APPENDIX L

Wildlife and Fish Noise Calculated Results and Estimated Number of Vessel Trips

APPENDIX L: WILDLIFE AND FISH NOISE CALCULATED RESULTS AND ESTIMATED NUMBER OF VESSEL TRIPS

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APPENDIX L-1

Wildlife and Fish Noise Calculated Results

APPENDIX L-1: WILDLIFE AND FISH NOISE CALCULATED RESULTS

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L-1 WILDLIFE AND FISH NOISE CALCULATED RESULTS

The principles of noise are described in section 4.16.1 of the environmental impact statement (EIS), and analyses of noise impacts on terrestrial wildlife, birds, marine mammals, fish, and threatened and endangered species are discussed in sections 4.6.1, 4.6.2, 4.6.3, 4.7.1, and 4.8 of the EIS, respectively. Noise disturbance calculation results based on agency guidance for marine mammals and fish are provided below. Calculations of noise thresholds for terrestrial wildlife have not been included because there is no standardized literature for how to conduct these calculations, and noise thresholds have not been identified for terrestrial wildlife species discussed in the EIS. Operational noise levels would not meet the criteria for avian disturbance; therefore, they are discussed qualitatively with construction noise in section 4.6.2 only.

Peak sound level (L_{peak}) is a measurement used to characterize maximum sound pressure generated by an activity and is often associated with intermittent activities such as pile driving. Decibels relative to 1 microPascal (dB re 1 µPa) are used to report underwater sound levels, which accounts for the difference between sound underwater and sound in air (California Department of Transportation, 2015). The root mean square (rms) is an averaged amplitude calculated using variable sound pressure waves. The sound exposure level (SEL) is a constant sound level over 1 second that has the same amount of acoustic energy as the original sound. Underwater noise thresholds have been developed using these measurement metrics.

L-1.1 MARINE MAMMALS AND FEDERALLY THREATENED AND ENDANGERED SPECIES

L-1.1.1 Underwater Noise

Project noise was evaluated using the National Marine Fisheries Services' (NMFS) updated *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing—Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts* (NMFS, 2016c) dated August 4, 2016. The NMFS Technical Guidance identifies underwater sound-exposure criteria corresponding to A and B injury and harassment levels, and provides guidelines assessing the onset of permanent threshold shifts from anthropogenic[1] sound. This guidance separates marine mammals into five functional hearing groups (low-frequency cetaceans, mid-frequency cetaceans, high-frequency cetaceans, phocid pinnipeds [underwater], and otariid pinnipeds [underwater]). Noise source types are separated into impulsive (e.g., impact pile driving) and non-impulsive (e.g., vibratory pile driving and dredging), and analyses are required for both the distance to the peak received sound pressure level and the 24-hour cumulative SEL. Table L-1.1-1 describes Level A injury and Level B disturbance thresholds for the five species groups as determined in the NMFS Technical Guidance. Marine mammal species have been categorized into five hearing groups based on available data on individual species' hearing capabilities. Further, based on available data, NMFS has determined at which thresholds marine mammals would be harassed by underwater noise: these are termed Level A and Level B harassment. The NMFS Technical Guidance defines Level A harassment as "…any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild." Level A harassment includes injury to marine mammals. The NMFS Technical Guidance defines Level B harassment as "…any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering." Level B harassment includes behavioral disturbance. Some Project activities' sound levels could exceed Level A and/or Level B thresholds established by NMFS in marine mammal habitat, resulting in incidental harassment. Noise disturbance calculation results have been organized by activity type.

[1] Human-generated

TABLE L-1.1-1

NMFS Marine Mammal Injury and Disturbance Thresholds for Underwater Sound [a]

Marine Mammal Groups	Species	Injury (Level A) Threshold – Impulsive $L_{peak, flat}$ (dB)	Injury (Level A) Threshold – Impulsive $L_{E, LF, 24h}$ (dB)	Injury (Level A) Threshold – Non-impulsive $L_{E, LF, 24h}$ (dB)	Disturbance (Level B) Threshold – Impulsive dB re 1 µPa rms	Disturbance (Level B) Threshold – Non-impulsive dB re 1 µPa rms
Low-frequency cetaceans	Minke whale Blue whale [c] Bowhead whale [c] Fin whale [c] Gray whale [c] Humpback whale [c] Right whale [c] Sei whale [c]	219	183	199	160	120
Mid-frequency cetaceans	Baird's, Cuvier's, and Stejneger's beaked whales Beluga whale Killer whale Narwhal Pacific white-sided dolphin Cook Inlet beluga whale [c] Sperm whale [c]	230	185	198	160	120
High-frequency cetaceans	Dall's porpoise Harbor porpoise	202	155	173	160	120
Phocid pinnipeds	Harbor seal Ribbon seal Spotted seal Bearded seal [c] Ringed seal [c]	218	185	201	160	120
Otariid pinnipeds and other [b]	Northern fur seal Northern sea otter [c] Pacific walrus [c] Polar bear [c] Steller sea lion [c]	232	203	219	160	120

Sources: NMFS, 2018e

$L_{E, LF, 24h}$ = 24-hour sound exposure level, low frequency, cumulative 24-hour; $L_{peak, flat}$ = peak sound pressure level (unweighted)

[a] Non-impulsive sounds are considered steady state. Examples include sonar and vibratory pile driving. Impulsive sounds are those with high peak sound pressures, are short, and have a fast rise-time and broad frequency content. Examples include explosives, impact pile driving, and air guns.

