the season. However, given the importance of the service sector in Mackinac, Emmet, and Cheboygan, unemployed labor does not necessarily have the skill set for direct construction work. However, for businesses providing goods and services to the pipeline project, or for businesses benefiting from local spending by construction workers (indirect and induced economic impacts), labor is likely to be available.

Appendix Q.7.1.3 Retail and Service Sector Impacts

As shown in the Appendix Q.3, the economic impacts of construction for alternatives 1, 4, and 6 are positive. Business along the Alternative 1 south pipeline route is likely to only benefit from the presence of temporary construction crews; the same can be said for business along the Line 5 abandonment route.

In the case of Alternative 4, although economic impacts are positive overall, impacts may be mixed across businesses due to the local dependency on seasonal workers. If the availability of the seasonal labor force to the area is affected because of reduced rental housing availability, businesses dependent on tourism may face an increased cost of service sector labor.

Appendix Q.7.1.4 Tourism

Operation activities associated with Alternatives 1 and 3 are not likely to impact tourism along the south pipeline or rail routes, as there would not be a noticeable influx of new workers. Operation activity associated with Alternative 4 would be as it is now: operation activity of Line 5 with a replaced Straits Crossing would be unchanged.

In the case of construction activities, although there may be some land disturbance associated with the construction of a new south pipeline (Alternative 1), it is unlikely to impact tourism levels in the affected counties.

Under Alternative 4, and the Straits Crossing abandonment part of Alternative 6, construction is centered in the tourism-dependent counties of Mackinac, Emmet, and Cheboygan. Tourists and seasonal residents may be negatively affected by:

1. land and water disturbances (shoreline access and waterway obstruction)
2. reduced rental accommodation (influx of construction crews)
3. traffic congestion (trucks and equipment activity)
4. construction noise and dust (trucks, machinery, equipment, rock/debris removal)
5. an influx of project opponents (traffic congestion, rental housing constraints).

To the extent that the construction period overlaps with the tourist season, these impacts could deter seasonal residents, seasonal workers, and tourists from returning to the area, or cause them to shorten their usual stay. This could reduce tourism revenues to the area. The importance of the tourism sector to counties adjacent to the Straits is discussed in more detail in Appendix Q.8.

Appendix Q.7.1.5 Family Impacts

The influx of temporary workers for construction projects typically stresses community resources as demand increases for policing, and for health and medical services. As discussed above, construction-related impacts are likely to be greatest in Alternative 4 and the Straits Crossing abandonment part of Alternative 6. In these alternatives, construction is centered in the Mackinac, Emmet and Cheboygan area for the duration of the project. When construction occurs in the urban areas near the Straits Crossing, a relatively larger number of people are exposed to construction dust, noise, and competition for medical and health services. In the case of Alternative 1 (south pipeline) and Alternative 6 (abandonment of the terrestrial segments of Line 5), worksites will move as segments of line are completed, and the areas through which construction moves are, for the most part, sparsely populated.

Appendix Q.8 Tourism in Areas of Interest

Tourism is vital to the economies of all three counties in the areas adjacent to the Straits: Mackinac, Emmet, and Cheboygan. Commonalities among them include:

- The natural environment is the most important natural resource for all three counties, supporting water recreation (boating, fishing, swimming), eco-tourism (camping, hiking, biking, wildlife viewing), winter sports (skiing, snowboarding, snowmobiling), cultural and historical interests (tribal and early American heritage sites), and hunting.
- Large populations of seasonal residents and tourists during the warmer months.
- The counties encourage local governments (townships/cities) to develop land use plans and regulations that preserve and protect local natural and historic features.
- County planning documents recognize the importance of tourism and contain objectives and strategies to further develop and promote the sector.
- The counties wish to diversify their economies to reduce the seasonality of employment that is characteristic of a dependence on tourism.

- Labor force employment is heavily weighted in the retail and services sector.
- A high percentage of housing units are rental units to accommodate tourism in the warmer months.

Appendix Q.8.1 Economic Contribution of Tourism

Tourism baseline information is provided here to show the economic importance of the industry both in the Straits area and to Michigan as a whole. While the scope of the Alternatives Analysis did not include provisions for primary research and data gathering, recent survey work and analyses do provide an indication of the scale of tourism activities. These analyses can serve as a baseline for assessing the construction and operations impacts of pipeline projects in the region, and also provide a baseline for investigating potential economic consequences of a hypothetical oil spill in the Straits environment (see Appendix R).

A 2015 study of Michigan tourism estimated the contribution of tourism at county levels.[5] Table Q-16 shows that total tourism spending in the three counties adjacent to the Straits – Mackinac, Emmet, and Cheboygan amounted to $661 million in 2014. Adjusting for inflation, that level of tourism spending would be about $700 million in 2017. The three counties account for nearly 20% of the combined tourism spending in Prosperity Regions 1, 2, and 3.[6]

The $661 million in tourism spending is estimated by the authors to generate 5,330 direct jobs in tourism sector activities: lodging, food and beverage, retail, recreation, and transportation. The associated direct earnings in tourism are $153 million (2014).

The direct tourism employment estimates of the 2015 study are low for the three counties when compared to USBEA employment data. In Mackinac, the estimated 1,288 direct jobs – in *five* tourism-related sectors – represent 21% of the county's total employment. USBEA employment data (see Table Q-4) indicates for Mackinac County, 29% of the labor force is employed in only *three* tourism-related sectors: entertainment, lodging, and food service. Other data sources note that on Mackinac Island, with a May-October influx of thousands of seasonal workers, 48% of employment is in the entertainment, service, and retail trade sectors; and in St. Ignace, the same proportion is 38%.[7] In Emmet County, the estimated 3,448 direct tourism jobs represent 13% of that county's total employment, while USBEA labor force data show Emmet with 15% of its labor force in the entertainment, lodging, and food service alone. The direct tourism employment estimate for Cheboygan County is particularly low at 6% of the labor force, when USBEA data, indicates that 17% of Cheboygan's labor force is employed in entertainment, lodging, and food service.

Table Q-16 also shows the distribution of tourism dollars across spending categories. For Mackinac and Emmet, the distribution shows lodging and recreation accounting for almost equal shares of spending. Note that casino-related spending is included in the recreation category.

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[5]Tourism Economics. 2015. The Economic Impact of Travel in Michigan. Tourism Satellite Accounts Calendar Year 2014. Regional Tables. Report prepared for the Michigan Economic Development Corporation.

[6]Prosperity Regions 1, 2, and 3 are, respectively, the Upper Peninsula, northwest Michigan, and northeast Michigan. Total tourism spending in those three regions is estimated at $3.5 billion in 2014.

[7]LanduseUSA. 2016. Ibid.

Using the results of the Tourism Economics (2015) study, for the area of interest to this report (Mackinac, Emmet, Cheboygan) the ratio of direct earnings from tourism sector activities to tourism spending is 23%. Using the same estimated level of tourism spending – $700 million (2017$), RIMS II Type 2 multipliers for the combined three counties produce an estimate of direct earnings of $200 million. The RIMS II estimate therefore provides a direct earnings to tourism spending ratio of 29%. The ratios imply that 23% to 29% of tourism spending is the return to labor (and proprietorships) engaged in the tourism sector. The remainder (71% to 77%) is attributable to other input costs.

RIMS II Type 2 multipliers were used to estimate the economic contribution to Michigan as a whole of tourism spending in the three counties of interest. Results showed that the $700 million in tourism spending generates about 14,000 direct and indirect jobs statewide, with associated earnings of $359 million. About 9,700 jobs are directly related to tourism activities located in the three counties of interest, an estimate considerably higher than that generated by the Tourism Economics (2015) study.

Table Q-16: Tourism Spending and Direct Job Impacts (2014)

County	Tourism Spending (million $)	Distribution of Tourism Spending					Tourism Employment		
		Lodging	Food & Beverage	Retail	Recreation	Transport	Direct Jobs	As a % of Total Employment 2014	Earnings from Direct Jobs (million $)
Mackinac	216	32%	17%	11%	27%	14%	1,288	20.6%	43
Emmet	358	26%	19%	13%	28%	14%	3,448	13.4%	96
Cheboygan	87	31%	21%	11%	13%	24%	594	6.0%	14
Total	661	-	-	-	-	-	5,330	-	153

Source: Tourism Economics. 2015.

Appendix Q.8.2 Seasonal Employment and Occupancy

The strong seasonality of employment in the tourism sector in the three counties is shown in Table Q-17. Mackinac County experienced the greatest swings, with unemployment reaching almost 24% in February 2017, after being at a low near 3% in August and September of the previous year. Cheboygan experienced similar swings from a low of 4% to a high of 20%. Emmet's unemployment rate for the 12-month period had a smaller range of variation – 4.3% to 9.7% – but it still exhibits strong seasonality.

Table Q-17: Monthly Unemployment Rates

Month	Cheboygan County (%)	Emmet County (%)	Mackinac County (%)
16-Mar	16.8	9.0	21.5
16-Apr	11.6	7.9	14.2
16-May	4.9	5.4	4.2
16-Jun	4.5	5.2	3.4
16-Jul	4.8	5.2	3.8
16-Aug	4.3	4.6	3.3

Month	Cheboygan County (%)	Emmet County (%)	Mackinac County (%)
16-Sep	4.0	4.3	3.2
16-Oct	4.5	4.6	3.6
16-Nov	9.0	5.6	10.2
16-Dec	14.1	7.3	17.7
17-Jan	17.9	9	21.1
17-Feb	19.9	9.7	23.5
Source: US Bureau of Labor Statistics Local Area Unemployment Statistics (LAUS). Labor Force Data by County, not seasonally adjusted. February 2016-March 2017. https://www.bls.gov/lau/#tables 2017.			

Housing units (2015) and household survey data (2011-2015) from the US Census Bureau indicate that 53% of housing units in Mackinac are unoccupied.[8] In Emmet and Cheboygan, the same percentage is, respectively, 35% and 39%. These estimates are consistent with county sources. The Mackinac County Master Plan states that 44% of the county housing units are for vacation, seasonal, or occasion use: Bois Blanc Township has the highest seasonal housing rate at 90%; the City of St. Ignace, the lowest, at 8.5%. In Cheboygan, 30.4% of the unoccupied houses are used for seasonal, recreational, or occasional use. In Emmet County, detailed research on occupancy found that on average, in any month of the year, 40% of the population was comprised of visitors or seasonal residents, and from June to August, the percentage ranged from 50 to 73% of the population.[9]

Appendix Q.8.3 Urban Shoreline Areas and Facilities

Appendix Q.8.3.1 Mackinac County

The incorporated cities of St. Ignace and Mackinac Island are the largest urban centers of Mackinac County. These cities have the largest concentrations of commercial, recreation, and institutional uses. Low and medium density residential clusters are scattered throughout the county, particularly along the coast.

Mackinac Island is a major tourist destination in Mackinac County. It is an island resort area of 3.8 mi^2 (6.1 km^2), separated from the mainland by 3 mi. (5 km). Due to its strategic importance for native and early American settlement, and the preservation of historical buildings, it is listed as a National Historic Landmark, recognized for its historical significance. Eighty percent of island's environment is protected by its designation as the Mackinac Island State Park. About half the island shoreline and its adjacent waters, and the island harbor is protected as part of a marine park: the Straits of Mackinac Shipwreck Preserve.

The City of Mackinac Island includes all of Mackinac Island and nearby Round Island. Mackinac Island has foot passenger ferry service to and from the upper and lower peninsulas; motor vehicles are prohibited on the island. Only some 500 residents live on the island all year. Round Island is a federally designated wilderness area managed by US Forest Services as part of Hiawatha National forest. It is 380 acres (154 ha) in size, has no year round population, and no development or ferry service.

[8]US Census Bureau. Quick Facts.

[9]Mackinac County Master Plan 2013; Emmet County Master Plan 2015 Update; Cheboygan County Master Plan 2014.

With a population of about 2,400, the city of St. Ignace is also an important tourism draw, for its historical importance, scenic environment, and casino. The Kewadin Casino St. Ignace is owned and operated by the Sault Ste. Marie Tribe of Chippewa Indians. A short drive from St. Ignace, another Kewadin Casino is located in the village of Hessel, Clark Township, Mackinac County.

Mackinac County has five public marinas: St. Ignace (largest with 120 slips), Mackinac Island State Harbor (80 slips), Hessel/Clark Township, Bois Blanc Island Marina, and Naubinway, Garfield Township. Naubinway Port is the largest commercial fishing port on the Great Lakes. Port Dolomite and Port Inland are also commercial ports. See Table Q-18 for a summary of port and marina facilities.

Appendix Q.8.3.2 Cheboygan County

Cheboygan City and the Village of Mackinaw City are the two main lakeside urban centers of the county. Cheboygan City, with a population of about 4,700, is a harbor city with a deep-water port that can accommodate domestic and international vessels. The city and its harbor is situated along Lake Huron and linked to the inland waterways of northern Michigan by way of the Cheboygan River. From Cheboygan harbor, boaters have quick access to Bois Blanc Island, Mackinac Island, Les Cheneaux Islands, and the North Channel.

The Port of Cheboygan has all designated functions to receive cargo, ferry, commercial, and recreational vessels. It harbors the US Coast Guard's heavy ice breaking resource: the cutter Mackinaw. It serves as the maritime travel-way for material that is not allowed on the Mackinac Bridge. Also from the Cheboygan Harbor, Plaunt Transportation provides ferry service to Bois Blanc Island: approximately 4 to 5 trips per day are made in the summer; in the winter, the Bois Blanc Island relies on air transportation.

The Village of Mackinaw City has a year-round population of just over 800 people. It is located at the northern tip of Michigan's Lower Peninsula. The population increases dramatically in the summer tourism season: according to the Mackinac County Master Plan, the City can have over 10,000 people stay overnight during the summer months. This stresses the capacity of the Mackinaw City Police Department, which has limited human resources for the summer population influx.

Mackinaw City is the primary base for ferryboat service to Mackinac Island. About 1,000,000 summer visitors are ferried to the island each summer, in addition to the commute of permanent island residents. The Shepler's Ferry and Star Line Ferry provide summer water transportation service between St. Ignace and Mackinaw City, and the Mackinac Island Ferry service is closed in winter months due to freezing of Lake Huron.

Appendix Q.8.3.3 Emmet County

The Village of Mackinaw City is split between Emmet and Cheboygan counties, although most of the area of the village falls within Emmet County. Emmet also contains the cities of Petoskey and Harbor Springs, both with important shoreline frontage on Little Traverse Bay, on Lake Michigan. Petoskey is the largest city in the county with a population of about 5,700 persons; Harbor Springs has about 1,200 people.

With ample public access and shoreline parkland, Little Traverse Bay is popular for boating, sailing, and swimming, and contains several marinas. Most of Emmet County's many Lake Michigan-side marinas are found in Little Traverse Bay (see Table Q-18).

Emmet County is home to the Little Traverse Bay Band of Odawa Indians. They have parcels of land scattered around the county, and are headquartered in Harbor Springs. They own and operate the Petoskey Casino Resort, which is a major tourist attraction for the area. The Little Traverse Bay Band of Odawa Indians also has land in Mackinaw City, Emmet County side, where they have recently established another casino.

Table Q-18: Marinas and Ports near the Straits

County	Marinas and Ports	Location
Mackinac County	St. Ignace Marina	St. Ignace City, east of Mackinac Bridge
	Hessel/Clark Township Marina	Cedarville, north of Marquette Island, Clark Township
	Mackinac Island State Harbor	City of Mackinac Island, south end island
	Naubinway Commercial fishing port	Garfield Township
	Port Dolomite Commercial port, serving the Cedarville Quarry	Clark Township, east of Cheneaux Islands
	Port Inland Commercial port	Hugues Point, west of Naubinway
	Bois Blanc Marina	Island Township of Bois Blanc
Cheboygan	Port of Cheboygan – commercial port	Lake Huron, mouth of Cheboygan River
	Mackinaw City Municipal Marina	Village of Mackinaw City, east of Mackinac Bridge
	Cheboygan County Marina	Lake Huron, mouth of Cheboygan River
	Cheboygan Village Marina	Further up Cheboygan river into the city center
Emmet	Petoskey City Marina, Bay Harbor Marina, Bay Harbor Yacht Club (Petoskey), Walstrom Marina (Harbor Springs)	Little Traverse Bay

Appendix Q.9 Fisheries Resources in Areas of Interest

The State and Federally recognized treaty tribes resident in Michigan manage the fisheries in areas of the Great Lakes adjacent to Michigan. The signatory tribes to the 1836 Treaty ceded large portions of Michigan to the US Government (the northwest third of the lower peninsula and the eastern portion of the upper peninsula), but they retained rights on those same areas and adjacent waters for subsistence activities. Negotiations since the 1836 Treaty clarified those treaty rights in the 2000 *Consent Decree* issued by the Federal court which governs allocation, management, and regulation of State and Tribal fisheries in the 1836 Treaty waters until 2020. The decree delegates to the Chippewa Ottawa Resource Authority (CORA) certain management and regulatory authority.[10]

The 1836 Treaty waters include: the Michigan side of Lake Michigan through the Straits, into the northern part of Lake Huron, northwest up the St. Mary's River into Lake Superior as far west as Baraga County; and southeast down into Lake Huron as far as

[10]CORA members are: Bay Mills Indian Community, Sault Ste. Marie Tribe of Chippewa Indians, Grand Traverse Band of Ottawa and Chippewa Indians, Little River Band of Ottawa Indians, and Little Traverse Bay Bands of Odawa Indians.

the county of Alpena. The Treaty waters relevant to this report consist of the northern waters of Lake Michigan and Lake Huron.

Appendix Q.9.1 Commercial, Recreation, Subsistence Fishing

The MDNR Fisheries Division and CORA jointly manage fishing in the Treaty waters. For commercial fishing, the State licenses and regulates non-native fishers, and fishers who are members of non-Treaty tribes. For recreational fishing, the State regulates all fishers, and licenses non-Treaty tribe member fishers. CORA licenses and regulates Treaty-tribe fishers for commercial and subsistence fishing.

The Technical Fisheries Committee – a collaborative group of tribal and MDNR representatives – oversees the projection of fish populations and recommended harvest limits and harvest regulation guidelines for Treaty fisheries. Jointly, the MDNR Fisheries Division and CORA aim to regulate fishing effort such that limits are respected in the Treaty waters. Harvest is monitored for each user group (commercial, recreational and subsistence) through direct reporting, wholesale fish reports, charter boat reports, and creel surveys. For certain fisheries, particularly lake trout and whitefish, when harvests exceed set thresholds, penalties may apply and harvest limits may be reduced for the subsequent year.

The main fish species fished for both commercial and recreational purposes include whitefish, lake trout, walleye, yellow perch, and Chinook and Coho salmon. In the Treaty waters *of interest to this report*, there is only one state-licensed commercial license – for whitefish. There are many state-licensed recreational fishers for all the aforementioned fish species, except whitefish. There are many tribal commercial and subsistence licensed fishers for all species.

Appendix Q.9.1.1 Fishing Effort

Commercial fishing effort in the Treaty waters is closely monitored by the tribes, the intertribal organizations, and the MDNR. For each commercial fishing zone within the Treaty waters, the 2000 *Consent Decree* provides regulations for both tribal and state licensed fishers: allowable number of trap nets; total length, mesh size, and placement of gill nets; and permitted catch and season.

Recreational fishing by state licensed fishers is permitted throughout the Treaty waters and is subject to state regulation. Treaty tribe members engaged in recreational fishing do not need a state license, but they are subject to state recreational fishing regulations including fishing seasons, equipment type, and take and size limits.

Subsistence fishing by Treaty tribe members is allowed in all Treaty waters, with some restrictions applying to fishing area and seasons. All traditional fishing methods are permitted (gill nets, snagging, traditional hook and line, tip-ups, dip nets, and spears), although some restrictions apply to the use of nets. Fishers are limited to 100 lb. (45 kg) of aggregate catch of all species, and the catch may not be sold or traded. Survey work (Kappen, et al., 2012) found that subsistence fishers typically fish near to the shores of the Great Lakes, or on tributaries of the Great Lakes.

Appendix Q.9.2 Fish Quantities and Values in the Treaty Waters of Interest

Fishery baseline information is provided here to show the economic importance of the resource in the Straits area. While the scope of the Alternatives Analysis did not include provisions for primary research and data gathering, ongoing monitoring of the resource and production provide an indication of its economic importance to the region. These analyses also provide a baseline for investigating potential economic consequences of a hypothetical oil spill in the Straits environment (see Appendix R).

For management purposes, the Treaty waters are divided into management units (MU). The MUs of most interest in this report are those that include the northern area of Lake Michigan into the Straits and over into the northern area of Lake Huron. These are the waters adjacent to the counties of Charlevoix, Emmet, Mackinac, Chippewa, Cheboygan and Presque Isle. These waters are part of the combined fisheries management units: MM-123, WFM-1234, MH-1, and WFH-1234. Table Q-19 shows preliminary harvest data for 2016. The total commercial and recreational fish harvest from these four MUs is 2.36 million lb. (1.07 million kg).

Extending the area to include four more management units – MM-4 and WFM-5 (Lake Michigan side), and MH-2 and WFH-5 (Lake Huron side) – increases the total commercial and recreational fish harvest of this larger area to 2.76 million lb. (1.25 million kg) in 2016. The commercial harvest is 2.35 million lb. (1.07 million kg); the recreational harvest is 0.41 million lb. (0.18 million kg). This area also includes all of the Zone of Exposure (to oil spills) as described within this report.

Whitefish and lake trout are the most important commercial species for tribal fishers. These two species account for 92% of the 2.2 million lb. (1 million kg) of their commercial harvest from all eight MUs in northern Lakes Michigan and Huron. State-licensed commercial fishers take only whitefish in these same waters, harvesting 147,183 lb. (66,761 kg) of the species in 2016.

The total value of commercial fish harvest in the eight MUs (2.35 million lb) is estimated using a retail price of $4.95 per pound of fresh whole fish.[11] The retail price captures the value of the harvest plus value added through distribution to final consumers. The value of the commercial harvest thus calculated is $11.7 million/y.

For recreational fishing, in all MUs shown in Table Q-19, lake trout is the most important species, accounting for 59% of the total catch of 413,180 lb. (187,600 kg) by sport anglers. The fishing effort associated with this total recreational catch is estimated at 650,000 angler hours.[12] Survey work done by Michigan Fish and Wildlife Service estimated expenditures of a recreational fisher on the Great Lakes to be $43/d in 2011.[13] Adjusting for inflation, the expenditure in 2017 would be about $50/d. Assuming a 7 hour angler day, the recreational value of fishing in the MUs shown in Table Q-19 is $4.6 million/y.

Subsistence fishers harvested a combined weight of all species of 141,262 lb. (64,075 kg) in the Treaty waters of northern Lake Michigan and Lake Huron. According to the harvest, in terms of weight, the species of greatest importance are northern pike, perch, steelhead, and walleye. Lake trout and whitefish were the next in importance. Most of the fish were harvested with gill nets.

The relatively low subsistence harvest is consistent with survey work (Kappen, et al., 2012) that found that the percentage of tribes directly involved in

[11] Price quote from Bodin Fisheries, Bayfield, MI. January 2017.

[12] MDNR Fisheries Division and Law Enforcement Division. 2017. *2016 Annual Report on Implementation of the 2000 Consent Decree for 1836 Treaty-Ceded Waters of the Great Lakes*. May. Table 4, p.11.

[13] United States Fish and Wildlife Service. 2013. 2011 *National Survey of Fishing, Hunting, and Wildlife-Associated Recreation*. Revised December. p.8.

subsistence is typically small. However, it was noted that subsistence activities carry unquantifiable cultural and social values, in addition to nutritional values.

Valuing the subsistence harvest in terms of the price of substitutes, the retail price of $4.95 per pound of fresh whole fish was used to calculate a total subsistence harvest value of $0.7 million/y. Of course, the monetary value of the subsistence harvest does not capture the non-monetized social and cultural values of tribal subsistence fishing activities.

Within the broader fishing area, the total monetized value of the fishery is $17 million/y.

Appendix Q.9.3 Subsistence Fishing in Inland Waters

The 1836 Treaty also covers subsistence fishing on inland lakes and rivers in the ceded lands. Negotiations on subsistence rights on the inland water resources resulted in the 2007 *Inland Consent Decree*, which extends into perpetuity. Rights – for treaty tribes – are confirmed on most public lands and waters in the ceded territories, unless the area is protected for fisheries or wildlife. Unlike the 2000 *Consent Decree*, commercial harvesting is prohibited. CORA is the regulatory authority. Non-treaty tribes do not enjoy subsistence rights under the 1836 Treaty and subsequent consent decrees. However, many continue to practice subsistence fishing in the watersheds of their tribal lands.

Table Q-19: 2016 Preliminary Fisheries Harvest Data (lbs) for 1836 Treaty Ceded Waters of Interest

Fisheries Management Area	Northern Lake Michigan				Northern Lake Huron			
	Adjacent Counties: Grand Traverse, Antrim, Charlevoix, Emmet		Adjacent Counties: Emmet, Charlevoix, Delta, Mackinac, Schoolcraft		Adjacent Counties: Mackinac, Chippewa, Cheboygan, Presque Isle		Adjacent Counties: Presque Isle, Alpena	
	MM-4	WFM-5	MM-123	WFM-1234	MH-1	WFH-1234	MH-2	WFH-5
Commercial: State License								
Whitefish	-	-	-	147,183	-	-	-	-
Commercial: Tribal License								
Whitefish	-	45,740	-	977,199	-	80,912	-	30,350
Trout	124,632	-	401,688	-	253,273	-	-	-
Walleye	2,599	-	4,418	-	37,710	-	-	-
Yellow Perch	587	-	5,164	-	4,386	-	-	-
Chinook & Coho	2,184	-	456	-	125,954	-	-	-
Recreation: State License								
Trout	47,208	-	48,261	-	78,352	-	69,250	-
Walleye	372	-	10,260	-	3,828	-	16,421	-
Yellow Perch	580	-	13,119	-	11,763	-	347	-
Chinook & Coho	47,624	-	30,745	-	28,963	-	6,087	-
Total Commercial and Recreation Harvest	**225,786**	**45,740**	**514,111**	**1,124,382**	**544,229**	**180,912**	**92,105**	**30,350**
Total Subsistence Harvest (All Species)	**36**	**-**	**106,130**	**-**	**23,956**	**10,840**	**300**	**-**

Source: Michigan Department of Natural Resources Fisheries Division and Law Enforcement Division. 2017. 2016 Annual Report on Implementation of the 2000 *Consent Decree* for 1836 Treaty-Ceded Waters of the Great Lakes. May.

Appendix Q.10 Hunting and Trapping Resources

Hunting and trapping baseline information is provided here to show the economic importance of the industry both in the Straits area and to Michigan as a whole. While the scope of the Alternatives Analysis did not include provisions for primary research and data gathering, recent survey work and analyses do provide an indication of the scale of hunting and trapping activities. These analyses can serve as a baseline for assessing the construction and operations impacts of pipeline projects in the region, and also provide a baseline for investigating potential economic consequences of a hypothetical oil spill in the Straits environment (see Appendix R).

The MDNR regulates hunting and trapping for the state of Michigan. Big game hunting includes black bear, moose, elk, deer, and turkey. Small game includes, for example, pheasant, rabbit, quail, and coyote. Waterfowl hunting includes duck and geese, among other water birds. Trapping involves otter, bobcat, and fisher, among others. All game and waterfowl hunting and trapping by non-treaty tribe members requires licensing.

The Great Lakes Indian Fish and Wildlife Commission (GLIFWC) manages and provides minimum hunting and trapping regulations for treaty tribe members hunting in ceded territories of Michigan, Wisconsin and Minnesota. Regulations proposed by GLIFWC are authorized by tribal governments, reviewed by individual state departments of natural resources (DNRs), and approved by the US Fish & Wildlife Service (USFWS). Individual member tribes may impose additional restrictions, which, for example, apply to closures, harvest limits, or subsistence or commercial use. The tribes issue Treaty Harvest Permits (and tags) to tribe members for hunting and trapping on public land in the treaty-ceded territories.

Appendix Q.10.1 Hunting and Trapping in Areas of Interest

Hunting and trapping activity was considered in the areas of interest to this report. These areas include most of Michigan:

- the counties of Emmet, Cheboygan and Mackinac, which are adjacent to the existing Straits Line 5 crossing (Alternative 5), and potentially affected by a replaced trench or tunnel crossing (Alternative 4)
- the counties that would be affected if Line 5 were abandoned (Alternative 6)
- the southern counties affected by a new pipeline (Alternative 1) or increased rail traffic (Alternative 3).

Subject to local designation, public hunting areas are found in:

- state forest land
- state recreation areas and parks
- state wildlife/game areas
- Commercial Forest Act Lands
- Hunter Access Program (HAP) area on private lands
- lands under the National Park Service, USFWS, and US Forest Service.[14]

[14]Michigan Department of Natural Resources. 2017. “Open to Public Hunting” Lands Approximation Maps. http://www.michigan.gov/dnr/0,1607,7-153-10371_14793_51784-200319--,00.html

The Upper Peninsula is characterized by large areas of public, state and commercial forestland. Of particular significance is the Hiawatha National Forest, which covers 894,836 acres (362,127 ha). In two blocks, it lies in some of the same counties through which Line 5 passes; namely, Marquette, Delta, Schoolcraft, and Mackinac. Activities related to the abandonment of Line 5 would need to consider impacts on hunting and trapping throughout the Upper Peninsula. In the northern Lower Peninsula, there are also large tracts of public forestlands in Line 5 ROW counties (Cheboygan, Emmet, Crawford, Ogemaw, Oscoda, and Otsego). In the southern Lower Peninsula, State Wildlife/Game areas and HAP areas are found in the Line 5 ROW counties surrounding Saginaw Bay (Arenac, Bay, Saginaw and Tuscola), and in St. Clair County bordering Lakes Huron and St. Clair. Again, Line 5 abandonment activities would need to assess potential impacts on hunting and trapping in these counties of the Lower Peninsula.

Counties in the southern Lower Peninsula, through which a new pipeline would cross (Alternative 1) or existing rail traffic would increase (Alternative 3), are characterized by wildlife/game and park/recreation areas, and by HAP areas. HAP areas are found in at least 7 of the counties intersecting the southern pipeline and rail routes. State Wildlife/Game Areas and State Park/Recreation Areas are found in Cass, Van Buren, Kalamazoo, St. Joseph, Jackson, Livingston, Oakland, and Macomb counties. Pipeline construction would need to assess proximity and potential impacts to these areas. However, pipeline construction (or rail traffic expansion) would occur along existing ROWs, where it is likely that wildlife and hunting considerations have already been addressed to some extent.

Appendix Q.10.2 Hunting and Trapping Harvests in Areas of Interest

Appendix Q.10.2.1 Large and Small Game

Deer hunting is "one of the most widely observed rituals in Northern Michigan."[15] For the entire state, in 2016 nearly 1 million deer licenses were sold.[16] An MDNR deer harvest survey for the 2016 season found that an estimated 585,994 hunters harvested 348,000 deer, a level essentially unchanged from 2015. Regarding areas of interest to this report, the survey estimates that 1% of the deer harvest is taken by the eastern Upper Peninsula (Mackinac, Schoolcraft, Luce, and Chippewa); and 16% of the harvest is taken by the northeast Lower Peninsula (Emmet, Charlevoix, Antrim, Cheboygan and the other 10 counties of the northeast region of the Lower Peninsula).[17]

After deer, small game licenses account for the largest number of licenses: statewide 786,000 were purchased in 2016. Fur harvester licenses counted 58,000; bear and elk licenses counted, respectively, 5,500 and 200.[18] Harvest numbers for all small game were unavailable, but an MDNR 2017 survey provided some insight into the hunting and trapping of furbearing animals for Michigan as a whole.[19] In 2015, about 15,000 license buyers hunted or trapped an estimated 354,000 animals – muskrat, mink, raccoon, opossum, skunk, weasel, bobcat, fox, coyote, badger, beaver, fisher, otter, and marten. Harvest levels were essentially unchanged from the previous year.

[15] Emmet County Planning Commission. Emmet County Master Plan 2015 Update.

[16] Michigan Department of Natural Resources. 2017. Annual Report Fiscal Year October 1, 2015 – September 30, 2016. Wildlife Division.

[17] Michigan Department of Natural Resources. 2017. Michigan Deer Harvest Survey Report 2016 Seasons. June.

[18] Michigan Department of Natural Resources. 2017. Annual Report Fiscal Year October 1, 2015 – September 30, 2016. Wildlife Division.

[19] Michigan Department of Natural Resources. 2017. 2015 Michigan Furbearer Harvest Survey. April.

Appendix Q.10.2.2 Waterfowl

About 57,000 waterfowl licenses were sold in 2016.[20] An MDNR waterfowl harvest survey for 2012 estimated that about 49,000 people hunted waterfowl (duck and geese) in Michigan, and that level was associated with a similar number of licenses – 58,000.[21] Hence, given the number of waterfowl licenses sold in 2016, the number of people that actually went hunting in 2016 is likely to be similar to the 2012 number of hunters. Moreover, the waterfowl survey found that waterfowl hunting in 2012 was at the same level as in 2009, after having declined in the intervening years.

The estimated 2012 statewide waterfowl harvest – which is likely to be indicative of the 2016 harvest – was 672,000 ducks and geese combined. The Upper Peninsula took 9% of the harvest; the northern Lower Peninsula took 35% of the harvest.

Tribal waterfowl hunting activity was estimated by GLIFWC.[22] A 2015 survey of treaty tribe members in the combined off-reservation treaty areas of Michigan, Wisconsin and Minnesota estimates that 2,727 waterfowl hunters harvested 3,511 ducks, geese and coots in 2015. If the effort and harvest were equally distributed among the three states, Michigan tribal hunters may be taking just over 1,000 birds/y.

Appendix Q.10.2.3 Hunting Resource Value in the Core Area of Interest

The above reported harvests are primarily the results of hunting activity on public lands open to hunting. Large and small game hunting, as well as grouse and woodcock hunting, is done primarily in wooded/forested areas. Waterfowl hunting would occur in or close to public wetland areas, as would the hunting and trapping of some furbearing animals. This section examines the areas open to hunting in the core counties of interest to this report: Emmet, Cheboygan, and Mackinac. These are the counties most likely affected by a hypothetical oil spill in the Straits.

Hunting and trapping activity is considered in light of its proximity to the lakeshore, and the likelihood that it would be affected by an oil spill. In Emmet and Cheboygan counties, with the exception of Wilderness State Park (Emmet) and Cheboygan State Park, most public land open to hunting does not border the lakeshores. In Mackinac County, however, national and state forestland often reaches to the shorelines of Lake Michigan or Lake Huron.[23] Where public land does reach the lakeshore – and hunting and trapping is allowed – large game (deer, bear) is likely to move away from an oiled shoreline. Waterfowl game, on the other hand, is likely to be more susceptible to shoreline oiling. Small game such as river otter, mink, muskrat, raccoon, and beaver, while less affected

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[20]Michigan Department of Natural Resources. 2017. Annual Report Fiscal Year October 1, 2015 – September 30, 2016. Wildlife Division.

[21]Michigan Department of Natural Resources. 2013. 2012 Waterfowl Harvest Survey. Wildlife Division Report No. 3575. October.

[22]Great Lakes Indian Fish and Wildlife Commission. 2016. Summary of the 2015 Off-Reservation Treaty Waterfowl Season. May.

[23]In Emmet County, the Wilderness State Park located 11 mi. (18 km) west of Mackinaw City covers about 10,000 ac. and borders 26 mi. (42 km) of Lake Michigan. The park permits game hunting except in areas managed for camping. Another nearby hunting area is French Farm Lake Flooding State Wildlife Management Area. It is close to Lake Michigan, but it is not on the shoreline.

Cheboygan State Park is a 1,230 ac. park bordering Lake Huron, to the southeast of Cheboygan City and 15 mi. (24 km) to the east of the Mackinac Bridge. Hunting is allowed in most of the park except in shoreline camping areas. Another parcel of public land is situated to the north of the county about 3 mi. (5 km) from the Cheboygan/Emmet county border, but it does not reach to Lake Huron. It does border the Dingman Marsh Flooding State Wildlife Management Area, which lies to its south in the interior of Cheboygan County.

Mackinac County is dominated by national and state forestland. The eastern block of the Hiawatha National Forest (about 358,000 ac.) is situated in Mackinac County, and it borders both Lake Michigan and Lake Huron. Between the Hiawatha Forest to the east, and the Mackinac/Schoolcraft county border to the west, various parcels of state forestland also extend to the Lake Michigan shoreline.

by water pollution than waterfowl, may be more affected than large game animals. Given these considerations, the values of waterfowl hunting, and furbearing animal hunting and trapping, are estimated for the core area of interest.

Appendix Q.10.2.4 Waterfowl Harvest Value in Core Area of Interest

The MDNR promotes waterfowl hunting in its seven Managed Waterfowl Hunt Areas (MWHAs). All seven of these areas are located in the southern Lower Peninsula. However, the data gathered by the MDNR waterfowl survey show that significant waterfowl hunting occurs throughout the state. Michigan duck and geese hunters in 2012 spent a total of 634,000 days afield. Nine percent of that effort was spent in the Upper Peninsula, and 37%, was spent in the northern Lower Peninsula.

The 2012 MDNR waterfowl survey estimates that the expenditure associated with statewide waterfowl hunting (ducks and geese) was $22.7 million in 2012.[24] Inflated to 2017, that amount equates to $25.1 million/y. Assuming that effort patterns in 2017 are unchanged from those in 2012, 9% or $2.3 million/y in waterfowl hunting value would be apportioned to the Upper Peninsula, while 37% or $9.3 million/y would be apportioned to the northern Lower Peninsula.

Waterfowl hunting occurs around the many inland and lakeshore wetland areas throughout Michigan. While survey-based estimates of hunting effort and harvests are available for the state and regions, site-specific hunting effort and harvest estimates are not readily available. However, as waterfowl are likely to occasion the lakeshore, it is reasonable to estimate a minimum coastal value of waterfowl resources (to hunters) by apportioning regional waterfowl values to lakeside stretches.

The lakeshore length of counties in the Upper Peninsula (on Lakes Superior, Huron and Michigan), plus the lakeshore length of counties in the northern Lower Peninsula (on Lakes Michigan and Huron) totals about 2,700 mi. (4,345 km).[25] The total estimated value of waterfowl hunting in the Upper Peninsula and the northern Lower Peninsula is $11.6 million/y. Evenly distributing the waterfowl value along the lakeshore results in an estimated waterfowl resource hunting value of about $4,300/mi. of lakeshore in 2017.

Appendix Q.10.2.5 Furbearer Harvest Value in Core Area of Interest

The value of furbearing animal hunting and trapping is estimated using the same approach as above for waterfowl valuation. Michigan's total lakeshore length bordering Lakes Michigan, Superior, Huron and St. Clair is about 3,224 mi. (5,189 km).[26] For all of Michigan, the 2017 MDNR furbearer harvest survey estimated that furbearer hunters spent about $6.4 million in 2015.[27] Evenly distributing total Michigan harvest value along the lakeshore results in a furbearer hunting/trapping resource value of $2,100/mi. of lakeshore in 2017.

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[24] For subsequent evaluation purposes, expenditures are used as a minimum *value* of the resource. This is regarded as a rough approximation and acknowledged to exclude any potential consumer surplus associated with the activity.

[25] Michigan State University Extension (MSUE) County Tourism Profiles cited in: VanderMolen, BJ. 2013. Discovering Michigan County by County. Thunder Bay Press. Holt, Michigan.

[26] National Oceanic and Atmospheric Administration. Office for Coastal Management. 2017. Shoreline Mileage of the United States. https://coast.noaa.gov/data/docs/states/shorelines.pdf

[27] Michigan Department of Natural Resources. 2017. 2015 Michigan Furbearer Harvest Survey. April.