[b] Pacific walrus and sea otter are included with this group (NMFS, 2018d). We have also included polar bear for conservative analysis purposes.

[c] Federally listed under the Endangered Species Act.

L-1.1.1.1 West Dock Pile Driving

Table L-1.1-2 details the estimated number of piles to be installed at the West Dock Causeway, which includes both standard piles and sheet pile. AGDC estimated potential impacts on marine mammals associated with installation of the West Dock Causeway. The area of impact where marine mammals would experience temporary or permanent changes to hearing sensitivity from exposure to underwater anthropogenic sources (Level A) for West Dock Causeway pile driving activities are shown in tables L-1.1-3 and L-1.1-4. The area of impact where marine mammals would experience behavioral disturbance (Level B) for West Dock Causeway pile driving activities is shown in table L-1-5.

L-1.1.1.2 Cook Inlet Pile Driving

Table L-1.1-6 details the estimated number of piles to be installed in Cook Inlet for the Marine Terminal material offloading facility (MOF), Mainline MOF, and product loading facility (PLF), which includes both standard piles and sheet pile. Sound levels for each of the pile and hammer types are included in table L-1.1-7. AGDC estimated potential impacts on marine mammals associated with pile driving activities. The distance from the noise source where marine mammals would experience temporary or permanent changes to hearing sensitivity from exposure to underwater anthropogenic sources (Level A) for pile driving activities in Cook Inlet are shown in tables L-1.1-8 and L-1.1-9. The distance from the noise source where marine mammals would experience behavioral disturbance (Level B) for pile driving activities in Cook Inlet are shown in table L-1.1-10.

TABLE L-1.1-2

Piles to be Installed for the West Dock Causeway

Project Facility	Number of 11.5-inch H-Piles	Number of 14-inch Piles	Number of 48-inch Piles	Sheet Piling (feet)	Hammer Type	Number of Days	Months
South bridge abutment	4	0	0	646	Impact/vibratory [a]	46	Summer
North bridge abutment	4	0	0	560	Impact/vibratory [a]	40	Summer
Barge bridge mooring dolphins	0	16	4	0	Impact/vibratory [b]	7	Summer
Dock Head 4 mooring dolphins	0	48	12	0	Impact/vibratory [b]	19	Summer
Total	**8**	**64**	**16**	**1,206**		**112** [c]	

[a] 11.5-inch anchor piles would be installed using impact pile drivers.
[b] 48-inch piles would be installed using impact pile drivers.
[c] Some pile driving could be conducted on the same days.

TABLE L-1.1-3

Area of Level A (Injury) Impact for West Dock Pile Driving Activities – Pinnipeds

	Phocids			Otariids		
Pile Type	Impulsive (peak) (mi^2)	Impulsive (SEL) (mi^2)	Non-Impulsive (SEL) (mi^2)	Impulsive (peak) (mi^2)	Impulsive (SEL) (mi^2)	Non-Impulsive (rms) (mi^2)
11.5-inch H-pile	0	<0.01	N/A	0	0	N/A
14-inch pipe pile	0	0.09	N/A	0	0	N/A
48-inch pipe pile	N/A	N/A	0	N/A	N/A	0
Sheet pile	N/A	N/A	0	N/A	N/A	0

mi^2 = square miles; N/A = not applicable;

TABLE L-1.1-4

Area of Level A (Injury) Impact for West Dock Pile Driving Activities – Cetaceans

Pile Type	Low Frequency Cetaceans			Mid Frequency Cetaceans			High Frequency Cetaceans		
	Impulsive (peak) (mi^2)	Impulsive (SEL) (mi^2)	Non-Impulsive (SEL) (mi^2)	Impulsive (peak) (mi^2)	Impulsive (SEL) (mi^2)	Non-Impulsive (rms) (mi^2)	Impulsive (peak) (mi^2)	Impulsive (SEL) (mi^2)	Non-Impulsive (SEL) (mi^2)
11.5-inch H-pile	0	0.15	N/A	0	0	N/A	0	0.02	N/A
14-inch pipe pile	0	0.27	N/A	0	0	N/A	0	0.36	N/A
48-inch pipe pile	N/A	N/A	0	N/A	N/A	0	0	0	0
Sheet pile	N/A	N/A	0	N/A	N/A	0	0	0	0
Screeding	N/A	N/A	0	N/A	N/A	0	0	0	0

mi^2 = square miles; N/A = not applicable

TABLE L-1.1-5

Area of Level B (Disturbance) Impact for West Dock Pile Driving Activities – All Marine Mammals

Pile Type	Impulsive (rms) (mi^2)	Non-Impulsive (rms) (mi^2)
11.5-inch H-pile	0.06	N/A
14-inch pipe pile	N/A	0.41
48-inch pipe pile	1.59	N/A
Sheet pile	N/A	6.16

mi^2 = square miles; N/A = not applicable

TABLE L-1.1-6

Piles to be Installed in Cook Inlet for the Project [a]

Project Facility	Number of 24-inch Piles	Number of 48-inch Piles	Number of 60-inch Piles	Sheet Piling (feet)	Hammer Type	Number of Days [a]	Months
Year 1							
Marine Terminal MOF [b]	36 [c]	0	35	3,529	Vibratory	78	July – October
Year 2							
Marine Terminal MOF [b]	58 [c]	28	0	2,447	Impact/vibratory [d]	68	April – June
Mainline MOF	0	0	0	1,400	Impact/vibratory [e]	14	May – October
Year 3							
PLF	0	80	63	0	Impact	74	April – August
Year 4							
PLF	0	40	80	0	Impact	52	April – June
Year 5							
PLF	0	10	48	0	Impact	36	April – June
Total	**94**	**158**	**226**	**7,376**		**322 [f]**	

Source: Fairweather Science, 2018

[a] Assuming it takes 2 days of pile driving to install one pile. Vibratory and impact hammers would be operated only a portion of each workday. Actual time for full pile installation is typically 6 or 8 days; however, hammer use is not occurring the entire time. Construction could include more than one pile driven at a time.

[b] These piles and sheet piling would be removed after construction. Removal would be done with the vibratory pile driving method.

[c] These would be removed after each coffer cell until sheet piling installation is complete.

[d] 24- and 48-inch piles would be driven in using an impact hammer, and sheet piling would be driven in by a vibratory hammer.

[e] The first 50 feet of embedment would be conducted with a vibratory hammer, and the remainder with an impact hammer – assume half of the pile driving days with each hammer type.

[f] Some pile driving would be conducted on the same days during Year 2.

TABLE L-1.1-7

Sound Levels for Pile Driving in Cook Inlet

Equipment Type	Measured Distance (feet)	Average Sound Pressure Level (dB)		
		Peak	rms	SEL
Impact Pile Driving				
24-inch-diameter steel pipe [a]	33	207	194	178
48-inch-diameter steel pipe [a]	33	210	200	185
60-inch-diameter steel pipe [a]	33	210	195	185
Sheet pile	33	205	190	180
Vibratory Pile Driving				
24- and 60-inch-diameter steel pipe	33	183	170	170
Sheet pile	33	175	160	160

Source: Illinworth and Rodkin, 2007

[a] Sound levels also represent vibratory pile removal at the Marine Terminal MOF.

TABLE L-1.1-8

Distance to Level A (Injury) Impact for Cook Inlet Pile Driving Activities – Pinnipeds

Pile and Hammer Type	Phocids			Otariids		
	Impulsive		Non-impulsive	Impulsive		Non-impulsive
	218 dB peak (feet)	185 dB SEL (feet)	201 dB SEL (feet)	232 dB peak (feet)	203 dB SEL (feet)	219 dB SEL (feet)
18- and 24-inch pile, impact	3	2,277	N/A	0	167	N/A
48- and 60-inch pile, impact	7	6,670	N/A	0	486	N/A
All sizes pile, vibratory [a]	N/A	N/A	155	N/A	N/A	10
Sheet pile, impact	3	3,094	N/A	0	226	N/A
Sheet pile, vibratory	N/A	N/A	33	N/A	N/A	3

N/A = not applicable

[a] Impact distance for these piles also represents vibratory pile removal at the Marine Terminal MOF.

TABLE L-1.1-9

Distance to Level A (Injury) Impact for Cook Inlet Pile Driving Activities – Cetaceans

	Low-Frequency Cetaceans			Mid-Frequency Cetaceans			High-Frequency Cetaceans		
	Impulsive		Non-impulsive	Impulsive		Non-impulsive	Impulsive		Non-impulsive
Pile and Hammer Type	219 dB peak (ft)	183 dB SEL (ft)	199 dB SEL (ft)	230 dB peak (ft)	185 dB SEL (ft)	198 dB SEL (ft)	202 dB peak (ft)	155 dB SEL (ft)	173 dB SEL (ft)
18- and 24-inch pile, impact	7	4,255	N/A	0	151	N/A	0	5,069	N/A
48- and 60-inch pile, impact	10	12,460	N/A	0	443	N/A	3	14,843	N/A
All sizes pile, vibratory [a]	N/A	N/A	253	N/A	N/A	23	N/A	N/A	374
Sheet pile, impact	10	5,784	N/A	0	207	N/A	0	6,890	N/A
Sheet pile, vibratory	N/A	N/A	56	N/A	N/A	3	N/A	N/A	82

ft = feet; N/A = not applicable
[a] Impact distance for these piles also represents vibratory pile removal at the Marine Terminal MOF.

TABLE L-1.1-10

Distance to Level B (Disturbance) Impact for Cook Inlet Pile Driving Activities – All Marine Mammals

Pile and Hammer Type	Impulsive (rms) (miles)	Non-impulsive (rms) (miles)
Impact Pile Driving		
18- and 24-inch pile	1.1	N/A
48-inch pile	2.9	N/A
60-inch pile	1.3	N/A
Sheet pile	0.6	N/A
Vibratory Pile Driving		
All size piles [a]	N/A	13.4
Sheet pile	N/A	2.9

N/A = not applicable
[a] Impact distance for these piles also represents vibratory pile removal at the Marine Terminal MOF.