Appendix Q.11 Selected Bibliography

This section is provided for the reader's convenience to show thematic sources contained in the appendix text, its footnotes, and graphically presented tables and figures.

Appendix Q.11.1 General Statistics

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--------------- Table CA5N Personal Income by Major Component and Earnings by NAICS Industry.

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--------------- 2017. “Open to Public Hunting” Lands Approximation Maps. http://www.michigan.gov/dnr/0,1607,7-153-10371_14793_51784-200319--,00.html

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Appendix Q.12 References

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[2] Pratt, Elizabeth; Zin, David, "February 2017 Monthly Revenue Report. Senate Fiscal Agency.," February 2017. [Online]. Available: www.senate.michigan.gov/sfa. [Accessed March 2017].

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Appendix R Spill Cost Analysis

This appendix reflects comments on the Draft Final Report provided during the public review process described in the Preface of the current Final Report. Summarizing the main points, the reader should note the following:

1. As described in Appendix N, spill consequences and costs are based on worst-case spill volumes, but are not themselves further assessed under terms of worst-case consequences that might conceivably occur. The spill costs represent credible consequences, which are assessed at the expected means of various assessment parameters (such as shoreline oiling). This procedure provides an appropriate basis for comparing alternatives. A sensitivity analysis is also conducted at a 95% quantile of spill length only to illustrate results at this extreme case; such a result would only be used in actuarial purposes if risk pooling were unavailable or if the insured entity might be regarded as high-risk in comparison to industry standards.
2. A common comparison in public comments was that the shoreline oiling in this study (20 to 25 mi. or 32 to 40 km) was not credible in light of results derived elsewhere (Schwab, University of Michigan) showing a potential area of vulnerability of 700 mi. (1,127 km) of coastline. This issue is further discussed in this appendix as a validation exercise showing that the model results are comparable if properly interpreted: the Zone of Exposure (ZOE) in the Dynamic Risk study is in fact about 1,000 mi. (~1,600 km) and single spill shoreline oiling (which is the basis of impacts, as opposed to cumulative spills) is also comparable under the two models.
3. Comments frequently “imagined” a worst-case consequence to assert that spill costs would be considerably higher under certain circumstances. Such comments do have merit, but the task of the Alternatives Analysis was not to imagine worst-case fates or consequences. To assist the reader, additional validation information and analytical detail is provided in this appendix to show the expected values of various impacts on key environmental and economic values. These values are not based on worst-case fates or consequences; for example, they do not assume worst-case conditions for season, nor do they consider what might happen in worst-case weather conditions. Similarly, shoreline impacts are assessed for a 20 to 25 mi. (32 to 40 km) spill along an average shoreline within the core counties of Cheboygan, Emmet and Mackinac: there is no attempt to select a potential worst-case location for a spill to strike shore.
4. Comments frequently sought detail on worst-case impacts associated with specific resources or resource uses assuming that a bottom-up derivation was being used to assess costs. The spill cost model used within the Alternatives Analysis is based on statistical data and relies on various spill attributes (size, oil type, general environment, remoteness, etc.). This approach is characterized as a top-down methodology and provides a direct estimate of total cleanup and damage costs (as outlined in the Statement of Work) for a credible worst-case spill. Credibility is interpreted probabilistically as a worst-case spill volume event during a typical year having impacts within a typical area of a ZOE. This approach contrasts to a style of Natural Resource Damage Assessment (NRDA) which is a bottom-up line-by-line cost assessment typically done after a spill occurs. Such a bottom-up approach is often done by trustees responsible for demonstrating due diligence in ensuring that adequate restoration for damages is done after a spill. Bottom-up methodologies (e.g., those described by

Grigalunas et al. 1988 and subsequently elaborated by NOAA)[1] serve the purpose for assessing ex-post damages once a spill occurs in a known location, season and circumstances with specific impacts to property, people and the environment. A hypothetical spill under average conditions (albeit worst-case spill volumes) can be evaluated using procedures that rely on historical information that has been adjusted for general local conditions. In using the top-down method employed in the Alternatives Analysis, it is also helpful to test or validate the results by preparing a “contributions analysis”, which is a partial line-by-line validation method of key impacts that provides stand-alone damage estimates across various categories of interest. This validation has been extended in this appendix to include potential impacts on local fisheries, and more detail is provided on potential spill consequences on tourism, wetlands, and hunting.

5. Additional information was provided by the State relating to drinking water sources in Michigan. A review of this information prompted further internal review of assumptions relating to the determination of the amount of High Consequence Area (HCA) within the southern pipeline and southern rail corridors. The additional information underlined that some uncertainty exists in determining actual current and potential groundwater uses within the state. Similarly, lack of detailed information on groundwater uses in the other three states prompted a revision in the assumed amount of HCA through which the pipeline and rail corridors passed. The original assumption in the Draft Final Report reflected a contingency expressed as an incidence of “Other Sensitive Areas (OSA)” of 10% of the total of populated areas and environmentally sensitive areas otherwise determined. Given the uncertainty around groundwater resources and their usage, this was increased to 25% for the purposes of the risk analysis. The resultant increase in HCA for the terrestrial corridors is documented in this appendix; it should be noted that this does not impact spill costs (which are determined by presence or absence of HCA) but does impact the weighted spill costs.

6. Comments at times referred to the 30-day response period as unrealistic, but this is a misinterpretation. Spill modeling is done for a 30-day period to allow the full modeled development of the unmitigated fate of a spill. Such modeling is routinely used in risk analyses to allow formulation of spill preparedness needs within a certain ZOE, and to provide a conservative estimate of ultimate consequences. Response is actually much more immediate, and also focuses on protecting assets (such as water supplies) or specific resources at risk (such as known fish hatchery sites). Discussions and diagrams in the report (see Attachment 2 in Appendix S) also show the time it takes for an unmitigated spill to reach certain areas, noting that for areas outside of the Core Zone (defined herein as Emmet, Cheboygan and Mackinac counties) the time period is typically adequate to place protective booms or use other mitigation actions. Similarly, the miles of shoreline “oiled” by an average spill considered in this appendix are also a conservative estimate as they represent unmitigated conditions.

[1] Grigalunas T, Opaluch J, French D, Reed M. 1988. “Measuring Damages to Marine Natural Resources from Pollution Incidents under CERCLA: Application of an Integrated, Ocean Systems/Economics Model”. Marine Resource Economics 5(1):1-21.

Appendix R.1 Introduction

Appendix R.1.1 Scope

Spill costs are estimated for the following four alternatives designated here as:

1. Alternative 5 – Line 5 operations with existing 20-in. pipelines
2. Alternative 4a – new 30-in. pipeline in a trenched crossing at the Straits
3. Alternative 1S – southern routing of a new 30-in. pipeline
4. Alternative 3S – southern routing of a rail line.

Alternative 5 and Alternative 4a involve hypothetical releases into the Great Lakes environment. Alternative 1S and Alternative 3S involve potential releases into corridors along the southern routing of the pipeline and rail, respectively.

The role of the spill cost estimates is to provide *contingent* economic consequence estimates to a risk analysis of each of the above alternatives. In addition, to the extent that environmental costs can be monetized, a portion of total economic consequence related to the environment informs the environmental consequence analyses.

The spill costs are *contingent* upon a spill event occurring. They enter the risk calculation through an eventual weighting that considers the probabilities of the spill occurring. These probabilities and weightings are not addressed in this appendix: they are addressed in the main text of the report.

This appendix provides additional detail on approach, alongside a discussion of the general parameters and assumptions involved in the spill cost estimation. It summarizes key inputs into the spill model for each of the spill estimates conducted for this study. Results are presented for all of the above-noted alternatives.

This appendix concludes with two types of validation exercises:

- The first is a general comparison of total cost results to values in the literature. This comparison uses a common benchmark expressed in terms of $/bbl of oil released. As part of this validation exercise, values relating to environmental damage estimates found in the literature are also presented to validate those derived in this analysis. A comparison is also made to Enbridge's estimates of worst-case spill costs for a spill in the Straits of Mackinac (Straits) area.
- The second validation exercise involves estimates of potential contributions associated with specific costs of local concern within the Straits area. This involves estimating the expected costs from a mean spill event on tourism, fisheries, hunting, water supply contamination, and property value impacts. These estimates are not added to the total costs, but are conducted for control and validation purposes: if any of these exceed the upper bound of expected costs derived from the spill cost model, then the model may generate underestimates of the costs.

This introductory section continues with elaborations regarding:

- The role and use of the cost estimates.
- The treatment of market impacts associated with spill costs.
- The treatment of shoreline oiling.

Appendix R.1.2 Role of Cost Estimate

Appendix R.1.2.1 Use in Comparative Analysis

In general, the reader is reminded that it is not possible to predict the financial cost of any single spill, as it generally will depend on a range of biophysical factors, which themselves exhibit normal natural variations through time and space. Location, season, weather, product shipped, site access, mitigation methods applied after a spill, and remediation endpoints all play a role in determining the eventual cost of a spill. The regulatory regime in which a spill occurs also has a bearing on cleanup costs. The approach taken in any such assessment therefore relies on using best available existing information and then on applying such information to a given hypothetical scenario. It must be stressed that spills remain low probability events. Spills are to be avoided, and regulators, operators, and users of transportation infrastructure correctly seek to achieve a safe operation with zero spills. Where they do occur, assessments document the circumstances of the spills that in turn inform future operations to achieve a zero spill target. Experience thus draws from a wide array of rare events, and applies statistical methods coupled with informed judgment over what is relevant in various situations.

The spill cost analysis is informed by statistical findings related to global spills over the past three decades. The spill sets include those available through public sources such as the Ship-Source Oil Pollution Fund (Canada), the International Oil Pollution Compensation Funds, and the Pipeline and Hazardous Materials Safety Administration (PHMSA). These are complemented by a variety of spill sets that are maintained, updated and validated in-house, including those from various states (e.g., Washington Department of Ecology), from published regression results and meta-studies[2], from reinsurers, from the World Bank/IFC Group, and from companies in oil, gas and mining sectors. The model has been used in regulatory proceedings in Canada (e.g., Northern Gateway Project, Trans Mountain Expansion Project) and damage costs are validated periodically through literature reviews[3].

The estimating model used for these analyses is *not* intended for assessing post-spill damages related to a single event; instead, it is intended for use in estimating total costs of hypothetical spills where the information will be used in risk analyses. Such risk analyses are typically associated with planning decisions, insurance underwriting, or (as is the case for this report) comparative analyses of risk using a common methodology. As with other risk analyses, the intent is to represent likely costs within a confidence interval consistent with prefeasibility design standards (cost estimates for these results reflect -30%/+50% confidence intervals). The methods are premised on following actuarial standards and general international guidelines on establishing *credible* estimates of losses (see Appendix N).

[2]These include: (i) Etkin, D.S. 1999. *Estimating Cleanup Costs for Oil Spills*. Paper #168. Proceedings of the 1999 International Oil Spill Conference. (ii) Etkin, D.S. 2000. *Worldwide Analysis of Marine Oil Spill Cleanup Cost Factors*. Arctic and Marine Oilspill Program Technical Seminar (June). (iii) Kontovas, Christos A.; Psaraftis, Harilaos N.; Ventikos, Nikolaos P. *An empirical analysis of IOPCF oil spill cost data*. Marine Pollution Bulletin, Vol. 60, No. 9, 2010, p. 1455-1466. (iv) Transport Canada. 2007. *Synopsis Report – Environmental Oil Spill Risk Assessment for the South Coast of Newfoundland*, Edition 1 September 2007, Revised 11/2007. Report TP14740E.

[3]The original reviews were based on the Environmental Valuation Reference Inventory (EVRI) database originally supported by Environment Canada and currently archived at the Office of Environment and Heritage in New South Wales, Australia (http://www.environment.nsw.gov.au/publications/evri.htm). Subsequent validation was conducted based on reviews carried out for Statistics Canada within its “Measuring Ecosystem Goods and Services (MEGS)” effort involving departments in Environment and Climate Change, Fisheries, Oceans and the Canadian Coast Guard, Natural Resources Canada, Parks Canada, Agriculture and Agri-Food Canada, and Policy Horizons Canada (Statistics Canada. 2013. Environmental Accounts and Statistics Division. Human Activity and the Environment. Measuring ecosystem goods and services in Canada. December).

Although there are instances where liquids spills will cause fatalities, the model as used for this analysis does not estimate casualty costs. It should, however, be noted that the statistical data on which the model relies will often implicitly include damages associated with injuries or other health impacts if these form part of a successful claim. Inspection of claims data shows that, while there may be some single events with high claims, the contribution of these to mean values is not expected to bias the estimates. The model does not provide a separate estimate of such casualty costs or values.

The model excludes fines and penalties associated with a spill event. Results in this appendix and report cannot and should not be used for the purpose of making claims or seeking damages in association with a specific spill event.

Appendix R.1.2.2 Selected Conservative Assumptions

The model avoids excessive attempts to determine a worst-case consequence, although it does permit a weighting of conditions or selection of assumptions to be conservative in some estimates. Examples of this within the context of this report include:

- Separate modeling of spills *with* and *without* the influence of ice to reflect different conditions, and subsequent weighting of the spills according to actual data regarding levels of ice cover.
- Screening out of potential use of low cost response options, such as dispersants and in-situ burning.
- Shoreline oiling assumption was based on a 30-day unmitigated fate from MIKE model (Attachment 2 in Appendix S), although response would in reality be more rapid and boom deployment could be expected to protect some assets and resources.

Appendix R.1.3 Treatment of Market Impacts

A spill that coincides with a service disruption (of delivered product) may result in a prolonged outage period. This may impact downstream refiners or customers, and/or upstream producers in the United States (US) and Canada. The economic consequences of this outage would be expected to persist during a period of potential supply shortages or increased prices during the unavailability of the transport infrastructure. The spill cost model does not estimate these explicitly because these market impacts represent a higher round of effects beyond the direct consequences of a spill. Also, various mechanisms may mitigate the potential impacts of the spill. The market impacts can, however, be considered as belonging to various categories described as follows.

Appendix R.1.3.1 Product Loss

This category corresponds to the value of product lost, and is small across all spills in relation to total spill costs. For example, a spill involving 5,000 bbl would generate a direct loss in product of $250,000 at oil prices in the neighborhood of $50/bbl. This loss is often absorbed by the shipper or operator and does not factor into the cost model. Attempts are also often made to recover as much of this oil as possible for subsequent processing and reinjection. The value of net product loss is therefore not included in spill costs reported in this appendix.

Appendix R.1.3.2 Service Interruption

Service interruption impacts depend on the nature of the infrastructure, the ability or inability of a quick return to service, and the availability of stored product to refiners or customers. Operational outages of a few days are not uncommon during normal pipeline operations for scheduled maintenance or other reasons. Also, the common use of *batch* shipments through Line 5 and other operations implies that many customers do not necessarily rely on daily deliveries. Large industrial customers and refiners can meet demands through drawing upon on-site storage for such short periods; strategic use of such stocks will also mitigate impacts of longer outages. Storage of refined product at refineries will also serve as an additional measure for mitigating impacts to final consumers. Line pack downstream of the spill can also represent potentially available storage within the pipeline itself.

Significant market impacts would only occur for Alternative 5 (existing operations) if both 20-in. pipelines were shut down in the event of a spill from one of the twin pipelines. For analytical purposes, it is assumed that the undamaged pipeline would still continue normal operation, permitting throughput of 270,000 bbl/d. While this constrains Line 5 throughput, it would permit ongoing delivery of natural gas liquids (NGLs) to Rapid River (~2,000 bbl/d), and continued injection of crude at Lewiston (~10,000 bbl/d). Apportionment protocols related to the Lakehead System (as described in Appendix J and in Section 4) would also restrict some crude deliveries to the Toledo and Detroit refineries, but no apportionment would occur on the Mid-Valley system.[4] The final impact on the crude prices at these refineries is estimated to be $0.018/bbl. Michigan consumers would experience an increase in price of 0.051¢/gal; this equates to approximately $2.9 million/y. Recall that these impacts are limited to these levels *only if* one of the 20-in. pipelines is assumed to continue operation; if all Line 5 throughput were interrupted, then the impacts would be similar to those associated with abandonment, as described below for Alternative 4a.

For all other alternatives prone to interruption (e.g., Alternative 4a, Alternative 1S, and Alternative 3S), the upper bound impact of a longer service interruption is equivalent to the market impacts associated with an interruption of throughput of 540,000 bbl/d within the Lakehead System. These impacts are similar to the potential stand-alone impacts of full abandonment of Line 5 (Alternative 6b), and would not occur until these alternatives are commissioned at some future date:

- >2 years for the trench crossing
- >3 years for rail
- >5 years for a new pipeline.

For Alternative 4a (new Straits Crossing), these impacts (see Section 4) are estimated to be 10¢/gal to 35¢/gal for propane consumers in the Upper Peninsula; this would translate to

[4] Section 4 provides analyses of apportionment of Mid-Valley and how supply shortages might arise if Line 5 volumes are unavailable due to abandonment. The models used in Section 4 show that Mid-Valley pipeline (240 kbbl/d capacity) would have inadequate capacity to serve the Detroit and Toledo refineries in the event of full abandonment; these refineries would need to nominate apportioned throughput on the Mid-Valley pipeline to meet their refinery capacity, and also revert to additional trucking and rail shipments at higher costs. A reduction of throughput in Line 5 by 270 kbbl/d would not place Mid-Valley into an apportionment situation, and the Detroit and Toledo refineries would not be required to rely upon additional truck or rail shipments. There is, however, a potential moderate increase in delivered costs through the Lakehead System on some portion of the refinery crude supplies. Impacts reported here reflect those increases. These increases in delivery costs do not reflect a potential reduction in NGL deliveries to the Sarnia fractionator. Because much of the NGL could still find its way to Sarnia via the Lakehead System even under apportionment, the eventual propane deliveries from Sarnia to Michigan will be reduced by an estimated 5,500 bbl/d if the Sarnia fractionator were to have no other feedstock available. Within the PADD 2 current supply position of 500,000 bbl/d, and available storage expected in the Midwest, market impacts are expected to be minimal and, as noted in Section 4 and Appendix J, out-of-state propane producers are likely to absorb some increases in such delivery costs.

$3.1 million/y to $10.7 million/y based on average demand of 2,000 bbl/d. The interruption would also entail an increase in transportation costs of $2.40/bbl for producers relying on injection at the Lewiston terminal, corresponding to $8.8 million/y based on average injections of 10,000 bbl/d. The Rapid River propane price impacts and Lewiston crude tariff impacts are regarded as likely market impacts only in the event of a spill under Alternative 4a (new Straits Crossing). These local price and tariff impacts will have already occurred for Alternative 1 (new southern pipeline) and Alternative 3 (rail) as a result of Line 5 abandonment associated with these alternatives.

More extensive impacts in broader gasoline and propane markets could, however, occur for Alternative 4a (new Straits Crossing), Alternative 1 (new southern pipeline), and Alternative 3 (rail) in the event of a spill. Because of apportionment on the Lakehead and Mid-Valley systems, refiners in Detroit and Toledo would see an increase in the average cost of crude supply by $0.76/bbl. Michigan consumers of gasoline could experience a price increase of 2.13¢/gal for the duration of a prolonged service outage.[5] Recall that Michigan refined petroleum product consumption is estimated to be 5,700 million gal/y. A one year interruption in service would have gasoline market impacts of $121 million and Lower Peninsula propane market impacts of $23 million maximum. The duration of the impacts would coincide with a return to service period that permits repair or replacement of infrastructure, plus the time required to obtain regulatory approvals for operations to recommence.

It should be noted that market impacts of the nature described above are not normally included in spill cost data, nor are they normally regarded as eligible amount for claims. Such costs are therefore excluded from spill costs reported in this appendix.