L-1.1.1.3 Anchor Handling

Anchor handling noise source levels would be 178.9 dB re 1 µPa rms; these activities are unlikely to cause Level A injury to low- and high-frequency cetaceans, and phocids, but could cause Level B disturbance to all marine mammals. The sound level for anchor handling is included in table L-1.1-11. AGDC estimated potential impacts on marine mammals associated with anchor handling activities. For anchor handling activities in Cook Inlet, table L-1.1-11 shows the distances from the noise source at which three of the five types of marine mammals would experience temporary or permanent changes to hearing sensitivity from exposure to underwater anthropogenic sources (Level A). The table also shows the distance from the noise source for marine mammal behavioral disturbance (Level B).

TABLE L-1.1-11

Underwater Noise Impacts from Anchor Handling Activities in Cook Inlet

Equipment Type	Sound Energy at Source (dB re 1 µPa rms)	Distance to Level A Injury Threshold (feet) – Low-frequency Cetaceans	Distance to Level A Injury Threshold (feet) – High-frequency Cetaceans	Distance to Level A Injury Threshold (feet) – Phocids	Distance to Level B Disturbance Threshold (feet/miles) – All Marine Mammals
Anchor handling	178.9	<1	<1	<1	6,683 / 1.3

Source: Illinworth and Rodkin, 2007

L-1.1.1.4 Dredging/Screeding

Sound levels for the potential dredging equipment and screeding activities are included in table L-1.1-12. AGDC estimated potential impacts on marine mammals associated with dredging and screeding activities. These activities are unlikely to cause Level A injury to marine mammals. The distances from the noise source where marine mammals would experience behavioral disturbance (Level B) for dredging and screeding activities are shown in table L-1.1-12.

TABLE L-1.1-12

Underwater Noise Impacts from Dredging and Screeding Activities

Equipment Type	Sound Energy at Source (dB re 1 µPa rms)	Distance to Level B Disturbance Threshold (feet)
Mechanical dredge	141	450
Hydraulic cutter dredge	152.9	145
Clamshell dredge	142.6	350
Winching in/out	140.5	350
Dumping into barge	132.5	140
Empty barge at placement site	139.0	445
Screeding	125	330

Source: Dickerson et al., 2001
N/A = not applicable

L-1.1.1.5 Cook Inlet Mainline Pipeline Shoreline Installation

The Mainline Pipeline would be trenched in at the Cook Inlet shorelines; however, we have recommended that AGDC incorporate use of the directional micro-tunneling continuation methodology for the shoreline crossings, if possible. For the two potential Mainline Pipeline Shoreline installation methods in Cook Inlet, table L-1.1-13 shows the distance from the noise source where marine mammals would experience temporary or permanent changes to hearing sensitivity from exposure to underwater anthropogenic sources (Level A) and the distance where they would experience behavioral disturbance (Level B).

TABLE L-1.1-13			
Underwater Noise Impacts from Mainline Pipeline Shoreline Installation Activities			
Equipment/Activity	Sound Energy at Source (dB)	Distance to Level A Injury Threshold (feet)	Distance to Level B Disturbance Threshold (feet)
Trenching			
Trailing hopper suction dredge	189.9	23 (high-frequency cetaceans)	10,257 (1.9 miles)
Clamshell dredge	142.6	N/A	351
Winching in/out	140.5	N/A	350
Dumping into barge	132.5	N/A	140
Empty barge at placement site	139.0	N/A	445
Backhoe in shallow water	145	N/A	585
Dozer in shallow water	134	N/A	168
Trenchless			
Directional micro-tunneling [a]	155	N/A	183

Sources: Reine and Dickerson, 2014; Dickerson et al., 2001; URS, 2007

N/A = not applicable

[a] The direct pipe method would briefly produce additional noise at the immediate exit of the trenching machine from the seabed; however, this would be limited in duration to the extent the machine is near the seabed.

L-1.1.1.6 Marine Terminal MOF Removal

The Marine Terminal MOF would be removed after construction. Piles would be removed using vibratory pile driving. Noise impacts would be similar as described for vibratory pile driving in tables L-1.1-8, L-1.1-9, and L-1.1-10 for installation.

L-1.1.2 Airborne Noise

Airborne noise also has the potential to affect marine mammals, in particular those species that haul out on land or ice and those that spend significant time at the surface, such as seals and otters. NMFS has established an airborne disturbance threshold of 90 dB re 20 μPa (un-weighted) for harbor seals and 100 dB re 20 μPa (un-weighted) for other seal species. Because Pacific walrus haul out on land and polar bears spend a significant amount of time on land or sea ice and would be susceptible to airborne noise harassment, we are using the thresholds for "other seal species" for these other marine mammals. Table L-1.1-14 describes the radius to disturbance from various activities that generate airborne noise near marine waters.

TABLE L-1.1-14 **Airborne Noise Impacts on Marine Mammals**			
Activity	Marine Mammal Group	Radius to Disturbance	Marine Mammal Species Potentially Affected
General construction (Gas Treatment Facilities)	Harbor seals Other seals [a]	N/A 0.2 mile	Ribbon seal, spotted seal, bearded seal,[b] Pacific walrus,[b] polar bear,[b] ringed seal [b]
General construction (Liquefaction Facilities)	Harbor seals Other seals [a]	0.4 mile 0.2 mile	Harbor seal, Steller sea lion [b]
Mainline excavation, Cook Inlet shorelines	Harbor seals Other seals [a]	180 feet At source [c]	Harbor seal, Steller sea lion [b]
Aircraft overflights	Harbor seals Other seals [a]	244 feet 79 feet	Harbor seal, northern fur seal, ribbon seal, spotted seal, bearded seal,[b] Pacific walrus,[b] polar bear,[b] ringed seal,[b] Steller sea lion [b]

N/A = Not applicable
[a] Other seals also include non-seal species such as polar bears and Pacific walrus (see section 4.8.1.3 in the EIS).
[b] Federally listed under the Endangered Species Act.
[c] Seals and sea lions are not expected to haul out near the shoreline excavation sites; therefore, they would not be affected by airborne noise generated from these activities.

L-1.2 FISH

The impacts of sound on marine fish species can be pathological, physiological, and/or behavioral. Pathological effects include physical damage to fish, physiological effects include stress responses, and behavioral effects include changes in fish behavior. Underwater noise effects criteria have been established by the Fisheries Hydroacoustic Working Group (e.g., a coalition of NMFS; the U.S. Fish and Wildlife Service; the Federal Highway Administration; the U.S. Department of Transportation offices from California, Oregon, and Washington; as well as national experts on sound propagation) for fish (see table L-1.2-1).

TABLE L-1.2-1 **Fish Injury and Disturbance Thresholds for Underwater Sound**		
Fish Size	Injury Effects Threshold	Behavioral Effects Threshold
Fish ≥ 2 grams	187 dB cumulative SEL	150 dB_{rms}
Fish < 2 grams	183 dB cumulative SEL	150 dB_{rms}
Fish all sizes	Peak 206 dB	150 dB_{rms}

Source: Fisheries Hydroacoustic Working Group, 2008; California Department of Transportation, 2009

The onset of physical injury is determined by peak pressure and SEL. Adverse behavioral effects are measured using the RMS threshold. For pile driving, RMS is the square root of the mean square of a single pile driving impulse pressure event. For the purposes of this report, the underwater area of effect is defined as those areas exposed to underwater noise where behavioral modifications to species may be expected. Underwater sound from pile driving is expected to extend to the point where the sound intersects a land mass or where it is reduced to background levels. Table L-1.2-2 describes the radius to disturbance from various activities that generate underwater noise that could affect fish.

TABLE L-1.2-2

Underwater Noise Impacts on Fish

Activity	Source Level	Distance to Injury Threshold (feet)			Distance to Behavior Threshold (feet)
		Fish ≥ 2 grams	Fish < 2 grams	Fish all sizes	Fish all sizes
Prudhoe Bay					
11.5-inch pile, impact	183 dB rms @ 10 m	20	33	8	2,523
14-inch, vibratory	150 dB rms @ 10 m	N/A	N/A	N/A	33
48-inch pile, impact	195 dB rms @ 10 m	94	159	29	12,231
Temporary spud, vibratory [a]	150 dB rms @ 10 m	<1	<1	<1	33
Sheet piling, vibratory	143 dB rms @ 100 m	1	2	<1	131
Screeding	122 dB rms @ 100 m	<1	<1	0	8
Sealift tugs	180 dB rms @ 1 m	1	2	<1	170
VSM In-stream Installation	145 dB rms @ 1 m	N/A	N/A	N/A	2
Cook Inlet					
18-inch pile, impact	194 dB rms @ 10 m	96	178	38	28,140
24-inch pile, impact	197 dB rms @ 10 m	152	282	38	44,600
48-inch pile, impact	200 dB rms @ 10 m	242	446	61	70,682
60-inch pile, impact	195 dB rms @ 10 m	112	207	61	38,808
Sheet piling, impact	190 dB rms @ 10 m	52	96	28	15,230
All piles, vibratory	170 dB rms @ 10 m	2	5	1	705
Sheet piling, vibratory	175 dB rms @ 10 m	5	10	<1	151
Anchor handling	178.9 dB rms @ 1 m	1	2	<1	277
LNG carrier	180 dB rms @ 1 m	1	2	<1	328
Dredging	153 dB rms @ 1 m	N/A	N/A	N/A	5

m = meters; N/A = not applicable; VSM = vertical support member; LNG = liquefied natural gas

[a] Temporary spuds are round piles installed temporarily for a template.