Appendix R.1.3.3 Long-term Tariff Impacts

In the event of a spill, some proportion of spill costs could be recovered through rate setting mechanisms that might impact transportation tariffs in the Lakehead System. The costs could be recovered either through capitalizing some portion of the costs or treating some as recurrent (e.g., for post-spill monitoring). Their inclusion may not occur until some years after the initial event. Their inclusion will also depend on other factors such as amounts recoverable and settled through insurance held by the operator or others. Such settlements, similarly, may take some time to occur. Both the admissibility of costs and the extent of insurance coverage of such costs is not possible to determine for a hypothetical spill. Potential long-term impacts on tariffs are therefore excluded from spill costs reported in this appendix.

[5]These impacts are not noticeably different than the full abandonment (Alternative 6b) impacts documented in Section 4. Because of apportionment on the Lakehead and Mid-Valley pipeline systems, analyses undertaken in support of Alternative 6b conclude that refiners in Detroit and Toledo would see an increase in the average cost of crude supply by $0.76/bbl. Michigan consumers of gasoline could experience a resultant increase in price of 2.13¢/gal for the duration of a prolonged service outage. Michigan consumers of propane in the Lower Peninsula could experience a resultant increase in price of 5¢/gal for the duration of a prolonged service outage, although this could be mitigated substantially because of available storage in PADD 2 and because propane producers are likely to absorb some part of such increases. These estimates include an amount for abandonment costs, which would not be incurred for an oil spill scenario. The impacts of the abandonment costs are not detectable within the rounding of these figures: impacts to refiner average crude costs are $0.004/bbl greater when abandonment costs are included.

Appendix R.1.4 Shoreline Oiling from Spills in the Straits

Appendix R.1.4.1 Summary

As described in Appendix R.5.3.2, land use impacts on the shoreline are cast in probabilistic terms by referring to shoreline oiling in Alternative 4a and Alternative 5. Model inputs involve parameters relating to total spill volume, and shoreline length oiled. The highest total spill costs were associated with the south shore leaks from each of these alternatives. The leak volumes and mean shoreline oiling from each of these alternatives is presented in Table R-1.

The spill sets represented in Table R-1 involve spills of 4,527 and 9,801 bbl in a shallow near shore environment. Shoreline oiling from a south shore leak within the ZOE is expected to be 20.8 mi. (33.5 km) for the existing crossing and 24.7 mi. (39.8 km) for the trenched crossing. Less than 2 mi. (~3 km) of each of these figures is expected to be in six counties not within the Core Zone: Chippewa, Alpena, Presque Isle, Charlevoix, Antrim, and Grand Traverse. Oiling within the three core counties of Mackinac, Emmet and Cheboygan is thus expected to be 19.5 mi. (31.4 km) for the south shore spill in Alternative 5. In Alternative 4a, oiling within these three core counties is expected to be 23.2 mi. (37.3 km). For ease of reference, this overall range is characterized as spill oiling in the range of 20 to 25 mi. (32 to 40 km). The lower bound represents approximate oiling in the core counties under Alternative 5 and the upper bound represents approximate oiling in the entire ZOE under the larger spill from Alternative 4a.

Inspection of all 720 spills showed that other spill sets (with lower volume spills) may have had slightly higher shoreline oiling for some individual spills. However, the deposition of material, and the extent of shoreline oiling, in the south shore spill set makes the mean oiling associated with this spill set a credible economic worst-case spill set. In interpreting this result, the reader is reminded that all 120 spills are included within the mean values used for the analyses.

A spill-by-spill analysis of the Alternative 5 spills showed that 95% of these generated shoreline oiling in Michigan in the range of 0 to 57 mi. (0 to 92 km) This threshold for the south shore leak spill set can be regarded, for statistical purpose, as a potential upper bound for estimating a credible worst-case consequence within the context of the operating conditions and environment of the existing pipeline. These conditions reflect the highest rupture size (4,527 bbl) and the fate and behavior of a spill generating 57 mi. (92 km) of shoreline oiling from a near shore event. The total cost consequences of this spill are estimated to be approximately $200 million. This value is characterized, using the actuarial definition elaborated in Appendix N, as a 95th quantile result.

A spill-by-spill analysis of the Alternative 4a spills showed that 95% of these generated shoreline oiling in Michigan in the range of 0 to 58 mi. (0 to 93 km). This threshold for the south shore leak spill set can again be regarded, for statistical purpose, as a potential upper bound for estimating a credible worst-case consequence within the context of the operating conditions and environment of the 30-in. trenched pipeline. This upper bound oiling is similar to that of the upper bound oiling for Alternative 5, confirming that the spill sets have similar fates although the larger spills will create more material deposition on impacted shorelines. These conditions for Alternative 4a reflect the highest rupture size (9,801 bbl) and the fate and behavior of a spill generating 58 mi. (93 km) of shoreline oiling from a near shore event. The total cost consequences of this spill are estimated to be approximately $310 million. This value is characterized, using the actuarial definition elaborated in Appendix N, as a 95th quantile result.

While the above spill cost estimates provide upper bound hypothetical single spill values at the 95th quantile within the south shore leaks, this appendix focuses on presenting the mean spill conditions for the entire set (including *all* 120 spills within a given set).

Table R-1: Spill Volumes and Shoreline Oiling – Pipeline South Shore Leak

Indicator	Alternative 5 Existing Crossing	Alternative 4a Trenched Crossing
Spill Volume	4,527 bbl	9,801 bbl
Total Shoreline Oiling (mean 120 spills)	20.8 mi. (33.5 km)	24.7 mi. (39.8 km)
Total in Core Zone 3 Counties(1)	19.5 mi. (31.4 km)	23.2 mi. (37.3 km)
Total in Remaining 6 Counties in ZOE(1)	~1.3 mi. (~2.1 km)	~1.6 mi. (~2.6 km)
Notes: (1)Core Zone counties include Cheboygan, Emmet, and Mackinac. The remaining counties in the ZOE include three neighboring counties (Charlevoix, Chippewa, and Presque Isle) and three other counties (Alpena, Antrim, and Grand Traverse).		

Appendix R.1.4.2 Exposure by Township

A number of comments observed that the 20 to 25 mi. (32 to 40 km) mean oil spill described in the Draft Final Report seemed inconsistent with the analysis by University of Michigan (U of M), which shows oil spill vulnerability of the order of 700 mi. (~1,100 km) of shoreline for typical spills.[6] The vulnerability measure citing 700 mi. (~1,100 km) of shoreline in the U of M study is comparable to (and is, in fact, less conservative than) the ZOE determined for the existing Straits pipelines in the Alternatives Analysis, which, as described below, is approximately 1,000 mi. (~1,600 km). The mean length of shoreline oiling of 20 to 25 mi. (32 to 40 km) described in this study is comparable to the median length of shoreline oiling of 38 mi. (~60 km) obtained by Schwab as described in his 21 July 2017 comment referring to an initial discharge of 5,000 bbl.

The expected spill exposure zone is always considerably more than the expected mean or median spill, since the spill exposure zone reflects an aggregate of impacted shoreline lengths from multiple simulations; each spill would have a unique set of conditions (such as wind speed and direction, wave height, etc.) that determines the trajectory and shape of an oil spill, and ultimately the length of shoreline that is oiled. The expected exposure zone should therefore, in no way be confused with the length of shoreline that could be oiled by a single spill. Judging from the number and nature of comments made that relate to comparisons between U of M findings on shoreline oiling and those published in the Alternatives Analysis Draft Final Report, it is apparent that considerable confusion exists.

The ZOE for different spill sets is shown in a map-based format in Attachment 2 (see Appendix S), but can also be simplified by combining all spill sets for a given alternative. For the reader's convenience, information presented in tables 4-1 to 4-6 in Attachment 2 (see Appendix S) is summarized in Figure R-1 and shows the normalized length of the township shoreline that is potentially vulnerable. This shoreline is not equivalent to the hypothetical shoreline oiled in any given spill, such as those presented in tables 4-7 to 4-12 in Attachment 2 (see Appendix S). Oiled shoreline is a measure generated by the MIKE software. The measure shown in Figure R-1 represents the entire shoreline of the township

[6]Schwab, David. 2016. *Statistical Analysis of Straits of Mackinac Line 5 Worst Case Spill Scenarios*. University of Michigan Water Center, Graham Sustainability Institute.

– the length that could be walked or cycled if there were a convenient path, for example. The ZOE defined by “hits within a township” is a useful way to look at potential areas of incidence.

The reader will note that not all townships in a county are listed; this is because only townships with non-zero hits are included. None of the 720 spills, for example, reached the Newton township, which is on the western extreme of Mackinac County and borders Schoolcraft County on the shore of Michigan’s Upper Peninsula.

A number of results can be deduced from Figure R-1 and its underlying information. Notably:

1. For 360 spills from the existing pipeline (Alternative 5), the potential spill incidence covers townships and cities representing approximately 1,000 mi. (~1,600 km) of shoreline. For 360 spills from a trenched 30-in. pipeline (Alternative 4), three additional townships are involved and the potential spill incidence represents approximately 1,100 mi. (~1,800 km) of shoreline.
2. The hits are distributed similarly across the two alternatives. This is consistent with observations that oil tends to move to similar locations but in quantities consistent with the original spill volumes: larger spills tend to deposit larger amounts of product, but the shoreline stretches at risk are similar.
3. There is some minor variation between the alternatives associated with the locations of the existing 20-in. pipelines and the new 30-in. pipeline. The variation is not significant in defining the overall area of interest for consequence modeling.
4. The results underline that a Core Zone can be represented by the shorelines within Mackinac, Emmet and Cheboygan counties.
5. The shorelines at risk are consistent with those recounted in the U of M study. Table R-2 shows a 97.5th quantile result with 680 to 692 mi. (1,094 to 1,114 km) of potential exposure within a sample spill set of 720 spills (and corresponds to releases at six different locations).

Table R-2: Exposure of Michigan Townships to Mackinac Straits Oil Spills

Quantile (%)	Alternative 4 (30-in. trenched pipeline)	Alternative 5 (existing 20-in. pipeline)
95	424 mi. (682 km)	424 mi. (682 km)
97.5	692 mi. (1,114 km)	680 mi. (1,094 km)
100	1,105 mi. (1,778 km)	1,024 mi. (1,648 km)

Notes:

Exposure represents the length of shoreline that could be affected as derived from a set of 360 spill scenarios. A single spill will *not* impact the entire shoreline indicated. The 100% quantile implies that, of the 360 spills, none among the simulated spills are expected to fall outside of the townships defined by the indicated shoreline length; all spills are expected to fall somewhere within this length of shoreline. The 95% quantile implies that, of the 360 spills, at most 5% (18) among the simulated spills are expected to fall outside of the townships defined by the indicated shoreline length; 95% of spills (342 of 360) are expected to fall somewhere within this length of shoreline. Similarly, a 97.5% quantile result corresponds to a shoreline length inside of which 97.5% of spills (351 of 360) are expected to fall.

Number of Spills out of 360 Oil Spill Simulations that reach Township/City Coastlines*

*The 360 oil spill simulations are a composite of 120 oil spill simulations that were done for each of 3 oil spill scenarios: full rupture, north shore leak, south shore leak.

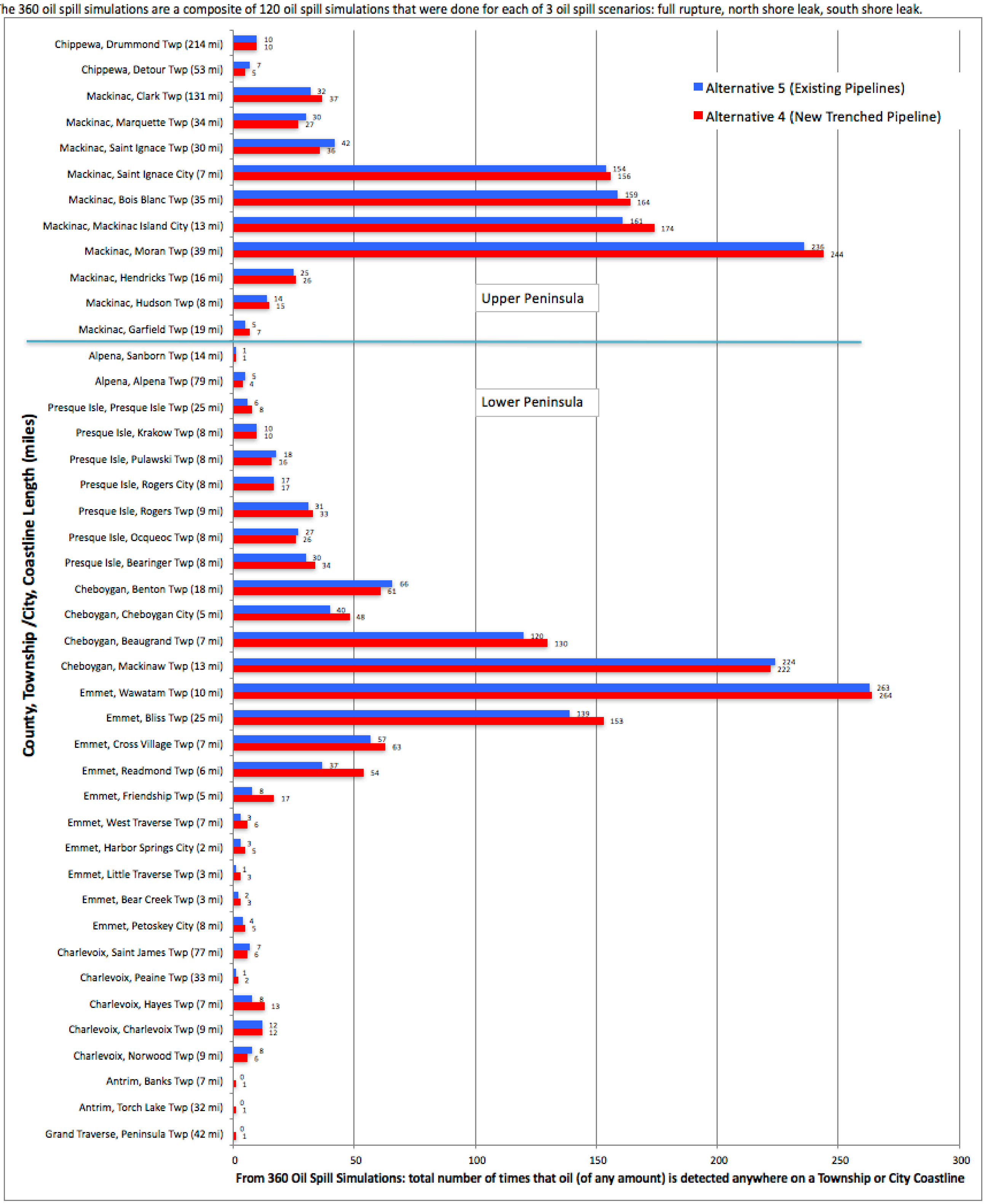

Figure R-1: Oil Spill Distribution Incidence on Michigan Coastal Townships

Appendix R.2 Approach

Appendix R.2.1 Total Spill Costs

The economic analysis of the spill costs involves the direct estimation of cleanup costs and a factored estimate for eventual damages. In simplest terms:

Total Spill Costs = Total Response & Cleanup Costs + Total Damage Costs

The response and cleanup costs are a function of factors such as spill remoteness, spill size, amount of onshore oiling, type of cleanup technique used, time of year, and oil density and chemistry. Cleanup costs are also affected by the nature of onshore areas that are impacted by the spill. The damage estimate reflects potential longer-term social and environmental costs associated with damages to natural resources, restoration of environmental functions, and impacts on both commercial and subsistence resource harvesting.

The spill cost modeling provides linear and non-linear functions for a number of the factors associated with the spill. The model is based on historical experience with spills in the US and with global maritime spills. It is informed by historical spill cost literature in North America (Etkin)[7] and global literature from maritime and coastal spills (Kontovas, 2010; IOPCF).[8,9] It has been tested and calibrated against coastal spill data available from Washington State[10] relating to spills above 1,000 gal, and has benefited from access to international claims in coastal areas associated with spills impacting sensitive shorelines.[11]

[7]Etkin, D.S. 1999. *Estimating Cleanup Costs for Oil Spills*. Paper #168. Proceedings of the 1999 International Oil Spill Conference.
Etkin, D.S. 2000. *Worldwide Analysis of Marine Oil Spill Cleanup Cost Factors*. Arctic and Marine Oilspill Program Technical Seminar (June). Etkin's cleanup costs demonstrate relationships of spill costs to spill size, remoteness, oil type and other factors. For example, her findings show that spill cleanup of heavy oil is expected to be 4.7 times that of a reference light oil in the 10,000 to 100,000 gal spill size range. Her scalar spill size bins show that a reference intermediate grade crude oil spill in the 10,000 to 100,000 gal spill size range would expect to have unit cleanup costs (in $/gal terms) 1.6 times more than a spill in 100,000 to 1,000,000 gal spill size range. The bin sizes noted here represent spill sizes from 10,000 gal (238 bbl) to 1,000,000 gal (23,800 bbl) and are regarded as relevant to the spill sizes considered in this study. The spill model for the Alternatives Analysis study uses similar relationships except transformed to a continuous function to eliminate edge-effects of the bins.

[8]Kontovas, Christos A.; Psaraftis, Harilaos N.; Ventikos, Nikolaos P. *An empirical analysis of IOPCF oil spill cost data*. Marine Pollution Bulletin, Vol. 60, No. 9, 2010, p. 1455-1466. Their analysis is based on global spills from the International Oil Pollution Compensation Funds (IOPCF) spill cost database and addresses the scale relationship (unit spill cost as a function of spill size) and the share of environmental costs in settled claims relating to pollution in water. The spill model for the Alternatives Analysis uses the same information from IOPCF primarily to validate environmental damage ratios as a proportion of total spill costs (although updates to the spill data set from 2010 to 2013 have also been incorporated where they represent finalized claims). IOPCF claims include a statutory 7 year claims period after a spill occurs and recent spills are thus excluded as they have an incomplete claims record or are awaiting damage assessments to inform those claims.

[9]International Oil Pollution Compensation Funds (various). Annual Reports. Annual reports are available for the entire operation of the funds dating from the *1971 Fund Convention* to 2016.

[10]Washington State Department of Ecology. Natural Resource Damage Assessment (NRDA). http://www.ecy.wa.gov/programs/spills/restoration/nrda.html. Washington State tracks all spills of any size and has historically applied a compensation schedule as part of the NRDA evaluations. The nature of Washington's geography involves a complex coastline and small island environment on an international border with Canada, including US tribal lands and Canadian First Nations territories. The region experiences substantial commercial and recreational shipping traffic to the port cities of Vancouver and Seattle. The State of Washington recently completed public reviews of its NRDA schedules which included viewpoints from all stakeholders (including out-of-state).

[11]Specifically, the model benefited from independent reviews and validation of third-party claims submitted to the United Nations Compensation Commission (http://www.uncc.ch) mandated to oversee damages associated with Iraq's unlawful invasion and occupation of Kuwait in 1990-91. The claims encompassed terrestrial damages in Kuwait and shoreline damages in Saudi Arabia, with validation of 1.5 million claims being informed by global experience regarding damages to environment, human health, and infrastructure associated with oil spill pollution and air pollution (from smoke). General claims were finalized in 2005 and mainly subrogated to Governments, but ongoing independent reviews occurred up to 2013 with the UNCC requiring reviews before final payments were made to Governments. Validation permitted access to and use of confidential information from global claims databases provided by insurers and re-insurers.

The model has also been used as a basis for providing expert evidence to pipeline regulators in Canada over the past five years.

The spill model permits calibration or validation to local conditions. This involved:

- Setting the reference period to 2017 through the use of inflationary factors from the US Bureau of Economic Analysis
- Adding an additional inflationary adjustment to base costs for Michigan equivalent to a factor of 1.26, which is consistent with recent assumptions for the Midwest in the 2017 *API Infrastructure Study.*[12]

The model can also be calibrated to reproduce results of stand-alone local spill-events if those events may be relevant to a spill region. The model-based parameters were applied to the Marshall release of July 26, 2010 and derived an expected value of $935 million (-30%/+50%). Recall that the Marshall release involved a spill volume of approximately 20,000 bbl of diluted bitumen (dilbit). The released crude oil affected approximately 38 mi. (~60 km) of shoreline along the Talmadge Creek and Kalamazoo River waterways, including residential areas, businesses, farmland and marshland between Marshall and downstream of Battle Creek, Michigan. In its corporate regulatory filings, Federal Energy Regulatory Commission (FERC) Form 6 (for 2016 filed in April 2017), Enbridge records a spill cost of $1,215 million.[13] The Enbridge spill costs documented in FERC Form 6 include $68.5 million in fines and penalties, of which $62.0 million are civil penalties pursuant to the *Consent Decree*.