APPENDIX L-2

Estimated Number of Vessel Trips

APPENDIX L-2: ESTIMATED NUMBER OF VESSEL TRIPS

List of Tables

TABLE L-2-1

Estimated Numbers of Vessel Trips Associated with Project Construction and Operation

Transit Route	Vessel Type	Typical Vessel Speed (knots) [a]	Number of Round Trips Per Year	Number of Vessels	Peak Months	Construction Years	Total Number of Vessel Round Trips For the Duration of Construction [b]	Potential for Vessel Strike [e]
Construction								
Gas Treatment Facilities								
Prudhoe Bay West Dock / Beaufort Sea/ Chukchi Sea/ Bering Sea / Gulf of Alaska / Lower 48	Breach bridge barges: purpose built (300 x 120 x 20 foot)	12–20	2 (Sunk in position during season then stored ashore over winter)	9–12	Aug – Oct	Year -2 [f] Year -1 [f] Year 1 Year 2 Year 3 Year 4	61	Yes
	Ocean tug (100- to 120-ton bollard pull [BP]) & pre-construction barge	12–20	9	9	July to October (open water)	Year -2 [f] Year -1 [f]	18	Yes
Prudhoe Bay West Dock / Beaufort Sea / Chukchi Sea / Bering Sea / North Pacific	Ocean Tug (100- to 120-ton BP) & Module Barge	12–20	12	12	July to October (open water)	Year 1 Year 2	24	Yes
		12–20	10	10	July to October (open water)	Year 3	10	Yes
		12–20	9	9	July to October (open water)	Year 4	9	Yes
On station during open water season and then Beaufort Sea, Chukchi Sea / Bering Sea / Gulf of Alaska for winter	Assist docking tug (40-ton BP with ~12-ft draft)	11–15	2	2	July to October (open water)	All years (8 total)	16	Yes
	Assist docking tug (15-ton BP with ~12-ft draft)	11–15	6	6	July to October (open water)	All years (8 total)	48	Yes
Liquefaction Facilities								
Marine Terminal MOF Construction								
Lower 48 via Gulf of Alaska / Cook Inlet	Pre-construction ocean TUG (100- to 120-ton BP) & Barge	12–20	N/A [c]	N/A [c]	April 1 to Nov. 30	N/A [c]	N/A [c]	Yes

TABLE L-2-1 (cont'd)

Estimated Numbers of Vessel Trips Associated with Project Construction and Operation

Transit Route	Vessel Type	Typical Vessel Speed (knots) [a]	Number of Round Trips Per Year	Number of Vessels	Peak Months	Construction Years	Total Number of Vessel Round Trips For the Duration of Construction [b]	Potential for Vessel Strike [e]
Local vessels or from Washington State via Gulf of Alaska	Clamshell crane barge	<10	1	1	April 1 to Nov. 30	Year 1	1	No
	Deck barge with tug	9–12	1	1	April 1 to Nov. 30	Year 1	1	Yes
	Split-hull dredge barge/scow	8–10	14	3	April 1 to Nov. 30	Year 1	14	No
	Tractor tug (1,800 to 3,000 horsepower)	11–15	3	3	April 1 to Nov. 30	Year 1	3	Yes
	Work boat	10–26	2	2	April 1 to Nov. 30	Year 1	2	Yes
	Survey boat	10–26	1	1	April 1 to Nov. 30	Year 1	1	Yes
	Hydraulic suction cutter-head barge	13	1	1	April 1 to Nov. 30	Year 2	1	Yes
	Deck barge	9–12	3	3	April 1 to Nov. 30	Year 2	3	Yes
	Split-hull dredge barge/scow	8–10	190	5	April 1 to Nov. 30	Year 2	190	No
	Tractor tug (1,800 to 3,000 horsepower)	11–15	4	4	April 1 to Nov. 30	Year 2	4	Yes
	Work boat	10–26	2	2	April 1 to Nov. 30	Year 2	2	Yes
	Survey boat	10–26	1	1	April 1 to Nov. 30	Year 2	1	Yes
Cook Inlet or from Washington State via Gulf of Alaska, or local craft	Derrick barge (600 tons)	<10	1	1	April 1 to Nov. 30	Year 2	1	No
	Derrick barge (300 tons)	<10	1	1	April 1 to Nov. 30	Year 2	1	No
	Derrick barge (200 to 300 tons)	<10	1	1	April 1 to Nov. 30	Year 2	1	No

TABLE L-2-1 (cont'd)

Estimated Numbers of Vessel Trips Associated with Project Construction and Operation

Transit Route	Vessel Type	Typical Vessel Speed (knots) [a]	Number of Round Trips Per Year	Number of Vessels	Peak Months	Construction Years	Total Number of Vessel Round Trips For the Duration of Construction [b]	Potential for Vessel Strike [e]
	Barge for materials and staging	12–20	4	4	April 1 to Nov. 30	Year 2	4	Yes
	Work boat	10–26	2	2	April 1 to Nov. 30	Year 2	2	Yes
	Survey boat	10–26	1	1	April 1 to Nov. 30	Year 2	1	Yes
	Ocean tug (~120-ton BP)	12–20	7	7	April 1 to Nov. 30	Year 2	7	Yes
	Derrick barge (600 tons)	<10	1	1	April 1 to Nov. 30	Year 3	1	No
	Derrick barge (300 tons)	<10	1	1	April 1 to Nov. 30	Year 3	1	No
	Derrick barge (200 to 300 tons)	<10	1	1	April 1 to Nov. 30	Year 3	1	No
	Derrick barge (500 tons)	<10	1	1	April 1 to Nov. 30	Year 3	1	No
	Barge for materials and staging	12–20	5	5	April 1 to Nov. 30	Year 3	5	Yes
	Work boat	10–26	2	2	April 1 to Nov. 30	Year 3	2	Yes
	Survey boat	10–26	1	1	April 1 to Nov. 30	Year 3	1	Yes
	Ocean tug (~120-ton BP)	12–20	8	8	April 1 to Nov. 30	Year 3	8	Yes
	Derrick barge (600 tons)	<10	1	1	April 1 to Nov. 30	Year 4	1	No
	Derrick barge (300 tons)	<10	1	1	April 1 to Nov. 30	Year 4	1	No
	Derrick barge (200 to 300 tons)	<10	1	1	April 1 to Nov. 30	Year 4	1	No

TABLE L-2-1 (cont'd)

Estimated Numbers of Vessel Trips Associated with Project Construction and Operation

Transit Route	Vessel Type	Typical Vessel Speed (knots) [a]	Number of Round Trips Per Year	Number of Vessels	Peak Months	Construction Years	Total Number of Vessel Round Trips For the Duration of Construction [b]	Potential for Vessel Strike [e]
	Barge for materials and staging	12–20	4	4	April 1 to Nov. 30	Year 4	4	Yes
	Work boat	10–26	2	2	April 1 to Nov. 30	Year 4	2	Yes
	Survey boat	10–26	2	2	April 1 to Nov. 30	Year 4	2	Yes
	Ocean tug (~120-ton BP)	12–20	7	7	April 1 to Nov. 30	Year 4	7	Yes
Marine Terminal MOF Use								
Cook Inlet / Gulf of Alaska or North Pacific from Asia	Self-propelled (roll-on/roll-off) RO-RO vessel - module carrier	17–21	7	7	May to Sept.	Year 3	7	Yes
	Self-propelled (lift-on/lift-off) LO-LO vessel - module carrier	15–20	10	10	April to Oct.	Year 3	10	Yes
	Self-propelled RO-RO vessel - module carrier	17–21	20	20	April to Oct.	Year 4	20	Yes
	Self-propelled LO-LO vessel - module carrier	15–20	7	7	Sept. to Oct.	Year 4	7	Yes
	Self-propelled RO-RO vessel - module carrier	17–21	5	5	April to May	Year 5	5	Yes
Cook Inlet Barge Traffic / Gulf of Alaska	Ocean-going tug & barge (~120-ton BP)	12–20	144	144	April to Oct.	Year 3	144	Yes
	Ocean-going tug & barge (~120-ton BP)	12–20	5	5	April to Aug.	Year 3	5	Yes
	Ocean-going tug & barge (~120-ton BP)	12–20	42	42	April to Oct.	Year 3	42	Yes

TABLE L-2-1 (cont'd)

Estimated Numbers of Vessel Trips Associated with Project Construction and Operation

Transit Route	Vessel Type	Typical Vessel Speed (knots) [a]	Number of Round Trips Per Year	Number of Vessels	Peak Months	Construction Years	Total Number of Vessel Round Trips For the Duration of Construction [b]	Potential for Vessel Strike [e]
	Ocean-going tug & barge (~120-ton BP)	12–20	4	4	May to Oct.	Year 3	4	Yes
	Ocean-going tug & barge (~120-ton BP)	12–20	144	144	April to Oct.	Year 4	144	Yes
	Ocean-going tug & barge (~120-ton BP)	12–20	5	5	April to Aug.	Year 4	5	Yes
	Ocean-going tug & barge (~12- ton BP)	12–20	42	42	April to Oct.	Year 4	42	Yes
	Ocean-going tug & barge (~120-ton BP)	12–20	4	4	Sept.	Year 4	4	Yes
	Assist tug (42.5-ton BP)	11–15	2	2	April to Oct.	All years (4 total)	8	Yes
	Assist tug (15-ton BP)	11–15	4	4	April to Oct.	All years (4 total)	16	Yes
Mainline MOF								
Cook Inlet / Gulf of Alaska	Tug & RO-RO ATB ramp barge (1,034 tons)	17–21	73	73	April to Oct.	Year -2 [f]	73	Yes
	Tug & LO-LO flat deck barge (4,300 tons)	15–20	14	14	April to Oct.	Year -2 [f]	14	Yes
	Tug & double hull barge (273,000 gallons)	9–12	1	1	April to Oct.	Year -2 [f]	1	Yes
	Tug & RO-RO ATB ramp barge (1,034 tons)	17–21	81	81	April to Oct.	Year -1 [f]	81	Yes

TABLE L-2-1 (cont'd)

Estimated Numbers of Vessel Trips Associated with Project Construction and Operation