Appendix R.2.2 Vulnerability

Appendix R.2.2.1 Concept

The concept of vulnerability is important in assessing consequences of a spill. Environmental vulnerability of species or ecosystems is typically captured through identifying environmentally sensitive areas based on land use or sensitivity mapping. Similarly, human populations that are dependent on local resources may be vulnerable because of direct or indirect connections to their natural environment. The water people drink, the air people breathe, and the soils that grow food may all suffer from impacts associated with a spill.

Experience has shown that, just as environmental vulnerability can be mapped, profiles of human activities and population characteristics can be used as a screening mechanism to determine which areas are most vulnerable. Population size, population income, and human use of the land base at risk are all potential contributors.

The analyses of spill costs first require identification of potential zones in which a spill might occur, and gathering relevant information on environmental or human vulnerability within those zones. The following sections summarize the assumptions in defining these zones, and the human and land use characteristics within these zones. It should be noted that additional detailed information regarding county-level activities in various parts of Michigan impacted by facilities is provided in Appendix Q. Baseline information including mapping for environmental conditions and some socioeconomic receptors is provided in Attachment 7 (see Appendix S).

[12] API. 2017 US Oil and Gas Infrastructure Investment through 2035. Regional Cost Multipliers [Exhibit 7; Exhibit 9]

[13] FERC. FERC Form No. 6: ANNUAL REPORT OF OIL PIPELINE COMPANIES and Supplemental Form 6-Q: Quarterly Financial Report. Enbridge Energy, Limited Partnership: FERC FORM No. 6/6-Q (ED. 02-04). FERC Financial Report, Filed April 2017. [Page 123.10]

Appendix R.2.2.2 High Consequence Areas – Terrestrial

The spill cost analyses are sensitive to the presence or absence of High Consequence Areas (HCAs). These are classified consistent with protocols defined in 49 CFR Part 195, §195.450. In terrestrial zones at risk to spills, HCAs are defined as populated areas or those with high environmental or cultural sensitivity. Alternative 1S and Alternative 3S each pass through a corridor of counties in southern Michigan. The routings and counties within them are described in Appendix Q, providing also baseline county information relating to population, income and land use within these counties. For more detailed consequence weighting, the spill cost analyses define the proportion of a route that passes through various types of populated or sensitive areas.

Table R-3 provides a summary of the HCA distribution of the Southern Pipeline and Southern Rail alternatives; this distribution is for the entire corridors from Superior WI to the international border near Marysville MI. High population areas (HPAs) and other population areas (OPAs) are defined from PHMSA information, which is based on the 2010 census and serve as guidance for routing design in the pipeline industry. Environmentally sensitive areas (ESAs) represent wetlands identified within the National Wetlands Inventory. Other Sensitive Areas (OSAs) represent a 25% contingency of the above to reflect areas not otherwise captured by HPAs, OPAs or ESAs. The OSAs are intended to reflect cultural heritage resources, traditional use areas, or sites of local significance that have no area or linear feature that can be identified using standard geographic information system (GIS) interpretation methods. The contingency also accounts for potentially sensitive drinking water areas in sparsely populated areas.

Table R-3 shows two measurement methods for proportion of the corridor within a specific land type. A *direct* measure represents a linear intersect of the centerline of the corridor with a specific land type or feature. An *indirect* measure is the overlap between a defined corridor area and the area of a specific land type or feature. The defined corridor area, for this analysis, includes a corridor with outer boundaries of 1,500 ft. (457 m) to either side of the centerline. The advantage of using an indirect corridor method for analyses is that a direct intersect will not necessarily recognize nearby sensitive areas that may be affected by a spill; raised rail beds following alongside a river course may have no intersects, but a spill would likely have impacts on the river if one were to occur. Most of the analyses conducted for this report use the indirect proportions to define the area of impact. An exception involves smaller pipeline spills, which typically stay on company property or an already disturbed right-of-way: these still have consequences and require cleanup, but damage estimates are usually lower.

Table R-3: High Consequence Area Characteristics of Southern Alternatives

Indicator	Alternative 1S Southern Pipeline	Alternative 3S Southern Rail
Length (Wisconsin, Illinois, Indiana, Michigan)	~762 mi. (1,226 km) (Michigan ~226 mi. or 364 km)	~800 mi. (1,287 km) (Michigan ~240 mi. or 386 km)
Direct Intersects (Total Proportion)	1.0000	1.0000
HPA/OPA	0.1729	0.4107
ESA	0.1053	0.0819
OSA	0.0696	0.1231
non-HCA	0.6522	0.3843

Indicator	Alternative 1S Southern Pipeline	Alternative 3S Southern Rail
Indirect Intersects (Total Proportion)	1.0000	1.0000
HPA/OPA	0.1809	0.4463
ESA	0.1404	0.1587
OSA	0.0803	0.1512
non-HCA	0.5984	0.2438

Appendix R.2.2.3 High Consequence Areas – Coastal

Spill volumes and fates of 720 individual spill events were modeled for this study. About 94% of the shoreline oiling and 99% of deposition of oil by mass occurred in the core counties of Mackinac, Emmet, and Cheboygan; these three counties are the focus of quantitative work relating to spill costs and damages. The full ZOE includes nine counties that may experience impacts from some spills. The neighboring counties of Chippewa, Charlevoix, and Presque Isle also, at times, experienced spill impacts; however, total shoreline oiling was on average 5% of their cumulative shorelines. In Antrim, Grand Traverse and Alpena, the likelihood of a spill reaching shore is very low. The amount of shoreline oiling is also relatively low. The time that a spill takes to reach their shores is typically a week or longer after the event. Michigan counties not included among these nine did not have any shoreline incidences of spills in the 720 hypothetical spill incidents considered in Alternative 5 and Alternative 4a.

In coastal areas, HCAs can be similarly defined. As with terrestrial areas, the principle is that populated areas or environmentally sensitive areas may be more vulnerable to the impacts of a spill. For the purposes of this analysis, profiles of the coastal area were developed that characterize in simple terms the socioeconomic circumstances of these areas. Experience shows that for screening purposes, a small number of indicators are adequate to inform whether a coastal area is vulnerable. Three sets of indicators have been identified for such purposes.

1. Population

   A simple count of population proximate to the coast is a good screening tool for identifying highly populated areas. This information is provided for coastal townships and cities in Table R-9 for the following counties: Cheboygan, Emmet, Mackinac, Charlevoix, Chippewa, Presque Isle, Alpena, Antrim, and Grand Traverse.

2. Per capita income

   An income variable has no normative importance but can be a measure of economic diversity, of concentration of activity, of adaptability (usually ascribed to high income areas) or of vulnerability to shocks (usually ascribed to low income areas). In Michigan, this information is typically most reliable when aggregated at a county level; these indicators are provided in Table R-9 for the nine counties noted above. (Per capita income data for other counties potentially affected by the alternatives discussed in this report are provided in Appendix Q.)

3. Land use

   Land use has been interpreted using GIS tools applied to 63 coastal townships and cities in the nine counties noted above. The interpretation is done for an area defined as that within 1,500 ft. (457 m) of the shoreline. Land use is potentially a useful indicator of coastal dependence or connection, as well as a means of validating environmentally sensitive areas. For example, land use categories include coastal wetlands, developed areas, and other landscapes that might represent dunes or other ecologically important features on which people depend. Table R-10 provides level summary information for land use within the 1,500-ft. (457-m) wide coastal area for the nine counties of the ZOE. Table R-11a, Table R-11b and Table R-11c provide township level data for land use in three parts respectively, corresponding to:

a. Core Zone counties

b. neighboring counties

c. other counties.

The Straits are designated as an HCA in accordance with the regulations established by 49 CFR Part 195 §195.450. Beyond that, the Straits are a culturally significant resource with associated tribal fishing and Treaty rights, and the oil spill factors reflect that by using higher response costs and damage levels.

Also, the entire coastline is treated as an HCA. Although the indicators above can assist in identifying specific hot spots, no single area is weighted in the spill costs as particularly higher consequence than another area. The treatment of the entire coastline as HCA is also done because of the designation of this area of the Great Lakes as Treaty waters (with special fishing rights) under the 1836 Treaty between the US Government and five federally recognized Treaty tribes in Michigan (see Appendix Q).

Within the Straits, the core spill zone includes Emmet, Cheboygan, and Mackinac counties, in which 99% of spill material deposition would occur. The damage estimate reflects potential longer-term social and environmental costs associated with damages to natural resources, restoration of environmental functions, and impacts on both commercial and subsistence resource harvesting.

Appendix R.3 Model Parameters and Assumptions

Appendix R.3.1 Role of Spill Volume and Oil Type

Spill volume and oil type are key parameters in estimating spill costs. Large spills exhibit scale economies, implying that per-unit cleanup and damage costs ($/bbl) tend to decline with the size of the spill. Spill response has some associated fixed costs, which lead to declining average costs as spills get larger. Damages also exhibit non-linear behavior: once a damage threshold is exceeded, it is no longer possible to do more damage to an organism. Spill fate also contributes to lower average costs: spilled oil often pools or aggregates in certain places, permitting more efficient response efforts (source control contributes significantly to the ability to direct such behavior through, for example, deploying booms on water).

Oil type, especially oil persistence, impacts spill persistence and oil toxicity. The State of Washington determines damages based on a weighting of a number of factors.[14] Heavy oils, for example, can be costlier to clean or may persist longer in the environment. Volatile oil fractions may have more toxic effects in such environments. Modeling conducted for the Straits spills (Attachment 2) consider oil properties and thus key indicators – such as

[14]Washington Administrative Code. Oil Spill Ranking WAC (173-183-340) [http://apps.leg.wa.gov/WAC/default.aspx?cite=173-183-340].

shoreline oiling – will already reflect the behavior of the oil through having considered other fates such as evaporation. Shoreline oiling is a parameter in the cost estimating model.

Appendix R.3.2 Role of Remoteness

This parameter reflects a number of potential factors and is usually applied in the event of remote conditions that hamper spill response and, more critically, for deployment of mitigation measures (such as protective booms) and source control. The only conditions for which no adjustment is made for remoteness are if a spill occurs in sight of company personnel or is small and would remain on company property. This is often the case for small spills at company facilities, at loading stations, or in the event of some third party damages such as backhoe damage. Most other cases involve increasing degrees of remoteness. An index from 1.0 to 1.2 is used to specify remoteness, with 1.0 being the case described above permitting immediate response. All the Straits spills are designated as 1.2 because of limited possibilities for source control.

Appendix R.3.3 Role of Season

Spill season can impact spill consequences. This analysis provides separate results for spill costs with and without the influence of ice for spills at the Straits Crossing. No seasonal adjustments are made for the terrestrial spills because spill inputs are already annual averages with no seasonal component. Because the spill is regarded as a mean consequence spill of worst-case spill volumes, no specific adjustments are made for seasonal impacts. It is acknowledged, however, that a worst-case consequence analysis might identify higher impacts in some seasons at some specific locations (such as spawning sites during spawning season, or seasonally important habitats favored by migratory species).

Appendix R.3.4 Role of Response Technique

Spill response cost modeling involves selection of a technology that is appropriate to a particular spill situation. In order of increasing costs, technology examples are in-situ burning (ISB), mechanical methods, and manual cleanup methods. For HCA cost estimating, it is conventional to use manual cost estimating factors both for cleanup, boom deployment, and other protective efforts. It is acknowledged that mechanical methods will also be appropriate and likely be used, but manual cost estimating factors are assumed as a conservative factor. A screening analysis was conducted to determine whether ISB might be technically suitable for the spill circumstances. Adequate spill thickness is required to initiate and sustain an effective ISB and such conditions only exist for a short period of time before dispersion of the spill from evaporation and surface conditions make ISB an inefficient method. Although it might, technically, be appropriate in some isolated cases – usually it is not. Also, current guidelines for Great Lakes spill response are to avoid the use of ISB, herding agents and chemical dispersants.

Appendix R.3.5 Role of Shoreline Oiling in HCAs

The spill cost model is sensitive to the amount of shoreline oiling. It relies on an index, which is derived from the spill fate modeling presented in the report. A value for the index can be compared to a similar indexed value of shoreline length.[15] The ratio is simply a percentage of shoreline oiled. These ratios become parameters to the estimating model.

Appendix R.3.6 Treatment of Government Costs

Government costs are not specifically estimated in the model. Experience shows these are typically of the order of 5% to 15% of total costs. Within international results reflected in the statistically pooled samples, cost accounting does not usually permit separation of government costs. This is because governments frequently take on claims on behalf of other citizens or businesses before passing a consolidated claim to insurers or funds meant to compensate claims. This practice is encouraged because it also permits potential claimants to receive funds before their claims are heard.

Also, claim settlements are typically only against incremental costs which can be directly related to the spill. Mobilization of salaried personnel permits reimbursement for some but not all costs, as some of the fixed overheads are not regarded as incremental. Experience also shows that the higher cost spills may also see smaller shares of expenses attributable to government.

Appendix R.4 Results

Table R-4 provides a summary of the results for the Alternative 5 spill and for spills associated with the other alternatives.

Appendix R.4.1 Alternative 5 Spill – Contingent Consequences

Spill modeling involved identifying three separate spill scenarios corresponding to different spill volumes at different locations in the existing 20-in. twin pipelines. For Alternative 5, total spill costs ranged from $92 million for a mid-channel rupture during a period where ice influences spill fate to $147 million for a shoreline leak on the south shore.

For the risk analysis, the contingent consequences were weighted within their respective rupture and leak classifications and based on the likelihood that they resulted in non-zero shoreline oiling. All south shore leaks resulted in shoreline oiling, but north shore leaks and mid-channel ruptures did not result in shoreline oiling when there was influence from ice. Specifically, north shore leaks had no shoreline oiling in 18 of 120 spills modeled. Mid-channel rupture had no shoreline oiling in 19 of 120 spills. Consequences were further aggregated for the leak category by weighting north shore and south shore leaks equally.

[15] The index is derived from the kilometer measure of spill length and of shoreline length using the same measurement methodology. The indices are not necessarily comparable to shoreline length measured using other measures: coasts have fractal-like geometries and the method of measurement can generate different lengths depending on how much granularity there is in the measurement. Consider a small rocky outcrop a yard wide at the beach that juts out into the water terminating at a point three yards off the beach. Somebody measuring the beach with a long tape measure would likely step across the rock and count it as one yard of beach. Another person with the same type of measuring tape would get a longer measure if she measured to the base of the outcrop, then measured around the rock, before continuing with her measurements. This longer measurement (by about 5 yards) stems from how such details are measured, and how homogeneous the coastline is. The index used for the analysis in the models is therefore translated to a percentage of shoreline oiling.

An example calculation follows. For leaks on north shore, Table R-4 shows the total cost to be $97.92 million during conditions with influence from ice and $111.67 million during conditions without influence from ice. Ice influences 15% (18/120) of spills and ice does not influence 85% (102/120) of spills. The expected total cost of a north shore spill is therefore $109,607,500 ($97,920,000x18/120 + $111,670,000x102/120). For leaks on the south shore, Table R-4 shows the total cost to be $128.91 million during conditions with influence from ice and $146.71 million during conditions without influence from ice. Ice did not, however, influence any of the spills and all (120/120) of spills reached shore. This is attributable to the proximity of the leak to shore and to conditions that caused oil to migrate to shore within 30 days of release, even if some ice may have been present.[16] The expected total cost of a south shore spill is therefore $146,710,000. As consequences are weighted equally (50%:50%) for north and south shore leaks, the expected total spill costs are 50% of the expected north shore leak costs (0.5x$109,607,500=54,804,000) plus 50% of the expected south shore leak costs (0.5x$146,710,000=$73,355,000); this equates to expected total spill costs of a leak of $128,159,000. For rupture events, there is only a single spill scenario. Table R-4 shows the total cost of a rupture to be $92.10 million during conditions with influence from ice and $105.44 million during conditions without influence from ice. Ice influences 15.83% (19/120) of spills and ice does not influence 84.17% (101/120) of spills. The expected total cost of a mid-channel rupture is therefore $103,328,000 ($92,100,000x19/120 + $105,440,000x101/120). Similar calculations can be completed for the expected contribution of environmental damages costs using the Damage Costs column in Table R-4.

The resultant expected total spill costs for this alternative are:

- rupture: $103.33 million
- leak: $128.16 million.

The expected contribution of environmental damage costs within these is:

- rupture: $62.00 million
- leak: $76.90 million.

Appendix R.4.2 Alternative 4a Spill – Contingent Consequences

Spill modeling involved identifying three separate spill scenarios corresponding to different spill volumes at different locations in a 30-in. trenched pipeline. Total spill costs were $151 million for a mid-channel rupture or north shore leak under conditions influenced by ice: the costs were similar because of similar spill volumes. A south shore leak under normal conditions without influence from ice generated an expected total cost of $237 million.

For the risk analysis, the contingent consequences were weighted within their respective rupture and leak classifications and based on the likelihood that they resulted in non-zero shoreline oiling. All south shore leaks resulted in shoreline oiling, but north shore leaks and mid-channel ruptures did not result in shoreline oiling when there was influence from ice. Specifically, north shore leaks had no shoreline oiling in 18 of 120 spills modeled. Mid-channel ruptures had no shoreline oiling in 17 of 120 spills. Consequences were further aggregated for the leak category by weighting north shore and south shore leaks equally.

[16]Attachment 2 (see Appendix S) describes the mechanisms by which ice may influence the fate of oil.

The resultant expected total spill costs for this alternative are:

- rupture: $169.95 million
- leak: $202.99 million.

The expected contribution of environmental damage costs within these is:

- rupture: $101.97 million
- leak: $121.79 million.

Appendix R.4.3 Alternative 1S Spill – Contingent Consequences

Spill modeling involved modeling of spill costs for three circumstances in total, including a leak, puncture and rupture. The lowest cost of $3.15 million was for a 57 bbl leak occurring in a non-HCA area. The highest cost was for a rupture of 3,784 bbl in an HCA.

The costs in Table R-4 are used directly in the risk analysis in the report. The contingent consequences are weighted within their respective spill volume classifications and based on the likelihood that they impacted an HCA. The smaller leak and puncture spill volumes have a 34.78% probability of impacting an HCA. The rupture has a 40.16% probability of impacting an HCA. The probabilities are based on land use through all states in the pipeline corridor: Wisconsin, Illinois, Indiana and Michigan.

Appendix R.4.4 Alternative 3S Spill – Contingent Consequences

The cost of a median 482 bbl rail spill is expected to be in the range of $14 million for a non-HCA area spill to $22 million for a spill that occurs in an HCA.

The expected total spill costs for this alternative are:

- HCA: $21.97 million
- non-HCA: $14.20 million.

The expected contribution of environmental damage costs within these is:

- HCA: $8.09 million
- non-HCA: $5.22 million.

The spill has a 75.62% probability of impacting an HCA. The probability is based on land use through all states in the rail corridor: Wisconsin, Illinois, Indiana and Michigan.

Table R-4: Oil Spill Total Costs

Scenario	Oil Volume bbl	Total Costs million $	Total Costs (million $) Cleanup Costs	Damage Costs
Alt 5 Mid-Channel	2,629	105.44	42.18	63.26
		92.10	36.84	55.26
Alt 5 North	2,902	111.67	44.67	67.00
		97.92	39.17	58.75
Alt 5 South	4,527	146.71	58.68	88.03
		128.91	51.56	77.35
Alt 4a Mid-Channel	5,859	173.05	69.22	103.83
		151.20	60.48	90.72
Alt 4a North	5,820	171.88	68.75	103.13
		150.58	60.23	90.35
Alt 4a South	9,801	237.29	94.92	142.37
		207.85	83.14	124.71
Alt 1 Rupture	3,784	112.45	44.98	67.47
		72.66	29.06	43.60
Alt 1 Puncture	300	15.34	11.13	4.21
		9.91	7.19	2.72
Alt 1 Leak	57	4.88	4.55	0.33
		3.15	2.94	0.21
Alt 3 S Rail	462	21.97	13.88	8.09
		14.20	8.97	5.22

Appendix R.5 Validation and Contribution Analyses

Appendix R.5.1 Introduction

The validation exercises conducted here are primarily in reference to spills at the Straits Crossing. As described previously, the spills modeled generate contingent economic consequences ranging from $3.1 million for a small pipeline leak in southern Michigan, to $237 million involving a leak in the 30-in. pipeline on the south shore. Recall that the confidence interval is -30%/+50%.

This section includes two types of validation exercises:

- The first is a general comparison of total cost results to values in the literature. Such comparisons conventionally use a common benchmark expressed in terms of $/bbl of oil released. As part of this validation exercise, values relating to environmental damage values and ratios found in the literature are also presented to validate those derived in this analysis. A comparison is also made to Enbridge's estimates of worst-case spill costs for a spill in the Straits area.
- The second validation exercise involves estimates of potential contributions associated with specific costs of local concern within the Straits area. This involves estimating the expected costs from a mean spill event on tourism, fisheries, hunting, water supply

contamination, and property value impacts. These estimates are not added to the total costs, but are conducted for control and validation purposes: if the sum of any subset of these exceeds the upper bound of expected costs derived from the spill cost model, then the model may generate underestimates of the costs.

Appendix R.5.2 Cost Comparisons

Appendix R.5.2.1 Unit Costs

Table R-5 provides the resultant oil spill unit costs for the spills enumerated in Table R-4. Recall that these are all for a typical oil transported on Line 5. Costs are thus associated with a light oil. Patterns detailed earlier regarding spill size are evident:

- The smallest spill at 57 bbl has a unit cost of $86,000/bbl.
- The largest spill at 9,801 bbl, with mean consequences, has a unit cost of $24,200/bbl.

Table R-5: Oil Spill Unit Costs

Scenario(1)	Oil Volume (bbl)	Total Spill Costs million $(2)	Total Spill Costs ($/bbl)
Alt 5 Mid-Channel Rupture	2,629	105.4	40,100
Alt 5 North Shore Leak	2,902	111.7	38,500
Alt 5 South Shore Leak	4,527	146.7	32,400
Alt 5 South Shore Leak (95th)	4,527	~200	44,200
Alt 4a Mid-Channel Rupture	5,859	173.0	29,500
Alt 4a North Shore Leak	5,820	171.9	29,500
Alt 4a South Shore Leak	9,801	237.3	24,200
Alt 4a South Shore Leak (95th)	9,801	~310	31,600
Alt 1 Rupture	3,784	112.4	29,700
Alt 1 Puncture	300	15.3	51,000
Alt 1 Leak	57	4.9	86,000
Alt 3 S Rail	462	22.0	47,600

Notes:
(1)All spill releases are into an HCA and, for Alternatives 5 and 4a, exclude influence of ice. Results are shown at the means, except those indicated as 95th quantile spills for Alternatives 5 and 4a.
(2)Spill costs include cleanup and damage costs and are -30%/+50% confidence interval.

The overall unit costs for the spills described in Table R-5 are generally large compared to the meta-analyses and regression analyses referenced previously in this appendix. This is to be expected because the values in Table R-5 all represent spills into HCAs and some additional conservative assumptions were made for planning purposes. As these are not related to spill volumes, but spill circumstances, the hypothetical spill unit costs are expected to be higher than mean spill unit costs found in the literature. Etkin (2000), for example, estimated US spill costs to be on average $6,765/bbl (adjusting for inflation to 2017). Although this figure reflects cleanup costs and not damage costs, it is customary to use a damage multiplier of up to 1.5 to estimate a maximum value of environmental damages.

This implies that total spill costs based on Etkin would be approximately $17,000/bbl.[17] Psarros (2009) argues that for risk assessment a value of $80,000/t should be used as a total unit cost estimate: this equates to approximately $16,000/bbl escalated to 2017 and using standard conversions.[18] All of the estimates in Table R-5 exceed both of these figures.

Kontovas et al. (2010) argue that a 1.5:1 damage cost to cleanup cost ratio is appropriate for risk and planning studies, although spills within their data set over the period 1979 to 2006 frequently exhibited lower ratios: the data set has a median value of 1.287. Transport Canada's (2007) study addressed a broad range of damages, including those to fisheries, aquaculture, and tourism, and had implied factors of 0.85 for spills under 10,000 bbl and 0.6 for larger spills. The spill cost model used in this appendix constrains larger spills and those into water to generate damage costs of at least 1.5 times the estimated cleanup costs and is thus expected to result in conservative estimates compared to the literature. Only smaller terrestrial spills, which partially impinge company property or already disturbed pipeline or rail corridors, will feature damage:cleanup ratios of less than 1.5.

Appendix R.5.2.2 Selected Spills

It is also sometimes relevant to compare unit damage costs or unit total costs to those of known spills, although care must be taken in interpreting results. Table R-6 lists other actual spills and unit cost comparisons. For simplicity, no escalation is provided in spill costs, and for each spill only the damage cost or total cost has been recorded. This exercise is conducted primarily to demonstrate factors that might become important in comparing different spill cost estimates, as well as to demonstrate that unit cost estimates in the Alternatives Analysis are conservative when compared to some well-known or lesser-known spills. The following can be noted:

- The *Cosco Busan* spill is regarded as one of the highest profile spills into a coastal environment as it occurred inside San Francisco Bay. Total damage costs from that spill equated to $24,000/bbl, of which almost two-thirds were for recreational damages in a heavily populated area. Non-recreational uses associated with environmental damages approached $10,000/bbl; this is in line with estimates in the literature. It should be noted that the oil type in this spill (Intermediate Fuel Oil) would sometimes have properties that would incur higher total costs than the light oils shipped on Line 5.
- The *Bouchard 120* spill in Buzzards Bay of 2,333 bbl is comparable in size to those modeled for the Alternatives Analysis, but the No. 6 Fuel Oil is a residual fuel oil with variable properties that can make cleanup more expensive than a light crude oil. The damage costs from this spill equated to $3,257/bbl in 2003.
- An incident in Lake Huron in 2012 resulted in the sinking of the *Arthur J* dredging barge and concurrent capsizing of its tugboat (the *Madison*) in bad weather. The unit spill cost of $28,000/bbl is largely attributable to the relatively small size of the spill (11 bbl). Another important factor in this case, however, was the risk to human life on relatively small vessels in bad weather. Such conditions can elevate response costs as human life and safety take priority over other damages in spill response procedures.[19]

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[17] Etkin (2000) documents mean US spill costs to be $25,615/t in 1999. An escalation of 1.848 and a 7 bbl/t conversion yields a result of $6,765/bbl. The multiplier of 1.5 implies damage costs of $10,150/bbl. The total spill cost thus equates to $16,915/bbl.

[18] Psarros G, Skjong R, Enderson O, Vanem E. 2009. *A Perspective on the Development of Environmental Risk Assessment Criteria related to Oil Spills*. Annex to International Maritime Organization document MEPC 59/INF.21, submitted by Norway.

[19] The response conditions for this spill, as with all other incidents eliciting a response by the US Coast Guard, are documented in Incident Investigation Reports retained in the publicly accessible Marine Information for Safety and Law Enforcement (MISLE) system (Case Number 604265 for this incident).

- Table R-6 also documents two pipeline spills in the Lakehead System, both in 2012, both carrying heavy oil. The Marshall spill involved a dilbit blend. Unit spill costs of the Marshall spill ($60,000/bbl) are among the highest on record for the size of spill. As described in Appendix R.2.1, the Marshall spill was used as a control for testing the spill model and the major contributor to higher unit spill costs was the crude oil type being carried. The highest cost comparable spills within Table R-5 are the 95th quantile releases from a south shore leak, which have unit cost estimates of $44,200/bbl (Alternative 5) and $31,600/bbl (Alternative 4a). Recall that Etkin (1999, 2000) found cleanup of heavy oil is expected to be 4.7 times higher than light crude.

Table R-6: Unit Cost Comparisons of Other Spills

Event	Spill Size (bbl)	Cost ($ million)	Year of Spill (y.o.s.)	Damage Cost $/bbl (y.o.s.)	Total Cost $/bbl (y.o.s.)
Deepwater Horizon – Gulf of Mexico (Assay SRM 2779)	4,900,000	8,800.0	2010	1,796	-
American Trader – Orange County Coast CA (Assay: Alaska North Slope)	9,919	18.1	1990	1,825	-
Cosco Busan – San Francisco Bay CA (SF Bay) (IFO-380 Bunker)	1,275	30.3 (total)(1) 18.8 (rec) 11.5 (non-rec)	2007	23,765 (total) 14,745 9,020	-
Bouchard 120 – Buzzards Bay MA (No. 6 Fuel Oil)	2,333	7.6	2003	3,257	-
Arthur J (dredge) + *Madison* (tug) – Lake Huron MI (2) (350 gal diesel; 100 gal motor oil)	11	0.3	2012	-	28,000
Enbridge Line 6A – Romeoville IL(2) (Saskatchewan Heavy Oil)	9,000	53.0	2010	-	5,900
Enbridge Line 6B – Marshall MI(2) (Heavy Crude Oil – dilbit)	20,000	1,200	2010	-	60,000

Notes:
(1) Damages separated into recreational use corresponding to 1.08 million user days of losses and non-recreational uses corresponding to bird, fish, eel and their habitats.
(2) These are total spill costs.

Appendix R.5.2.3 Comparison to Enbridge Spill Cost Estimate

The preceding sections involve a comparison of a hypothetical spill cost (derived using a spill cost model) to actual spill costs reflected in the literature or specific spill incidence reports. This section compares two costs of hypothetical spills into the same region. In 2014, Enbridge submitted a stand-alone cost estimate prepared by LP Environment US as a response to the question "How much would it cost to cleanup a worst-case discharge?"[20]

[20] LP Environment US. Questions and Requests for Information to Enbridge regarding the Straits Pipelines. *Contingency Planning and Spill Response: Question 4b*. June 4, 2014. It should be noted that subsequent documentation of this hypothetical spill suggested that Enbridge interpreted a "worst case spill" to cost $400 million; this is documented in: *Michigan Department of Attorney General and Department of Environmental Quality, Michigan Petroleum Pipeline Taskforce Report*, July 2015, p. 46.

The response assumed a discharge of 8,583 bbl, and included an additional contingency of 25%. Total costs of approximately $454 million resulted from a summer/spring release; a fall/winter release scenario generated total costs of $976 million. Selected worst-case consequence assumptions for bulk cleanup appear to have been used, including a four-to-nine-month period for such activities. As the Alternatives Analysis spill costs did not include such additional contingencies, the normalized values of the Enbridge estimate (i.e., without contingency) are $363 million to $780 million. The estimate did not provide a confidence interval, but unlike auditable spill costs from actual spills, any hypothetical spill also has a potential range of estimating uncertainty. If it is assumed that a -30%/+50% confidence interval also applies to the Enbridge estimate, then the spring/summer scenario results in a range of normalized spill costs of $254 million to $545 million. The fall/winter scenario results in a normalized range of $546 million to $1,170 million.

The cost estimate for such a spill is most readily compared to the spill volume in a south shore leak from a 30-in. pipeline in Alt 4a in the Alternatives Analysis. This spill, at a 95th quantile level, involves a spill volume of 9,801 bbl during a season with no influence of ice. The base costs of such a spill are $310 million and fall within a confidence interval of -30%/+50%, placing the expected spill cost in a range of $217 million to $465 million.

These calculations show that the spring/summer scenarios generate overlapping normalized spill cost ranges in the two studies. The LP Environment US study has a statistically significant higher cost for a winter spill. This can be attributed to more conservative worst-case consequence assumptions than those used in the Alternatives Analysis, which relied on determining *credible* consequences rather unbounded consequences.

Appendix R.5.3 Contribution Analyses

Appendix R.5.3.1 Introduction

Contribution analyses provide qualitative and quantitative information about potential costs of specific consequences in the event of a spill. They are not added to overall spill cost calculated within the context of this report.

The intent of this contribution analysis is to provide insights into the potential values at risk, and to the potential impact on these values as a result of an oil spill. The analyses focus in particular on those values of interest to local populations, as daily use benefits are derived from resources that may be vulnerable to a spill. The primary category values considered in this section include tourism and recreational land uses in the region, fisheries in the Mackinac area, drinking water supplies, and property value close to the waterfront. Hunting is also considered for stand-alone valuation purpose, although many of these expenditures will also have been implicitly included in consideration of tourism consequences. Wetland values are also considered as a stand-alone category.

Tourism and fisheries activities are treated somewhat differently than water sources and shoreline property. Water intakes and housing are essentially immovable. Fish, fishers and tourists are mobile: experience elsewhere shows that this mitigates potential costs of a spill. Extensive background on both tourism potential and fisheries is provided in Appendix Q. This appendix expands on those analyses to estimate a potential impact for a worst-case spill.

It is acknowledged that navigational impacts may occur as a consequence of a spill, but these impacts are not treated as a stand-alone category. Spills rarely impact industrial or commercial water borne transportation and navigation for extended periods. Commercial and industrial vessels are capable of avoiding slicks and will navigate to avoid interference with spill response operations; the use of tugboats can facilitate safe operations in confined waters. As commercial vessels also receive priority over recreational traffic in confined waters, impacts on recreational fishing and tourism are more prone to temporary disruption. Impacts on fisheries and tourism are treated within their own categories.

As noted above, individual costs should not be added to the estimates of the spill cost model. They should also not necessarily be added to each other, as it risks double counting. Adding all such costs together ignores the potential relationships among them, and potential off-setting effects common in a complex system. Hunting expenditures, for example, are largely already counted within tourism expenditures. Measures of wetland value that implicitly include a value to duck hunting would also risk double counting if a separate hunting value were added to a wetland value estimate. This contribution analysis, therefore, calculates various values to provide information that may be useful in validating total cost and damage cost estimates of the spill model. The following analyses show that in all credible cases, the spill cost estimates are adequate to cover the individual category values.

Appendix R.5.3.2 Quantifying Probabilities of Land Use Impacts

In considering the spill impacts on land use values, it is important to recall that spills will not impact the entire region's shorelines in any of the scenarios modeled. The 120 spills from the highest cost events (south shore leaks in Alternative 4a and Alternative 5) serve to illustrate this. Table R-7 summarizes the statistics for these spills as used by the spill cost consequence model. The oiling index is a normalized length measure that can also be used to compare spill incidence. For example, the mean leak from the 30-in. pipeline impacts approximately 20% more shoreline than the mean leak from the 20-in. pipeline. Also, for both spill sets, oiling of the northern shore (Mackinac) and the southern shore (Emmet and Cheboygan) are approximately the same (27.3:27.1 for Alternative 4a and 23.8:21.7 for Alternative 5). Individual spills in the spill set will tend to drift in one direction or another: these figures and ratios capture averages over a one year period. The oiling index is converted to shoreline oiling, which represents the average incidence of oiling within a county. For example, the results indicate that, for the south shore leak in Alternative 5, 9% of the shoreline of Cheboygan will be oiled, and the balance (91%) will not be oiled. This information provides insight into how much of the area is potentially oiled: it is consistently 10% or less. This also indicates that, although some areas may be impacted, considerable area is not impacted.

When combining this information with land use information, it provides further insights into the probabilities of certain land use types being impacted. For example, returning to Cheboygan and the 9% of shoreline oiled, the HPA/OPA information shows that approximately 14% of the coastal area is developed for residential or similar habitation, or potential commercial use. In the analyses undertaken for this report, it is also usually assumed that developed open space could be characterized potentially as OPA. Township and county planning documents frequently identify cleared spaces as available for future development. In Cheboygan's case, this brings the *potentially populated* proportion of the coastline to 20.7%. The product of shoreline oiling (9%) and the proportion of potentially populated coastline (20.7%) equates to a value of 1.86%. This value is the correct weight to place on a particular oiling event within a specific land use. If it is known that *potentially populated* land use will suffer a quantifiable loss in value, then one can ascribe a *conditional consequence* to that loss of 1.86%: it is still conditional on the occurrence of the spill.

The interpretation of this is *not* that a spill is of no consequence: it is definitely of consequence to someone who is impacted by the spill. Instead, the interpretation is that if a spill impacts these shores, then not all values or land uses will be impacted equally, and many will not be impacted. Nonetheless, the model still treats all coastal areas as an HCA for cost estimates.

As described previously, the model is not intended for use with a specific spill: it is a probabilistic model that considers expected circumstances. The approach described here provides a means to quantify expectations on likely damages to specific land use types. Property value impacts are considered later in this section and will use this approach to estimate the *expected value of damage* to shoreline property.

Table R-7: Spill Oiling and Coastal Land Use Characteristics – Pipeline South Shore Leak

Spill Location: South Shore Leak (mean of 120 spills)

	Cheboygan	Emmet	Mackinac	Other	Sum
Alt 4a Oiling Index	9.8	17.3	27.3	3.7	58.1
Alt 5 Oiling Index	8.9	12.8	23.8	3.1	48.6
Alt 4a Shoreline Oiling	9.9%	9.4%	3.3%	0.2%	2.4%
Alt 5 Shoreline Oiling	9.0%	7.0%	2.9%	0.2%	2.0%
Total Population (Coastal Townships)	9,773	23,115	9,352	n.e.	42,240
Total Coastal Area (acres) [a]	6,264	12,197	38,800	n.e.	57,261
Developed Area (HPA/OPA) [b]	13.9%	12.5%	8.1%		
Deveoped Area (open space) [c]	6.8%	11.0%	4.5%		

n.e. not estimated
[a] within 1500' of shoreline
[b] Highly/Other Populated Area - Land Use of County within this Classification
[c] No population - Land Use of County within this Classification

Appendix R.5.3.3 Tourism

As described in Appendix Q, tourism is of considerable economic importance to the region around the Straits. It generates direct expenditures of the order of $700 million/y, of which 23% to 29% accrues to labor or proprietor income. Multiplier analyses demonstrate that this contribution further leads to a total of 14,000 jobs (direct and indirect) in the entire Michigan economy. A spill will have consequences for the tourism sector, especially if it partially or entirely overlaps with the summer tourist season. Recall, however, that the consequence analysis assumes average impacts, rather than selecting a worst-case time or location for a spill to happen. The estimates here therefore rely on average and typical conditions.

To estimate spill consequences, this study uses the same basis as compensation mechanisms used for insurance claims. Businesses or individuals normally are compensated for lost net income or profits from an activity; gross receipts are not compensated, because a slowdown or shutdown would also reduce cost of goods purchased as inputs. An estimate is made based on net margin of receipts; for this analysis a 30% level is assumed. This is higher than the wage and proprietorship margins suggested from the expenditure surveys, but it can be higher or lower depending on the business. Some businesses that are not dependent on the resource base will likely lose no income, as they will not necessarily be impacted: casino tourism is an example of such a business.[21] Others that are highly dependent on the resource base (e.g., those involving sports in water) will be more impacted. An average margin level of 30% is regarded as a credible basis for estimating losses.

A second necessary assumption is the proportion of the area at risk. Although the entire region may be vulnerable, a spill will not impact every shoreline. As a first approximation, the study assumes that the losses are proportional to local shoreline oiling, with 100% losses of net income accruing to areas that experience shoreline oiling. This is a conservative estimate because a proportion of tourism receipts is not necessarily dependent upon, or linked to, shoreline quality or the resource base. The mean shoreline oiling is assumed to be 25 mi. (40 km) of a total vulnerable shoreline of approximately 450 mi. (~725 km) in the Core Zone counties.[22] Under these assumptions, tourism impacts from an oil spill are expected to result in costs of $11.7 million for a mean spill and $28 million for a 95th quantile spill (60 mi. or ~100 km).