Transit Route	Vessel Type	Typical Vessel Speed (knots) [a]	Number of Round Trips Per Year	Number of Vessels	Peak Months	Construction Years	Total Number of Vessel Round Trips For the Duration of Construction [b]	Potential for Vessel Strike [e]
	Tug & LO-LO flat deck barges (4,300 tons)	15–20	64	64	April to Oct.	Year -1 [f]	64	Yes
	Tug & double hull barge (273,000 gallons)	9–12	2	1	April to Oct.	Year -1 [f]	2	Yes
	Tug & RO-RO ATB ramp barge (1,034 tons)	17–21	35	35	April to Oct.	Year 1	35	Yes
	Tug & double hull barge (273,000 gallons)	9–12	6	1	April to Oct.	Year 1	6	Yes
	Tug & RO-RO ATB ramp barge (1,034 tons)	17–21	35	35	April to Oct.	Year 2	35	Yes
	Tug & double hull barge (273,000 gallons)	9–12	6	1	April to Oct.	Year 2	6	Yes
	Tug & RO-RO ATB ramp barge (1,034 ton)	17–21	35	35	April to Oct.	Year 3	35	Yes
	Tug & double hull barge (273,000 gallon)	9–12	15	1	April to Oct.	Year 3	15	Yes
	Tug & RO-RO ATB ramp barge (1,034 ton)	17–21	35	35	April to Oct.	Year 4	35	Yes
	Tug & double hull barge (273,000 gallon)	9–12	1	1	April to Oct.	Year 4	1	Yes
Mainline Pipelay Across Cook Inlet								
Gulf of Alaska / North Pacific / Pipe from Seward	Pipe laying vessel	<10	1	1	April to Oct.	Year 3	1	No
	Anchor handling tug	12–16	1 [d]	3	April to Oct.	Year 3	3	Yes

TABLE L-2-1 (cont'd)

Estimated Numbers of Vessel Trips Associated with Project Construction and Operation

Transit Route	Vessel Type	Typical Vessel Speed (knots) [a]	Number of Round Trips Per Year	Number of Vessels	Peak Months	Construction Years	Total Number of Vessel Round Trips For the Duration of Construction [b]	Potential for Vessel Strike [e]
	Anchor handling tug (shallow water)	12–16	1 [d]	2	April to Oct.	Year 3	2	Yes
	Dynamic positioned survey vessel	10–26	1	1	April to Oct.	Year 3	1	Yes
	Pipe carrier (2,200-ton carrying capacity)	4–14	1 [d]	3	April to Oct.	Year 3	3	Yes
	Pipe laying vessel	<10	1	1	April to Oct.	Year 4	1	No
	Anchor handling tug	12–16	1 [d]	3	April to Oct.	Year 4	3	Yes
	Anchor handling tug (shallow water)	12–16	1 [d]	2	April to Oct.	Year 4	2	Yes
	Dynamic positioned survey vessel	10–26	1	1	April to Oct.	Year 4	1	Yes
	Pipe carrier (2,200-ton carrying capacity)	4–14	1 [d]	3	April to Oct.	Year 4	3	Yes
Port of Anchorage								
Cook Inlet / Gulf of Alaska	Container ship added to existing service (potential)	12–25	7	1	April to Oct.	Years 1 through 7	49	Yes
Port of Seward								
Gulf of Alaska / North Pacific	Handymax self-propelled pipe carrier (18,000 tons)	11–15	1 [d]	11	Year-round	Year 1	11	Yes
	Handymax self-propelled pipe carrier (18,000 tons)	11–15	1 [d]	16	Year-round	Year 2	16	Yes
Local	Assist tug for pipe vessels	11–15	1 [d]	3	Year-round	Year 1 through 3	3	Yes

TABLE L-2-1 (cont'd)

Estimated Numbers of Vessel Trips Associated with Project Construction and Operation

Transit Route	Vessel Type	Typical Vessel Speed (knots) [a]	Number of Round Trips Per Year	Number of Vessels	Peak Months	Construction Years	Total Number of Vessel Round Trips For the Duration of Construction [b]	Potential for Vessel Strike [e]
Operation								
Marine Terminal								
Cook Inlet / North Pacific / Asia	LNG carrier	14–21	204 to 360 [d]	252 [d]	Year-round	N/A [g]	6,120 to 10,800	Yes
Cook Inlet	Tugs	11–15	4	4	Year-round	N/A [g]	120	Yes
Cook Inlet - Dredging	Hydraulic suction cutter-head barge	13	1	1	April 1 to Nov. 30	Once during operation	1	Yes

Sources: Damen, 2018; GlobalSecurity, 2011; Port of Hamburg, 2018; Tropical Shipping, n.d.; Van Loon, 2018

ATB = articulated tug barge; BP = bollard pull; LO-LO = load-on/load-off; N/A = not applicable; RO-RO = roll-on/roll-off

[a] Vessels could travel at faster speeds en route to the Project area than when in use for specific Project activities. A range has been provided since transiting vessels would also be a risk to marine mammals.

[b] Calculated by multiplying the number of round trips per year and total construction years.

[c] Existing marine facilities in the area of the Liquefaction Facilities (e.g., rig tenders) would be used for a Pioneer MOF. The Pioneer MOF would support construction prior to completion of the Marine Terminal MOF and during peak construction periods. Vessel trips during peak construction are already accounted for in the numbers for the Marine Terminal MOF.

[d] It is assumed that each vessel would only make partial round trips, totaling the equivalent of one round trip between all of the vessels.

[e] Vessels that could travel at 10 knots or more have potential to strike large whales (Jensen and Silber, 2003; NMFS, 2004, 2017i).

[f] Vessels would be used pre-construction.

[g] Project lifetime is 30 years.