Appendix R.5.3.4 Fisheries

As described in Appendix Q, fish management areas between the counties of Charlevoix, Emmet, Cheboygan, and Presque Isle, on the Lower Peninsula; and Delta, Schoolcraft, Mackinac, and Chippewa, on the Upper Peninsula account for most of the commercial and recreation fish harvest in the waters of northern Lake Michigan, the Straits, and northern Lake Huron. Preliminary data for 2016 indicate a harvest of 2.4 million lb. (1.1 million kg) of whitefish, trout, walleye, yellow perch, and salmon. The management areas adjacent to the counties of Antrim and Grand Traverse on Lake Michigan, and Alpena County on Lake Huron, show a harvest of another 400,000 lb. (181,437 kg) of the same species. Preliminary data for subsistence fisheries for all these same areas show a harvest of 141,000 lb. (63,957 kg) for all species.[23]

In the event of a spill, it is likely that some part of this fishery will be impacted by closures in impacted areas. Closures rarely extend beyond one season, and are routinely considerably shorter. The closures will be at the discretion of those managing the resource. Claims for closures are already reflected in the cost estimates as fishery impacts are not uncommon after spills. Claims for such extend to lost income, lost subsistence values, replacement of lost gear (also gill nets), and – if travel is required to other locations that are not subject to the closure – then costs associated with travel form part of permitted claims.

Although the actual closures are at the discretion of the resource managers, a high level estimate of spill impacts can be made based on imputing a value to the foregone catch. The calculation provided here is illustrative only: actual impacts will depend on Tribal management in conjunction with other stakeholders.

[21] In addition, it is acknowledged that oil spill response will bring some economic activity to an area, but this is not estimated within the context of this study or the consequence analyses.

[22] The core counties have a shoreline slightly longer than this, but some townships are not included because they are not among those impacted by the Alternative 5 or Alternative 4a spill sets. As noted previously, Newton township (with approximately 17 mi. or 27 km of coastline) experienced no spills on its shore among the 720 simulations.

[23] 2017 Annual Report on Implementation of the 2000 *Consent Decree* for 1836 Treaty-Ceded Waters of the Great Lakes. Michigan Department of Natural Resources Fisheries Division and Law Enforcement Division. See Appendix Q.

The total catch is estimated (see Appendix Q) to be $17 million/y, an amount that includes commercial fishing, recreational fishing, and subsistence harvesting by tribal members. Unlike retail industries, fisheries can be conservatively valued at an amount close to their gross catch if the price used for valuation represents a local value that captures a local supply chain. The value derived in Appendix Q is based on a high-level estimate of captured value and is appropriate for impact valuation purposes. The overall impact, however, will not be on the total fishery. A single year closure for 12 months represents a conservative estimate, and most fishers would normally be able to fish outside of the closed area.[24] As a proxy for impacts, this study again relies on mean shoreline oiling as an indicator of the proportion potentially lost. As above, the mean shoreline oiling is assumed to be 25 mi, of a total vulnerable shoreline of approximately 450 mi. (~725 km) in the Core Zone counties. Under these assumptions, fishery impacts from an oil spill are expected to result in costs of approximately $1.0 million for a mean spill and $2.3 million for a 95th quantile spill (60 mi. or ~100 km).

Appendix R.5.3.5 Game and Hunting

A spill at the Straits Crossing will potentially impact hunting activities for waterfowl and game. It is assumed that terrestrial animals and waterfowl would be impacted by shoreline contamination, and that inland hunting could suffer because impacts on shoreline habitats would in turn have some impact on wildlife populations. For analytical purposes, it is assumed that losses are proportional to shoreline oiling and that impacts on activities will be equivalent to one year of lost hunting value.

The locations and values of waterfowl and game hunting are treated in Appendix Q. The analyses generated an estimated waterfowl resource hunting value equivalent to about $4,300/mi. of lakeshore in 2017. Also, the analyses found that evenly distributing total Michigan furbearer harvest value along the lakeshore results in a furbearer hunting/trapping resource value of $2,100/mi. of lakeshore in 2017. These results suggest that the contribution of these activities in the region of the Straits is estimated to be $6,400/mi. of lakeshore annually. A one year loss of this value along a 25 mi. shoreline would equate to $160,000 for a mean spill. For a 95th quantile spill (60 mi. or ~100 km) the value equates to approximately $400,000.

[24] Closures and fishery losses depend on management responses, which are frequently adaptive and may depend on ongoing monitoring and associated research both within an impacted zone and in control sites not impacted by the spill. The resilience and adaptive capacity of ecosystems recovering from a spill are at times under-estimated. An example is the MV *Sea Empress* single-hull oil tanker spill in February 1996 close to the Welsh coast; the vessel experienced multiple groundings and hull breaches. The 500,000 bbl spill of North Sea light low-sulfur crude oil generated a cash call among international insurers fearing substantial damages. Actual impacts fell far short of those feared, even though oil came ashore along some 200 km (~120 mi.) in a prime tourist area, much of it in a National Park. Immediately after the spill occurred, the UK Government established the *Sea Empress* Environmental Evaluation Committee (SEEEC) as an independent committee to monitor damage and conduct research. The SEEEC report concluded: “It appears that although a very large amount of oil was spilled in a particularly sensitive area, the impact was far less severe than many people had expected. This was due to a combination of factors -- in particular, the time of the year, the type of oil, weather conditions at the time of the spill, the cleanup response and the natural resilience of many marine species. … Fish and mammals were able to avoid the worst of the oil, and any oil they may have absorbed probably broke down fairly rapidly through their efficient enzyme systems.”

The management response was a temporary precautionary fishery ban, with the ban on major species being lifted over a period of 3 to 6 months after the spill for all fish and whelk, and for some lobster and crab areas. Restrictions were progressively removed: no restrictions remained 19 months after the spill. Sources: (i) *Sea Empress* Environmental Evaluation Committee. 1998. The Environmental Impact of the *Sea Empress* Oil Spill: SEEEC Report Summary. 17 February. Archived: December 2013: http://webarchive.nationalarchives.gov.uk/20131205123821/http://www.archive.official-documents.co.uk/document/seeec/impact/summary.htm; (ii) International Oil Pollution Compensation Funds (1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003), Annual Report.

In interpreting these results, the reader is reminded that some proportion of these values is already likely to be included in tourism receipts and they are thus not necessarily additive to the tourism consequences.

Appendix R.5.3.6 Water Supply

A spill at the Straits Crossing will impact water quality and authorities would take precautionary measures – in the interest of public health and safety – to limit the use of contaminated water until relevant water standards are met. The longest duration impacts are those that affect public drinking supplies, or recreational boaters or other nearshore residents who use lake water. At least two points are marked on marine charts as freshwater intakes near the Straits Crossing. Standard practice is to issue contaminated water warnings to the public, in addition to potential access restrictions and closure of water supply sources. Closures may last from a few days to a few months. For analytical purposes, a closure event of 100 days (~3 months) is considered with restricted or closed access that affects drinking water of 10,000 people; this is approximately equivalent to the entire population in coastal townships in Cheboygan County for a period of one season.

The Federal Emergency Management Agency (FEMA) has protocols for addressing water charges, and these are costed on the basis of bulk or bottle water provision to impacted populations. The international standard for safe daily water requirements is 15 L (4 gal) a day[25]. FEMA and the United States Environmental Protection Agency (USEPA) prescribe 1 gallon a day as a standard (citing USACE), but note that 5 gallons a day should be a planning target; a planning cost of $1.85/gal is used.[26] Including some contingencies, a $10/person-day cost is a realistic planning target that would meet international standards and FEMA targets. The relevant requirement is 1 million person-days of water; hence, an expected cost is $10 million for a mean spill. The likely cost provisions for the larger aquatic spills are adequate (within the -30%/+50% confidence interval) to include this within the damages or response costs; claims experience shows that some of these are reimbursed as immediate response through emergency water provision.

A factored estimate for a 95th quantile spill impacting up to 60 mi. (~100 km) of shoreline can be derived based on shoreline oiling, but this is likely to represent a conservative estimate because a large concentration of population near the Straits will already be impacted – even by a mean spill. Such a spill would have a proportionally larger impact of up to $24 million.

Appendix R.5.3.7 Property Values

This section provides a discussion of the impact of a spill on property prices. Because spills are rare events, there are no statistically significant analyses that permit a thorough analysis of property price impacts. The events canvassed typically show local effects after a single spill, and data do not lend themselves to being pooled. Although the literature on spill impacts is sparse, broader literature is available on the impacts of water quality on waterfront and near-waterfront housing and property. These hedonic valuation studies have typically been conducted to determine the impact of regulations that set minimum water quality standards, such as the work by Ara on water quality impacts on housing prices and

[25]OXFAM. 2010. Water and Sanitation. Maintaining Standards. http://www.oxfam.org.uk/what-we-do/issues-we-work-on/water "*In emergencies, many more lives are put at risk by inadequate water supplies and poor sanitation. It's estimated that each person needs 15 litres of water per day for drinking, cooking, and washing in an emergency.*" Accessed January 2017.

[26]USEPA. 2011. Planning for an Emergency Drinking Water Supply. EPA 600/R-11/054.

the household willingness to pay for houses around Lake Erie[27]; unlike spill information, such studies also benefit from a large number of observations permitting a statistically significant analysis of land values. A full survey of the hedonic studies literature relating to property prices is provided in Walsh and colleagues[28] (2017) of Landcare Research (NZ) and the USEPA; their empirical study accompanying the survey represents an analysis of over 200,000 households in the Chesapeake Bay (MD) with a view to determining long- and near-term impacts of water quality changes on housing and property prices. Their research also considers proximity to shore (as do many other studies) as a potential explanatory variable, and considers the impacts of short-term (one year) and longer-term (three year) changes in water quality. This section thus outlines some of the illustrative findings from specific spills, as well as hedonic valuation studies which involve statistically significant assessments of larger property value data sets to determine how various characteristics (such as water quality) contribute to property prices.

The econometric studies (as in the Chesapeake Bay Study) typically distinguish waterfront from near-waterfront; the nearshore area for Chesapeake was considered to be up to 1,650 ft. (500 m) from the shoreline. This corresponds to within 10% of the 1,500 ft. (457 m) coastal land-use areas assessed in the Dynamic Risk Pipeline Alternatives Analysis; also, like some of the counties within the ZOE Alternatives Analysis, the Chesapeake Bay area is also characterized by high levels of seasonal recreational use. The findings were that within the properties considered, 7 of the 14 counties demonstrated statistically significant responses to water clarity and water quality. Further away from shore, impacts were less discernible and at times counterintuitive; the authors note that this was also a feature of other studies in their meta-analysis. Where statistically significant values were noticed, price elasticities showed approximately a 1% to 1.5% increase in price for a 10% improvement in water quality over a one year period. The nature of the function implied that a 0.5% to 1% increase could be attributable to a 10% decrease in water clarity.[29] These values suggest that significant levels of light attenuation, of the order of 50%, would generate impacts of the order of 2.5% to 5% on property prices.

By comparison, Ara's assessments consider the Willingness to Pay (WTP) for clarity improvements. In Lake Erie, over a statistically significant sample, this corresponded to a value of $230/household for every 10 in. (25 cm) of clarity improvement in the nearshore areas, but notes that "the welfare changes are larger for the degradation of water quality compared to the improvements of water quality in the same amount" (p. iv). This characteristic is not uncommon in how individuals respond to payment questions: people will usually demand a higher compensation to tolerate poorer water quality than if they were asked to contribute to an improvement in water quality.

In short, one can take away from the statistically significant literature that negative impacts in water quality may create larger impacts on values than if water quality were to improve by a similar amount. Second, literature does suggest that some, but not all properties will suffer value declines in the nearshore area if water quality declines. Third, the impacts on property values of any change in water quality tend to abate or disappear relatively quickly once properties are further from the water. Although the measures used in these studies focused on water clarity, the Chesapeake Bay Study noted that this parameter was regarded as a good proxy for most other pollution parameters investigated in the literature; they note that

[27]Ara, Shihomi. 2007. "The Influence of Water Quality on the Demand for Residential Development Around Lake Erie", Ohio State University.

[28]Walsh, Patrick; Griffiths, Charles; Guignet, Dennis; Klemick, Heather. 2017. "Modeling the Property Price Impact of Water Quality in 14 Chesapeake Bay Counties", *Ecological Economics,* vol. 135, pp. 103-113.

[29]Queen Anne's County home price mean of $392,945 and impact of "The price premium for a 10% improvement in light attenuation in the 0–500 m buffer is smaller in magnitude, with implicit prices up to $3,233 in Queen Anne's County, but generally smaller and less significant." (page 110) [i.e., 0.8%]

"The early literature that examined different measures suggested that the indicators most visible to people, such as clarity, oil content and turbidity, were most likely to explain variation in property values" (p. 104) impacts.[30]

Specific recent reviews of single oil spill price impacts also support the finding that impacts of up to 10% of property prices may be possible.[31] The highest sustained impact on property prices canvassed in these reviews dates back to a series of recurring spills in a region of Ohio along the Inland pipeline between 1948 and 1962. The terrestrial pipeline leaks depressed housing prices of the order of 25%. The review also notes real estate predictions of depressed property prices of the order of 5% to 15% in the coastal property market after the 2009 Deep Horizon sustained oil release in the Gulf of Mexico. Neither of these events are regarded as analogous events for a spill in the Straits, which is not of the same magnitude or duration as the events in Ohio or the Gulf of Mexico. The review also identified other single spills in Maryland (2000) and Texas (1994), which resulted in property price impacts of 11% and 10.2%, respectively.

To illustrate the potential spill impact on property prices in the Core Zone, an estimate of coastal township property values in the ZOE was made. The estimate is based on median housing values in the last quarter of 2016, and also considers household size, population, and adjustments for non-residents and vacant units.[32] The residential property in coastal townships is estimated to be of the order of $5.0 billon, approximately half of which is in Emmet and the remainder is approximately equally divided between Cheboygan and Mackinac. As described previously, however, not all areas will be impacted by a spill. Table R-7 demonstrated that for all south shore leaks less than 10% of any given county shoreline in the Core Zone is expected to be impacted. It is estimated that the mean shoreline oiling for the counties is approximately 6.3% in Alternative 5 and 7.9% in Alternative 4. Also, because not all of the coastline is developed (approximately 21.5% is populated or developed open space), a further adjustment is made to these factors. In Alternative 5, the expected value of property that will be impacted by a spill is 1.35% of the total ZOE coastal property. This is approximately $68 million in value. A similar calculation for Alternative 4 is that the expected value of property that will be impacted by a spill is 1.7% of the total ZOE coastal property; this equates to approximately $85 million.

Impacts on property prices are expected to occur to those impacted, valued in the above example between $68 million and $85 million for the given spill scenarios. Recall that some developed open space is also included within these estimates, and that vacant housing is also included. A 10% property price impact would be expected to result in up to $8.5 million in damages to these types of properties. A 95th quantile spill impacting up to 60 mi. (~100 km) of shoreline would have a proportionally larger impact of up to $20 million.

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[30]Brashares, Edith., 1985. *Estimating the Instream Value of Lake Water Quality in Southeast Michigan* (University of Michigan. Ph.D)

Feenberg, D., Mills, E., 1980. *Measuring the Benefits of Water Pollution Abatement*. Academic Press, New York.

[31]Conversations for Responsible Economic Development (CRED). 2013. *How do Pipeline Spills Impact Property Values*? URL: http://credbc.ca/wp-content/uploads/2013/12/Pipeline-spills-property-values.pdf [accessed November 2016].

[32]Median housing prices for the indicated quarter were derived from the National Association of Realtors Median Home Values estimates for all nine counties in the ZOE. (See: https://www.nar.realtor/topics/county-median-home-prices-and-monthly-mortgage-payment [Accessed interactive map January-May 2017]).

Populations for coastal townships are shown in Table R-9 of this appendix.

A ratio of total housing units to occupied housing units is based on: US Census Data. American Fact Finder. Selected Housing Characteristics DP04: 2015 American Community Survey. 5-year estimates.

Persons per household are based on: United States Census Bureau. QuickFacts. https://www.census.gov/quickfacts/table/PST045216/00 [Accessed April-June 2017].

Appendix R.5.3.8 Wetland Values

Wetlands provide a wide range of ecological services and functions having direct and indirect connections to economic activities. This section provides an estimate of potential wetland value impacts for a mean spill and a 95th quantile spill within the Core Zone counties. The Core Zone counties represent a shoreline length of approximately 470 mi. (~755 km) and contain about 50,000 acres of coastal wetlands.[33] A mean spill of 25 mi. (40 km) would be expected to oil approximately 2,700 acres; a 95th quantile spill would be expected to oil approximately 6,500 acres.

Land use interpretation of the coastline (Table R-10) shows that 4.9% of the coast is emergent herbaceous wetlands, 29.1% is woody wetlands, and 0.7% is open water. The definition of open waters includes areas with up to 25% herbaceous cover and is treated within this analysis as a wetland for analytical and valuation purposes. Through this interpretation, a randomly selected coastline is expected to include approximately 35% wetland. This distribution is significant and more than twice the proportion of coastal area represented by developed land of any classification.

As with other components of the ecosystem described previously in this appendix, damage valuations can reasonably expect that the systems will exhibit some resilience and adaptive capacity. Conventions of environmental valuation have previously found that ignoring this resilience will tend to over-estimate ecosystem values for marginal (incremental) impacts.[34] To reflect this and to generate a credible valuation, impacts are simulated for a single year observing that the use of average values, and mean oiling, is regarded as appropriate. It is acknowledged that worst-case consequences could be greater than this, for which a 95th quantile spill represents a credible sensitivity case.

Valuation of these wetland areas relies on documented values used by FEMA in assessing wetlands and other ecosystems. The FEMA values are regarded as appropriate for planning purposes such as this, and are based on averages of ecosystem values used for water, flood plain, and storm water management in the US. These values are not a substitute for the types of spill-specific valuations that might be required for an ex-post analysis required by a Trustee subsequent to a NRDA. Selection of an appropriate value must ensure that double counting of other values does not occur. For example, wetlands are acknowledged to potentially provide food provisioning services, recreational services, and erosion control services. Food provisioning services are use values normally associated with fishing and hunting: these are already included as stand-alone categories and are hence excluded here. Recreational services are already treated in other categories including tourism, recreational fishing, and hunting; recreational services are therefore excluded from the wetland valuation estimate. Similarly, recent research suggests that oil spill impacts on herbaceous wetlands

[33]The coastal length is taken from coastlines in all townships within a county. Recall that for the other analyses, a distance of 450 mi. (~725 km) was used as a measure of potential oiling within the Core Zone townships. The lower value reflects that some townships were not oiled in any of the 720 spills: Newton township is an example. The area estimate is provided by DEQ (Submission to Public Comments, August 4, 2017; p. 4): “There are approximately 50,512 acres of coastal wetland in the Straits area (Cheboygan, Emmet, and Mackinac Counties)”.

[34]For example, Ruitenbeek and Cartier (2001) describe economic valuations in marine systems, in which substitution effects permit more mobile species (especially migratory species) to substitute habitats on a temporary basis, although local resident population impacts may suffer greater near-term impacts. An example in the wetland context would be the ability of some species to select nearby wetlands as habitat. [Ruitenbeek J., Cartier C. (2001) Prospecting for Marine Biodiversity. In: Turner R.K., Bateman I.J., Adger W.N. (eds) Economics of Coastal and Water Resources: Valuing Environmental Functions. Studies in Ecological Economics, vol 3. Springer, Dordrecht.].

can undermine their erosion control function and impact property values.[35] Because property value impacts are treated as a separate category within this contribution analysis, they are excluded from the wetland valuation. Also, some values of wetlands and other riparian systems are identified by FEMA as being important if conversion is permanent (such as building on a wetland): *flood hazard reduction* is one such category. Flood hazard reduction is less relevant for transient impacts and would not normally be considered as it represents the impact of one rare event (an oil spill) on the likelihood of another rare event (abnormal flooding). Also, the impact measure of any such value is usually expressed as impacts on private property, and this category is treated separately within the contribution analysis.

In the context of environmental service provision – excluding erosion, food provision, recreational, and flood hazard reduction values – other values total $6,252/acre (2013 $).[36] This includes:

- aesthetic value ($582/acre)
- air quality ($215/acre)
- biological control ($164/acre)
- climate regulation ($204/acre)
- habitat ($835/acre)
- water filtration ($4,252/acre).

For analytical purposes, an annual value of $7,000/acre is selected as a total current value of these categories. For a mean spill of 25 mi. (40 km), this equates to a wetland value of approximately $18.9 million. A 95th quantile spill of 60 mi. (~100 km) generates a wetland value of $45.5 million.

Appendix R.5.3.9 Passive Use Values

Passive use values are explicitly excluded in cost estimates in the model. These represent a category of values associated with ecosystem goods and services (EGS) that are experienced by some parts of the population even though they do not directly use the EGS; an example of a passive use value is the knowledge that rainforests exist in a pristine state. Loss of such values is not explicitly separated and compensated in any jurisdiction.[37] The compensation issue remains problematic because payments are normally awarded on the basis of current or future use, rather than existence or non-use values.

Also, methodological issues do not permit credible measurement and attribution of passive use values. The issues include practical considerations such as the inability in survey design

[35] Silliman, B.R. et al. (2016) Thresholds in marsh resilience to the *Deepwater Horizon* oil spill. *Sci. Rep*. 6, 32520; doi: 10.1038/srep32520. The authors observe that "analyses revealed a threshold for oil impacts on marsh edge erosion, with higher erosion rates occurring for ~1–2 years after the spill at sites with the highest amounts of plant stem oiling (90–100%)." The authors further observe that "The resistance threshold of marshes to oil-induced, elevated erosion rates was high, non-linear and occurred at 90–100% stem oiling. This high level of resistance was likely driven by the demonstrated tolerance of belowground plant material to light and moderate levels of oiling. Empirical data such as these that identify levels of stress at which an ecosystem's threshold to disturbance occurs are uncommon, but are critical to understand [how] to better protect and restore valuable coastal systems…."

[36] US Department of Homeland Security. 2013. FEMA Mitigation Policy – FP-108-024-01. *Consideration of Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance (HMA) Programs*. Table 1.

[37] The State of Washington, in its spill compensation schedule, lists 'passive use' values as among the damages that are encompassed within the statutory compensation levels, currently set at a maximum of $300/gal spilled ($12,600/bbl). It does not, however, provide a separate estimate of the component or assignment of value to that component; its inclusion represents a common practice in settlements to include a wide variety of potential values that some parties regard as relevant.

to separate effectively use from non-use (including passive use) values. Other issues arise in applying values via benefit transfer methods from sites that are not analogous to a study site. Finally, passive use surveys do not acknowledge or test for the possibility that respondents may also hold (non-use) option values for potential development of an area.

Appendix R.5.3.10 Summary

Table R-8 provides a summary of the contribution to total spill costs for a 25 mi. (40 km) spill and a 95th quantile spill with 60 mi. (~100 km) of shoreline oiling.

These values can be juxtaposed against the spill costs of a mean spill, which range from $147 million to $237 million for Alternative 5 and Alternative 4a respectively, as estimated by the spill cost model for a south shore spill that represents the most costly *credible* worst-case spill set. Recall that these estimates reflect a confidence interval of -30%/+50%. Although the values in Table R-8 are not additive because of various linkages described in this appendix, the contribution analysis at the means demonstrates that the category costs are consistent with the total cost estimates of the spill cost model. Furthermore, a 95th quantile spill previously generated a range from $200 million to $310 million for Alternative 5 and Alternative 4a respectively. Inspection of the contribution analyses at the 95th quantile again demonstrates consistency of the category costs with this range.

Table R-8: Summary of Contribution Analyses

Cost Category	Mean Spill ($ million)	95th Quantile Spill ($ million)
Tourism	11.7	28.0
Fisheries	1.0	2.3
Game and Hunting	0.16	0.40
Water Supply	10	24
Property Value	8.5	20
Wetland Values	18.9	45.5
Notes: Values are not additive.		

Table R-9: Zone of Exposure: County Population and Per Capita Income (2015)

Core Counties, Townships & Cities	Per Capita Income	Coastal Population	Neighboring Counties, Townships & Cities	Per Capita Income	Coastal Population	Other Counties, Townships & Cities	Per Capita Income	Coastal Population
Cheboygan	**$34,608**	**9773**	**Charlevoix**	**$46,000**	**7536**	**Alpena**	**$36,467**	**21095**
Beaugrand Township		1135	Charlevoix City		2540	Alpena City		10175
Benton Township		3120	Charlevoix Township		1658	Alpena Township		8869
Cheboygan City		4733	Hayes Township		1939	Sanborn Township		2051
Hebron Township		261	Norwood Township		732	**Antrim**	**$39,731**	**7516**
Mackinaw Township		524	Peaine Township		296	Banks Township		1576
Emmet	**$48,882**	**23115**	St James Township		371	Elk Rapids Township		2592
Bear Creek Township		6296	**Chippewa**	**$31,358**	**27125**	Milton Township		2171
Bliss Township		630	Bay Mills Township		1465	Torch Lake Township		1177
Cross Village Township		286	Bruce Township		2106	**Grand Traverse**	**$43,876**	**53762**
Friendship Township		906	Detour Township		799	Acme Township		4676
Harbor Springs City		1201	Drummond Township		1050	East Bay Township		11373
Little Traverse Township		2423	Pickford Township		1579	Garfield Township		16890
Petoskey City		5719	Raber Township		640	Peninsula Township		5797
Readmond Township		592	Sault Ste Marie City		13827	Traverse City		15026
Resort Township		2749	Soo Township		3121			
Wawatam Township		670	Sugar Island Township		645			
West Traverse Township		1643	Superior Township		1322			
Mackinac	**$38,607**	**9352**	Whitefish Township		571			
Bois Blanc Township		93	**Presque Isle**	**$34,262**	**7243**			
Clark Township		2014	Bearinger Township		355			
Garfield Township		1129	Krakow Township		675			
Hendricks Township		152	Ocqueoc Township		630			
Hudson Township		184	Presque Isle Township		1594			
Mackinac Island City		481	Pulawski Township		330			
Marquette Township		603	Rogers City		2712			
Moran Township		972	Rogers Township		947			
Newton Township		423						
St Ignace City		2387						
St Ignace Township		914						

Source: US BEA, US Census Bureau

Table R-10: Zone of Exposure Land Use/Land Cover: County Summaries

ZOE Core Counties in Area of Interest	Total Coastal Area (acres)	Land Use/Land Cover within 1500 ft of the Shoreline (% of total coastal area)														
		Barren Land (Rock/Sand /Clay)	Cultivated Crops	Deciduous Forest	Developed High Intensity	Developed Low Intensity	Developed Medium Intensity	Developed Open Space	Emergent Herbaceous Wetlands	Evergreen Forest	Grassland/ Herbaceous	Mixed Forest	Open Water	Pasture/ Clay	Shrub/ Scrub	Woody Wetlands
Cheboygan	6264	5.7%	0.2%	12.3%	1.2%	9.7%	3.0%	6.8%	5.6%	10.6%	3.4%	7.3%	1.0%	0.1%	0.9%	32.2%
Emmet	12197	14.0%	1.4%	22.4%	0.9%	7.7%	3.9%	11.0%	1.2%	4.7%	1.4%	4.4%	1.1%	0.1%	0.8%	25.0%
Mackinac	38800	4.2%	0.0%	10.5%	0.3%	5.7%	2.1%	4.5%	5.9%	28.0%	2.5%	5.3%	0.7%	0.1%	0.4%	29.9%
Core Counties Grouped	57261	6.5%	0.3%	13.3%	0.5%	6.6%	2.6%	6.1%	4.9%	21.1%	2.4%	5.3%	0.8%	0.1%	0.6%	29.1%

ZOE Neighboring & Other Counties in Area of Interest	Total Coastal Area (acres)	Land Use/Land Cover within 1500 ft of the Shoreline (% of total coastal area)														
		Barren Land (Rock/Sand /Clay)	Cultivated Crops	Deciduous Forest	Developed High Intensity	Developed Low Intensity	Developed Medium Intensity	Developed Open Space	Emergent Herbaceous Wetlands	Evergreen Forest	Grassland/ Herbaceous	Mixed Forest	Open Water	Pasture/ Clay	Shrub/ Scrub	Woody Wetlands
Alpena	9862	9.6%	0.1%	3.9%	1.9%	6.6%	3.6%	4.2%	3.8%	18.9%	3.7%	2.2%	1.3%	0.1%	4.2%	35.8%
Antrim	4728	11.5%	0.3%	26.7%	0.3%	5.5%	1.4%	9.2%	0.8%	6.2%	0.7%	9.0%	1.9%	0.5%	0.5%	25.5%
Charlevoix	17415	9.9%	0.3%	38.5%	0.1%	3.8%	0.9%	4.7%	2.5%	5.2%	3.7%	6.8%	1.6%	0.1%	0.7%	21.3%
Chippewa	64639	4.3%	0.3%	12.0%	0.1%	3.5%	0.9%	4.6%	8.1%	26.5%	2.0%	7.0%	2.4%	0.6%	0.6%	27.2%
Grand Traverse	10406	6.6%	15.8%	26.0%	2.1%	12.3%	4.6%	10.3%	0.2%	4.2%	5.3%	5.5%	0.8%	2.6%	1.2%	2.6%
Presque Isle	13106	14.2%	0.1%	6.6%	0.4%	8.1%	1.9%	5.1%	1.8%	23.7%	6.0%	7.4%	3.0%	0.1%	1.8%	19.9%
Neighboring & Other Counties Grouped	120156	7.1%	1.6%	16.4%	0.5%	5.1%	1.6%	5.3%	5.3%	19.7%	3.0%	6.6%	2.1%	0.6%	1.1%	24.0%
All 9 Counties Grouped	177417	6.9%	1.2%	15.4%	0.5%	5.6%	1.9%	5.6%	5.1%	20.2%	2.8%	6.2%	1.7%	0.4%	0.9%	25.7%

Table R-11a: Zone of Exposure Land Use/Land Cover: Core Counties

Counties in Area of Interest	Land Use/Land Cover within 1500 ft of the Shoreline (acres)															
	Total Coastal Area	Barren Land (Rock/Sand /Clay)	Cultivated Crops	Deciduous Forest	Developed High Intensity	Developed Low Intensity	Developed Medium Intensity	Developed Open Space	Emergent Herbaceous Wetlands	Evergreen Forest	Grassland/ Herbaceous	Mixed Forest	Open Water	Pasture/ Clay	Shrub/ Scrub	Woody Wetlands
Cheboygan	**6264**	**355**	**10**	**773**	**74**	**608**	**188**	**427**	**351**	**662**	**214**	**457**	**63**	**6**	**55**	**2020**
Beaugrand Township	1274	47		77		153	9	60	4	235	28	176	7	4	27	446
Benton Township	2668	161	0	496	1	163	4	149	183	269	49	170	17		15	992
City of Cheboygan	784	60	10	72	4	72	27	152	152	4	32	7	35		1	157
Hebron Township	20									7		4				9
Mackinaw Township	1518	87		127	69	221	149	65	13	147	105	100	5	2	12	415
Emmet	**12197**	**1711**	**172**	**2726**	**105**	**937**	**475**	**1340**	**149**	**574**	**172**	**541**	**129**	**18**	**99**	**3049**
Bear Creek Township	556	67		77	14	107	38	109		63	21	58	1		1	1
Bliss Township	3007	731		187		67	2	67	98	134	11	62	6		47	1596
City of Harbor Springs	413	39		16	18	86	49	71	1	21		29	12			70
City of Petoskey	1393	135	5	78	62	313	287	358	1	19	10	31	73	4	2	16
Cross Village Township	1265	205	58	441		31	10	101	7	128	41	159	1		22	61
Friendship Township	950	91	10	651		3		75		60	5	42	5		6	2
Little Traverse Township	609	102		64		71	7	88	5	26	3	33	6			205
Readmond Township	1040	60		692		2	1	80	6	62	8	78	0	0	11	40
Resort Township	212	6	8	39	4	51	33	47		9	2	4		1	5	4
Wawatam Township	1725	125	19	131	7	182	48	146	28	3	22	10	12	0	1	989
West Traverse Township	1028	150	72	352		24	1	197	3	48	49	36	14	12	4	66
Mackinac	**38800**	**1643**		**4092**	**117**	**2215**	**801**	**1738**	**2283**	**10856**	**963**	**2056**	**264**	**24**	**166**	**11584**
Bois Blanc Township	5633	246		1081		157	5	218	236	2163	113	604	54		23	732
City of Mackinac Island	1645	88		454	6	101	55	355	3	325	8	136	4		11	99
City of St Ignace	910	22		14	60	266	241	128	6	116	13	21	4		3	16
Clark Township	9661	453		279	36	432	115	373	780	3783	292	267	85	10	54	2703
Garfield Township	3124	129		66	3	199	54	168	139	938	44	151	6		7	1221
Hendricks Township	1574	52		361		87	11	53	96	111	16	41	4	3		738
Hudson Township	1291	16		41		124	54	44	62	450	22	90	2		9	376
Marquette Township	2761	53		102		104	0	93	263	629	25	99	3		39	1350
Moran Township	5201	356		1464	11	561	193	195	209	1005	186	345	32	8	13	623
Newton Township	2890	84		94		7		33	191	574	25	159	7		3	1712
St Ignace Township	4110	144		137	1	175	72	79	298	761	218	144	63	3	2	2014

Table R-11b: Zone of Exposure Land Use/Land Cover: Neighboring Counties

Counties in Area of Interest	Land Use/Land Cover within 1500 ft of the Shoreline (acres)															
	Total Coastal Area	Barren Land (Rock/Sand /Clay)	Cultivated Crops	Deciduous Forest	Developed High Intensity	Developed Low Intensity	Developed Medium Intensity	Developed Open Space	Emergent Herbaceous Wetlands	Evergreen Forest	Grassland/ Herbaceous	Mixed Forest	Open Water	Pasture/ Clay	Shrub/ Scrub	Woody Wetlands
Charlevoix	**17415**	**1723**	**52**	**6708**	**26**	**654**	**155**	**816**	**438**	**907**	**646**	**1178**	**279**	**12**	**114**	**3705**
Charlevoix Township	1259	253	10	254	14	134	34	157	5	169	11	60	8	0	18	132
City of Charlevoix	219	17		0	10	112	60	18					1			
Hayes Township	1277	118	14	201		99	18	80	7	343	11	68	0		24	293
Norwood Township	1321	151	6	278		30	5	77		305	5	92	2	6	17	348
Peaine Township	5262	435	11	2872		144	4	231	33	67	292	570	104	4	17	477
St James Township	8077	749	11	3103	1	136	34	252	393	23	326	387	165	3	38	2455
Chippewa	**64639**	**2755**	**223**	**7732**	**63**	**2259**	**589**	**2969**	**5214**	**17116**	**1292**	**4514**	**1576**	**411**	**367**	**17559**
Bay Mills Township	5292	85	10	1537	5	107	38	500	143	694	65	299	207		26	1576
Bruce Township	2959	44	114	735		71	4	194	350	210	78	359	11	118	7	664
City of Sault Ste Marie	1954	38		129	25	350	300	253	178	35	49	46	75		15	462
Detour Township	5032	314	5	156	6	425	123	124	158	2404	77	196	35		18	993
Drummond Township	19948	1483	13	1139	10	632	52	622	1073	9911	558	962	528	4	80	2882
Pickford Township	1503	5		168				3	498	76	9	36	8		3	697
Raber Township	5306	121	33	442		140	4	171	419	1181	93	213	52	21	69	2347
Soo Township	5774	163	37	1162		105	7	194	666	581	91	678	192	111	83	1704
Sugar Island Township	9173	203	11	1674		53	3	415	909	1312	142	1458	200	152	32	2610
Superior Township	782	5		94	10	89	23	113	22	25	14	18	27	4	8	330
Whitefish Township	6916	295		497	7	288	35	382	798	687	117	249	242		27	3292
Presque Isle	**13106**	**1857**	**10**	**866**	**53**	**1065**	**253**	**666**	**234**	**3101**	**785**	**967**	**390**	**8**	**239**	**2612**
Bearinger Township	1517	88		190		209	15	81	31	213	68	193	4		33	392
City of Rogers City	910	305	4	5	47	164	173	44		55	45	46	13		2	7
Krakow Township	1505	26		106		9		31	12	624	24	67	23		5	577
Ocqueoc Township	1353	43		39		219	14	119	2	448	114	160	3		30	162
Presque Isle Township	4392	1090		22	3	200	26	198	145	972	294	69	302	5	23	1043
Pulawski Township	1614	185	6	256	3	64	4	86	45	378	158	104	40	3	33	250
Rogers Township	1816	119		248		200	21	108	1	412	81	327	6		112	181

Table R-11c: Zone of Exposure Land Use/Land Cover: Other Counties

Counties in Area of Interest	Land Use/Land Cover within 1500 ft of the Shoreline (acres)															
	Total Coastal Area	Barren Land (Rock/Sand /Clay)	Cultivated Crops	Deciduous Forest	Developed High Intensity	Developed Low Intensity	Developed Medium Intensity	Developed Open Space	Emergent Herbaceous Wetlands	Evergreen Forest	Grassland/ Herbaceous	Mixed Forest	Open Water	Pasture/ Clay	Shrub/ Scrub	Woody Wetlands
Alpena	**9,862**	**951**	**9**	**386**	**187**	**653**	**354**	**413**	**372**	**1,868**	**362**	**220**	**131**	**13**	**414**	**3,530**
Alpena Township	7,116	706	8	188	20	403	79	267	273	1,645	304	148	83	13	386	2,592
City of Alpena	852	125	0		167	177	267	38	3	7	11	10	43		2	4
Sanborn Township	1,894	119		199		73	8	108	96	215	48	62	5		26	934
Antrim	**4,728**	**543**	**16**	**1,262**	**15**	**262**	**66**	**434**	**37**	**294**	**31**	**427**	**88**	**23**	**23**	**1,207**
Banks Township	1,143	151		194		14		95	1	147	10	70	21		2	439
Elk Rapids Township	1,268	120	16	264	15	223	63	142	18	68	17	106	58	21	18	120
Milton Township	582	60		80		10	1	32	14	42		103	2	2		236
Torch Lake Township	1,736	211		725		15	1	166	5	37	4	148	8		3	413
Grand Traverse	**10,406**	**683**	**1,648**	**2,703**	**217**	**1,276**	**482**	**1,077**	**21**	**435**	**546**	**570**	**80**	**276**	**121**	**272**
Acme Township	1,776	125	247	235	15	222	86	293	12	165	35	124	51	33	24	107
City of Traverse City	960	9	21	40	155	300	249	133		9	3	35	1		1	5
East Bay Township	461	4		4	44	131	93	87	1	13		29				55
Garfield Township	10				0	2	1	0		1		2			1	1
Peninsula Township	7,199	545	1,380	2,424	3	621	53	565	8	247	509	380	28	242	94	103

Appendix S List of Attachments

This appendix lists attachments to this report.

No.	Title	File Name
1.	*Pipeline Rupture Analysis Report*	Attachment 01, Interglobe Final Report.pdf
2.	*Oil Spill Modeling for Straits of Mackinac, Michigan: Oil Spill Modeling*	Attachment 02, Spill Modeling Report.pdf
3.	*Geotechnical Report: Independent Alternatives Analysis for the Straits Pipeline*	Attachment 03, Geotechnical Report.pdf
4.	*RIAM Environmental Scores*	Attachment 04, RIAM Environmental Scores.pdf
5.	*Oil Spill Modeling for Straits of Mackinac, Michigan: Hydrodynamic and Spectral Wave Numerical Modeling*	Attachment 05, Hydrodynamic and Spectral Wave Numerical Modeling.pdf
6.	*Review of Timm Documents*	Attachment 06, Review of Timm Documents.pdf
7.	*Ecological Baseline & Basis for Analysis*	Attachment 07, Ecological Baseline & Basis for Analysis.pdf